ALUMNI NEWS

Earth Sciences
UNIVERSITY OF TORONTO

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Cover: A spectacular photo from the Cappadocia area in Turkiye! It shows a sequence of Miocene ignimbrites (pyroclastic lava flows) composed of two hard flows separated by a thin softer one. The hardest unit is the uppermost one. The photo is taken from inside a cave in the lower flow (the steep sides). A partially eroded-out segment of the softer flow which in turn is capped by the harder flow forms the roof. The photo, courtesy ***Jamie Chow****, has been so positioned that the distant cliff top exactly aligns with the position of the same geological horizon within the cave. In the valley below, two members of the field party are seen, but missing from the photo are many hoodoos, known as "Fairy Chimneys", tall pinnacles capped by the hard uppermost flow.*

Alumni News

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Assistant Editor: Karyn Gorra
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Message from the Chair

Welcome to the 2023 Earth Sciences Alumni News! We've had a fantastic year in the Department, and it has been particularly good to see our in-person activities return in full force. Although Department members brought incredible creativity and fortitude to the long months of pandemic isolation, we all realized just how much we cherish seeing one another in person, in the classroom, in the lab, at Departmental seminars and other events, and of course, in the field. In-person interactions across the rich breadth and diversity of our Department facilitate collaborations, new ideas and spontaneous exchanges that spark innovation and I saw these many times over the past year. As the world emerged from the throes of the pandemic, humanity's other challenges have now returned to the fore, including the climate and biodiversity crises, inequities globally and within our own Province in terms of access to clean and safe water, the proliferation of microplastics and other pollutants, earthquakes and other geohazards, and the need for critical minerals to power our transition away from fossil fuels. All of these problems relate centrally to the geosciences and now more than ever, we must redouble our efforts to study the basic science underlying these problems, and to engage in cross-disciplinary conversations and collaborations to address them. I believe there has never been a more exciting or more important time to be a geoscientist or to be supporting geoscience activities. When teaching and speaking with our remarkable students, I feel hopeful for our future. Our community of highly motivated and passionate undergraduate and graduate students, and post-doctoral fellows, constantly amazes me in terms of their energy, enthusiasm, and innovative ideas. Some of their accomplishments are highlighted in the pages that follow. Supporting students and facilitating their learning and discovery has been a highlight of my work as Chair. I have greatly enjoyed meeting with many alumni and friends of Earth Sciences over the last year at our poster fair, the two PDAC receptions held over the past year and at other gatherings and meetings. I hope to connect with more of you over the next year and I hope the pages that follow fill you with inspiration.

Sarah Finkelstein
Professor and Chair

Miriam Diamond elected a Royal Society of Canada Fellow

Miriam L. Diamond, a professor cross-appointed between the Department of Earth Sciences and the School of the Environment, is a leading international expert on environmental chemical contaminants, internationally recognized for ground-breaking work uncovering sources and pathways for exposure to persistent organic pollutants. Her research has helped to confirm serious threats to ecosystems and human health. Her work plays a significant role in engaging the public and informing policy development to address the control and elimination of toxic and persistent chemical pollutants.

“I’m delighted and honoured to be joining the Royal Society of Canada as a Fellow. This important recognition is shared with my many students and collaborators, all of whom have worked for environmental protection through science and action.”

Nick Eyles wins Queen Elizabeth II Platinum Jubilee Award

The Queen Elizabeth II Platinum Jubilee Awards were instituted in 2022 by the Government of Canada, to mark the 70th anniversary of Her Majesty’s accession to the Throne, prior to Her Late Majesty’s passing, and are awarded Canada-wide to individuals in recognition of their public service, dedication and unwavering commitment to improving our community. **Nick Eyles**’ nomination emphasized his work outside of the university, stating that “Nick is passionate about the communication of information regarding important geological and environmental issues to the public”, and the Award highlighted “the breadth of Nick’s experiences ranging from environmentalism to advocacy, and multi-talented capabilities.”

2022 Schmidt Science Postdoctoral Fellowship

Congratulations to alumna **Liz Phillips**, PhD 2021, who was awarded a 2022 Schmidt Science Fellowship.

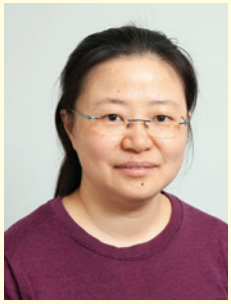
The Schmidt Science Fellowship is an international competition identifying and bringing together the world’s best emerging scientists to develop novel solutions to society’s challenges and accelerate ground-breaking discoveries. Fellows receive US $100,000 per year to pursue interdisciplinary postdoctoral studies at an institution of their choice.

During her PhD, Liz’s worked with Barbara Sherwood Lollar’s Stable Isotope Lab research group focusing on chlorinated alkane (e.g., chloroflorocarbons, chloroform) contamination and degradation in the environment, extending the discipline of compound-specific isotope analysis in new directions to study new enzymes with applications in cleaning up contaminated environments. As a Schmidt Science Fellow, she plans to pivot from groundwater contamination to sustainable decarbonization in the energy sector at the University of Oxford.

To learn more and hear from new Fellows about thier research plans visit the Schmidt Science Fellows website at schmidtsciencefellows.org.

Promotions to Full Professor

Sarah Finkelstein
paleoecology & paleoclimatology



Qinya Liu
seismology & geophysics

Kimberly Tait
mineralogy & meteoritics

Canadian Mining Hall of Fame

Alumna **Maureen Jensen** (BSc 1979) was inducted into the the Canadian Mining Hall of Fame (CMHF) at a ceremony in Toronto. A video story about her accomplishments can be viewed at the Canadian Mining Hall of Fame website at mininghalloffame.ca/meet-the-inductees.

Photo courtesy CMHF

Deputy Mayor of Toronto

In October 2022 **Jennifer McKelvie** (MSc 2002; PhD 2006; Sherwood Lollar) was elected to a second term on Toronto City Council representing Ward 25 Scarborough-Rouge park and appointed Deputy Mayor of Toronto in November. In February when John Tory resigned as Mayor, Jennifer assumed the responsibilities of Mayor until a new Mayor is elected in June. On her website she states ”I am focused on ensuring good governance and stability at City Hall over the coming months, working with City Council and other orders of government to build more housing, get more transit built, and to keep communities safe.” *Photo/City of Toronto*

*Jennifer reconnected with Earth Sciences alumni at the annual Alumni and Friends Receptions. Pictured in the photo, left to right, are **Natalie Caciagli Warman** (PhD 2010), **Jennifer McKelvie**, **Penny Morrill** (PhD 2005), **Silvia Mancini** (PhD 2010), **Nawojka Wachowiak** (MSc 2001), **Sarah Finkelstein.***

*Photo at left: Professors and alumni attended the CMHF dinner and induction ceremony. Left to right: **Melissa Anderson**, **Danica Pascua** (BSc 2012), **Joanna West** (MSc 2016), **Ed Spooner**, **Alexandria Marcotte** (BSc 2008), **Nick Tintor** (BSc 1980), **Natalie Caciagli Warman** (PhD 2010), **Laurie Curtis** (PhD 1979). Photo courtesy Melissa Anderson.*

Don Davis from the Jack Satterly Geochronology Laboratory

Don grew up in Moncton, New Brunswick and obtained a BSc.in Physics at the Université de Moncton among Acadians, whom he found to be the most welcoming people he had ever encountered. Don's research has always involved the measurement of time. He stayed at U de M to do an MSc thesis (1973) on measuring the life-times of positrons (about 100 picoseconds). He did his PhD in physics at the University of Alberta which had and still has a leading radiometric dating group. ^{87}Rb-^{87}Sr dating was popular at the time but there was no precise and accurate measurement of the ^{87}Rb decay constant. About 20 years earlier a group at McMaster University had purified a stock of $RbClO_4$ to remove Sr and his project was to determine the decay constant by measuring the amount of ^{87}Sr that had accumulated in the $RbClO_4$. Since the half-life is about 50 billion years, there wasn't very much so it was a challenge to measure such a small quantity without contaminating it. His supervisor warned him at the beginning that it would be tedious but that he would have the satisfaction of being quoted every time a Rb-Sr age was measured! As it happened the members of a committee that accepted the number got quoted, but the number was wrong due to an unforeseen problem with the original sample, which hadn't been properly purified. The PhD was not wasted since Don also purified a new stock of $RbClO_4$, which allowed his student, **Ethan Rotenberg** (PhD 2009), to measure the correct decay constant at U of T about 30 years later.

Don finished his PhD in 1978. At the time **Tom Krogh** was setting up a new U-Pb dating lab at the Royal Ontario Museum (ROM) with funding from the Ontario Geological Survey. It was called the Jack Satterly Geochronology Lab (JSGL) after a respected field geologist. Tom hired Don as a post-doc after a phone interview and Don flew out to northern Ontario to meet him and his technician, **Bohdan Podstawskyj**, in the field. They recognized Don because he was carrying an umbrella, which no geologist would do in the field! Tom, originally from Peterborough, had studied at Queen's, then MIT and did a post-doc at the Carnegie Institution where he studied U-Pb dating of zircon. This had much more potential to provide precise (±0.1%) ages on rocks than Rb-Sr but was beset by technical challenges. Tom had introduced several major improvements at Carnegie and Don was hired to apply them to zircon from Archean rocks in the western Wabigoon greenstone belt in northwest Ontario. Chemistry had to be done under a clean air environment because a grain of dust had lots of Pb since it was used in gasoline and paint at the time. The normal approach to building a clean lab involved (and still does) making the entire room dust-free and working in a Teflon suit. Tom's approach, which was about 100 times cheaper and also more effective, was to keep only the space where you worked on the sample clean and be fanatically careful. As Don recounts it, Tom had the informality and self-reliance of a farmer, which is how he thought of himself. An early memory he has is watching Tom do chemistry in a clean air box while chewing gum and drinking coffee, a cigarette dangling out of the side of his mouth!

*Don with a sample of the Acasta gneiss, the oldest known rock on Earth (4.0 Ga), which he collected in the North West Territories. Courtesy **Kim Kwok***

In 1982 Don was awarded an NSERC University Research Fellowship (URF) for 5 years in our Earth Sciences department but did not see himself as an aspiring academic so never applied for a faculty position. Don took over management of the lab when Tom was retiring, with the help of **Sandra Kamo**. Geochronology is essential to geological mapping programs so there was a ready source of income from geological surveys, which allowed the lab to become fairly self-sufficient and also to carry out independent research. Tom had conceived of the lab as a Canadian Carnegie and dozens of individuals were trained there who went on to form their own labs in Canada and elsewhere. In 2003 the JSGL moved to our department, where **Mike Hamilton** became director after Don, followed by Sandra Kamo.

