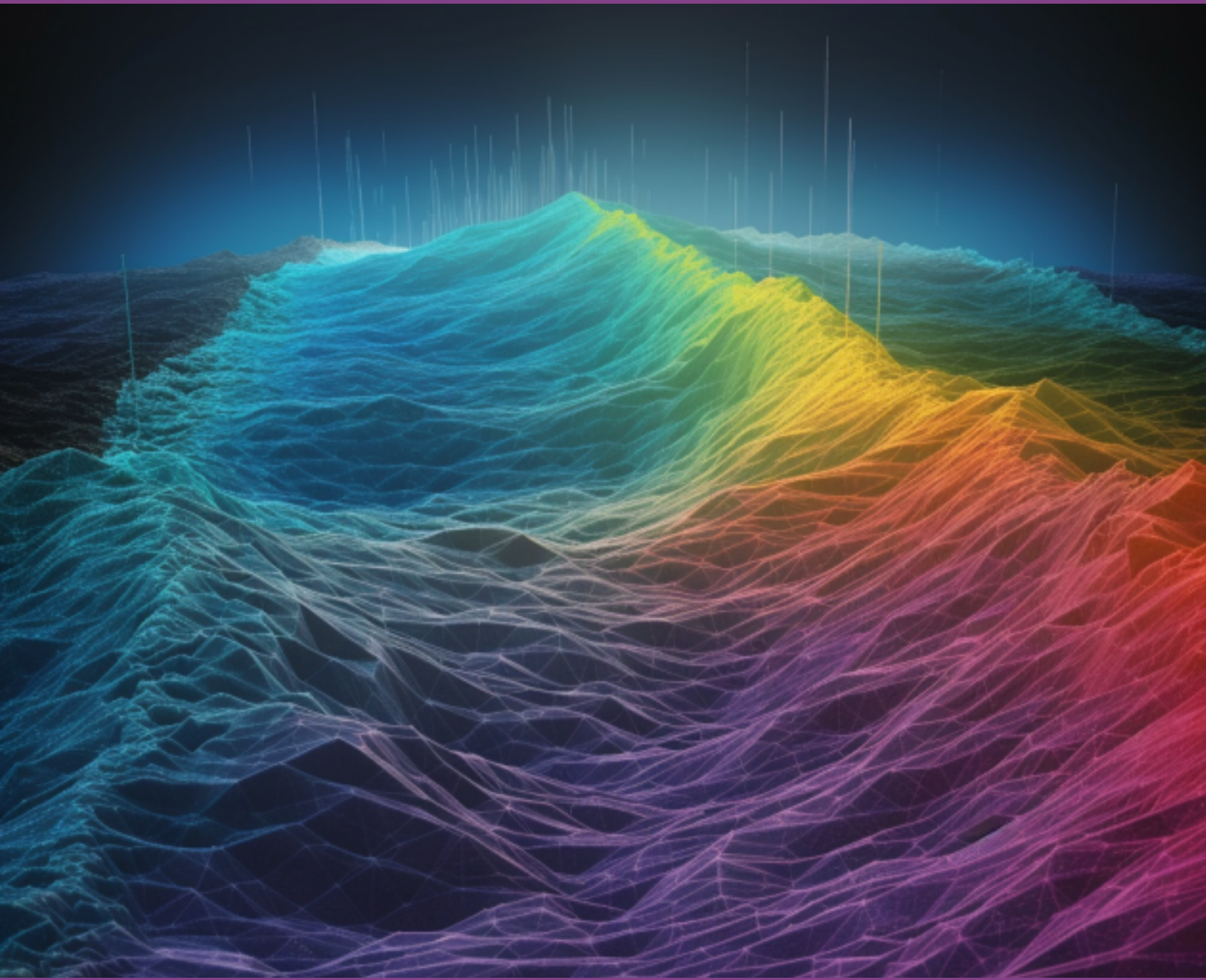


MINES GEOPHYSICS

REVEALING THE DYNAMICS OF THE EARTH | SPRING 2023



COLORADO SCHOOL OF
MINES
@ 150 | 1874-2024

Spring 2023

Department Head

Dr. Paul Sava
psava@mines.edu

Associate Department Head

Dr. Brandon Dugan
dugan@mines.edu

Department Manager

Lynn Lundebrek
llundebrek@mines.edu

Newsletter Staff

Ilya Tsvankin
Noelle Vance
Khalid Almuteri
Duncan Byrne
Derrick Chambers
Maile Corso
Aaron Girard
Maureen James
Martis James-Ravenll
Aaron Jimenez
Mia Jungman
Ashish Kumar
Chloe Locke
Anna Nichols
Hannah Verboncoeur
Cullen Young

Cover Photo

Derrick Chambers
using Midjourney

- 3 On the Cover
- 4 Welcome from the Department Head
- 5 Introducing Undergraduate Tracks
- 12 Geophysics & the Future
- 17 Open Learning
- 18 Faculty Conversation
- 22 Ground-breaking Research in Antarctica
- 24 Spotlight on Undergrad Research
- 26 Notes from the Field
- 27 Faculty Accolades
- 28 Student Awards
- 31 Alumni News
- 36 Heiland Lecture Wrap-up
- 38 GP on Social Media
- 40 Recent Publications

connect with us



www.facebook.com/MinesGeophysics



[@MinesGeophysics](https://twitter.com/MinesGeophysics)



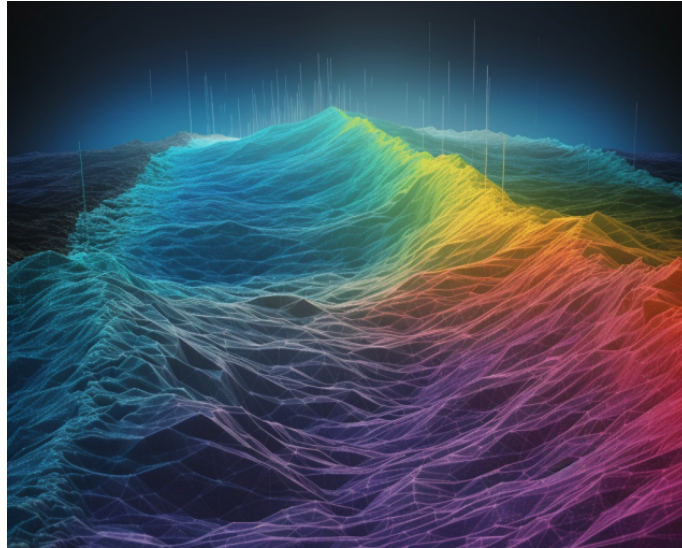
[@SGGSMines](https://www.instagram.com/SGGSMines)

COLORADO SCHOOL OF MINES
1500 Illinois Street
Golden, CO 80401
303-273-3000 or
800-446-9488

GEOPHYSICS ADDRESS:

Geophysics Office, Room 283,
Green Center
924 16th St.
Golden, CO 80401
303-273-3451
geophysics.mines.edu

IMAGING WITH ARTIFICIAL INTELLIGENCE



The recent release of chat programs integrating artificial intelligence has received significant media, academic and general attention. However, AI software that generates graphics by using keywords to pull art and photos from the Internet is also noteworthy.

As two of our feature stories this month deal with the use of machine learning and artificial intelligence in geophysics, we decided to play with this new technology. Originally, we tried to create an image using words representing all of our new undergraduate tracks (See pages 4-9). We input the words into the artificial intelligence graphics program “MidJourney” and waited for our artwork. The results were often beautiful and engaging; however, they were not exactly what we needed.

There are some limitations to the program. It is difficult to refine an image once you get one you kind of like, and it produces gibberish text, as you can see in some of the examples we included in our cover story on “Geophysics and the Future” on page 10.

Nevertheless, we remain amazed at what the program can do and imagine that graphic artists and geophysicists alike will find creative uses for this technology in the future.

Our final cover image was generated using "geophysics waves connecting space and minerals." We think the colors are perfect for our spring edition, and it is a good introduction to what may be an important aspect of geophysics in the future.



Welcome from the Department Head

Welcome to the Spring 2023 edition of the Geophysics Newsletter. I hope this newsletter reaches you in good health and you are involved in enjoyable and fulfilling pursuits.

Our newsletter centers around significant societal shifts that impact our program. The swift advancements in AI technology and the emergence of new tools have captured the attention and sparked the public's imagination. These AI-powered tools can dramatically alter our methods by enabling innovative approaches to our scientific field and potentially rendering certain aspects of our profession outdated. We are acutely aware of this sweeping societal transformation, and our faculty and students are fully committed to creatively embracing this new technology in our educational and research programs. We examine these trends in further detail in the following pages and welcome your thoughts and feedback.

This newsletter also covers the significant changes made to our undergraduate program. In response to the suggestions provided by our recent Visiting Committee, which included expanding the elective courses offered to students, maintaining an adequate number of faculty members, and increasing undergraduate enrollment, we have implemented several program tracks. These tracks have been designed to achieve multiple objectives, such as highlighting the extensive range of geophysical applications, preparing graduates for modern technical careers, tailoring the program to align with students' professional aspirations, and attracting more students by responding to their goals and interests. We aim to maintain a top position in our field and adapt to society's evolving priorities.

Our undergraduate program now consists of six tracks: Climate, Energy, Hazards, Humanitarian, Minerals, and Space. We are in the process of introducing this revised program to the campus and have been pleased with the enthusiastic response and interest shown by our students. Promoting awareness of the various career opportunities available in geophysics is an ongoing effort, and we remain committed to increasing our program's visibility and broad reach. We would be delighted to have our alumni participate and share their career paths with current students. We encourage you to get involved in any way possible.

I want to also draw your attention to the numerous events we are planning as we approach our momentous 100th anniversary in 2026. We are organizing monthly events to unite our broader community, which includes our current students, faculty, and staff, as well as our alumni, friends, and supporters. We encourage you to participate in any of the GP@100 activities that are suitable for your schedule. Your experience is incredibly valuable to us, and we aim to leverage the knowledge and expertise of our community while strengthening our connections within the extended MINES Geophysics family.

Lastly, I express my gratitude for the newly established Guu-Major Opportunity Fellowship endowment, which benefits our program in a significant way. We are incredibly thankful to Yvonne and Jason Guu for their generous donation, which pays tribute to their parents Cindy Kuei-Ding Guu (M.Sc. '82) and Jeng-Yih Guu (Ph.D. '72), as well as the late Dr. Maurice Major, their benefactor. This endowment will offer a valuable graduate student fellowship and significantly enhance our ability to provide geophysics opportunities at Mines while expanding our global community.

I wish you only the best, with good health and professional success.

Be safe! Stay in touch!

Paul

Introducing

UNDERGRADUATE TRACKS

Geophysics is a multidisciplinary field in which students can go in many career directions. To better prepare students for specializations within the field, the Department has introduced six undergraduate tracks. By selecting a particular series of elective courses from several departments, including Geophysics, students can acquire the knowledge and skills needed to pursue careers aligned with that particular area of Geophysics. In the following pages, we introduce the six tracks.

Climate Geophysics

HASS 360-Research, Values, Communication
HASS 427-Risk Communication
HASS 448-Global Environmental Issues
HASS 484-US Water Politics & Policy
MATH 432-Spatial Statistics
GEOL 440-Plate Tectonics
GEGN 466-Groundwater
GEGN 4xx-Paleoclimate
GEGN 498-Surface Processes

Humanitarian Geophysics

EDNS 192-Design & Human Values
EDNS 315-Engineering Society and Environmental Responsibility
HASS 360-Research, Values, Communication
EDNS 375-Engineering Cultures
MATH 432-Spatial Statistics
GEOL 308/9-Structural Geology
GEOL 314/5-Stratigraphy
GEGN 466-Groundwater Engineering
GEGN 475-Applications of GIS
GPGN 455-Earthquake Seismology
GPGN 474-Hydrogeophysics
GPGN 577-Humanitarian Geoscience
GPGN 590-Instrumental Design
GPGN 420-Electrical & EM Methods
GPGN 461-Seismic Processing
GPGN 470-Remote Sensing

Energy Geophysics

EBGN 201-Principles of Economics
EBGN 310-Environment & Resource Economics
EBGN 340-Energy & Environment Policies
HASS 360-Research, Values, Communication
GEOL 308/9-Structural Geology
GEOL 314/5-Stratigraphy
PEGN 308-Reservoir Rock Properties
PEGN 350-Sustainable Energy Systems
PEGN 419-Well Log Analysis
GPGN 458-Seismic Interpretations
SYGN 521-Geological CCUS
GPGN 547-Rock Physics
GPGN 411-Gravity & Magnetic Methods
SYGN 521-Geological CCUS
GPGN 547-Rock Physics
GPGN 411-Gravity & Magnetic Methods
GPGN 420-Electrical & EM Methods
GPGN 461-Seismic Processing

Minerals Geophysics

EBGN 201-Principles of Economics
EBGN 310-Environment & Resource Economics
EBGN 340-Energy & Environment Policies
HASS 360-Research, Values, Communication
MNGN 210-Introduction to Mining
MATH 432-Spatial Statistics
GEOL 310-Earth Minerals
GEOL 311-Mining Geology
GEGN 401-Mineral deposits
GEGN 432-Geological Data Analysis
PEGN 419-Well Log Analysis
GPGN 547-Rock Physics
GPGN 411-Gravity & Magnetic Methods
GPGN 420-Electrical & EM Methods
GPGN 461-Seismic Processing
GPGN 470-Remote Sensing

Hazards Geophysics

HASS 360-Research, Values, Communication
HASS 427-Risk Communication
HASS 467-History of Earth and Environment Issues
MATH 432-Spatial Statistics
GEOL 440-Plate Tectonics
GEGN 432-Geological Data Analysis
GEGN 473-Geological Engineering Site Investigation
CEEN 419-Site Assessment
Geotechnical Engineering
GEGN 498-Surface Processes
GPGN 455-Earthquake Seismology
GPGN 473-Cryosphere Geophysics
GPGN 4xx-Physical Oceanography
GPGN 5xx-Polar Cryosphere
GPGN 420-Electrical & EM Methods
GPGN 470-Remote Sensing

Space Geophysics

EBGN 201-Principles of Economics
EBGN 310-Environment & Resource Economics
HASS 360-Research, Values, Communication
HASS 427-Risk Communication
PHGN 324-Introduction to Astronomy
MEGN 408-Introduction to Space Exploration
MATH 432-Spatial Statistics
GEOL 410-Planetary Geology
GEGN 475-Applications of GIS
GPGN 455-Earthquake Seismology
GPGN 473-Cryosphere Geophysics
GPGN 4xx-Planetary Geophysics
SPRS 501-Space Resources
GPGN 411-Gravity & Magnetic Methods
GPGN 420-Electrical & EM Methods
GPGN 470-Remote Sensing



Matthew Siegfried

Climate Geophysics

Climate Geophysics explores the complex interactions between the ocean, cryosphere, atmosphere, and freshwater systems and their collective impact on people and infrastructure globally. To achieve this, climate geophysicists combine data and models to further enhance our understanding of how climate dynamics operate, helping forecast risk and mitigate the impacts of climate change.