Don has been involved with, and at the forefront of, U-Pb dating over a span of forty years. His name appears on 185 refereed publications and a similar number of reports whose

work extends over all continents including Antarctica, and includes meteorites. He was awarded the Goldich Medal for his work on precise dating of Mid-Continent Rift magmatism. He was the lead curatorial designer of the INCO Earth Science gallery at the ROM, which explained Earth systems through the prism of plate tectonics and environmental change. He has worked to improve the precision of U-Pb ages to the sub-Ma level for Precambrian zircon, introduced new methods of dating such as thermal extraction of Pb, new approaches to data analysis such as Bayesian regression, and studied the crystallographic effects of U decay. His present focus is the precise U-Pb dating of hydrogenic/diagenetic minerals and fossils. This allowed him and his students and post-docs to date ancient fluid movements that deposited carbonate veins in Paleozoic strata in Ontario to test suitability for nuclear waste storage. In collaboration with his former student, **Heriberto Rochin-Banaga** (PhD 2022), he is currently working on combining stable isotope data with precise ages on pedogenic carbonate to document the composition and temperature of the atmosphere during mass extinctions.

We thank Don for his many contributions to our department and wish him well in retirement, but of course hoping that he will still be working in the JSGL on his ongoing projects!

Henry Halls, Emeritus Professor and Editor

New Staff

Heidi Tomes is the new Teaching Lab and Field Coordinator

Heidi Tomes is the new Teaching Lab and Field Coordinator, a position which provides a broad range of teaching and equipment support to the undergraduate and graduate courses in the Earth Sciences department.

Heidi holds a BSc in Geology from the University of Alberta, an MSc in Geology from our department, and has worked in mineral exploration as a Geological consultant. Currently, she is a PhD candidate in Earth Sciences with research focusing on the geochemistry and mineralogy of the Rapid Creek Formation, Yukon Territory. She has extensive field experience in Ontario, Quebec, and in the Arctic including the Yukon, Greenland, and Nunavut, and has expertise in numerous analytical methods, alongside a well-established track record of engagement and support of student learning.

Since starting in her role in August 2022, Heidi has been working on updating, cataloguing and maintaining the teaching and field equipment. She is working with undergraduate work-study students to catalogue and create an up-to-date database of the rocks, minerals, fossils and maps in the department. At the same time, her focus since starting has also been on increasing departmental investment in experiential learning infrastructure and equipment as part of a Faculty of Arts and Science funding initiative. This has included purchasing new and innovative aids for teaching within the department. Most recently, she has been busy with preparations for the Whitefish Falls and Benny Belt Geology Field camps and is gearing up for a full summer organizing both the new and historical collections and getting all the newly purchased equipment set up and tested.

Emeritus Professor **Fried Schwerdtner** *kindly offered to share his memories and recollections of the structural geology samples in the Tectonics lab, as he collected many of them himself. Left to right are Fried, Heidi, Assistant Professor* **Tasca Santimano**, *undergraduate work-study students* **Clemence Korwin-Szymanowska** *and* **Deng Tor** *working to catalogue these samples. They have been able to match many stunning specimens to Fried's published papers! A huge thanks to Fried and his outstanding memory on the details of samples & locations collected many years ago—an amazing opportunity to strengthen our sample collection.*

Joubin James Scholar Program

The Joubin James Visiting Scholar program brings internationally recognized scholars to our department for a period of 1-3 months to share their research and foster new collaborations with our students and faculty. The award for the program was created by a former graduate, **Lloyd Tough Chandler** (UT1948), who donated shares of his uranium properties at Elliot Lake, acquired during the uranium rush of the 1950s. Revenue from the sale of the shares in 1977 provides annual funds for the programme. Chandler chose to name the award after his mentors, Dr Franc Joubin and Dr William James, both of whom are in the Canadian Mining Hall of Fame.

2022 Joubin James Visitors

Alberto Vitale Brovarone

Dr Alberto Brovarone visited the Department in mid-2022. He was invited by **Xu Chu** for a first visit in late 2019. Alberto started his research with a binational PhD in Italy and France, and then continued his career at IMPMC, CNRS Paris. In 2020, he became Full Professor at the Department of Biological, Geological, and Environmental Sciences of the Alma Mater Studiorum, University of Bologna, Italy. His research interests centre on fluid-rock interactions and volatile cycling in the deep Earth. In late 2019, he was awarded a 5-year European Research Council (ERC) Consolidator grant focused on the genesis of metamorphic hydrogen and deep abiotic hydrocarbons through the process of high-pressure serpentinization. The goal of this project is to improve our understanding of deep natural energy production, carbon mobility, and strain localization at convergent margins.

Alberto and Xu have been collaborating for several years on topics spanning deep carbon cycling, metamorphism and deformation of the Chinese Southwestern Tianshan belt and Trinidad Island, and recently on metamorphic hydrogen and methane production in Northern Vermont.

During his visit, Alberto delivered a research talk entitled “Metamorphic Methane degassing: the big unknown”. Also, Xu and Alberto led a one-week field trip to Vermont with an international team of scientists and students from Italy, France, Canada, and China.

Rolf Kipfer

Dr. Rolf Kipfer (otherwise known as Roki) is a senior research scientist at the Department of Water Resources and Drinking Water of the Swiss Federal Institute of Aquatic Science and Technology (EAWAG) where he leads the Environmental Isotopes research group. He is adjunct professor at the Institute for Biogeochemistry and Pollution Dynamics of the Department of Environmental System Science at the Swiss Federal Institute of Technology Zurich (ETHZ) where he lectures on aquatic physics, tracer hydrology and noble gas isotope geochemistry.

His research group uses transient tracers and time-series analysis to study physical processes operating in aquatic environments and to analyze the response of water bodies to environmental and climate change. The group analyzed deep water formation and fluid emissions in the world’s largest inland water masses, such as Lake Baikal, the Caspian and the Black Sea. The research on groundwater is focused on paleoclimatic reconstructions using noble gases and on the analysis of the physics of gas/water partitioning in porous media. Most recently, novel experimental techniques were developed to enable the analysis of noble gases in minute amounts of water (< 1 mg) and to determine (noble) gas concentrations in various terrestrial fluids online under field conditions. These methods allow retrieval of past environmental information from noble gases in fluid inclusions of speleothems. They also yield information on the fluid transport around black smokers and ocean sediments, on submarine groundwater discharge, and on the possible effect of CH_4 formation on the mobilization of arsenic in groundwater.

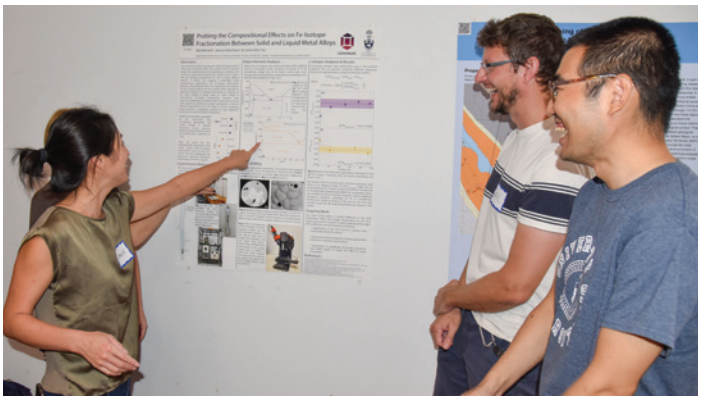
Barbara Sherwood Lollar, **Sarah Finkelstein** and **Ulrich (Uli) Wortmann** invited Roki as a Visiting Lecturer for 2022 from June to November. Alas, COVID prevented planned field work, so Roki took the opportunity to interact with the students—a task which he really enjoyed. He gave lectures on the use of noble gases to analyze fluid emission in marine systems and to study arsenic dynamics in groundwater.

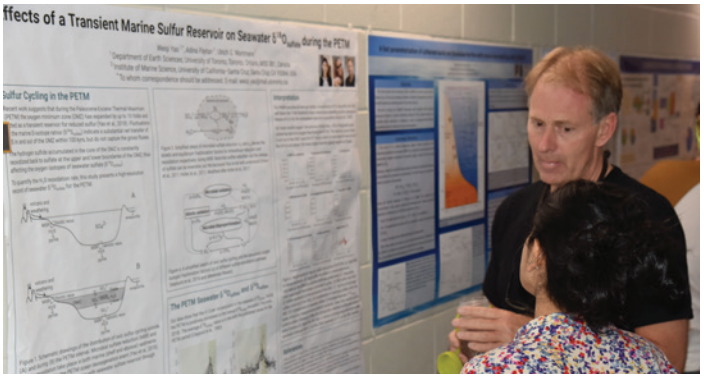
Tim Lyons

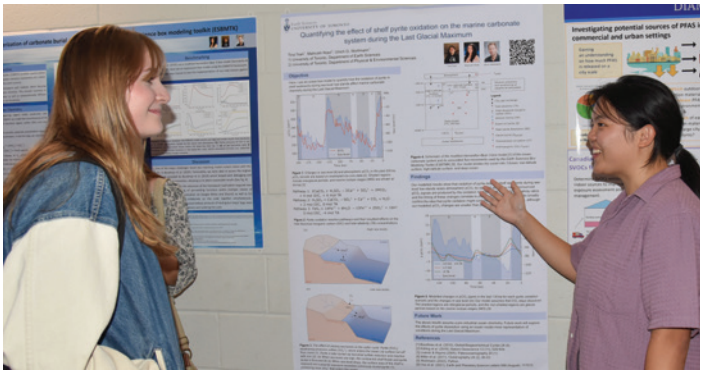
Dr Tim Lyons, a professor from the University of California-Riverside enjoyed a three-and-half-month visit to the department this past summer. Lyons and his primary U of T host, **Dan Gregory**, have collaborated for more than a decade and jumped at the opportunity to advance several promising projects and papers, including one just published claiming capture of primary micro-inclusions of seawater—in Devonian pyrite! Dan and Tim also brainstormed on their NSF/NASA-funded studies of modern oxygen-free fjords in British Columbia, which are bringing much needed validation and calibration to tools now widely used in reconstructions of the chemistry and microbial life of very ancient oceans. To further these efforts, Tim brought a team that included members of Dan's group and colleagues from UCLA to their first-ever study of anoxic Green Lake in Fayetteville, NY. Modern lakes can also help in studies of the ancient ocean. A summer of successful field sampling was capped off with reconnaissance of a promising new study area—oxygen-lean McGinnis Lake in Petroglyphs Provincial Park—which is bound to yield close-to-home student projects for years to come. Tim was also delighted to initiate a project with **Barbara Sherwood Lollar** and **Olly Warr** as part of his NASA Astrobiology Team. The focus is on methane as a modulator of early climate on Earth and potential biosignature gas on distant exoplanets. Also taking form is a mercury study with **Bridget Bergquist** designed to explore the role of volcanic eruptions during Earth's first great diversification of animal life. A few days were spent getting to know the classic Great Oxidation Event sequence near Elliot Lake, first with Dan and then with a film crew from Japanese public television!

Research Poster Party

As a kick-off to the fall term and a celebration of the Joubin James Visiting Scholars, a research poster party was an opportunity for faculty and students to share research they had presented at conferences over the past couple of years. Pictured on the right, top to bottom: Assistant Professor **Corliss Sio** points to detail while assistant professors **Neil Bennett** and **Xu Chu** look on; Professor **Uli Wortmann** discussing his work; graduate students **Josie Di Maurizio** and **Tina Tsan**; Professor **Barbara Sherwood Lollar** with alumnus **Stefan Ioannou** (PhD 2004) and **Glen Brown,** who held RA and assistant professor positions in the department from 1988-1997; Professor **Bridget Bergquist** and Emeritus Professor **Pierre Robin**.







Graduating Class of 2022

PhD:

Samantha Athey
Erkan Gün
Payman Janbakhsh
Jacob Kvasnicka
Katie Maloney
Mitchell McMillan
Heriberto Rochin Banaga
Natalie Szponar

MASc:

Diwen Yang
Ozan Akca
Naci Sertug Senol

MSc:

Matthew Belanger
Christian Beros
Joy Megumi Carter
Praveena Minoli Dias
Forrest Char McAdam
Robert J. McGrory
Alessio Scurci
Sukhmani Brar Singh
Jasmine Thea Yu

BSc:

Namee Choi
Alexander Copeland
Sicheng Dai
Tristan Daniel Dalueg
Vinh Kien Diep
Hunter Fargey
Nicole Emily Freij
Fareez Shah Ghazali
Aritra Gupta
Dana Rose Haneberg
Jane Qianrong Hu
Nishad Islam
Daniel Kahn
Rina Kollari
Ekaterina Kozina
Akuei Nyol Kuol
Jun Yi Li
Fiona Si Ying Lim
Jia Jie Lu
Emily D. McDonald
Danielle McGill
Hooria Mohammad
Daniel Mul
Jezebel Ng
Tommy Oliver
Sofia Panasiuk
Quang Nhat Vince Pham
Marc Roberge-Pika
Tina Tsan
Angie Kuan Ting Tseng
Daixi Zhang

Graduate Student Awards

Natural Science and Engineering Research Council of Canada Post-Graduate Doctoral Scholarship

David Aceituno-Caicedo

Connaught International Scholarship for Doctoral Students

Anna Whitaker

Faculty of Arts and Science Top Doctoral Fellowship (FAST)

David Summer
Megan Swing
Sarah Mount

Ontario Graduate Scholarship (OGS)

Sheila Ballantyne
David Summer
Ivan Strahkov
Megan Swing
Sophia Zamaria *(endowed by Ruth E. & Harry E. Carter)*

Queen Elizabeth II Graduate Scholarship in Science and Technology (QEII) Awards:

QEII / Canadians Resident Abroad Foundation Graduate Scholarship in Science and Technology

Sarah Lavoie-Bernstein
Sara Vaezafshar

QEII / J. J. Fawcett Graduate Scholarship in Science and Technology

Danielle McGill
Minoli Dias
Jonathan Umbsaar
Tina Tsan
Jonathan Sorrentino

QEII / Lamontagne Geophysics Graduate Scholarship in Science and Technology

Armagan Kaykun

QEII / Reford Scholarship in Science and Technology

Julia Andersen

QEII / Harold O. Seigel Graduate Scholarship in Science and Technology

Afeez Popoola

Eric L. Hoffman Memorial Scholarship

Brianna Barnhart
Junxing Chen

James P Nolan Explorers Fund Graduate Scholarship

EvelynLove Fosu Duah
Jonathan Umbsaar

David Strangway Award in Earth Science

Krystal Nason

Graduate Student Awards continued

Hugh Snyder International Scholarship in Earth Sciences
Octavio Acuna Avendano
Bruna Da Silva Ricardo
Yuly Paola Rivera Parra
Nelson Roman Moraga

Emeritus University Professor A. J. (Tony) Naldrett Graduate Scholarship Fund
Xinyu Tan

D.H. Gorman Explorers Fund Graduate Scholarship
Shannon Murtonen
Megan Swing

Jeff Fawcett and John Gittins Graduate Explorers Fund
David Aceituno-Caicedo
Krystal Nason
Joshua Wolpert

Laurence and Theresa Curtis Explorers Graduate Scholarship
Nanqiao Du
Sara Vaezafshar
Jessica Verschoor

Irene Gale-Rucklidge Explorers Fund Graduate Scholarship
Sheila Ballantyne

Cameron Allen Graduate Scholarship
Junxing Chen

Richard Bedell Graduate Scholarship
Hoi-Leung Pun

Graduate Student Scholarship/Bursary Fund in honour of Emeritus Professor Steven D. Scott and Joan Scott
Minoli Dias

H.V. Ellsworth Graduate Fellowship in Mineralogy
Jose Dominick Guballa

Dr. H.O. Seigel Scholarship in Applied Geophysics
Alexandra Korolev
Armagan Kaykun
Julia Andersen

W.W. Moorhouse Fellowship
Ruth Hall

A.T. Griffis Memorial Graduate Scholarship
Danielle McGill

Margaret Amelia Miller Scholarship
Jonathan Sorrentino

P.C. Finlay Q.C. President's Fellowship in Geology
Mauricio Barcelos-Haag
Matthew Belanger
Alexandra Korolev
Ivan Strahkov
David Summer
Anna Whitaker
Zhong-zheng Yuan

Dr. Norman Keevil President's Fellowship in Geology
Brianna Barnhart
Josephine Di Maurizio
Emily McDonald
Elizaveta Zvereva
Julia Hathaway
Riddhi Mandal
Afeez Popoola
Ozgur Tekin
Himani Yadav
Sophia Zamaria

Laurence Curtis Teaching Assistantship Award
Joy Carter

Geoscientists have to adapt to their field life...

Erkan Gün, on the right, receiving his PhD degree from a student in a field convocation ceremony in the theatre of the ancient Lycian city of Pinara. Dr Gün was leading a field trip in Turkiye during his November convocation ceremony and the students held an impromtu ceremony for him. Photo by Russ Pysklywec

Undergraduate Student Awards

NSERC Undergraduate Student Research Awards
Danielle McGill
Fannie Yiu
Alexandre Guillierez

University of Toronto Excellence Award
Esther Isadora Falkson
Jamie Chow

Coleman Gold Medal in Geology
Nicole Freij

Wesley Tate Scholarship in Geology
Nicole Freij

James P. Nowlan Explorers Fund Undergraduate Scholarship
Fannie Yu

Edward Blake Scholarship in Earth Sciences
Katherine Bormann

Daniela and Alexander Tintor Undergraduate Scholarship
Hailey Ribble

The Undergraduate Explorers Fund Award
Nicole Freij

Alexander MacLean Scholarship in Geology
Katherine Bormann

Roger E. Deane Memorial Scholarship in Geology
Quang Pham

Joseph Michael Housam Memorial Leadership Award
Kathryn Cheng

Ed Spooner Undergraduate Scholarship in Mineral Deposits Geology/Exploration
Alex Copeland

The H.V. Ellsworth Undergraduate Award in Mineralogy
Katherine Bormann

Joubin James Scholarship and Prize
Kathryn Cheng

The Garnet W. McKee-Lachlan Gilchrist Scholarship
Hailey Ribble

The Dr. E.T. Tozer Scholarship in (Triassic) Stratigraphy/Palaeontology
Alina Kostyuk

Russell Pysklywec Field Study Opportunity Fund
Morgan Wolfe
Fannie Yiu

Troilus Experiential Learning Fund
Nouf Mohsin Hassan Al Raisi
Aidan William Armstrong
Nyah Lan Thi Bay
Catherine Bormann
Jennifer Cann
Andrea Caratsch
Kathryn Cheng
Alex Copeland
Katrina Cristino
Oliver Dong
Matthew Dunkerley
Esther Falkson
Nicole Freij
Daniel Giannotti
Alexandre Guillerez
Akshit Hooda
Nishad Islam
Yi-Chih SabrinaJuan
Clemence Korwin-Szymanowska
Alina Kostyuk
Weijiang Lu
Danielle McGill
Chelsey Merrick
Yiwen Pang
Hannah Victoria Stuve
Tina Tsan
Zeynep Uzunel
Grace Wei
Morgan Wolfe
Matthew Xia
Fannie Yiu
Shaoyu Zheng

Student Industry Field Trip - SIFT
Kathryn Cheng

Don Salt Scholarship
Eve Carrothers
Alan Yu

KEGS Foundation Scholarship
Jamie Chow

APGO Education Foundation Scholarship
Kathryn Cheng

KEGS Foundation Steers Bursary
Kathryn Cheng

PDAC Student Trailblazer Award
Kathryn Cheng

International Course Module (ICM) Trips

Spectacular Scenery in Turkiye

In November 2022, thirteen students from Dr. **Erkan Gün**'s ESS445–Global Tectonics and Professor **Grant Henderson**'s ESS223–Earth Systems courses set off on flights to Turkiye's Central Volcanic Province accompanied by Professor **Russ Pysklywec**. Our goal was to explore the unique and stunning geology of Turkiye.

We arrived in Goreme, an ancient town in central Turkiye, at night. Restaurants serving kebab in clay pots and cauldrons full of hot wine lined the streets on the way to our cave hotel. The countryside in this region is scattered with massive sprawling underground cities made up of carved stairwells and narrow passageways, and we explored the deepest of these, Derinkuyu—a subterranean complex once sheltering up to 20,000 people. The unique buildings and underground cities of Central Volcanic Province are carved into the soft but stable volcanic ignimbrite in the region. These welded ash layers were produced by successive eruptions of the three towering volcanoes in the area over the past ~10 Myr. After exploring the caves and geology of Central Turkiye we left for the coast. In the Mediterranean, we kayaked through

the ruins of Kekova, an ancient Lycian city now submerged under the Mediterranean by earthquake-related subsidence and sea level rise. The final stop on our trip was Istanbul. The endless markets and grand mosques invite any visitor to explore the city. For every student who went to Turkiye, this was undoubtedly a highlight of their time at U of T.