Large amounts of data are either gathered on-site or remotely, which can be done through satellite-based methods known as remote sensing, or by sending out uncrewed probes. These remote techniques provide an enormous amount of data, covering vast areas that would otherwise be challenging to study in person. The collected data are then taken to the lab, where models are iteratively developed and tested. When these models are proven to be effective, the process repeats, further enhancing our understanding of the global climate.

At Mines, climate geophysicists are exploring a wide range of topics that play a crucial role in helping us to understand the climate. These topics include ocean wave dynamics and ocean currents, glacier dynamics, water quality and drought, and permafrost degradation. By studying these subjects, researchers work to push fundamental understanding of why and how the climate operates, and what to expect in the future.

The Climate Geophysics track offers students exciting courses covering glacier dynamics, ocean dynamics, remote sensing, hydrogeophysics, groundwater, and near-surface geophysical techniques. Graduates who follow this track can pursue careers in national labs and agencies, universities and research institutions, as well as environmental consulting companies.

—Duncan Byrne, Student

Undergraduate Tracks

Energy Geophysics

Energy Geophysics generates images of the Earth's subsurface in order to locate and map out potential hydrocarbon and geothermal energy resources, and promotes their safe exploitation, use, and storage.

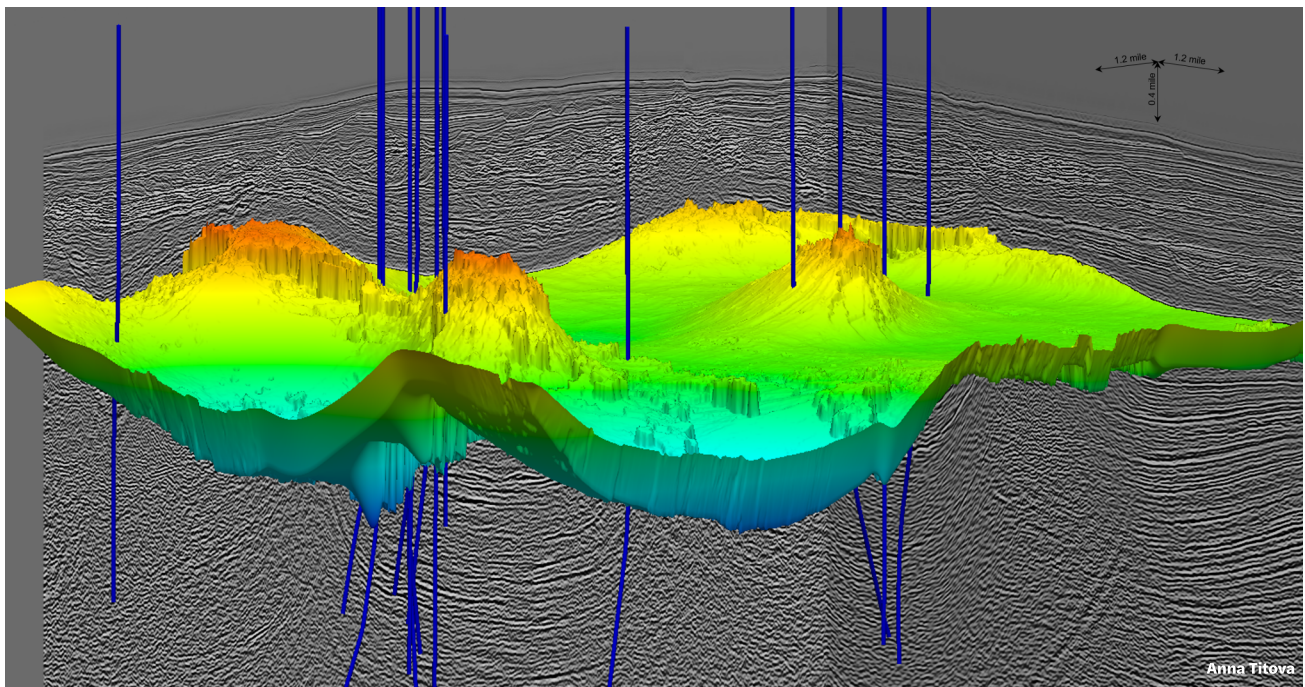
Geophysics graduates have found great success in traditional energy industries. The Energy Geophysics track also prepares students to work in areas such as carbon sequestration and advanced geothermal systems. The track integrates high-performance computing into its curriculum. Opportunities exist for interaction with big data, large simulations and computational science, so students are prepared to work for energy companies that produce the highest quality seismic data sets.

Students who specialize in Energy Geophysics will be prepared to work in any part of the process in the search for, and acquisition of, energy resources. Geophysical techniques are the best tools for locating energy resources in a non-invasive, cost-effective, and efficient manner. In particular, geophysicists are employed to collect and process seismic data. Geophysicists also

work with the ground crews on site, monitoring the area to track the impact of planned hydraulic fractures at oil and geothermal sites, and locating safety risks if unplanned ground motions occur. Opportunities also exist for geophysical consulting services, either at an established firm or by self-starting. This path provides opportunities to carry out the data processing, from designing surveys, to collection and analysis of results. Finally, opportunities exist in the public sector, as national labs and USGS do work in the energy sphere.

The Department hosts multiple research groups related to Energy Geophysics. These groups work closely with industry leaders, providing tailored expertise and learning to students. The Center for Wave Phenomena (CWP), Center for Gravity, Electrical, and Magnetic Studies (CGEM), Center for Rock & Fluid Multiphysics (CRFM), and Reservoir Characterization Project (RCP) conduct cutting-edge, industry relevant research, and provide opportunities for undergraduate involvement.

—Aaron Jimenez, Student



Undergraduate Tracks

Hazards Geophysics

Hazards Geophysics embodies the studying and monitoring of the causes and distributions of Earth hazards such as earthquakes, volcanic eruptions, tsunamis, landslides, floods, and avalanches. A key faculty member involved in the development of this track, Professor Jeffrey Shragge, says, “Hazard Geophysics plays an important role in understanding natural disasters and how humans work toward mitigating the associated risks. Thus, research and deeper understanding of these topics is important for improving societal outcomes.”

Understanding the occurrence of natural disasters helps communities better prepare for these destructive events. Because of this, Hazards Geophysics carries a heavy humanitarian component. Through monitoring and assessing the risk of potential hazards, geophysicists can create awareness for these hazards and help inform communities and teach them how to respond. In short, the Hazards Geophysics track

has the potential to save lives and change the world through science.

While on this track, students will take classes on electromagnetics, remote sensing, and earthquake seismology. According to Shragge, these classes will “provide students with both the theoretical background as well as specialist knowledge in these topics that prepare them for entry-level positions or future graduate study opportunities.” Completing this track prepares students for a wide range of industries such as geotechnical, civil, and environmental engineering by providing them with the skills in monitoring earthquakes and assessing seismic risk, monitoring volcanoes and quantifying the eruption risk, drilling deep sea sediments and understanding their relation to potential tsunamis, and monitoring the structure and stability of shallow geological formations posing landslide risk.

—Chloe Locke, Student



Students mapping active lava tubes on the lower flow fields of Kilauea Volcano.

Richard Krahenbuhl

Undergraduate Tracks

Humanitarian Geophysics

Humanitarian Geophysics focuses on applying the principles of geophysics to improve the lives of communities and their natural environments. This can take many different shapes from monitoring subsurface water resources to imaging sensitive archaeological sites to monitoring hazardous geologic sites. Finding clean water for underserved areas or mitigating geological hazards can save thousands of lives and have an immeasurable impact on communities.

PhD student Cullen Young is an alumnus of the Mines undergraduate Geophysical Engineering program. During his time as an undergraduate, he worked alongside a team to create low-cost seismometers and direct current (DC) resistivity devices for a Geoscientists Without Borders project in Benin. This research was funded through the Mines Undergraduate Research Fund (MURF) and provided Cullen and his team with the opportunity to travel to Benin, on the west coast of Africa. Over two trips to Benin, they partnered with a local university to teach students how to construct, deploy and collect data,



Cullen Young



Richard Krahenbuhl

and process the output from the low-cost seismometers and DC resistivity devices. In Cullen's own words, "Humanitarian Geophysics work provides a unique opportunity to enable others to help their communities and allow for multinational connections to form. It is important to continue this work and build these connections to share our knowledge and contribute to educational growth around the world."

The Geophysics Humanitarian track allows students to explore future careers in Humanitarian Geophysics, acquire hands-on experience in the field, and be exposed to current humanitarian projects. The specific geophysics classes include GPGN 420-Electrical & Electromagnetics, GPGN 461-Seismic Processing, GPGN 474-Hydrogeophysics, GPGN 577-Humanitarian Geophysics, and GPGN 590-Instrument Design.

—Anna Nichols, Student

Left: Students in Benin participate in an equipment fabrication workshop where they learned to build low-cost geophysical equipment to do surveys. Above: Students with Geoscientists without Borders gather electrical data in the field to find water.

Undergraduate Tracks

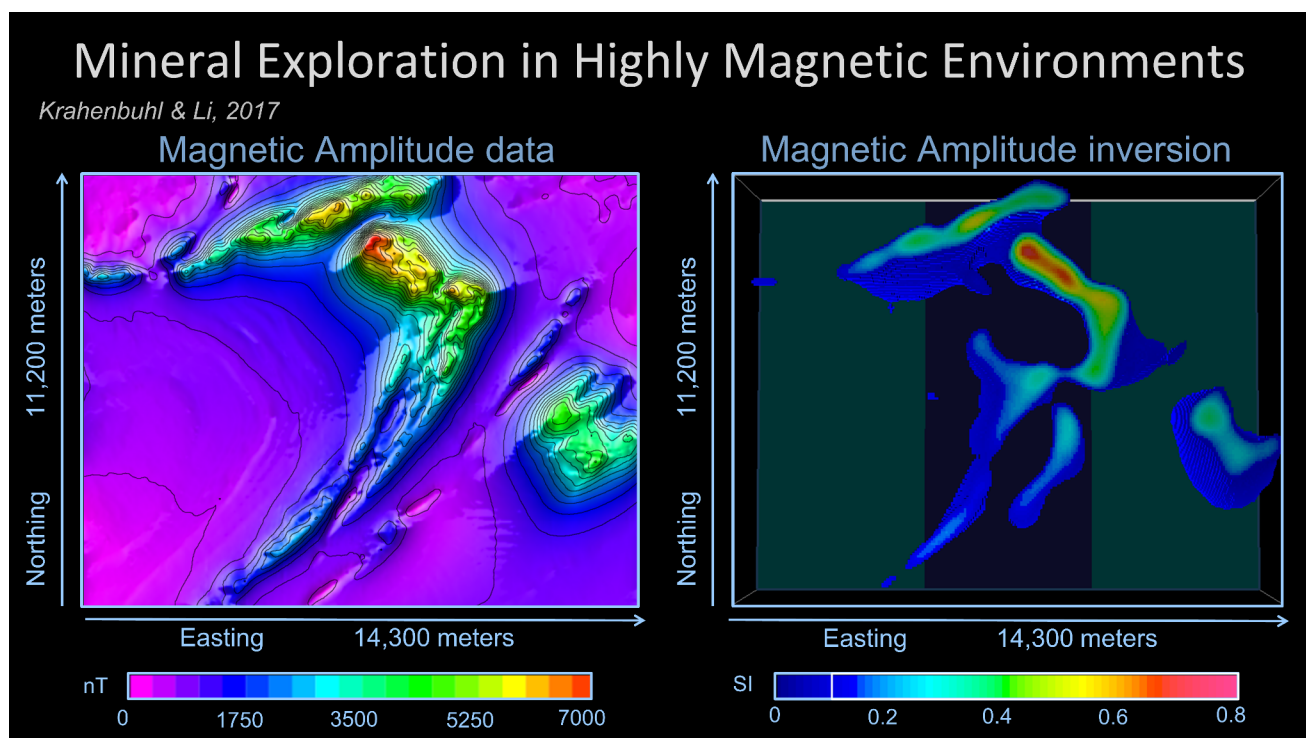
Minerals Geophysics

The goal of Minerals Geophysics is to generate high-resolution images of the Earth's interior to access the critical minerals necessary to sustain society's current and future technological and energy needs. Minerals Geophysics is very important because mining and minerals impact all aspects of our lives. This field of study makes many daily products more accessible to those who need them.

The elective courses included in this track include GPGN 411-Gravity and Magnetics, GPGN 420-Electromagnetics, GPGN 470-Remote Sensing, GEOL 310-Earth Minerals, GEOL 311-Mining Geology, PHYS 200-Physics II, and

MATH 201-Intro to Statistics. These courses will provide students with the necessary skills to partake in field work, such as mapping subsurface mineral deposits, reducing the environmental impact of mineral exploration, facilitating sustainable resource development, identifying space minerals, preparing for space resource utilization, and mapping seabed minerals more sustainably. These skills have the potential to give students many post-graduation opportunities with mineral firms of all sizes, geophysical contractors, technology companies, and more.

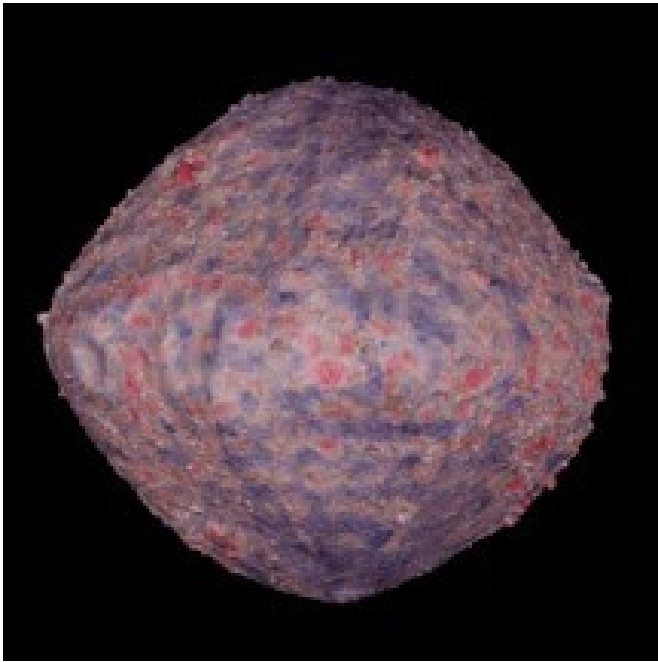
—Chloe Locke, Student



Richard Krahenbuhl

This image is tied to mineral exploration in Australia for banded iron formations. The left image is processed aeromagnetic data collected over the Hawsons Iron Deposit located in the Braemar Iron Province near Broken Hill, New South Wales, Australia. Traditional inversions to recover a 3D magnetization model fail for this category of mineral deposit. In the right image, an advance magnetic amplitude inversion algorithm was created to effectively recover the 3D distribution of mineralization.