Jennifer Cann, third-year geoscience major

Earth Sciences students return from Chile's Atacama Desert with rocks, minerals and memories

While most travelers return home with mementoes like postcards and t-shirts, earth sciences professors **Dan Gregory** and **Corliss Sio** and their students returned from a trip to Chile with over 25 kilograms of rocks and minerals. The "souvenirs" were collected during their International and Indigenous Course Module (ICM) trip late last year, part of Gregory's fourth-year Mineral Deposits course and Sio's third-year Igneous Petrology course.

"I brought back so many rocks!" says **Daniel Giannotti**, a fifth-year, New College student majoring in chemistry and geoscience. "When I was checking in for my return flight, the customs agent wanted to know what the giant lump in the x-ray of my bag was. He was a little shocked and kind of confused."

The Faculty of Arts & Science's ICM program provides undergraduate students with the opportunity to travel outside Toronto, often internationally, for a hands-on learning experience. For the earth sciences ICM, Gregory, Sio and 11 students spent nine days visiting geologically interesting sites and mining operations in Chile's Atacama Desert. They were accompanied by Chilean U of T earth sciences PhD student, **Nelson Roman Moraga** and Universidad Austral de Chile earth sciences professor Irene del Real.

"Chile is a great location for students because geologically, the country is very different from Ontario," says Gregory. "The rocks are geologically very young compared to those we find here. The country is a subduction zone where one tectonic plate is submerging beneath another. There are

volcanoes, as well as mineral deposits that are very different from what we have here."

The trip provided students with an opportunity to go beyond the classroom and lab and see the geological formations, rocks and minerals they'd only read about before.

Students inspecting a rare orbicular granite on the coast near Caldera, Chile

"In class, we can show them rocks, but they're completely out of context," says Sio. "On a trip like this, students get to see real outcrops and get a sense of the true scale of things. The experience really puts what they learn in class into a physical context."

Says Gregory, "It's so valuable for the students to be able to go to the top of a hill and look at a fault zone and actually see this feature that stretches for hundreds of kilometres." It was also a chance for them to see what it would be like to work as a geologist.

"They would just let us loose at some of the mine sites," says **Hannah Eaton-Tessier**, a fourth-year Victoria College student pursuing majors in geoscience and ecology & evolutionary biology. "Everyone brought their rock hammers, and we climbed up this hill and were breaking rocks and finding cool crystals and minerals. I really enjoyed that."

Chile is rich in iron, copper and gold and has a very strong mining sector. The group visited three mines: one an active, open pit mine, and two which were no longer operating. The different sites illustrated for the students the contrast between modern, less intrusive mining practices and more harmful, outdated practices. They also witnessed remediation efforts to repair the damaging effects of mining.

"It was a really cool opportunity — especially after COVID — to work in the field and, for me, to visit South America for the first time," says Eaton-Tessier. "And we had a great group of people who've all become close friends who still hang out."

"It was amazing," says Giannotti. "I got to see some incredibly interesting stuff academically and culturally. I made great connections with classmates and professors and strengthened connections I already had."

Like all ICMs, this one helped students chart their academic paths.

"Earlier in my undergrad career, I was leaning more toward biology," says Eaton-Tessier. "I was taking earth sciences more for fun and out of interest. But now, with this trip and with many of my friends leaning towards earth sciences, I'm definitely leaning more in that direction now."

"I like both geoscience and chemistry and discovered that both are important in the extraction of minerals from rock," says Giannotti. "And I heard on one of the mine tours about a system that uses a chemical polymer to extract sulfate minerals from the rest of the rock. I found that incredibly interesting. So, I'm really looking forward to learning more about that process. That would be something I'd have fun learning about and working on. And who knows, maybe someday, I can even improve the process."

But the trip wasn't just about academics. The professors and students learned about the country's history from their Chilean colleagues, and they all experienced the country's culture — including the food.

And in addition to rocks and minerals, they brought back memories they won't soon forget — like an unscheduled stop to "surf" down a giant sand dune, viewing flocks of flamingos, and the sight of a rare blooming of wildflowers in the middle of one of the driest deserts on the planet.

Posing for a group photo with wildflowers in the background.

"We couldn't have chosen a better destination," says Sio. "For some of the students, it was a once-in-a-lifetime experience."

Chris Sasaki - originally published online at A&S News

Capstone Field Trip 2022: Newfoundland & Labrador

June 15th dawned sunny in Toronto as we made our way to Pearson Airport for an early morning departure to "The Rock." These fair-weather beginnings were not to last and this year's **Capstone Field Course (ESS490)** to Newfoundland and Labrador saw multiple days of heavy rain and winds in excess of 40 knots! Our small but steadfast group, however, took these conditions in their stride to map exposed coastal islands, tackle the steep slopes of Gros Morne National Park, and log submarine debris flows.

Our group was comprised of **Tina Tsan**, **Jessica Verschoor**, and **Joyce Lu** from the St George Campus, with **Andreia Hamid** joining us from the Scarborough Campus. The trip was co-led by Professors **Neil Bennett** and **Mike Hamilton**. After landing at Deer Lake Airport, Newfoundland, we headed north, taking in spectacular views of the Long Range Mountains on route to the Torrent River Inn. It was an early start the next morning to catch the ferry across the Strait of Belle Isle to the mainland. Our mission there was to study Proterozoic rocks formed during construction of the Rodinian supercontinent, that were later rifted apart during opening of the Iapetus Ocean. Our main stop of the day was an outcrop of Paleoproterozoic metasediments, where we tried to discern the origin of enigmatic hematite-rich nodules. We then headed to Pinware River Provincial Park – our base for three nights.

The good weather that greeted us in Newfoundland slowly deteriorated during our time in Labrador, but not before we had the opportunity to map the south shore of Saddle Island – an Fe and P-rich layered mafic intrusion situated in the UNESCO world heritage site of Red Bay. We departed Labrador in deteriorating weather, which made for an exciting ferry crossing back to Newfoundland. The worsening weather made camping untenable, but with local assistance from the residents of St Anthony, we found accommodation for the night. After a busy evening drying clothes and camping equipment, Mike Hamilton delivered a lecture on U-Pb geochronology, providing students with some background on how ages for the ancient rocks they had seen were determined.

We were greeted the following morning by similar weather, before heading out to Cape Onion to study submarine volcanic rocks. Heading west along the coast to Burnt Cape, we identified a sequence of Cambrian sediments and volcanics thrust atop younger Ordovician sediments! After a brief drying-out stop for lunch, we headed back to the outcrops – this time to characterise mélange exposed along the north edge of the Hare Bay allochthon.

A break in the weather finally arrived the following day as we drove south towards Gros Morne National Park, allowing us to stop and discuss the palaeoenvironment of thrombolites

Standing on fossilized bacterial mounds in Flower's Cove.

Mapping the south shore of Saddle Island – an Fe and P-rich layered mafic intrusion situated in the UNESCO world heritage site of Red Bay. Photos by Neil Bennett

(fossilized bacterial mounds) exposed in Flower's Cove. We also visited Green Point, which hosts the global stratotype for the Cambrian-Ordovician boundary. Here, we used detailed stratigraphic logs to pin-down the exact location of the boundary based on variations in lithology and fossil content.

Over the next several days in-and-around Gros Morne national park, we were treated to a variety of geological features, from submarine debris flows containing car-sized clasts to three dimensional exposures of pillowed basalt flows. Our biggest challenge, however, was the steep hike to the Mohorovičić discontinuity, the boundary between mantle and crust. This deep-seated boundary is exposed in western Newfoundland due to obduction of oceanic crust during the closure of Iapetus.

After four days exploring the national park, we then spent the following morning in the volcanic and sedimentary rocks of Bottle Cove, where we identified several issues with the published map of the area and created revised interpretations in field guides. The afternoon was spent hunting for and describing fossilized trees in the Carboniferous sediments of Blanche Brook before a short drive to our final campground at Barachois Pond Provincial Park.

Our last day was spent touring sediments of the Port-au-Port Peninsula, that record the passage of a peripheral forebulge followed by progressive deepening of a foreland basin. After a morning dominated by carbonate sedimentology, we ended the trip in the siliciclastic rocks of Cape Cormorant, where we were able to identify partial Bouma sequences formed by turbidite flows. The next morning, we departed Barachois Pond for Deer Lake Airport and our flight to Toronto…but not before one last downpour to see us on our way.

Neil Bennett, Assistant Professor

Abitibi Greenstone Belt Trip April 2022

Fieldwork plays an essential role in Earth Sciences, but the ongoing pandemic has delayed many in-person field camp opportunities. When restrictions finally began to ease, many students were eager to return to the field after two long years of online learning.

In late April of 2022, the University of Toronto's Society of Economic Geologists (SEG) student chapter led a group of 11 students to Northern Ontario and Quebec with the help of Assistant Professor **Dan Gregory**. For some students in the group, the trip was their first experience in the field.

The goal was to provide students with an opportunity to see world-class features in an area where they may find future employment. The Abitibi Greenstone Belt is among the world's most geologically significant and economically productive regions. The different planned stops over the 5-day trip exposed students to the local geology and the history of mining in the region. Students mapped pillow basalts, climbed the Glenwood rhyolite dome in Rouyn-Noranda, saw the remnants of the silver rush in the historic town of Cobalt along the Heritage Silver Trail and admired the size of Canada's largest open pit mine at Malartic.

The group even had a chance to tour the core shack facilities of the gold exploration company Probe Gold Inc. in Val-d'Or, Quebec. There, students got to look at the day-to-day life of a junior exploration company. They even had the opportunity to check out gold-bearing cores!

"I wanted to learn more about ore deposits, exploration, and mining in case I decide to change my career in the future," says **Bruna da Silva Ricardo**, a 1st year Earth Sciences Ph.D. student. "The trip was excellent in this sense– I learned a lot about ore deposits, and the visit to the gold company helped give me an idea of what it's like to work in that environment."

We would like to thank the Society of Economic Geologists Stewart R. Wallace Funding, the Department of Earth Sciences at the University of Toronto, and the Toronto Geological Discussion Group (TGDG) for funding this trip. We would also like to thank Luc Théberge, Benjamin Blaise, and the Probe Gold Inc. team for providing us with the amazing opportunity to explore their core shack.

Tina Tsan

Trip participants checking out the Malartic open-pit mine, one of the largest gold mines in the world, at Malartic, Quebec. Photo by Dean Hiler.

Professor Dan Gregory points out features in the Archean Timiskaming sedimentary rocks to the students at a roadside outcrop. Photo by Joy Carter.

What causes glacial periods to end?

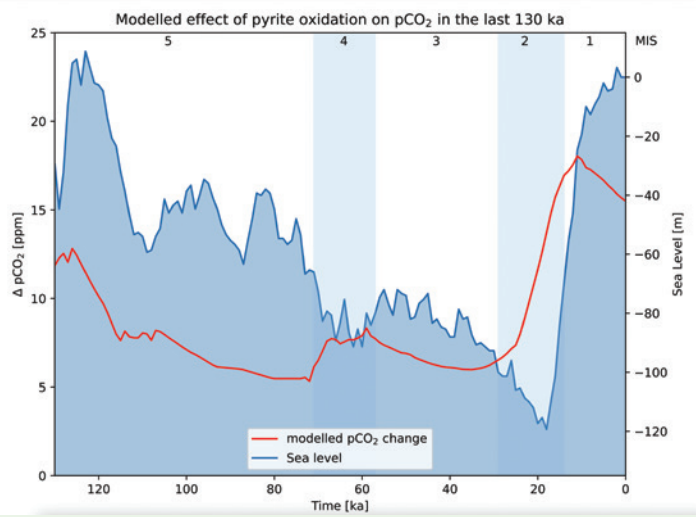
This intriguing question was among those studied during the 2022 Summer Undergraduate Data Science (SUDS) Research Program run by the Faculty of Arts & Science's Data Sciences Institute (DSI), U of T's hub for data science research.

SUDS pairs faculty members with undergraduate students from universities across Canada who are interested in data science careers.

The variety of SUDS projects reflects the growing number of disciplines increasingly reliant on data skills and expertise. One project involving Arts & Science faculty members and students addressed a major question in earth sciences, and is aimed at solving the vexing problem of what causes ice ages to end.

SUDS scholar and Innis College member, **Tina Tsan** is working on this problem with **Ulrich Wortmann**, an associate professor in the Department of Earth Sciences.

During glacial periods, ocean levels drop as water is taken up in glaciers. This exposes the continental shelf, triggering a chemical reaction that releases large amounts of carbon dioxide (CO_2). The oxidation of pyrite present in the shelf deposits generates a lot of protons. If the sediments are carbonate-bearing (as most shelf sediments are), these protons will dissolve $CaCO_3$ and release CO_2. In the absence of carbonates, the protons will acidify the ocean water, which in turn will deepen the CCD (Carbonate Compensation Depth) and thus also dissolve more $CaCO_3$ and thus liberate CO_2. Tina and Ulrich's analysis supports the new idea that this CO_2 may have warmed the atmosphere enough to end the last ice age.



"The work I'm doing in SUDS is an extension of my previous undergraduate research into changes in ocean chemistry," says Tsan. "By exploring the data science side of this work, I now have a better understanding of my research and this gives me a solid foundation for the fall (of 2022) when I start my master's degree in earth sciences at the U of T".

"The SUDS program is fantastic," says Wortmann. "Especially for students who are not embedded in a large research group or who are working in a field where few of their peers have an interest in data science. I really hope this program will continue."

A modified excerpt from an article in U of T's A&S News by Christopher Sasaki.

The role of deep and ancient crustal settings as life's power generators

This year a study[1], led by Research Associate **Oliver Warr** and University Professor **Barbara Sherwood Lollar** revealed 1.2-billion-year-old groundwater at a depth of 2.9 km in Moab Khotsong, an active mine in South Africa, with implications for how life can be sustained in Earth's subsurface and elsewhere in the solar system.

When naturally-occurring radioactive elements like uranium, thorium and potassium in subsurface rocks decay, they produce noble gases, such as helium, neon, argon, krypton, and xenon. At the same time the resulting radiation can generate radiogenic reactions in the surrounding rocks and fluids. This includes splitting apart water molecules in a process called radiolysis, which, over time, produces significant concentrations of hydrogen and other elements. These by-products can be harnessed by subsurface microbial communities deep in the Earth that are unable to access energy from the sun for photosynthesis. At Moab Khotsong, the team of international researchers discovered high concentrations of these radioactively-produced tracers, including the unprecedented discovery of an isotope of krypton, a never-before-seen tracer of this long-term process which helped reveal the fluids had been trapped underground for 1.2 Ga. As well as identifying the long

residence times, this study also revealed how 75 to 82 % of the light elements produced by these reactions had migrated out of the site via diffusive transport. This discovery reveals new information about the role of groundwater as a power generator for chemolithotrophic, or rock-eating, groups of microorganisms which inhabit Earth's deep subsurface.

As highlighted by Warr and Sherwood Lollar "For the first time, we have insight into how energy stored deep in the Earth's subsurface can be released and distributed more broadly through its crust over time. Think of it as a Pandora's Box of helium-and-hydrogen-producing power, one that we can learn how to harness for the benefit of the deep biosphere on a global scale." As well as applications for developing helium resource exploration strategies the researchers also note that quantifying these processes are vital for modelling how subsurface life may be sustained on Earth, on other planets and moons in the solar system and beyond, informing upcoming missions to Mars, Titan, Enceladus and Europa.

Funding for the study was provided by NSERC, NWMO, University of Oxford and CIFAR's Earth 4D: Subsurface Science and Exploration Program. NSF and ICDP funded the drilling and installation of sampling equipment.

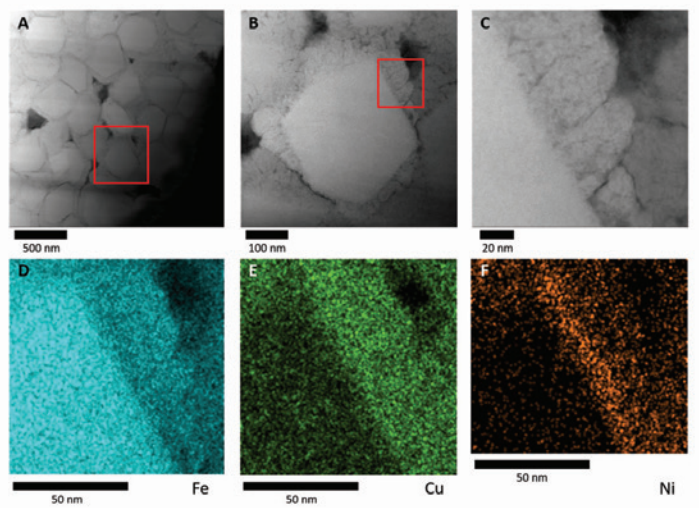
Oliver Warr
Department of Earth and Environmental Sciences, University of Ottawa

[1]Warr, O., Ballentine, C.J., Onstott, T.C., Nisson, D.M., Kieft, T.L. Hillegonds, D.J. & Sherwood Lollar, B. (2022) ^{86}Kr excess and other noble gases identify a billion-year-old radiogenically-enriched groundwater system. *Nature Communications* 13, 3768.

Photo: Dr. Warr collecting 1.2 Ga fluids at Moab Khotsong, South Africa. Photo credit: Stable Isotope Laboratory, University of Toronto, 2019

Euxinic pyrite: trace elements have both diagenetic and water contribution

The chemistry of the mineral pyrite has several uses, ranging from mineral exploration to past ocean chemistry. For the latter it has been argued that the trace element chemistry of sedimentary pyrite can be used to understand the trace element chemistry of the oceans throughout geologic history. This is because in euxinic (sulfidic) water columns pyrite forms in the water column and presumably any trace elements contained would reflect the concentration of those elements in the water column. To test this hypothesis we sampled pyrite framboids (microcrystalline masses of pyrite microcrystals) from two euxinic sites, the Cariaco basin and the Demerara Rise and analyzed them using transmission electron microscopy and atom probe tomography. These analyses showed that rather than gaining their trace elements from the water column much trace element concentration is actually incorporated into pyrite within the sediments during early diagenesis. This is shown by trace elements, such as nickel and copper, being enriched in extremely thin rims around microcrystals that make up the framboid. This shows that pyrite gains its trace element content from sediments early during diagenesis rather than directly from the water column. While the trace elements are likely affected by, and in some cases derived from, the ocean, a more complicated transference process from detritus to pyrite occurs. Thus, while still potentially viable, interpretations of past ocean chemistry from pyrite chemistry is more complicated than originally thought.



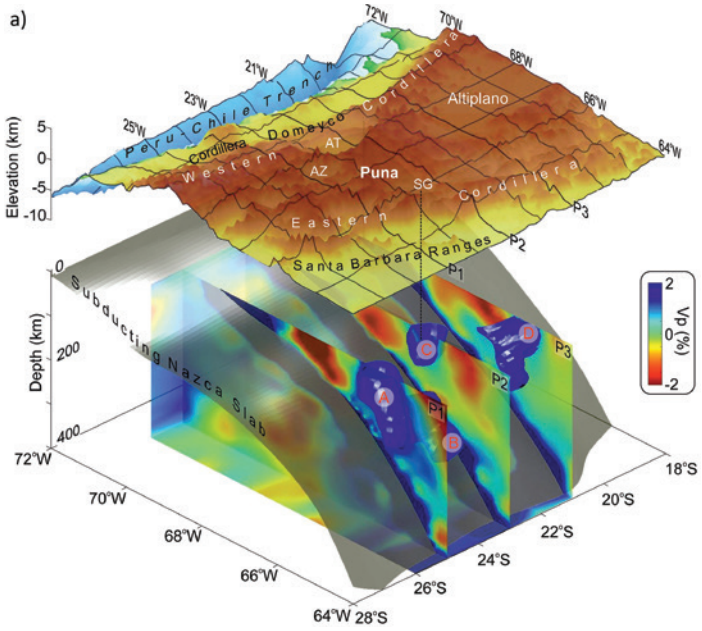
TEM analyses of a pyrite framboids from the Demerara Rise. A-C show a progressively zoomed in view of the areas of interest. D-F show zoning in trace elements, clearly the later growths of pyrite are more enriched in metals like Cu and Ni (from Gregory et al., 2022 in Geology).

Dan Gregory

Lithospheric drips trigger topographic rise and crustal deformation in the Central Andes

A tectonics study[1] led by PhD student Julia Andersen, Professor **Russell Pysklywec**, and PhD alumnus **Oguz Göğüş** (now a Professor at Istanbul Technical University) has discovered that the Earth's lithosphere—the outermost shell of the planet—is "dripping" into the deep fluid mantle beneath the Arizaro Basin in the central Andes in South America. This lithospheric dripping is currently causing widespread topographic uplift and tectonic damage to the surface over the past ~20 million years. The research uses innovative laboratory, physical analogue models—precisely scaled sandbox and fluid benchtop experiments—to allow exploration of the complex geodynamic process and how it drives changes in topography and the formation of folds and thrusts in the crust. Geologic mapping, elevation data, and geophysical imaging in the Andes verify the lab experiments, confirming that topography has risen by over one kilometre in the Arizaro Basin and that the surface crust has been severely tectonically crunched and folded. The changes in surface elevation and features in the crust correlate quite well with the analogue model that has been scaled to model physical changes in the crust over millions of years. Overall, the research helps expand a new kind of observation within plate tectonics—a paradigm theory in geosciences developed by J. Tuzo Wilson—and may even have implications for other terrestrial planets that do not have Earth-like plate tectonics such as Mars and Venus.