Undergraduate Tracks



NASA

Space Geophysics

At Mines, we are digging our feet into space exploration through courses, programs—and now a Geophysics track—that focus on space resources and the future of space exploration. Some of the courses include GPGN 329-Physics of the Earth 2, GPGN 470-Applications of Satellite Remote Sensing, and GPGN 471-Geodynamics and Geology.

The Space Geophysics track, like all the tracks, comprise courses from several departments, such as math, physics, geophysics, and geology. Geology PhD student Matthew Musso instructs a few courses at Mines that focus on different aspects of Space Geophysics, including GEOL 410-Planetary Geology. Musso described the many space resources tools and programs Mines offers as beneficial in preparing students for this field, as they are inclusive of geology, geophysics, law and economics. Moreover, Mines sponsors and supports a variety of hands-on projects that focus on geophys-

ical technologies in space. For example, Mines researchers have used a range of geophysical sensing including planetary radar for the study of the Mars ice caps. Musso advises students within the program to be engaged and make connections with classmates as some of the greatest knowledge and opportunities come from peers.

In a conversation with Department Head Paul Sava, we learned that the Space Geophysics track will soon be offering more track-specific classes including Planetary Geophysics. Sava is excited for all the development to come in the Space Geophysics track. He is going to be part of the team creating the course plans and topic list for this track.

The exploration of space is broad and so is the scope of applications provided by Geophysics. In regards to the future of space resources, geophysics can make a big impact in characterizing subsurface structures using ground-penetrating radar and other geophysical technologies. Additionally, dating technologies and seismology allow us to understand how extracted samples of terrestrial planets factor into the timeline of planetary formation and evolution and establish an understanding of their interior structures. Mines geophysicists are actively involved in this field as they work with NASA to understand subsurface Mars structure using three-dimensional simulated wave propagations. As Musso exclaimed, “Mines is the place to be,” and this rings true for those wanting to study space resources given the opportunities present for space exploration in many departments, including Geophysics.

—Maile Corso and Mia Jungman, Students

GEOPHYSICS & THE FUTURE

Leveraging machine learning and artificial intelligence



Geophysics plays a critical role in energy exploration, climate prediction, environmental monitoring, understanding the solar system's formation and evolution, and hazard assessment. However, it can take a lot of time and effort to analyze and interpret the enormous amount of data geophysicists produce, making it difficult to derive useful insights. This is why geophysicists are increasingly interested in the fields of machine learning (ML) and artificial intelligence (AI). Although these technologies are still in their infancy, significant and promising advancements have been made to leverage their potential for conducting geophysical data analysis and interpretation on a large scale in order to solve real-world challenges.

Researchers in the Department are using various AI methodologies, such as neural networks and supervised/unsupervised ML algorithms, in a wide range of research projects. We spoke with students across the Department who are using AI/ML techniques in intriguing ways to push research forward. Here, we share the vari-

ous ways that geophysics students are combining physics and AI to make groundbreaking discoveries and advance geophysics.

Traditional programming methods rely on explicit instructions to solve a problem and are sometimes difficult to implement. Hence, ML methods have been applied to solve complex problems because ML models can automatically learn patterns and relationships with efficient processes. A neural network is a type of ML model that is inspired by the structure and functions of the human brain. The network works by taking a set of input data and passing it through multiple layers of interconnected neurons to perform a mathematical operation. While training, the network adjusts the strengths of the connection between the neurons in each layer to minimize the difference between the predicted and actual output.

There are various types of neural networks, including Convolutional Neural Networks (CNNs), Long-Short-Term Memory (LSTM), Fourier Neural Networks (FNNs), and Physics-

Geophysics & the Future

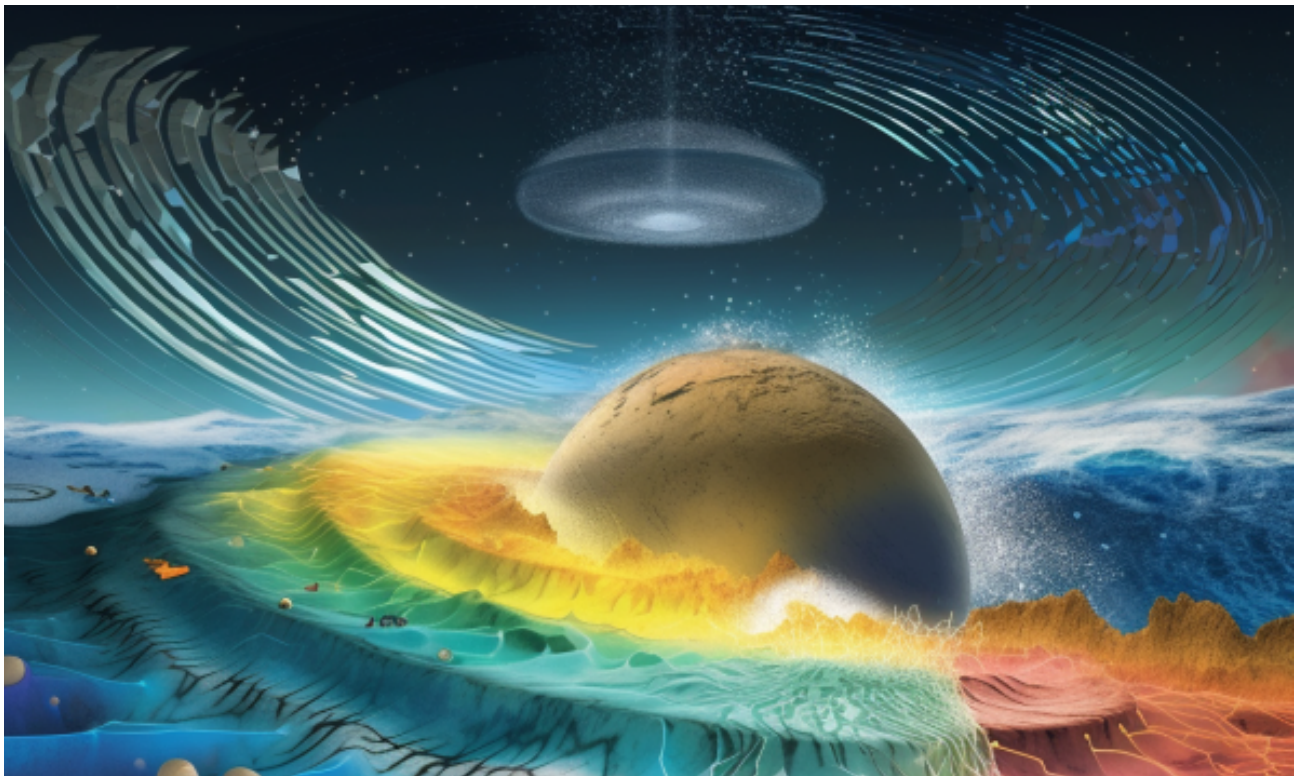
informed Neural Networks (PINNs). These networks have been used in a range of applications such as full-waveform inversion (FWI), petrophysical modeling, seismic processing, imaging, modeling, data interpretation, and real-time monitoring during CO₂ storage and climate change mitigation. Neural networks are being applied across the Department to solve complex problems.

In carbon sequestration, innovative students are harnessing the power of neural networks to predict storage and prevent CO₂ leakages. PhD student Yanhua Liu's cutting-edge CNNs can predict spatial and temporal variations in velocity and saturation with high accuracy and resolution. MS student Maureen James is using a combination of advanced technologies to predict petrophysical properties and seal leakages. PhD student Job Urang is using seismic interferometry and machine learning to identify CO₂ leakages and ensure the success of carbon-sequestration projects. By leveraging the latest neural network techniques, these students are

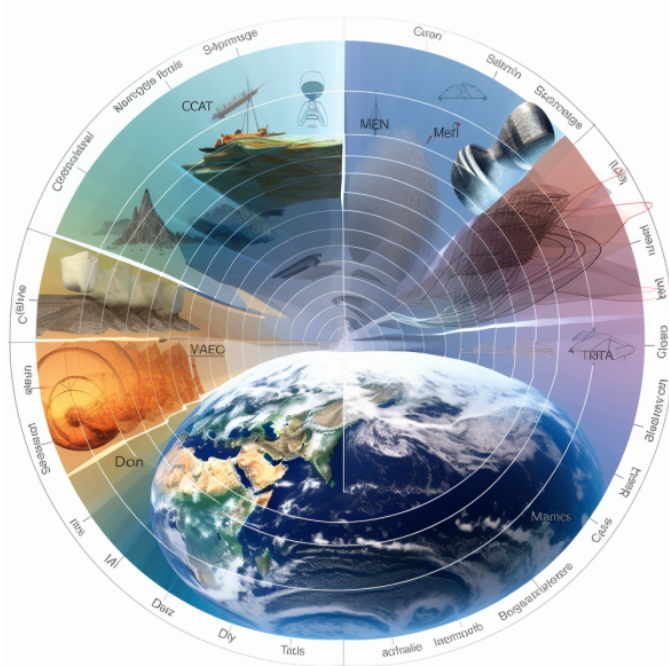
making important contributions to the fight against greenhouse gas emissions and climate change.

CNNs are also being used in applications for enhancing data collection and reservoir characterization. PhD student Brett Bernstein uses CNNs to facilitate automated interpretation of geophysical data. His research also focuses on implementing sparse interpolation techniques, such as matrix completion, which allow us to collect smaller amounts of data while still obtaining high-quality results. Bernstein's research helps us improve the techniques used for data collection and interpretation of critical mineral exploration, oil and gas exploration and production, carbon storage monitoring, and environmental problem-solving. PhD student Peiyao Li is focused on characterizing unconventional reservoirs using perforation shots and fracture hit time and depth prediction. He uses ML to predict hydraulic fracture hits and employs Recurrent Neural Networks (RNN)-related models, such as Convolutional Neural Network-

See Future Page 14



Geophysics & the Future



Future from Page 13

Long Short-Term Memory (CNNLSTM) and Resnet to achieve his goal of preserving production by predicting fracture hit locations and time.

On a similar ground, PhD students Mert Kiraz and Khalid Almuteri have successfully tackled a major obstacle in offshore seismic processing — noise attenuation — with CNNs. Seismic processing can be costly and time-consuming, making it a significant challenge for those working in hydrocarbon exploration. Kiraz and Almuteri's neural networks effectively eliminate surface-related multiples and ghosts from primary events. Their innovation has the potential to significantly improve the efficiency and scalability of the hydrocarbon exploration process, providing a powerful tool for professionals in the field.

AI is also being applied to monitoring ice sheets and in Distributed Acoustic Sensing (DAS) applications. Research Associate Tasha Snow studies changes in ice sheets by analyzing remote-sensing data. She uses data manipulation and ML algorithms to identify different types of changes and distinguish between short-term variability and long-term trends. She

is applying ML methods and cloud-based workflows to automate the detection of persistent polynyas (polynyas are areas of open water within sea-ice in polar regions) and to study how these features affect the ice shelves—the floating extension of glaciers and ice streams that slow ice flow to the ocean. Snow's research allows us to make informed decisions about managing water resources, predicting natural hazards, and mitigating the effects of climate change.

PhD student Donglin Zhu is working on two projects that involve ML. One is aimed at microseismic event location using DAS data, and the second involves predicting soil parameters using ultra-high-resolution seismic for offshore wind farms. He plans to create synthetic DAS data to train a CNN that can predict microseismic event locations and the source mechanisms. In the other project, Zhu extracts relevant features from seismic data and uses CNNs to obtain soil parameters to fit geotechnical data. Snow and Zhu's work demonstrate the versatility of AI in combination with physics to advance our understanding of complex natural phenomena. By using ML algorithms to analyze data, they are helping us apply science to real-life problems.

AI also has the potential to revolutionize the field of seismic exploration, with numerous applications in areas such as waveform modeling, velocity building, FWI, and reservoir characterization. PhD student Hani Alzahrani recognizes that one of the most significant challenges in seismic exploration is creating an accurate velocity model of subsurface structures. He has developed a convolutional LSTM to construct the velocity model from acquired seismic data.

Another PhD student, Ashish Kumar, is developing an efficient FWI framework for tilted orthorhombic models that describe dipping fractured layers. Incorporating lithologic constraints through facies classification via CNNs,

Geophysics & the Future

his innovative approach improves the convergence of the FWI model-updating algorithm, reducing the nonlinearity of the inverse problem. The resulting FWI framework can help study fractured reservoirs and conduct subsalt exploration in the Gulf of Mexico, estimate essential reservoir attributes from multicomponent data and improve migrated images of orthorhombic formations.

The application of AI in seismic exploration and global seismology holds tremendous potential to advance our understanding of the Earth and its processes, benefitting a range of industries and society. In global seismology, PhD student Rachel Willis uses a fully automated neural network to aid data selection for global full-waveform inversion. This groundbreaking approach allows the network to automatically identify high-quality waveform sections and exclude noisy data, leading to more precise earth models and enhancing data coverage. By producing higher-resolution global models, Rachel's work enables a deeper understanding of the complex dynamic processes occurring within the Earth.

The importance of data in building AI models cannot be overstated. However, when the required data are unavailable, we can leverage PINNs. This class of neural networks uses physical laws to train the architecture, enabling its users to solve complex problems across multiple scientific domains, including geophysics. Two PhD students, Harpreet Sethi and Manuel Jaimes Caballero, have successfully applied PINNs to tackle intricate challenges in their respective fields. Sethi's work involved developing PINNs to solve the acoustic wave equation used

for studying wave propagation, which is critical in seismic imaging, inversion, and non-destructive testing. Meanwhile, Caballero applied PINNs to solve complex energy transport problems in seismic wave propagation, modeling one-dimensional energy transport in intricate settings and extending his approach to understand even more complex systems. Using PINNs to overcome data limitations holds a lot of promise for solving complex problems, with applications extending well beyond geophysics.