[1] Andersen, J., Göğüş, O.H., Pysklywec, R.N. et al. Symptomatic lithospheric drips triggering fast topographic rise and crustal deformation in the Central Andes. *Commun. Earth Environ.* 3, 150 (2022). https://doi.org/10.1038/s43247-022-00470-1



Topographic map of the Central Andes including the Altiplano and Puna Plateaus. AZ, AT, SG represent the Arizaro, Atacama and Salinas Grandes Basins respectively. Beneath the map are shown p-wave seismic tomography images where purple fast anomalies (A, B, C, D) illustrate instances of descending dense lithosphere beneath the plateaus. These anomalies may have been diverted eastward by the subducting Nazca slab.

Julia Andersen, PhD Student

Earth Ring 2022

A group of recent graduates received their Earth Rings at a ceremony held at the U of T Faculty Club in June 2022. From left, Professor **Dan Gregory**, **Alexandria Marcotte** (BSc 2008, VP Exploration at Osisko Mining), **Daxie Yang**, **Tina Tsan**, **Dean Hiler**, **Yuefei Chen**, **Nicole Freij**, **Danielle McGill**, **Heather MacDonald** (MSc 1999, Canada Operations Manager / VP Jacobs).

Below is an abstract of a paper celebrating the scientific accomplishments of **Barbara Sherwood Lollar**, authored by many of the graduate students, post-doctoral fellows and research associates who have worked with Barbara in her laboratory and who have amplified and extended her pioneering work.

Compound Specific Isotope Analysis in hydrogeology

Journal of Hydrogeology v. 615 (2022) 128588.

ABSTRACT

Here, we review the contributions of Professor Barbara Sherwood Lollar to Compound Specific Isotope Analysis (CSIA) in contaminant hydrogeology and environmental chemistry. We first discuss the seminal work by Professor Sherwood Lollar's lab on establishing CSIA as a quantitative tool for contaminant (bio) transformation at contaminated groundwater sites. We describe the critical research by her lab in the development and validation of sample collection techniques, single- and multi-element CSIA, and isotope data evaluation for reliable interpretations. We highlight the contributions of Professor Sherwood Lollar's lab towards the development of best practices for the successful application of CSIA by industry to demonstrate the occurrence of (bio)transformation, identify (bio)transformation mechanisms, quantify the extent and rate of degradation and differentiate among potential contaminant sources. We then explore Professor Sherwood Lollar's applications of CSIA to hydrogeology of the deep subsurface and the fast widening of the field to new environments (e.g., sediments), contaminants (e.g., chlorofluorocarbons, pesticides), and systems (e.g., plant, enzymes).

The final section of the paper concludes with:

Professor Barbara Sherwood Lollar has had a remarkable research career. Her work has been recognized through numerous awards – the 2019 NSERC Gerhard Herzberg Gold Medal, the 2019 C.C. Patterson medal for Environmental Geochemistry, the 2016 John Polanyi Award, the 2012 Eni Prize for Protection of the Environment, and recognition as an international Fellow of the U.S. Academy of Engineering, the U.S. Academy of Sciences, and a Fellow of the Royal Society of London, to name a few. Furthermore, she was President of the Geochemical Society from 2014-2015. Throughout her career Sherwood Lollar has mentored and guided over 70 student undergraduate and graduate research projects and 40 postdoctoral fellows and research associates, which we have summarized in an online academic tree at this link: https://academictree.org/chemistry/tree.php?pid=351447. Prof. Sherwood Lollar has led teams to novel discoveries and insights, balancing big picture thinking with a keen eye for detail. She has trained a next generation of scientists to value scientific rigour and produce data of the utmost quality for both fundamental and applied applications.

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New scholarship

Professor Fried Schwerdtner Undergraduate Bursary

A bursary has been established in honour of Emeritus Professor **Fried Schwerdtner**, a leader in the Department of Earth Sciences for his work in field-based structural geology. Professor Schwerdtner is known for his empathetic encouragement for students in geology, which has been pivotal to the success of generations of alumni. The bursary will support domestic undergraduate students in the Department based on financial need and in perpetuity. This bursary was established through the generosity of Gordon Stabb and his wife Sharon through the University of Toronto's Boundless Promise Program.

"It was a pleasure and privilege for my wife Sharon and I to give and establish a perpetual bursary for UofT undergraduate earth science students in need. We both have exceptionally fond memories of our time as U of T students and are grateful for the life experience we gained there. Myself in particular, for personal encouragement that Professor Schwerdtner provided me at a critical juncture."

Gordon Stabb, BSc 1981, professional geologist
Sharon Stabb (nee Hare) BA 1982, professional social worker

Gordon and Sharon Stabb at the Gros Morne fiord in Newfoundland and Labrador. Photo courtesy of Gordon Stabb.

Thank you,
for staying in touch, mentoring and supporting our students!

We acknowledge, with thanks, donations made in 2022 to a variety of scholarship funds by the following individuals and organizationss:

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A dedication to Fried Schwerdtner

Fried was my PhD supervisor at the University of Toronto in the mid-1990s and he introduced me to the mysterious world of practical quantitative structural geology. I had just completed my MSc in sedimentology, which didn't involve any mathematics, so this was a huge learning curve for me. I remember that back then Fried would describe concepts of strain using matrix algebra, but his students couldn't really follow what he was talking about. Fried wasn't great at drawing, so he asked his students to draft diagrams for him, and only then something clicked in our heads about the meaning of his complex equations. Students sometimes typed out his text as he couldn't type at the time. Needless to say, we encouraged Fried to at least learn how to type, so we did influence him in a small way. However, Fried's influence on my way of doing structural geology was monumental because he stripped everything back to observing the field evidence and encouraged me to unravel what I saw using first principles of structural geology.

One time I was despondent about the fact that I was working on rocks in the Sudbury Basin that were expected to be strained but had no visible signs of strain in the field. Fried wisely told me that the lack of strain is as important as the existence of strain, and encouraged me further to investigate what this could mean. He was right. I eventually came up with an explanation of the Sudbury Igneous Complex that no-one had bothered to think about—and the critical observation was the lack of strain in the rocks. I came to the conclusion that the Sudbury Igneous Complex cannot be an impact melt as every other Sudbury researcher believes it to be and this conclusion was based on simple structural observations that anyone can observe in the field. My PhD research was the most difficult thing I had to do in my life, but everything else since then has been comparatively easy, thanks to the training I received from Fried and that includes the conception of *Leapfrog* software and the subsequent development of my own software *Orefind*.

Fried opened up a new world to me and continues to be my mentor almost three decades after I obtained my doctorate. Even though he's now retired from university, Fried is 88 years young and mentally sharp as ever. He is still very physically active and continues to conduct field work with students every summer in Ontario and publishes his ideas regularly.

I am very grateful for Fried and his positive contribution to my education and for his always sunny disposition and positive energy. I know I'm very lucky as there are many postgraduate students who don't experience such a supporting relationship with their thesis supervisors.

Jun Cowan

Fried (right) with Jun at the annual University of Toronto alumni reunion during the PDAC convention (2007)

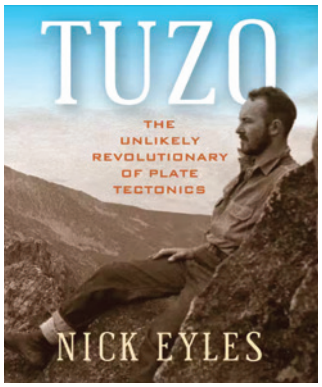
Entropy and sign conventions

It is a fundamental cornerstone of thermodynamics that entropy (SU, V) increases in spontaneous processes in isolated systems (often called closed or thermally closed systems when the transfer of energy as work is considered to be negligible) and achieves a maximum when the system reaches equilibrium. But with a different sign convention entropy could just as well be said to decrease to a minimum in spontaneous constant U, V processes. It would then change in the same direction as the thermodynamic potentials in spontaneous processes. This article discusses but does not advocate such a change.

Greg Anderson, Professor Emeritus

Abstract of a paper published January 2023 in *Foundations of Chemistry* can be read online at this link: https://doi.org/10.1007/s10698-022-09463

A book on Tuzo Wilson hits the headlines!



Nick Eyles' book "*TUZO- an unlikely revolutionary of Plate Tectonics*" was published in September 2022 and has been very well received. It is the story of Tuzo Wilson, from his childhood in Ottawa, to becoming Canada's most famous geoscientist as a result of his involvement in the concept of Plate Tectonics, a revolutionary idea developed mainly in the 1960's which proved that continents move and which explained the mechanism by which they accomplish this feat. The book has received accolades and congratulations from reviewers in being able to interweave the science of Plate tectonics with Tuzo's extraordinary and varied life. One insight (intriguing to me as an airship buff) was that Tuzo's father, as Controller of Civil Aviation in Canada, played a key role in the arrival of the R100 to Montreal from England in 1930 - the only giant dirigible ever to visit Canada!

Two reviews of Nick's book are given below, one by Bill Pearson who is the Founding President of the Association of Professional Geoscientists of Ontario (APGO), Chair of APGOs Education Committee and a past director of Geoscientists Canada, and the other by Gordon West who was a Geophysical colleague of Tuzo's for thirty years in the Department of Physics and who was the senior author of an earlier account of Tuzo's scientific contributions[1].

[1] G. F. West et al. 2014. Preface to Canadian J. *Earth Science Volume* 51, pp. xvii-xxxi.

Henry Halls, Editor

Readers of the Alumni News will know that our Scarborough colleague, Professor of Geology, Nick Eyles is not just an avid researcher in glacial and environmental geology, but author of numerous books and videos on earth science for the general public. In this new volume from UTP (former U of T Press), he explains to non-scientists the exceptional character of the late J. (Jock) T. (Tuzo) Wilson and his huge contributions to the 1960-1980 "revolution in the earth sciences" known as "Plate Tectonics". For many reasons, this is a formidable task; and I am pleased to report my opinion that Nick has hit a home run. The book is a fascinating read for any type of audience, and it provides much more information about the man himself than the many academic studies of how plate tectonics became accepted science. I believe it is the first to make substantial use of the archive of Wilson's papers at U of T and the family reminiscences of Wilson's daughter Susan.

I am amazed by how well Eyles has managed to balance providing his audience with an interesting personal biography, an outline of a century long science controversy, a clear trail to original sources, and geological tutorials on how the earth works, all in a highly readable style. Frequent and effective use of short quotations from original documents and many modern computer-generated colour graphics are key.

As one of several young and naive scientists Wilson brought to the geophysics laboratory of the Department of Physics 1950 -1970, I can say that Nick's portrait of Tuzo fits very well with the person I knew. I have huge respect for Tuzo's enthusiasm and drive in pushing earth science forward, and the importance of his contributions; and I strongly support this effort to make Canadians more aware of him.

Gordon F. West
Emeritus Professor of Physics (geophysics)
University of Toronto

Nick has done a tremendous job pulling together a vast amount of historical information not just on the remarkable life and prodigious achievements of Tuzo Wilson but also documenting in fascinating detail the long and protracted battle between those who believed in a contracting earth versus those who believed in continental drift which eventually evolved into what we now know as plate tectonics. This battle lasted for over 50 years starting with Wegener's original hypothesis of continental drift in 1915 to the mid 1960's when the evidence was clear that continents indeed moved. Ironically Tuzo Wilson for many years was on the contraction theory side until his epiphany in 1961 while sitting on a volcano in Hawaii when he realized that the only way to explain the origin of the Hawaiian Islands was by a plate riding over a mantle hotspot. From there he became the revolutionary that is the book's title and led the remarkable period of rapid development in plate tectonics through the 1960's for which he is world renowned.

The book wonderfully documents the incredible technical revolution especially following WWII that revolutionized the science of geology and moved it rapidly forward. Tuzo Wilson was quick to recognize the advantages of new technologies and was a rapid adopter from his early days of using air photos to geologically map large areas, to being a leader in the emergence of the new field of geophysics that was spurred by the tremendous wartime expenditures on technology, taking full advantage of the new radiometric

dating that gave geologists absolute ages for the first time and the enormous advances in computers which allowed complex problems to now be solved. Certainly, the first oceanographic maps, the paleomagnetic stripes along the Mid- Atlantic Ridge and the dating of oceanic rocks showing that none were older than 200 million years, all of which arose from these new technologies, finally put the contraction theory to bed.

Nick also documents Tuzo's early life and his early academic career with many interesting photos and stories. Much of this information came from his daughters who ironically knew little of what their father did as he considered geology a totally unsuitable profession for women. The account of his WWII service is outstanding, and Nick eloquently outlines how his experiences then gave Tuzo many lifelong skills in communication and leadership that would serve him well in future years. He was also remarkably well travelled and had a tremendous appreciation of global geology long before many of his peers.

TUZO is available from University of Toronto Press and on Amazon. It is a fitting tribute to a remarkable man who is unquestionably Canada's greatest geoscientist.

Bill Pearson
Chair, APGO Education Foundation

Alumni News

Jun Cowan (PhD 1996; Schwerdtner)

Jun Cowan moved from Sydney to Toronto in 1988 to study fluvial sedimentology with **Andrew Miall**. He graduated with an MSc (1991) and then studied Sudbury structural geology with **Fried Schwerdtner**, gaining his PhD in 1996. After three years as a post-doctoral fellow at the University of Western Australia, in 1999 Jun got his first (and last) real job as a structural geology consultant, at SRK consulting. Since 2007, he's worked independently as an applied structural geology consultant for exploration and mining companies worldwide.

In 2001 Jun was convinced that 3D interpolation was the future for creating 3D models of the ore bodies that were required for resource estimation and for exploring the extents of actively mined ore deposits. This 3D modelling approach was new and revolutionary—until 2001, all geologists hand digitised complex 3D geometries in 2D sections, just as was done before computers. But doing geological modelling by hand, even with computer assistance, took many weeks or months—3D interpolation could do the same job, more accurately, and within hours, resulting in significant cost savings.

Using the new Google search engine, he discovered a New Zealand company that had developed rapid 3D interpolation software code that wasn't making any significant sales for them. Jun believed their software had untapped potential and could revolutionise geological modelling and he convinced SRK Australasia to form a joint venture with them, with him leading the design and marketing of *Leapfrog* software (2001–2007). This new modelling method was the next logical step from the rapid interpolation methods Jun had learned and used to process his PhD structural data in the 1990s.

Today (2023), Jun's implicit geological modelling is not only represented by *Leapfrog* software—currently the bestselling geological modelling software in the mining industry—but also resulted in a brand-new field of geological research that didn't exist before 2001.

Jun continues to develop new software methods for the mining industry and is also known for his articles on LinkedIn which question accepted conventional wisdom. His work is a testament to the importance of innovation and questioning traditional ideas and methods that are accepted by academic economic geologists and by the mining industry.

Brock Edwards (BSc 2017; MSc 2018; Ferris)

Brock is a fourth-year PhD student at the University of Manitoba's Centre for Earth Science (CEOS) studying mercury emissions from volcanoes and geothermal systems. His fieldwork has focused on Iceland, where he has collaborated with scientists at the Icelandic Meteorological Office and the University of Iceland in measuring the emission of gaseous mercury and other volatiles like sulfur dioxide and carbon dioxide from active geothermal areas, as well as from two fissure eruptions at

Fagradalsfjall volcano in 2021 and 2022. This work included sending a drone into the plume directly above the volcano to measure near-source plume mercury concentrations – a first for atmospheric mercury research!

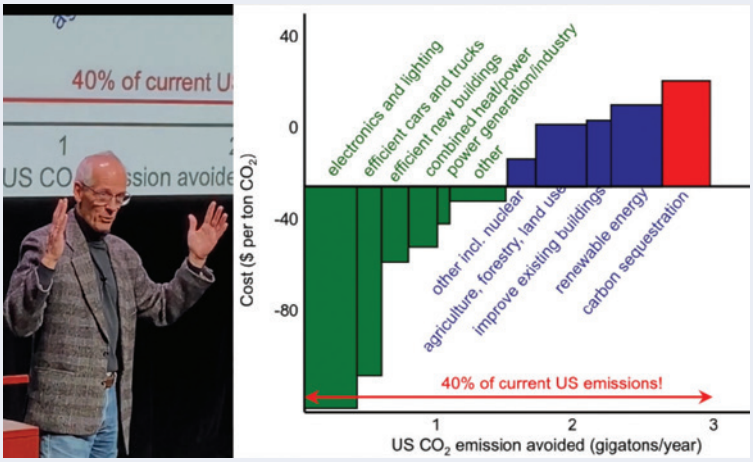
While this represents a shift in his previous work with **Grant Ferris** on iron biogeochemistry in groundwater systems, at the end of the day it is still within the broader field of environmental geochemistry in which he is most interested in working. It has allowed him to work with fellow U of T alum (and fellow TA of Field Techniques in Hydrogeochemistry, ESS410) **Natalie Szponar** (PhD, 2022) on atmospheric mercury, as well as co -author a textbook with her and lead author Grant Ferris in 2021 (*Groundwater Microbiology, The Groundwater Project*, https://gw-project.org/books/groundwater-microbiology/).

While staying in Toronto for a week for a friend's wedding in May 2022, Brock was back in the department using Grant Ferris's office as a space to study for his PhD candidacy exam (which he thankfully passed!). He fondly recalls **Henry Halls** laying waste to him at cribbage during the 2017 Graduate–Faculty trip to Killarney Provincial Park, by a score of six games to two. But he still won two games!

Brock Edwards at the Fagradalsfjall eruption, April 2021. Photo by Evgenia Ilyinskaya.

A group of alumni who graduated from Earth Sciences programs between 2018 -2022 gathered to celebrate a wedding and took the time to pose for a reunion photograph with one of their professors. Left to right: ***Jason Hinde, Dean Hiler, Zoe Evans, Athi Selvadurai, Adam Brudner, Nathan*** *and* ***Jessica (Patterson) Stoikopoulos, Sofia Panasiuk, Naomi Welt , Sam Duckworth Battye, Betka Ondercova, Charly Bank****. Photo by Alex of Spirits Intrigued Photography.*

J. Tuzo Wilson Lecture



The 2023 J. Tuzo Wilson Lecture took place at the Isabel Bader Theatre on Feb 28th, the first in-person Lecture since 2020. Prof. Roel Snieder from Colorado School of Mines delivered this year's lecture entitled 'Carbon Capture and Sequestration: Panacea or Indulgence?' and examined the nuanced details behind the Carbon Capture and Sequestration techniques in the broad scientific discussion of global climate change. More information about the event and the lecture video can be found online at these links:

https://tuzowilson.physics.utoronto.ca

https://www.youtube.com/watch?v=e-oC_5yk65A

Qinya Liu

Barbara Murck (1954 - October 2022)

Our Earth Sciences community was shocked and saddened at the recent passing of Barbara Murck. The outpouring of grief and sympathy, now numbering 65 tributes, has been indicative of how many lives Barb touched in so many different ways. These tributes come from faculty colleagues, grad students, TAs, UTM administrators and many of the thousands of undergraduates that Barb has taught. A short sample of words and phrases used to describe Barb include: brilliant mentor, embodiment of warmth, zest for life, compassion, generosity, empathetic, dedication to students, superb teacher, approachable, deeply caring, inspirational, environmentally passionate, lasting impact on students, absolute favourite teacher and a knack of making everyone feel included, appreciated and important. These tributes together with her obituaries mainly focus on her outstanding achievements as a lecturer in Environmental Science at UTM, where her on-line introductory course would reach well over a thousand students worldwide. In addition there is an excellent tribute from Princeton University, her alma mater, which mentions her Peace Corp work in Ivory Coast, her love of hiking, and various other aspects of her life in the USA before she came to Canada.

Arriving in the Geology (now Earth Sciences) department on the St. George Campus in 1980, she obtained her PhD in 1986 with a thesis on the geochemistry of the Stillwater Complex in Montana, under the supervision of **Ian Campbell**. However Campbell, a professor at University of Toronto Mississauga (UTM), left for a permanent position at the Australian National University sometime in 1984-5, and **Tony Naldrett** became her *de facto* supervisor. After graduation she held a Sessional Lecture position with the Earth Sciences department until 1995. During this time she taught an impressive list of courses in the Earth and Planetary Sciences Division at UTM, together with myself, **Pierre Robin**, **Bob Stesky** and **Bill Pearce**. Her courses included Igneous and Metamorphic Petrology, Optical Mineralogy, Environmental Geology, Geology and Public issues and the fourth year Field Course. One course, Phase Diagrams for Geologists, had such a high reputation for clarity that many students from the St. George campus took it for credit! In 1995 Barb was hired at UTM as a Senior Lecturer and in 2015 was promoted to Associate Professor, Teaching Stream, when she moved to the Department of Geography at UTM. Here her immensely successful environmental program, begun in 1996, flourished. In 2018 she was promoted to Professor, Teaching Stream. She was an author of seven university textbooks, published between 1992 and 2015. Several of them were co-authored with Dr.