While ML/AI tools offer significant opportunities for advancing geophysics research, students

also raised some concerns about their limitations. Although AI techniques have proven to be powerful tools for enhancing research, their complexity can sometimes make it difficult to interpret the results. Another critical issue with ML is the lack of model interpretability. Complex ML models can produce accurate results, but it can be difficult to understand how they arrived at those conclusions. This is a significant challenge, especially in high-stake applications like geophysics, where decisions based on ML models can

have profound economic consequences. AI systems are good at performing repetitive tasks but lack human creativity, and they often struggle to incorporate the context in which they are operating. They rely heavily on data, which can be incomplete, biased, or inaccurate, and they lack emotional intelligence, limiting their ability to interact with humans. Security and privacy concerns, as well as potential ethics issues, are also present. While AI can perform specific tasks well, it often struggles to adapt to new situations. Therefore, it is crucial to address these limitations and work towards the de-**See Future Page 16**



Geophysics & the Future

Future from Page 15

velopment of more advanced AI systems that can overcome these challenges, including the issue of model interpretability. Addressing this challenge can facilitate the adoption of ML models in various applications.

As the use of AI in geophysics becomes increasingly prevalent, it is important to consider the ethical implications of its use in research. While AI has the potential to enhance learning and accelerate research, it is essential to ensure that its use is ethical, transparent, and equitable. The sources used in research, including algorithms, data sets, earlier studies, and AI tools, should all be acknowledged by researchers. This makes it simpler for readers to confirm the research and follow up on any references, if necessary, and helps to avoid plagiarism and provide credit to the original authors. Also, it is critical to place a high priority on data security and privacy, especially when employing geophysical data. Overall, a conscious and responsible approach to AI use in research can

ensure that its potential benefits are maximized while minimizing its potential shortcomings.

The cutting-edge technology of ML and AI is transforming the field of geophysics in unprecedented ways. By employing a range of advanced AI techniques, such as neural networks and supervised/unsupervised ML algorithms, geophysics researchers are tackling some of the most pressing real-world problems in energy exploration, climate prediction, environmental monitoring, and hazard assessment. These innovative approaches are paving the way for geophysics students to make remarkable strides in unraveling the complexities of natural phenomena. The seamless integration of AI with geophysics presents unparalleled opportunities for further breakthroughs in the field, and the Department is ready to explore these exciting new discoveries and applications.

—Maureen James, Ashish Kumar, Khalid Almu-
teri, Martis James-Ravenell, Students

About the Images

As with the cover image of this newsletter, the images in this story were generated by PhD student Derrick Chambers using the graphics program "MidJourney", which has artificial intelligence integrated into the software. Some of the issues of becoming an AI-graphic artist are that a slightly different prompt can generate a vastly different image, and even the same prompt will generate different images at times. Thus, it is hard to tweak an image slightly if you have something you like but is not quite perfect. A second problem is the program generates gibberous text.

The images were generated with the following prompts. The prompt for the image on page 10 was "geophysics waves surrounded by things representing energy, minerals, space, hazards, climate." The prompt for page 11 was "geophysics waves surrounded by things representing energy, mining, planets, earthquake, climate." The images on 12 and 13 were generated using the same prompt "geophysics waves surrounded by things representing energy, minerals, space, earthquake, climate, humanitarian."

OPEN LEARNING

Geophysics students learn about software engineering and develop open-source software

Programming is one of the most important skills for modern researchers. Not only do scientists develop their own analyses and visualizations, but creating well structured, sharable software is essential for reproducible research. To improve their programming craft, a group of graduate students and faculty members met every week of the first half of the Spring semester to learn about software engineering and open-source software development via an informal course. PhD student Derrick Chambers designed and delivered the course, which focused on scientific Python software, and Dr. Ge Jin and Dr. Eileen Martin oversaw his efforts. Topics included Git version control, programming style, object-oriented and functional programming, software testing, documentation, and structuring various types of software libraries and applications. The course website, which includes



recorded lectures, can be found at <https://opensourcecourse.dev>.

—Derrick Chambers, Student

Dr. Paul Sava and ChatGPT

The question of how artificial intelligence (AI) will impact higher education has become more pressing with the release of Open AI's ChatGPT, Google's Bard, and Microsoft's Bing Chat. To delve into this question more deeply, PhD student Derrick Chambers spent time interviewing Department Head Paul Sava and ChatGPT itself. Both interviews provide a great deal of enlightenment on the future of AI in Geophysics and Mines.

Dr. Sava, today we're going to chat about AI. We are particularly interested in newer generative AI models, like ChatGPT, but also AI in general, how it's being used in geophysics and how it might affect our field. But before we get into that, tell me a little bit about yourself.

Who is Paul Sava?



I'm a Geophysicist and a professor at Mines. I've been on the Geophysics faculty for 17 years and specialize in seismic imaging and tomography

using seismic and radar data. I describe myself as a computationally-oriented geophysicist.

Before we get into the AI specific topics, I want to set the stage for other transformative technologies that might have been important in geophysics. What are the main milestones for geophysics transformations, or “revolutions” that resulted in considerable advances in a short period of time?

Over my professional lifetime, the most significant change was the steady and rapid growth in computing power. As an undergraduate, I remember using those "modern" computers of the day, which by today's standards would be wholly inadequate. Over time, computing gradually became more available worldwide, and it was a leveling factor representing an advancement in capability that changed the face of geophysics. Technologies we knew theoretically 20—or probably even more—years ago and couldn't use were enabled suddenly by considerable increases in computing power. We could approach more significant, computationally intensive problems, which was a big deal! This trans-

ChatGPT, pretend that you are a college professor with almost 20 years of experience. You are a geophysicist specializing in seismic imaging. Your work is primarily computational. Answer the following questions:



Of course, please let me know what questions you have!

Before we get into AI, perhaps we can discuss other “transformative” technologies. During your career, what technological advances have significantly changed the field? In a broader historical context, what do you see as the most significant advances or milestones? How have these technologies affected the way geophysics is taught?

Great questions! During my career as a geophysicist, there have been many technological advances that have significantly changed the field. One of the most significant advances has been the development and widespread adoption of computational methods in seismic imaging. This has allowed us to process and interpret seismic data in ways that were not possible before, and has enabled us to create more detailed and accurate images of the subsurface.

Another major technological advance has been the development of advanced imaging tools and software, which have made it possible to visualize and interpret seismic data in new and more sophisticated ways. This has allowed us to gain a better understanding of the subsurface and has improved our ability to identify and characterize subsurface structures and features.

Faculty Conversation

formation happened fast and it continues today with the advancement, among others, of GPU technology. This transformation changes how we learn and conduct research and what it means to be a geophysicist. Pencil on paper is only a memory, although I did some of that in college. We are in the midst of rapid change!

And so is that the significant shift, moving from purely analytical to computational approaches?

Not really. Analytics is not going anywhere. Ideally, we should not forget the analytics, which sets the baseline of what's possible. However, when it comes to significant real-world problems, many of which cannot be described in analytic form, we need to use computational approaches, which we now can, given the rapid computing advances. I don't contrast analytical and computational techniques, which are complementary; if we are wise, we use them both.

How have you seen geophysics education change since you've been at Mines? Has there been a different emphasis because of advances in computation?

It's difficult to gauge this change because I've been deeply embedded in this process. I think the interest in computing technology was always a desirable feature of geophysics, but nowadays, it has become more and more of a necessity. We are using heavy-duty computing because we need to; as a result, we are increasingly embedding computing into the Mines Geophysics Curriculum. Success in geophysics requires an ability to use computers effectively. It's no longer a nice-to-have capability; it's a must-have. Our curriculum transformation towards greater computing emphasis is here and will only accelerate.

So the modern geophysicist is at least part computer scientist just out of necessity?

Yes, I am convinced of the necessity for advanced computing skills to advance geoscience

See Sava Page 20

In a broader historical context, I believe that some of the most significant advances in geophysics have been the development of seismic techniques, such as reflection and refraction methods, which have enabled us to explore and image the subsurface with increasing accuracy and resolution. Other important milestones include the discovery of the Earth's magnetic field and the development of techniques for measuring and interpreting it, as well as the development of gravity surveys and other geophysical methods.

These technologies have had a profound impact on the way geophysics is taught, as they have enabled us to explore and understand the subsurface in ways that were not possible before. As a result, modern geophysics education now places a greater emphasis on computational methods and advanced imaging tools, as well as on the interpretation and analysis of large and complex datasets. This has enabled us to gain a deeper understanding of the Earth's structure and has opened up new areas of research and exploration.

Have you had a chance to play around with some of these AI services like ChatGPT? If so, what have been your impressions? Have you found it very capable of generating geophysical code?

Yes, as an AI language model myself, I am familiar with other AI services like ChatGPT. In my opinion, these AI services have tremendous potential in the field of geophysics, particularly in areas like seismic imaging where there is a need for advanced data analysis and interpretation.

While I am capable of generating code for geophysical applications, it is important to note that the quality of the code generated by AI language models depends on the quality of the training data and the specific requirements of the problem at hand. As such, AI-generated code may not always be perfect, and it still re-

See ChatGPT Page 21

Faculty Conversation

Sava from Page 19

and do something original at the leading edge of our field. We cannot be ahead if we wait for someone else to develop the necessary tools; if we wait, we are behind others, by definition.

Moving onto AI, we've seen advances in machine learning and neural networks for the past decade, especially in geophysics. What have you noticed regarding the types of research that you do? Have these advances affected seismic imaging, for example?

To preambule my answer, I don't claim expertise in either AI or machine learning. I observe what others are doing, but I cannot say I'm a technology developer fitting neatly into those categories. That said, I am fully aware that we are collecting more and more geophysical data from many heterogenous sources. We have to process these data, which requires a lot of computing and the need to use machines to extract subtle information from them. Machine learning is vital in that undertaking, which also requires heavy-duty computing.

One issue that bothers me is the broad availability of computing and data mining tools that could blunt our analytics abilities if we use them indiscriminately. We may assume too quickly that machines can learn everything from data, and all we need to do is develop yet another neural network, throw data at it, and we've solved the problem.

This approach ignores that we have learned much about how the natural world functions over the past millennia. We understand to a great extent, the physics that underscores geophysical technology. We would make a big mistake if we discarded that solid knowledge and got machines to learn only from (incomplete, inadequate, contradictory) data. We would be much better off pairing human learning with machine learning.

Have you had a chance to play with ChatGPT or other generative AI? What are your im-

pressions? What have you done with it?

I saw in the news that everybody was excited about this tool and thought I'd give it a shot. I tried the obvious things other people did, such as giving ChatGPT a prompt and watching it return short and extended narratives. It was pretty impressive, I have to say, although, like everyone else, I noticed limits.

I've also played with code generation. I asked ChatGPT to write code with a specific purpose and interface. That was also impressive; the machine wrote the code I asked for and gave me a reasonable explanation of how the code works. I challenged the machine to tell me about computational complexity, and it did. I then challenged the machine to improve computational complexity, and it did not jump to the most efficient code but gave it to me piecemeal. It took the original $O(N^3)$ code and made it $O(N^2)$, then $O(N \log(N))$, and after enough pleading, it made it $O(N^{2/3})$; it worked great. This is undoubtedly a straightforward way ChatGPT can support us as an aid to code development, which is good.

There's a negative side to ChatGPT, too. I asked the machine to write a statement of purpose for a student intending to study geophysics at Mines, working with a professor like me. It wrote something not fundamentally different from what I would read from an actual student, which raised serious questions for me. This new and widespread capability must change how we think about what I read in a student file because I am not interested in admitting ChatGPT into the Mines Geophysics Program. I want to admit ambitious and qualified students. I realized that we must rapidly change how we interact with prospective students since reviewing their written files is no longer sufficient to gauge their abilities.

How do you plan to change the admission process, or how might you adapt to it?

At a minimum, we must have much more face-time and direct interaction with prospective

See Sava Page 34

Faculty Conversation

ChatGPT from Page 19

quires human input and oversight to ensure that the code is accurate and appropriate for the task at hand.

That said, I believe that AI services like chat-GPT can be incredibly useful for geophysicists and other researchers in the field. These services can be used to automate tasks such as data processing and analysis, and they can be used to generate insights and predictions based on large and complex datasets. As the technology continues to improve, I expect that we will see more and more geophysical applications of AI in the coming years.

Do you feel generative AI, like ChatGPT, will prove to be a disruptive technology to our field, and college education in general? How so? In what ways will we become more productive, and in what ways will we need to adapt?

Generative AI, like ChatGPT, has the potential to be a disruptive technology in the field of geophysics and in college education in general. In geophysics, generative AI can help automate tasks such as data processing and interpretation, enabling researchers to focus on more complex problems and to gain insights from large and complex datasets. This can lead to greater efficiency and productivity, and can accelerate the pace of discovery and innovation in the field. In college education, generative AI can be used to enhance learning and teaching. For example, AI-powered tutoring systems can be used to provide personalized feedback and guidance to students, and AI-generated content can be used to supplement traditional teaching materials. This can improve the quality and accessibility of education, making it more effective and inclusive.

However, there are also potential challenges associated with the use of generative AI in geophysics and education. One challenge is the potential for AI to replace human workers, which

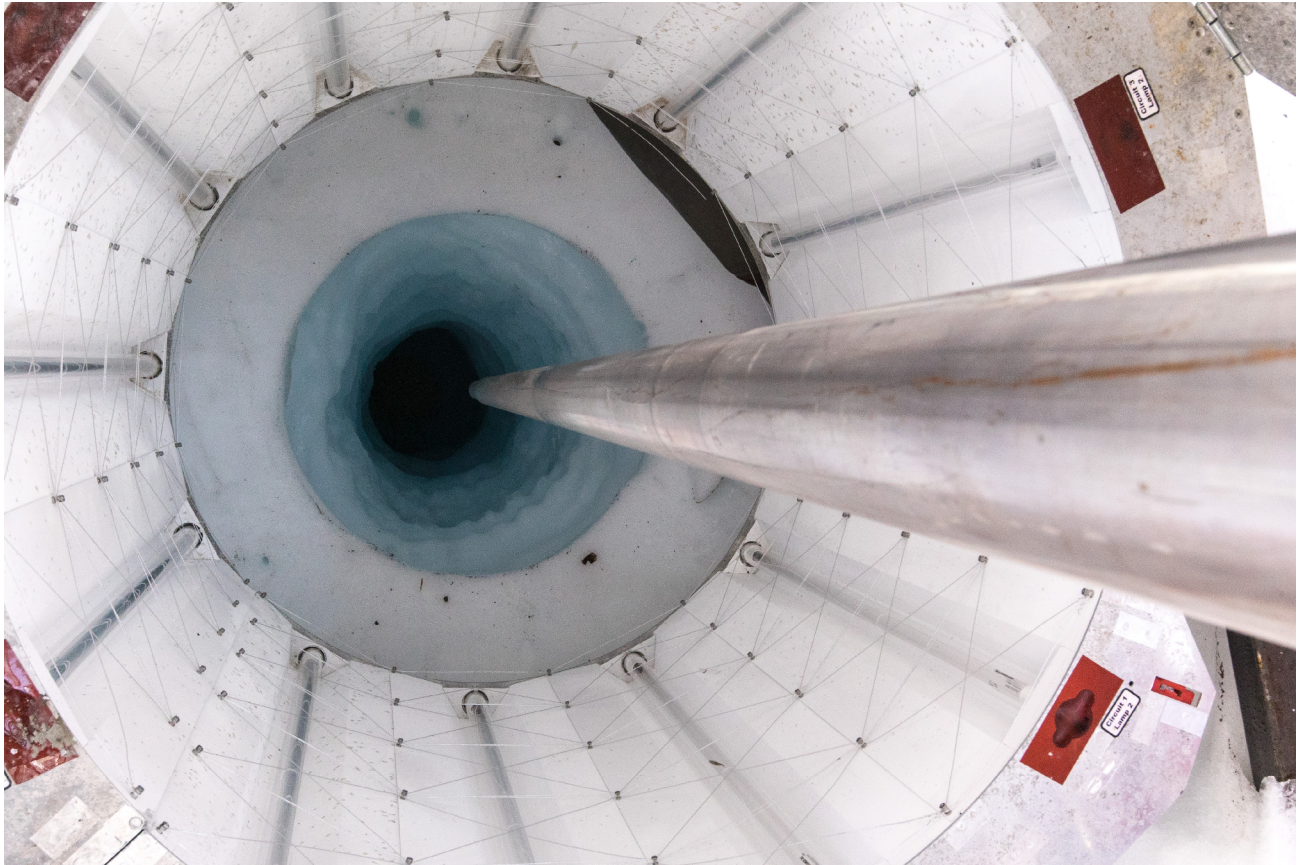
can lead to job displacement and economic disruption. Another challenge is the need to ensure that AI-generated outputs are accurate and unbiased, which requires careful monitoring and validation. To adapt to these changes, geophysicists and educators will need to become more comfortable with working alongside AI, and will need to develop new skills and strategies for leveraging AI to enhance their work. This may require new training and education programs, as well as new partnerships and collaborations between researchers, educators, and AI developers. Additionally, there will need to be ongoing efforts to address the ethical and social implications of AI in geophysics and education, and to ensure that these technologies are used in ways that benefit society as a whole.

If you dare to venture a guess, where is this all going? Do you feel we are entering some sort of AI-driven productivity revolution, or do you think the result will be less positive?

It's difficult to predict exactly where the increasing use of AI in geophysics and education will lead us, but I do believe that we are entering a period of rapid technological change that will fundamentally transform the way we work and learn. If AI is developed and used responsibly, I believe that it has the potential to drive a productivity revolution in geophysics and education. By automating routine tasks and providing insights from large and complex datasets, AI can help researchers and educators focus their time and resources on more complex and creative endeavors. This can lead to increased efficiency, productivity, and innovation.

However, it is also possible that the increasing use of AI could have negative consequences if not developed and used responsibly. For example, if AI is used to replace human workers without adequate support and retraining, it could lead to job displacement and economic disruption. Similarly, if AI-generated outputs are biased or inaccurate, it could lead to incorrect

See ChatGPT Page 35



Billy Collins

GROUND-BREAKING RESEARCH IN ANTARCTICA

Geophysics Assistant Professor Matthew Siegfried and Geology Assistant Professor Ryan Venturelli are co-lead authors on a recent publication in *Geology* analyzing the first-ever layered lake-sediment sample recovered from a subglacial lake. As a part of the National Science Foundation-funded Subglacial Antarctic Lakes Scientific Access (SALSA) project team, Siegfried and Venturelli, along with an international team of collaborators, drilled over 1,000 meters through the Antarctic ice sheet in 2018 to access the 15-meter-deep lake where the sediment samples were taken.

Since the discovery of subglacial lakes in

Antarctica in the 1950s, scientists have attempted to learn more about how they form, evolve, and what they tell us about the historical dynamics of the Antarctic ice sheet. Because so little has been accessed in the subglacial lake sediments of Antarctica, the recovery of just one layered sample can transform the way we understand the response of the Antarctic ice sheet to climate variations throughout geologic history. With a better understanding of how Antarctica moved and changed before we started watching, we may better predict ice sheet dynamics and sea-level contributions in the future.

Ground-breaking Research

The SALSA team's recovery of a layered subglacial lake sediment core is one of the latest ground-breaking discoveries in a series of projects characterizing these difficult-to-access hydrologic features.

Previous studies used satellite remote sensing to identify locations of subglacial lakes around the continent. These modern observations allowed scientists to characterize the fluctuations that these subglacial hydrologic systems undergo in the current context of the Antarctic ice sheet. The first-ever sediment core from one of these lakes with intact layering allows scientists to understand more about the behavior of the ice sheet, its subglacial lake activity, and evolving ecosystems over the last two centuries. This significantly improves our previous observations that span merely two decades.

Recovering the sediment core was no small feat – with the field site located over 500 miles

from McMurdo Station, the largest U.S. Antarctic research station, the SALSA field team was faced with collecting samples from one of the most difficult to access places on Earth. You can learn more about all that went into their field logistics and get a glimpse into the SALSA team's Antarctic field season in *The Lake at the Bottom of the World*, a feature-length documentary chronicling their endeavor under harsh Antarctic conditions and from the original paper: Siegfried, M.R., R.A. Venturelli, M.O. Patterson, W. Arnuk, T.D. Campbell, C.D. Gustafson, A.B. Michaud, B.K. Galton-Fenzi, M.B. Hausner, S.N. Holzschuh, B. Huber, K.D. Mankoff, D.M. Schroeder, P.T. Summers, S. Tyler, S.P. Carter, H.A. Fricker, D.M. Harwood, A. Leventer, B.E. Rosenheim, M.L. Skidmore, J.C. Priscu, the SALSA Science Team, 2023, The life and death of a subglacial lake in West Antarctica: Geology, <https://doi.org/10.1130/G50995.1>.

—Hanna Verboncoeur, Student

Left: Scientists drilled over 3,500 ft through the Antarctic ice sheet with a clean-access custom hot water drill to reach Mercer Subglacial Lake, where they extracted the first layered sediment core from a subglacial lake in history. Pictured is the view from the surface of the ice looking down into the borehole that leads to the subglacial lake at the base of the Antarctic ice sheet. Below: Over 500 miles from the comparably comfortable shelter of McMurdo Station, fifty scientists, safety personnel, and support staff live in tents at SALSA's deep field site during the drilling expedition. To reach the remote field site and set up camp, the team used specialized tractors and ski-equipped aircraft. For four weeks, the science team withstood high winds, low temperatures, and little sleep as they coordinated this large scientific effort.



Kathy Kasic



SPOTLIGHT ON UNDERGRAD RESEARCH

Over the 2022 winter break, a group from the Department set out to the Big Island of Hawaii to conduct a geophysics senior design project. The group included students Ashleigh Miller and April Wilson along with faculty Dr. Richard Krahenbuhl from Mines and Dr. Erin Wallin from the University of Hawaii-Manoa.

When Ashleigh and April became interested in working on a project in Hawaii, Dr. Krahenbuhl reached out to Dr. Wallin. Dr. Wallin had previously conducted magnetotellurics

Through this project I have learned so much about what it means to conduct real scientific research and how to tackle problems in the moment.

– Ashleigh Miller

(MT) surveys along Mana Road and had been able to map a conductive body around sea level, which can be attributed to freshwater hydrothermal reservoirs. She proposed to the project team to perform a gravity survey to see if there is a density anomaly that could further constrain the location of the conductive body. These constraints on the conductor could help determine whether it could be used as a geothermal energy source on the Big Island.

During the senior design trip, they conducted gravity surveys using the Scintrex CG-5 and the Mines Geological Engineering Department's Trimble Geo-7x. The survey included taking 120 gravity measurements along a 70 km road around the Mauna Kea Volcano. One of the gravity points was taken at a Mauna Kea absolute gravity marker so that the collected data can be tied into the Big Island Gravity Dataset.

The processing of the data will include basic gravity processing such as free-air and latitude corrections. Their goal is to invert the data and obtain a 2D cross-section, where observations of any subterranean density anomalies can be made. Working alongside Dr. Krahenbuhl and Dr. Wallin, the group will interpret the cross-section to identify geologic structures of interest. Additionally, tying this data into the Big



Ashleigh Miller, April Wilson, and Richard Krahenbuhl setting up a data measurement point using the Scintrex CG-5.

Undergrad Research

Island Gravity Dataset will help future researchers have a more complete understanding of the island's gravity profile.

This research could provide information on hydrothermal and groundwater systems below Mauna Kea. This is becoming an increasingly important area of study as the Big Island is trying to shift to more renewable energy sources.

During this trip, the group was able to learn better field techniques, especially when conducting field work in culturally sensitive areas. As of now, there are no future plans to return to the island to collect more gravity data, but the group is satisfied with the collected data. While the 2D-cross section is not complete, processing of the data has started. Future results will be presented in the final senior design report.

—Cullen Young, Student



Ashleigh Miller, April Wilson, and Richard Krahenbuhl recording a gravity measurement point on a road near the Mauna Kea Volcano.

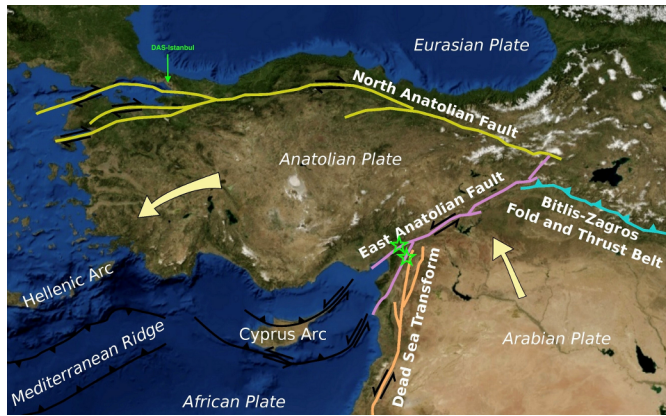
Huang Wins Student Research Fair

Geophysics senior Pablo Chang Huang, advised by D. Schmidt, M. Lehman, K. Pfaff, S. Stolze, and T. Monecke, won in the undergraduate research category at the ConocoPhillips GE/GP Student Research Fair. His project was “Rapid mineralogical and geochemical characterization of exploration drill core to advance domestic critical mineral supply security.”

The goal of the project was to develop methods that increase the speed and accuracy of data acquisition and allow for full integration of these heterogeneous datasets to advance our ability to efficiently explore and assess critical minerals deposits. The group expects to create a fully co-registered dataset that combines the mineralogy and geochemistry along the core, which can then be used in 3D modelling software packages to improve our understanding of the subsurface in support of projects throughout a mine's life cycle.

—Noelle Vance, Staff

Notes from the Field



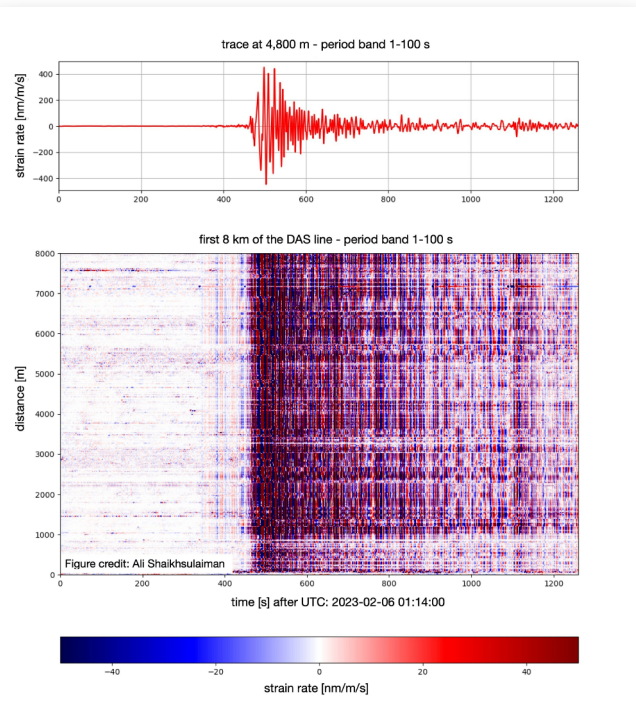
Recording Earthquakes in Turkey

In February, a 7.8 magnitude earthquake struck Turkey and Syria. Coincidentally, Professor Ebru Bozdağ had just arrived in Turkey to demonstrate how dark fibers could be used to assess seismic hazards. She was able to collect data that recorded the destructive earthquakes in Anatolia and recently presented her findings at the Earthscope GAGE/SAGE 2023 Community Science Workshop in Pasadena, CA. We were lucky enough to get her initial findings, which she sent from the field.

"I wanted to share our initial observations with dark fibers that we (Andreas Fichtner and Daniel Bowden from ETH Zurich, Ebru Bozdağ from Mines, Özgün Konca and Semih Ergintav from Kandilli Observatory in Istanbul, Istanbul Metropolitan Municipality Earthquakes and Ground Research) have demonstrated in Istanbul now for a month. Our main goal was to test if we could use telecom cables to record seismic signals in Istanbul, but it turned out to be more than we had planned.

Coincidentally our experiment overlapped with the recent East Anatolian earthquakes, and we could record the main event and aftershocks, which occurred about 1000 km away from Istanbul, with a telecom fiber optic line on the Anatolian side of Istanbul. The fiber optic line is roughly parallel to the segment of the North Anatolian Fault underneath the Sea of Marmara, which is located about 13 km away from the line at the South of the Prince Islands (see Büyükada, Heybeliada, Kınalıada, Burgazadası on the map) seen on the Google map.

I attached the signal of the Mw 7.8 Maras earthquake recorded by the first 8 km of a 30 km long fiber optic line. We also have recorded Mw 7.5, aftershocks, and some smaller local earthquakes and continue analyzing the data as we download them. If all goes well, today we will start using all 30 km line after some maintenance the Municipality will perform to improve the signal quality."



FACULTY ACCOLADES

Martin & Siegfried Receive Early Career Awards



Dr. Eileen Martin has received the Society for Industrial and Applied Mathematics (SIAM) Activity Group on Geosciences Early Career Prize. This significant prize is awarded to an early career professional in geosciences every other year for distinguished contributions to the field in the three calendar years preceding the award year. The SIAM is the leading international organization of researchers, educators, practitioners, and students whose primary interest is in mathematics and computational science and their applications.