Brian Skinner, a renowned economic geologist at Princeton University.

In addition to being a well loved and respected colleague, she was also the wife of Jack King, a well-known banjo player in several traditional jazz bands that performed regularly (and still do) in many different Toronto locations. One of these was Grossman's Tavern on Spadina Avenue on Saturday nights. Barb would regularly be seen chatting to everyone and taking part in the finale where all the audience members would jig around the floor led by the jazz band and several elderly ladies holding brightly coloured umbrellas who were revered for their roles in the origin and cultivation of the Toronto jazz scene. Nearly every New Year Barb and Jack would hold a party at their house which featured wonderful food, interesting guests and impromptu jazz performances by Jack and many of his colleagues.

Obituaries and tributes can be seen at these web links:

https://www.utm.utoronto.ca/geography/memory-professor-barbara-murck

https://www.kudoboard.com/boards/Onj9a3Nf

https://www.legacy.com/ca/obituaries/theglobeandmail/name/barbara-murck-obituary?id=39915428

https://paw.princeton.edu/memorial/barbara-w-murck-76

Henry Halls
Editor and Emeritus Professor of Earth Sciences

Yves Lamontagne (1944-2023)

On January 26, mining geophysics in Canada lost one of its most outstanding individuals, and department benefactor—Yves Lamontagne—to brain cancer at age 79. Yves graduated initially from Geological Engineering at Ecole Polytechnique (Montreal) and then attended U of T for both an MSc and PhD, and then stayed as a PDF until 1978. Yves was one of the first graduates in the Geology Department who entered a joint Geology-Physics PhD program and who spent most of his research time in the Geophysics Division in the Department of Physics. As his PhD supervisor, we worked together to improve methods of detecting massive sulphide mineralization by electromagnetic (EM) methods. A key outcome was the "UTEM" ground geophysical EM system, aimed at exploring deeper than most other EM systems of the time, and with a data output that made inference of the earth's electrical conductivity from the survey data much more straightforward. Financial and other support from Cominco was especially valuable at that stage.

In 1979, Yves set up his own company, Lamontagne Geophysics; initially in Toronto, but soon moving to Kingston, Ontario. Partnering with and employing other U of T and Queen's grads of the era, he began a long series of significant improvements of the UTEM methodology, concentrating especially on the ability to prospect effectively around very deep boreholes in the presence of deleterious EM noise sources (BHUTEM). Consequences of this for the Sudbury nickel camp have been mind-bending. Coupled with new geological ideas about ore formation that pointed to where deep exploration might be rewarding, BHUTEM has guided drilling in the Sudbury basin to eight major high grade ore bodies. With an in-situ metal value of several tens of billions of dollars, these discoveries have significantly extended the mining lifetime of Sudbury.

Yves was a fascinating quebecois character. Small and wiry of stature, helpful and friendly in manner, a lover of the bush and a good party, he was always a highly independent, resourceful, self-directed individual who was a lone night worker. His technical interests and skills were extremely broad and deep.

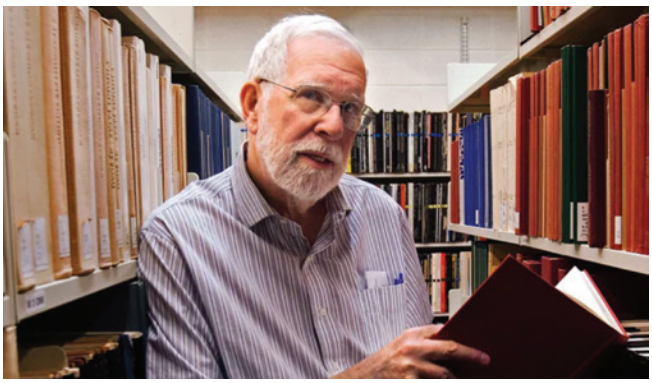
Challenges were rarely deflected. I recall one incident in the Geophysics Lab:
At afternoon tea, a grad student just returned from Europe and brought in a novel toy he had acquired there—a Rubics Cube—and was showing everyone how it was transformed. Everyone had a go at it, and realized how hard it was to twist it into the fully ordered state. Just then, Yves arrived. He began playing with the cube, and we left him with it. At morning tea time the next day Yves was (as usual) not present, but we found the cube sitting on the table fully ordered!

Yves focussed Lamontagne Geophysics on overcoming challenging problems, always plowing corporate profits back into development. Naturally, Inco/Vale has been a major client, but the company has many others, and has performed surveys in many countries, locating several notable deposits. One of the earliest discoveries was the Hellyer Pb/Zn deposit in Tasmania.

Yves and his company received the 2016 Cecil Green Enterprise award for outstanding innovation from the (international) Society of Exploration Geophysicists.

Gordon West, Emeritus Professor of Geophysics

Alan Ruffman (1940 – 2022)



In the late summer of 1963, Alan Ruffman, a third-year geology student at the University of Toronto, was returning to Canada from a student exchange program in Finland. Rather than fly home, he talked his way onto an 800-foot grain carrier bound for Churchill, Manitoba, with a hold full of sea-water as ballast. Somewhere off Greenland the ship ran into a storm so violent it lost steerage and found itself turned back toward Europe, storm-tossed on the heaving surge of a following sea. Alan began to doubt the wisdom of his choice, but the storm finally subsided and the ship was able to resume its course. "It was a gift," he

said later. “The sea was dead calm and in full-moonlight we saw a small forest of tall, majestic, cathedral-hewn icebergs marking the entrance to Hudson Strait. That sealed my decision to enter graduate studies in Oceanography.”

Alan Ruffman, marine geologist, civic activist, disaster historian, died peacefully at his home in Halifax on Dec. 28 at the age of 82. On graduating from the Department of Geology (now Earth Sciences) at U of T in 1964, he moved to Halifax to study marine geoscience at Dalhousie University. Over the next six decades, Alan pursued a multi-pronged career as a freelance marine geologist and a prominent Halifax civic gadfly. He mapped features and anomalies on the ocean floor from the Arctic to the South Atlantic, and provided the surveys necessary to develop offshore resources like the Venture gas field off Nova Scotia or Hibernia off Newfoundland. He was a founding member of many local citizens’ groups. His “Jane Jacobs” moment came when he played a leading role in stopping proposals that would have run elevated highways through the heart of Halifax’s historic waterfront district.

Alan Stuart Ruffman was born on July 10, 1940, in Newmarket, Ont., and grew up in Richmond Hill. Alan graduated from the University of Toronto Schools in 1959 and then attended Victoria College at the U of T, enrolling in an honours science course. He became president of his freshman class and was involved in so many extracurricular activities that he failed his first year. Undaunted, he re-enrolled in the same course and graduated in 1964 with a BSc in geology and a National Research Council fellowship to study marine geoscience at Dalhousie University’s Institute of Oceanography in Halifax.

He completed his MSc and was on his way to getting a doctorate when he was cautioned that he had to decide whether he was going to be an activist or a scientist. He chose to abandon his PhD but continued his career as a marine geologist and urban activist, determined to prove that he could be both.

Alan’s first major scientific coup came when he persuaded the Deep Sea Drilling Project (the first of several international scientific seabed drilling programs started in 1968) to take core samples from a “bump” on the ocean floor about 550 km northeast of Newfoundland. He named it “Orphan Knoll,” because he suspected it was an abandoned fragment of the continent from a time, about 100 million years ago, when the land masses of Europe and North American began to drift apart. The core sample proved his hunch right, and as a result, under the United Nations Convention on the Law of the Sea, Canada was able to claim jurisdiction over another 70,000 square km of seabed!

In 1973, with a colleague, John Stewart, he formed Geomarine Associates. Within a few years, the company had become Atlantic Canada’s most successful seafloor mapping company, with 32 employees, offices in St. John’s and Halifax, and major clients like Chevron and Mobil Oil. In 1985, the company divided, with Alan retaining the company name, its library of reports, and his office on Prince Street in Halifax.

Freed from the constraints of running a company, he pursued his investigations into historical disasters, both accidental and natural. In 1992, he organized a symposium to mark the 75th anniversary of the Halifax Harbour disaster when a ship loaded with munitions blew up, killing 2,000 and devastating much of the city’s waterfront. He co-edited *Ground Zero*, an anthology of contributions to the symposium that has since become a collector’s item.

Alan’s persistence and his ability to make inspired guesses led him to uncover two collections of lost drawings by Arthur Lismer, a member of the Group of Seven who had been an eyewitness to the Halifax Explosion.

He published a book of original research called *The Titanic Remembered: The Unsinkable Ship and Halifax*, and led a highly publicized investigation into the identity of several victims, including a small child drowned in the Titanic disaster and buried in Halifax’s Fairview Lawn Cemetery, hitherto known only as “Body No. 4.” Using mitochondrial DNA from several teeth and a tiny bone fragment that remained in the grave, Alan did the complex genealogical research that eventually led back to the child’s mother. His investigation was twice featured on the PBS series, “Secrets of the Dead.”

Alan’s studies of historical catastrophes like the Lisbon earthquake of 1755 or the tsunami that hit Newfoundland in 1929 are more than just technical accounts of long-forgotten disasters. Drawing on a variety of sources like ships’ logs, newspaper stories, diaries and journals, and eyewitness accounts, he was able to present a complex picture of their human and social impacts.

His title for a study of the greatest natural disaster to visit our shores is deceptively dry: *The Multidisciplinary Rediscovery and Tracking of The Great Newfoundland and Saint-Pierre et Miquelon Hurricane of September, 1775.* It’s a harrowing account of the superstorm that killed over 4,000 people two-and-a-half centuries ago.

One of the most poignant pieces of Alan’s legacy will remain, like Orphan Knoll, forever out of sight. Off the south coast of Newfoundland, near the site where the Titanic sank, there are seven undersea hills referred to collectively as the Fogo Seamounts. At Alan’s request, those features now have names: Algerine, Birma, Carpathia, Frankfurt, Mackay-Bennett, Montmagny, and Mount Temple. They are the names of the ships that responded to the Titanic’s calls for help.

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Photo by The Canadian Press

1920's *1930's* *1960's* *1970's*

A selection of Brunton compasses used to teach generations of U of T geoscience students since the 1920"s. Photo by Heidi Tomes.

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