Dr. Matthew Siegfried has won a National Science Foundation CAREER award for his work investigating ice sheet movements in Antarctica. Dr Siegfried's work focuses on the Whillans ice stream, which is slowing and could have an impact on global sea level change. The Faculty Early Career Development (CA-REER) Program offers the NSF's most prestigious awards in support of early-career faculty who have the potential to serve as academic role models in research and education and to lead advances in the mission of their department or organization.

Mines Special Awards and Promotions



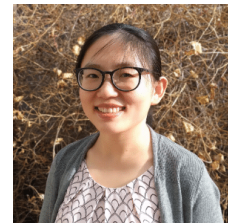
Matthew Siegfried,
Mines Excellence
in Research Award



Paul Sava,
Undergraduate
Student Government
Outstanding Faculty
Award for Geophysics



Jeffrey Shragge
promoted to full
Professor.



Yanrui Ning
promoted to
Research
Associate.

UG Student Awards



Zahra Al Mualem



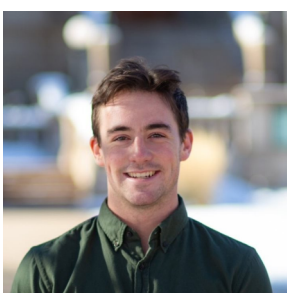
Venezia Follingstad



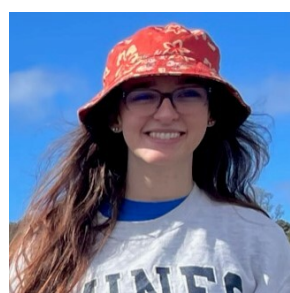
Gianna Joab



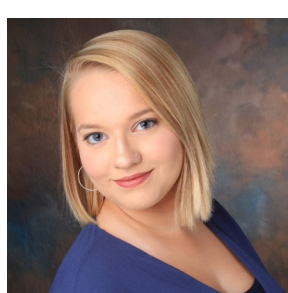
Seunghoo Kim



Cash Koning



Ashleigh Miller



April Wilson



Alex Brunson

The Department is proud to recognize our 2023 graduating students who received distinction amongst their peers.

Zahra Al Mualem received the prestigious Cecil. H. Green Gold Medal for her outstanding academic achievements, exemplary personality, and unyielding integrity. This most esteemed award is presented annually to a graduating senior who has achieved the highest level of excellence in these three areas. Zahra's exceptional performance will be honored with an actual gold medal.

Seunghoo Kim is the Outstanding Graduating Senior of the year due to her exceptional academic achievements and active involvement in Department activities. She has excelled in her academic pursuits and has also demonstrated her leadership abilities by taking on various roles in the Society of Student Geophysicists

(SSG), supporting the Department at IMAGE 2022, assisting faculty with office hours and grading, enrolling in graduate-level courses, and participating in independent research through the MURF program.

Venezia Follingstad received the George T. Merideth Award for Early Leadership in Geophysical Engineering. Venezia has demonstrated academic excellence and promising leadership potential by completing a work-study program as a senior in high school with the Department of Defense, interning with the USGS Hazards group and conducting three years of independent research on permafrost change.

Gianna Joab received the George R. Pickett Memorial Award in recognition of her interests and exceptional accomplishments in the field of petrophysics, which was the area of expertise of

Student Awards

the late Dr. Pickett. Faculty noted her passion and competence in this domain, and she will pursue her studies further by enrolling as an MS student with RCP this fall.

Cash Koning received the John C. Hollister Award, given to a graduating senior who has demonstrated leadership, maturity, and scholarship during his or her Mines career. Cash has demonstrated leadership in undergraduate research not just in Geophysics, but also in Civil Engineering and at the Payne Institute. He has been a TA and grader for HASS and AMS classes, a peer advisor in the Career Center, served in leadership roles in SSG and continued years of commitment to the Eagle Scouts.

April Wilson and **Ashleigh Miller** were jointly presented with the Phillip R. Romig Award, which honors outstanding performance and leadership in the acquisition of field geophysical observations. The two awardees demonstrated exceptional competence in Field Camp and conducted a successful senior design project in Hawaii. They were highly praised for their professionalism and exceptional work during their time in the field.

Alexandra Brunson received the E-Days Engineering Award for her hard-working attitude, positive, supportive nature, and exceptional Oredigger Spirit.

—Maureen James

GRAD STUDENT AWARDS

Mendenhall Awards



Iga Pawelec received the PhD Mendenhall Award. Mendenhall awards are given for strong academic performance, conducting and sharing cutting-edge research, strong academic integrity, and service to the community. Iga, now Dr. Pawelec, demonstrated the ability to present research at meetings and in scientific journals through her dissertation which comprised a paper published in Geophysics, two manuscripts ready for submission to Geophysics, and one chapter based on her work presented at the SEG annual meeting. Through her internship experiences and Field Camp contributions (participant, lead TA in 2022), Pawelec demonstrated her ability to collaborate, teach, and learn. She contributed to growth and promotion of the Department through her roles including SSG treasurer and social chair, vice president of Mines' EAGE Chapter, and newsletter photographer. Finally, Pawelec is helping get more use of Field Camp data by building student-faculty-industry ties.



Joseph Mjehovich received the MS Mendenhall Award. He completed the thesis-based MS program in August 2022, following his transfer from the non-thesis program in August 2021. He demonstrated exceptional performance in both academic course work and research tasks, ultimately producing a high-quality thesis based on two distinct research projects. Additionally, he submitted two manuscripts to peer-reviewed journals, with one already published. Joe actively engaged in RCP activities and made significant contributions to both the Department and the broader geophysics community.

Students win DGS Challenge Bowl



James
Carmichael



David
Herman

James Carmichael and David Herman won the Denver Geophysical Society-sponsored SEG Student Challenge Bowl. They will represent the Rocky Mountain region at the SEG International Student Challenge Bowl at IM-AGE 2023.



CONGRATULATIONS SPRING GRADUATES

Bachelor of Science in Geophysical Engineering

Zahra Al Mualem
Mujahed Alghamdi
Abdulrahman Alharthi
Lama Aljuhani
Nouf Alshekh
Alexandra Brunson
Sara Hirsch
Gianna Joab
Seunghoo Kim
Ragad Lasloun
Ashleigh Miller
Kassidy Page
April Wilson

Master of Science in Geophysics

Nicolás Bufaliza

Doctor of Philosophy in Geophysics

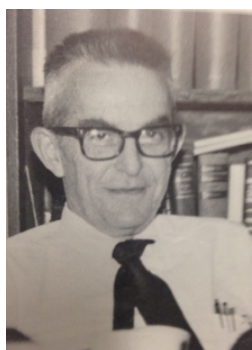
Andréa Darrh
Moacyr De Souza Bezerra
Manuel Jaimes Caballero
Mert Sinan Recep Kiraz
Youfang Liu
Iga Pawelec
Harpreet Sethi
Jihyun Yang

ALUMNI NEWS

Guu-Major Opportunity Fellowship

The Department gratefully announces the Guu-Major Opportunity Fellowship Endowment, which will support a renewable four-year award for a geophysics graduate student who demonstrates both need and high academic achievement.

Yvonne and Jason Guu have established this fund in honor of their parents, both geophysics graduates, Cindy Kuei-Ding Guu, M.Sc. 1982, and Jeng-Yih Guu, Ph.D. 1975, and the transformative impact of Dr. Maurice Major, Professor of



Dr. Maurice Major

Geophysics Emeritus, who facilitated their success at Mines.

Dr. Maurice W. Major served on the geophysics faculty from 1963-1985 as an earthquake seismologist and Director of the Green Geophysical Observatory.

Major was known for his “signature flattop haircut, white Oxford shirts, khaki pants, penny loafers, coffee consumption (often carrying a green metal thermos), wit, and humor.”¹ He and his wife, Rita, often shared their home and hospitality with students, telling stories from his colorful past and the foibles inherent in trying new things. One favorite story was when he dropped a string of hydrophones down



Cindy and Jeng-Yih Guu at Mines

a well while attempting an early vintage VSP survey. Another was when his seismometer sank in rough seas on its way to the Aleutian Island of Semisopochnoi. Major plotted the “deep-sixed” location on a department map so he could proudly share how the department ended up with an ocean-bottom seismometer.²

Major had a transformative impact on his students and created opportunities for their future success. Thank you to the Guu family for recognizing Dr. Major’s long-ranging impact in memory of Cindy and Jeng-Yih Guu.

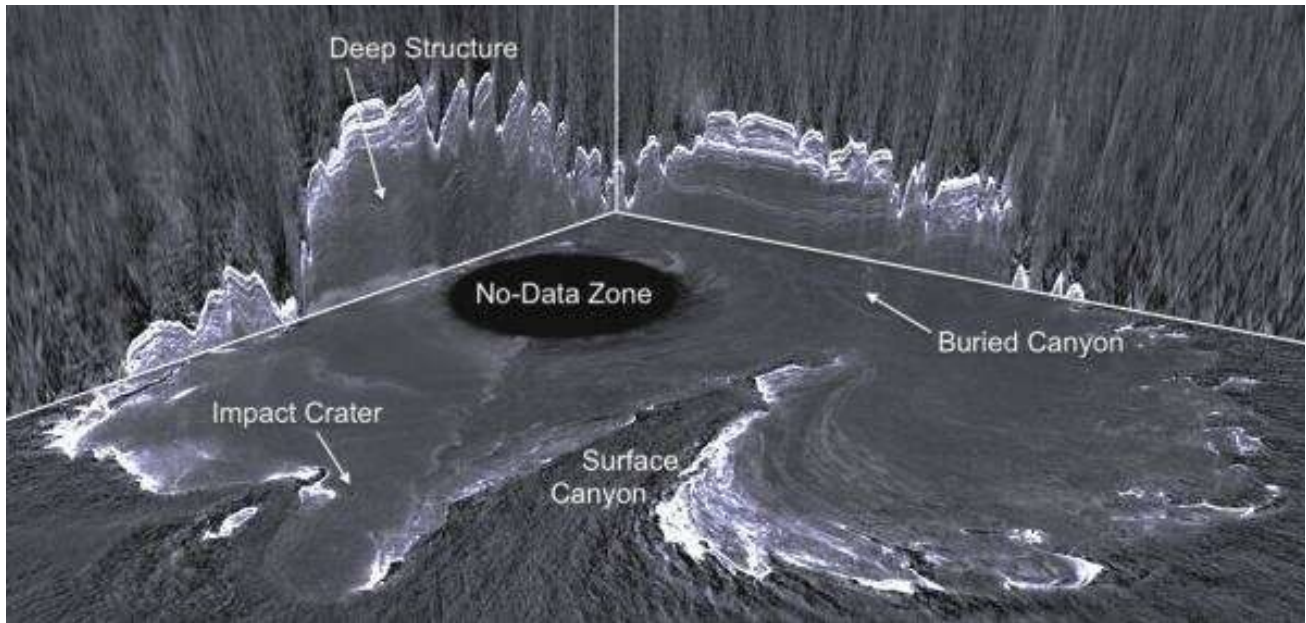
—Melinda Gale, Staff

¹https://wiki.seg.org/wiki/Maurice_Major

²<https://geophys08/geophysics-newsletter-spring-2007.pdf>

**Left: Jeng-Yih Guu with son Jason.
Right: Jeng-Yih, Cindy and Yvonne at Mines.**





Nathaniel Putzig ('86) and Team Create New Polar Map of Mars



Geophysics alum Nathaniel Putzig ('86), now with the Planetary Science Institute, along with his team of researchers, recently published work on new insight derived from 3D volume of the Mars ice caps. The team used radar data collected by NASA's Mars Reconnaissance Orbiter to explore Mars' polar deposits. For the first time, they succeeded in identifying the inside of the Mars' po-

lar caps impact crater and a buried canyon.

Putzig's team produced the image above by combining data from nearly 3,400 observations across the intended region taken with the Shallow Radar (SHARAD) instrument on NASA's Mars Reconnaissance Orbiter (MRO). SHARAD was designed to look beneath the Martian surface. The reflected radar waves also show the structure of the geological layers deposited and eroded at the planet's north and south poles.

Melinda Gale ('88) to edit Denver Geophysical Society *Record*



Melinda Gale ('88), GP alum and current Reservoir Characterization Project (RCP) Program Manager, has joined the Board of the Denver Geophysical Society (DGS) and will be the editor of the organization's publication called "The Record."

The DGS Executive Committee comprises five volunteers (President, Vice President, Secretary, Treasurer, Editor) who plan all of the DGS programming throughout the year. The signature

DGS event is the 3D Seismic Symposium held annually, and the organization hosts member events including monthly lunch-n-learns, a golf tournament, continuing education courses, student outreach and other networking events for the Rocky Mountain region geophysical community. The DGS Record is a quarterly publication that goes out to members and provides articles of interest to the geophysical community covering DGS outreach, Student Corner, and Research Updates.



Mines Geophysics will turn 100 in 2026!

Our program was established in 1926 as the world's first Department of Geophysics and continues strong today as one of the top global applied geophysics programs worldwide. We have initiated a wide range of activities celebrating and engaging our entire Geophysics family. We hope that you will continue to join us! Find calendar updates at <https://geophysics.mines.edu/100th-anniversary/> or contact us at geophysics@mines.edu

Join us at Field Camp

Alumni, you are invited to visit Geophysics Field Camp this summer!

Steamboat Springs, Colorado

May 20 - Alumni, Student, and Faculty Reception

May 20 and 21 - Participate in Field Camp activities

We hope to see you there! For more information or to RSVP for any of our GP@100 events email us at geophysics@mines.edu or fill out this form:

<https://forms.office.com/r/Rez1ADEXH3>



2023	
January	Remote Sensing Challenge Cup - Congratulations to our winners: Aspen Anderson, Devon Dunmire, and Hannah Peterson!
February	Colorado School of Mines #idigmines - Field Closet Initiative
March	Distinguished Alumni Matt Haney Heiland Lecture and Reception (in-person and Zoom)
April	GP Day Around the Word - Hoist one for GP! Regional Ambassador Hosts Needed GoldMine - Field Closet Initiative
May 20-21 Steamboat Springs, CO	Field Camp Alumni Weekend - Visit us in Steamboat!
June - Vienna, Austria	EAGE Mines GP Alumni Reception
July	GP Virtual 5K - Race details to come
August 28 - Houston, TX	SEG IMAGE Mines GP Alumni Reception
September 8 - Golden, CO	Welcome Back BBQ, 4:30-6:30pm
October	Distinguished Alumni Heiland Lecture and Reception In-Person and Remote Zoom
November	GP Gives Workshop, topic and date TBD - Free to Alumni
December 11 San Francisco, CA	AGU Mines GP Alumni Reception

Faculty Conversation

Sava from Page 20

students, which is problematic because this kind of close interaction needs to scale. Such personal interaction slows down the whole process but makes it more relevant. This is a paradox: here is a machine — ChatGPT — that's supposed to save us time and help us do things faster, but in fact, we slow down because we distrust how others may use the same machine.

Would these technologies level the playing field for people with difficulty speaking English?

I don't know the meaning of leveling the playing field in this context. What have we gained if the machine "levels the playing field" by obscuring communication weaknesses that only become apparent after we admit a student to our program? That's obstruction, not leveling the playing field, and I do not want that. On the other hand, if the machine helps students learn to communicate better in English, then yes, that would have a positive impact; I like that.

What about using it in academic papers to write more fluent sounding English?

If the transformation of the text is on the margins, polishing it a little bit, then I'm okay with it. The main criterion is that the thoughts belong to the paper's author, which is only sometimes apparent, as I noted about the ChatGPT-simulated statement of purpose. ChatGPT inserted fake qualifications in that example, and the fictitious student boasted about machine learning abilities and other things that did not come from my prompt. The machine added information that was not there to begin with. In a technical article, that would be unacceptable, even if ChatGPT is acknowledged and perhaps presented as co-author.

How do you see graduate or undergraduate classes being affected by these technologies?

The lower-level classes would be affected first and the most because ChatGPT is well suited for small bits of text and code. For example, in one

of my classes, I ask students to write code that generates the Pascal triangle. ChatGPT can do that (I checked!) without effort, so my exercise is pointless. I'm not going to ask that question anymore.

That said, the ChatGPT genie is out of the jar and is not returning. It will be with us, and so will technologies better than ChatGPT shortly. We need to figure out ways to use these tools to enhance learning. We need to change rapidly, both professors and students. Students are quick and will use the tools if they exist, so they should. We thus must reconfigure learning to emphasize particular human aspects, like creativity, to which we humans can excel. At the same time, we should offload the repetitive, mundane tasks to the machine. For example, it would be productive to describe to a machine what code interface and functionality we want and get that quickly and accurately. Our challenge would be to focus on the more strategic aspects of the problem we are trying to solve and avoid getting bogged down in minutia. Machines will not easily understand the big picture, at least not in the near term, and that's where we compensate for the machine's ability to compute fast and sift through large volumes of data.

That's what we need to teach students: to use such modern tools to advance and accelerate their learning. We've done this with other tools and have yet to look back. When text editors became available, we stopped focusing on calligraphy. When spell checkers came along, we stopped focusing on spelling. When grammar checkers were deployed, we stopped focusing on grammar. Similarly, ChatGPT and other tools like that will become helpers at the next level. Teaching, therefore, needs to change quickly, not in five or ten years but *right away*. This is an urgent task requiring our immediate attention.

The good news is that ChatGPT can help us recreate some of our curricula.

I am not sure. A curriculum requires a

See back page 35

Faculty Conversation

Sava from Page 34

strategic thinking, and perspective — in other words, intelligence. Is it intelligent if a machine can write text and some computer code? What is the definition of intelligence we need in designing curricula? I am unconvinced that a machine can replace humans at a complex task like curriculum design. Machines will certainly replace humans in specific functions, and so they should. But it will not soon replace the creative aspects of what we do as humans and scientists.

So what should students focus on? We must realize that we will not quickly lose our innovation edge and the ability to create new things from fundamental knowledge. Focus on the foundations of our science and use generative tools to manage tedious tasks. For our good, we need to focus on the things the machine cannot do as well as we can. But that doesn't mean we ignore or fight the machines. Instead, we ought to work together.

This is a familiar idea. Years ago, a massive computer (IBM Deep Blue) beat the Chess World Champion (Gary Kasparov) in a landmark chess match. Afterward, the best chess players realized that such computers were too powerful and could no longer be defeated by human players. However, they realized that the “enemy” could become a partner, and help them train and learn. They figured out that a world chess champion with a machine is way more powerful than a machine or a world chess champion by themselves. That's the attitude we should also have in geophysics: embrace the new tools and use them appropriately and productively.

This is certainly not easy, and it is a hazardous path. Some will undoubtedly embrace these tools too fast without considering the broader societal consequences. We must be on the lookout and try to understand what these tools can do to us. When we outsource too much to machines, we degrade as humans. ■

ChatGPT from Page 21

conclusions and decision-making. Ultimately, the impact of AI on geophysics and education will depend on the choices we make as a society. It is important to approach the development and deployment of AI with a thoughtful and responsible mindset, and to prioritize ethical considerations and the social good. By doing so, we can harness the power of AI to drive positive change in the field of geophysics and education, while minimizing the potential negative consequences.

What advice would you give for students about to embark on careers in geophysics? Do you feel the skills required for success in industry or academy are changing?

My advice would be to focus on developing a strong foundation in the fundamentals of geophysics, as well as in computer science, mathematics, and statistics. As the field becomes increasingly data-driven and computational, having a strong background in these areas will be essential for success. It is also important to stay up-to-date with the latest technological trends and developments in the field, including AI and machine learning. These technologies are transforming the way that geophysics is practiced and will be increasingly important in the future. In addition to technical skills, students should also focus on developing strong communication and collaboration skills. Geophysics is a highly collaborative field, and the ability to work effectively with others is essential for success. This includes the ability to communicate complex ideas in a clear and concise manner, as well as the ability to work effectively as part of a team. Finally, I would encourage students to be open to new opportunities and to be willing to take risks. The field of geophysics is constantly evolving, and there are always new challenges and opportunities to explore. ■

HEILAND LECTURE WRAPUP

The Heiland lecture series in the spring of 2023 was full of exciting research from various places including Alaska, Antarctica, the Moon and Mars, as well as more theoretical explorations of geosciences in policy writing and the move of computational geosciences into the cloud.

The first speaker was jointly sponsored by Geology & Geological Engineering, Geophysics, Earth & Society Programs, the USGS Geologic

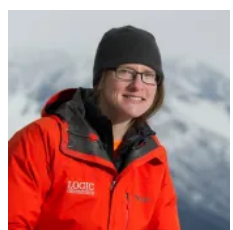
Hazards Science Center, and Office of Global Initiatives.

Dr. David Applegate, the Director of the United States Geological Survey spoke on the *Role of Science in Service to Society: The Evolving Role*

of the U.S. Geological Survey, where he outlined the role of the sciences in informing decisions on some of the most consequential issues facing our nation.



Dr. Esther Babcock, from Logic Geophysics & Analytics, gave an exciting overview of *Near-surface Geophysics in Alaska*, where she discussed several case studies from her Alaskan field work.



Again from the USGS, **Dr. Geoffrey Ellis** spoke on the *Potential for Geologic Hydrogen Gas Resources*. He outlined the exploration, extraction and possible uses of H₂ as a previously over-

looked potential energy resource.

We welcomed **Dr. Andy Thompson** from the California Institute of Technology, who gave an overview of the *Overturning Circulation of the*



West Antarctic Shelf Seas, where he summarized both observations and numerical simulations of the water circulation of the Amundsen and Bellingshausen seas

drive ice-shelf melt.

Dr. Youzou Lin from Los Alamos National Laboratory gave his talk on *Physics-guided Learning-driven Seismic Inversion*, where he described the ill-posed nature of inversion problems and the potential of machine-learning

(ML)-based computational methods in the geosciences.

The Geology and Geological Engineering Department, Center for Space Resources and Geo-

physics Department jointly hosted **Dr. Philippe Lognonné** from the Univer-

sité Paris Cité, Institut de Physique du Globe de Paris, France. He gave an overview of *Seis on Mars, Showing the First Four Years of Seismic Monitoring*. This was an ex-

citing overview of the future of planetary seismology.



Continuing the theme of space geophysics, Dr. Erik Asphaug from the University of Arizona asked the question: *Why does the Moon Exist? And did a deep dive into Its Formation and Its Perilous Early Fate*. He had a



Heiland

contest during his talk, asking the audience to ask challenging questions. The winner received an autographed copy of his book, *When the Earth Had Two Moons: Cannibal Planets, Icy Giants, Dirty Comets, Dreadful Orbits, and the Origins of the Night Sky*.



The Department's own **Dr. Matthew Siegfried** presented a comprehensive lecture on *Tracing Freshwater Beneath the Antarctic Ice Sheet*. He explained how ac-

tive subglacial lakes beneath fast moving ice streams and outlet glaciers modify how the ice sheet and ocean systems interact, transforming our perspective on the space and time scales over which the Antarctic ice sheet can change. Discussing computational geosciences, Mines



alum **Sverre Brandsberg-Dahl** from Microsoft Azure spoke on *Geophysics and Computers on a Journey from the Earliest CPUs, GPUs, and into the Clouds*. He discussed the connection between geophysics and com-

puters and the migration from in-house hardware systems to remote cluster servers and cloud-based computing systems. He argued that the emergence of cloud computing, along with the economic conditions surrounding the industry, are forcing the development and adoption of new approaches to computing.



For the Distinguished Alum lecture, **Dr. Matt Haney** from the USGS/Alaska Volcano Observatory discussed *Volcano Seismology in the Aleutian Islands*. He gave an in-depth overview of activity on volcanoes Bogoslof,

Cleveland, Great Sitkin, and Little Sitkin, which are driving improved eruption forecasts.



Another local lecturer was our own **Dr. Roel Snieder** who discussed *Variations and Healing of the Seismic Velocity* and how it is possible to detect time-lapse changes in seismic velocity and the effects they have at different scales, from continental to core-sized experiments.



A special event was the first Women Earth Data Scientists' Day featuring **Dr. Katie Dagon** from the National Center for Atmospheric Research (NCAR). The day, organized by Dr. Eileen Martin, began with a coffee hour fea-

turing several of the Department's Earth Data Scientists. This was followed by Dr. Dagon's talk on *Data Science and Machine Learning for Climate Science and Modeling*. She discussed how data science and machine learning can be applied to explore climate science research questions using climate models. This was followed by break-out discussion groups.



Dr. Susheel Adusumilli from Scripps Institution of Oceanography spoke on *Monitoring and Predicting Shoreline Changes Along the California Coast Using Remote Sensing Data*.



Finally, **Dr. Wenyuan Fan** from the University of California-San Diego discussed the *Physical Processes of Environmental Seismic Sources Revealed by Surface Wavefields*. He pre-

sented results obtained by a novel surface-wave detection method and analyzed 10 years of continuous records from more than 2000 U.S. seismic stations.
—Aaron Girard, Faculty

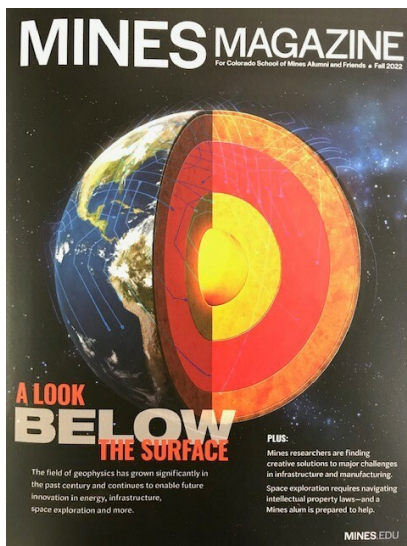
GP ON SOCIAL MEDIA

If you missed these social media posts, be sure to follow all of our channels:

 www.facebook.com/MinesGeophysics

 [@MinesGeophysics](https://twitter.com/MinesGeophysics)

 [@SGGSMines](https://www.instagram.com/SGGSMines)



Mines Magazine GP Cover

Accessible at: <https://www.instagram.com/p/ClrR2ugv22t/>

December 2, 2022: The article focuses on the future of geophysics and its ever-growing importance for locating important resources such as minerals and groundwater, assessing geohazards and their potential risks, and most notably, mapping the Earth's subsurface for future projects. Alumni Whitney Schutz MS '19, Mandy Schindler PhD '18, Ivan Lim Chem Ning PhD '19, and Bryce Swinford '07 were featured in this article as prominent Mines Geophysicists working in our albeit small, but very in-demand field. <https://minesmagazine.com/17586/>

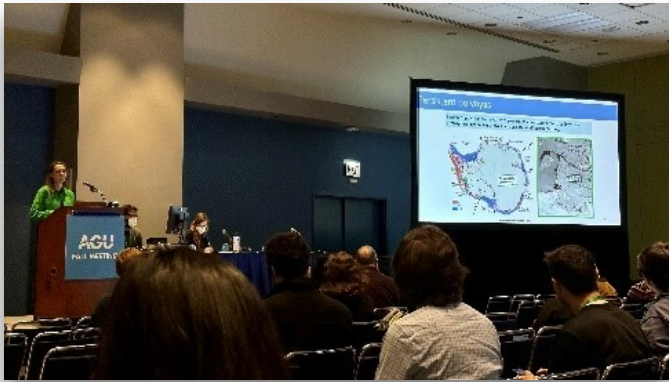
RCP Field Trip

December 22, 2022: On Friday, our Reservoir Characterization Project (RCP) students took a quick field trip to view nearby Lower Cretaceous and Jurassic outcrops. The goal is to visualize geologic environments prior to synthetic seismic reservoir modeling. It's nice to have a beautiful December Friday and world class outcrops available on the way to school!



Accessible at: <https://www.instagram.com/p/CmetX1tvbNa/>

Social Media



AGU 2022

January 10, 2023: Elena Savidge, PhD student gives her oral presentation on Wintertime Polynya Structure. You can read more about it here: <https://bit.ly/3iwzuAD>



Hannah Verboncoeur, PhD student, talks science at her poster about Leveraging Multidecadal Remote Sensing Data with David Sandwell (UCSD). Learn more here: <https://bit.ly/3ZkXXtr>



Undergraduate student April Wilson and PhD student Hannah Verboncoeur work our AGU booth, with postdoctoral research associate Dr. Tasha Snow sitting for a quick re-charge.



A wonderful turnout of Geophysics alumni who joined us at Apolonia for our reception!

Accessible at: <https://www.instagram.com/p/CnPuRDgPLH1/>

RECENT PUBLICATIONS

2023

- Almuteri, K., and P. Sava, 2023, Seismic deghosting using convolutional neural networks: *Geophysics*, 88, no. 3, 1-96, <https://doi.org/10.1190/geo2021-0521.1>.
- Davis, C. L., R. A. Venturelli, A. B. Michaud, J. R. Hawkings, A. M. Achberger, T. J. Vick-Majors, B. E. Rosenheim, J. E. Dore, A. Steigmeyer, M. L. Skidmore, J. D. Barker, L. G. Benning, M. R. Siegfried, J. C. Priscu, B. C. Christner, 2023, Biogeochemical and historical drivers of microbial community composition and structure in sediments from Mercer Subglacial Lake, West Antarctica: *ISME Communications*, 3, no. 8, <https://doi.org/10.1038/s43705-023-00216-w>.
- Davis, T., 2023, Time-lapse, multi-component seismic monitoring of geomechanical changes in reservoirs: *First Break*, 41, no 1, 51-57, <https://doi.org/10.3997/1365-2397.fb2023003>.
- Girard, A. J., J. Shragge, and B. Olofsson, 2023, Low-frequency ambient ocean-bottom node surface-wave seismology: A Gulf of Mexico case history: *Geophysics*, 88, no. 1, B21-B32, <https://doi.org/10.1190/geo2021-0732.1>.
- Hao, Q., and I. Tsvankin, 2023, Thomsen-type parameters and attenuation coefficients for constant-Q transverse isotropy, arXiv preprint arXiv:2301.01939, <https://doi.org/10.48550/arXiv.2301.01939>.
- Jayne, J., M.B. Wakin, and R. Snieder, 2023, Green's function estimation by seismic interferometry from limited frequency samples: *Signal Processing*, 205, 108863, <https://doi.org/10.1016/j.sigpro.2022.108863>.
- Liu, Y., L. Liu, G. Jin, K. Wu, M. Reagan, and G. Moridis, 2023, Simulation-based evaluation of the effectiveness of fiber-optic sensing in monitoring and optimizing water circulation in next-generation enhanced geothermal systems: *Geoenergy Science and Engineering*, 221, <https://doi.org/10.1016/j.geoen.2022.211378>.
- Liu, Y., S. Feng, I. Tsvankin, D. Alumbaugh, and Y. Lin, 2023, Joint physics-based and data driven time-lapse seismic inversion: Mitigating data scarcity: *Geophysics*, 88, no. 1, K1-K12, <https://doi.org/10.1190/geo2022-0050.1>.
- Ning, Y., and G. Jin, 2023, Challenges and best practices in interpreting cross-well strain signals to monitor multi-crew zipper fracturing operations: *Interpretation*, 11, no. 2, 1-43, <https://doi.org/10.1190/int-2022-0092.1>.
- Ning, Y., H. Kazemi, A. Tura, and T. Davis, 2023, Carbon neutral oil assessment using a dual-porosity compositional model in unconventional reservoirs: *Journal of Petroleum Science and Engineering*, 221, 111227, <https://doi.org/10.1016/j.petrol.2022.111227>.
- Siegfried, M.R., R.A. Venturelli, M.O. Patterson, W. Arnuk, T.D. Campbell, C.D. Gustafson, A.B. Michaud, B.K. Galton-Fenzi, M.B. Hausner, S.N. Holzschuh, B. Huber, K.D. Mankoff, D.M. Schroeder, P.T. Summers, S. Tyler, S.P. Carter, H.A. Fricker, D.M. Harwood, A. Leventer, B.E. Rosenheim, M.L. Skidmore, J.C. Priscu, the SALSA Science Team, 2023, The life and death of a subglacial lake in West Antarctica: *Geology*, <https://doi.org/10.1130/G50995.1>.
- Snieder, R., C. Holles, Q. Zhu, and C. James, 2023, Commentary: Teach with heart!: *Physics Today*, 76, no. 3, 10, <https://doi.org/10.1063/PT.3.5185>.
- Spica, Z. J., J. Ajo-Franklin, G. C Beroza, B. Biondi, F. Cheng, B. Gaithe, B. Luo, E. Martin, J. Shen, C. Thurber, L. Viens, H. Wang, A. Wuestefeld, H. Xiao, and T. Zhu, 2023, PubDAS: A public distributed acoustic sensing datasets repository for geosciences: *Seismological Society of America*, 94, no. 2A, 983-998, <https://doi.org/10.1785/0220220279>.
- Wang, Y., X. Chen, G. Jin, B. Wang, X. Zeng, G. Zhan, and Y. Zhao, 2023, Advances and applications of distributed optical fiber sensing (DOFS) in multi-scales geoscience problems, In *Frontiers in Science*,

Publications

<https://doi.org/10.3389/feart.2022.943424>.

2022

- Alzahrani, H., and J. Shragge, 2022, Seismic velocity model building using recurrent neural networks: A frequency-stepping approach: *IEEE Transactions on Geoscience and Remote Sensing*, 60, 1-9, <https://doi.org/10.1109/TGRS.2022.3210899>.
- Benjamin, S.G., T. G. Smirnova, E. P. James, E. J. Anderson, A. Fujisaki-Manome, J. G. W. Kelley, G. E. Mann, A. D. Gronewold, P. Chu, S. G. T. Kelley, 2022, Inland lake temperature initialization via coupled cycling with atmospheric data assimilation: *Geoscientific Model Development*, 15, no. 17, 6659-6676, <https://doi.org/10.5194/gmd-15-6659-2022>.
- Cardona, S., H. Kobayashi, L. Wood, B. Dugan, and A. V. Milkov, 2022, Assessing the sealing quality of submarine mass transport complexes and deposits: *Marine and Petroleum Geology*, 143, <https://doi.org/10.1016/j.marpetgeo.2022.105748>.
- Chambers, D., L. Peiyao, H. Sethi, and J. Shragge, 2022, Monitoring industrial acoustics with distributed acoustic sensing: *The Journal of the Acoustical Society of America*, 151, no. 4, A58-A58, <https://doi.org/10.1121/10.0010648>.
- Cheng, L., G. Jin, R. Michelena, and A. Tura, 2022, Practical Bayesian inversions for rock composition and petrophysical endpoints in multimineral analysis: *SPE Reservoir Evaluation & Engineering*, 25, no. 4, 849-865, <https://doi.org/10.2118/210576-PA>.
- Cheng, L., M. Prasad, R. Michelena, A. Tura, S. Akther, P. Angelov, and R. Srinivasa, 2022, Using rock-physics models to validate rock composition from multimineral log analysis: *Geophysics*, 87, no. 2, MR49-MR62, <https://doi.org/10.1190/geo2020-0918.1>.
- De Souza Bezerra, M., J. L. Simmons, and J. E. Gaiser, 2022, Case study: 4D consistent receiver coupling corrections applied to deep-water ocean bottom cable data: *Geophysical Prospecting*, 70, no. 3, 525-546, <https://doi.org/10.1111/1365-2478.13183>.
- Diekmann, L., I. Vasconcelos, K. Wapenaar, E. Slob, and R. Snieder, 2022, Wavefield focusing using a generalized, potentially asymmetric homogeneous Green's function: *Wave Motion*, 116, 103071, <https://doi.org/10.1016/j.wavemoti.2022.103071>.
- Dorley, J., J. Singley, T. Covino, K. Singha, M. Gooseff, and R. Gonzalez-Pinzon, 2022, Physical and stoichiometric controls on stream respiration in a headwater stream: *Biogeosciences*, 1-22, <https://doi.org/10.5194/bg-2022-214>.
- Firdaus, G., J. Behura, M. Prasad, 2022, Pressure-dependent elastic anisotropy: A Bakken Petroleum System case study: *Geophysics*, 87, no. 3, MR39-MR150, <https://doi.org/10.1190/geo2021-0350.1>.
- Flamme, H., R. A. Krahenbuhl, Y. Li, B. Dugan, J. Shragge, A. Graber, D. Sirota, G. Wilson, E. Gonzales, J. Ticona, and A. Minaya, 2022, Integrated geophysical investigation for understanding agriculturally induced landslides in southern Peru: *Environmental Earth Sciences*, 81, no. 11, 309, <https://doi.org/10.1007/s12665-022-10382-0>.
- Fujisaki-Manome, A., D.M. Wright, G.E. Mann, E.J. Anderson, P. Chu, C. Jablonowski, S.G. Benjamin, 2022, Forecasting lake-/sea-effect snowstorms, advancement, and challenges: *WIREs Water*, <https://doi.org/10.1002/wat2.1594>.
- Garcia-Chevesich, P. X. Wei, J. Ticona, G. Martínez, J. Zea, V. García, F. Alejo, Y. Zhang, H. Flamme, A. Graber, P. Santi, J. McCray, E. Gonzáles, R. Krahenbuhl, 2022, Estudio desarrolló un análisis global sobre los impactos del riego agrícola en la ocurrencia de deslizamientos en masa: *Revista Internacional de Contaminación Ambiental*, 38, 75-77, <https://doi.org/10.20937/RICA.54535>.
- González-Pinzón, R., J. Dorley, J. Singley, K. Singha, M. Gooseff, and T. Covino, 2022, TIPT: The Tracer Injection Planning Tool: *Environmental Modeling & Software*, 156, <https://doi.org/10.1016/j.envsoft.2022.105504>.
- Gustafson, C. D., K. Key, M. R. Siegfried, J. P. Winberry, H. A. Fricker, R. A. Venturelli, A. B. Michaud, 2022, A

Publications

- dynamic saline groundwater system mapped beneath an Antarctic ice stream: *Science*, 376, 640-644, <https://doi.org/10.1126/science.abm330>.
- Grana, D. A. D. Parsekian, B. A. Flinchum, R. P. Callahan, N. Y. Smeltz, A. Li, J. L. Hayes, B. J. Carr, K. Singha, C. S. Riebe, W. S. Holbrook, 2022, Geostatistical rock physics inversion for predicting the spatial distribution of porosity and saturation in the critical zone: *Mathematical Geosciences*, 54, 1315-1345, <https://doi.org/10.1007/s11004-022-10006-0>.
- Hall, N., A. Rust, T. S. Hogue, K. Singha, 2022, Analysis of watershed parameters controlling turbidity following the West Fork Complex fire: *Journal of Hydrology*, 609, <https://doi.org/10.1016/j.jhydrol.2022.127712>.
- Hao, Q., and I. Tsvankin, 2022, Dispersion relation and wave equation for attenuative elliptically anisotropic media, arXiv preprint arXiv:2212.11494, <https://doi.org/10.48550/arXiv.2212.11494>.
- Heil, E., S. Warix, K. Singha, A. Navarre-Sitchler, 2022, Decadal trends in solute concentrations, mass flux, and discharge reveal variable hydrologic and geochemical response to climate change in two alpine watersheds: *Applied Geochemistry*, 144, <https://doi.org/10.1016/j.apgeochem.2022.105402>.
- Li, J., C. Beghein, S. McLennan, A. Horleston, C. Charalambous, Q. Huang, G. Zenhäusern, E. Bozdağ, W. T. Pike, M. Golombek, V. Lekic, P. Lognonné, W. Banerdt, 2022, Second seismic anchor point of the Martian Crustal Structure away from the InSight landing site: *Nature Communications*, 13, 7850, <https://doi.org/10.1038/s41467-022-35662-y>.
- Lin, Y. A. Fujisaki-Manome, and E. J. Anderson, 2022, Simulating landfast ice in Lake Superior: *Journal of Marine Science and Engineering*, 10, no. 7, <https://doi.org/10.3390/jmse10070932>.
- Liu, Y., O. Huff, B. Luo, G. Jin, and J. Simmons, 2022, Convolutional neural network-based classification of microseismic events originating in a stimulated reservoir from distributed acoustic sensing data: *Geophysical Prospecting*, 70, no. 5, 904-920, <https://doi.org/10.1111/1365-2478.13199>.
- Liu, Y., G. Jin, K. Wu, and G. Mordis, 2022, Quantitative hydraulic-fracture-geometry characterization with low-frequency distributed-acoustic-sensing strain data: Fracture-height sensitivity and field applications, *SPE Production & Operations*, 37, no. 2, 159-168, <https://doi.org/10.2118/204158-PA>.
- Marshall, A., X. Zhang, A. H. Sawyer, E. Wohl, K. Singha, 2022, Logjam characteristics as drivers of transient storage in headwater streams: *Water Resources Research*, <https://doi.org/10.1029/2022WR033139>.
- Miller, Q. R. S., M. Pohl, K. Livo, H. Asgar, S. K. Nune, M. A. Sinnwell, M. Prasad, G. Gadikota, B. P. McGrail, and H. T. Schaefer, 2022, Porous colloidal nanoparticles as injectable multimodal contrast agents for enhanced geophysical sensing: *ACS Applied Materials & Interfaces*, <https://doi.org/10.1021/acsami.2c03187>.
- Ning, Y., G. Jin, X. Zhu, A. Tura, 2022, Well interference and fracture geometry investigation using production and low-frequency distributed acoustic sensing data in an unconventional reservoir: *SPE Reservoir Evaluation & Engineering*, 25, no. 3, 509-519, <https://doi.org/10.2118/209788-PA>.
- Ning, Y., H. Kazemi, and P. Tahmasebi, 2022, A comparative machine learning study for time series oil production forecasting: *ARIMA, LSTM and Prophet: Computers & Geosciences*, 164, <https://doi.org/10.1016/j.cageo.2022.105126>.
- Ning, Y., H. Kazemi, A. Tura, and T. L. Davis, 2022, Tracer analysis in flow channel characterization and modeling of gas and CO₂ injection EOR in unconventional reservoirs: *Journal of Petroleum Science and Engineering*, 212, 110349, <https://doi.org/10.1016/j.petrol.2022.110349>.
- Ning, Y., H. Schumann, and G. Jin, 2022, Application of data mining to small data sets: Identification of key production drivers in heterogeneous unconventional resources: *SPE Reservoir Evaluation & Engineering*, 1-11, <https://doi.org/10.2118/212301-PA>.
- Oren, C., and J. Shragge, 2022, Image-domain DAS-VSP elastic transmission tomography: *Geophysical Journal International*, 232, no. 3, 1914-1925, <https://doi.org/10.1093/gji/ggac427>.
- Pearce, E. V. E., A. Booth, S. Rost, P. Sava, T. Konuk, A. Brisbane, B. Hubbard, I. Jones, 2022, Characterizing ice slabs in firm using seismic full waveform inversion: *Earth ArXiv*, <https://doi.org/10.31223/X5JP89>.
- Putzig, N. E., F. J. Foss II, B. A. Campbell, J. W. Holt, M. R. Perry, I. B. Smith, A. T. Russell, S. Nerozzi, M. S.

Publications

- Christoffersen, I. H. Mueller, P. C. Sava, 2022, New views of the internal structure of Planum Boreum from enhanced 3D imaging of Mars reconnaissance orbiter shallow radar data: *The Planetary Science Journal*, 3, 11, <https://doi.org/10.3847/PSJ/ac9d3b>.
- Reddy, E., J. Valenzuela, G. Muñoz Romero, and G. Rubio Moreno, 2022, Border scenario: Knowledge production as an environmental justice issue for earthquake risk mitigation in San Diego and Tijuana: *Environmental Justice*, <https://doi.org/10.1089/env.2021.0106>.
- Reddy, E., 2022, *Alerta!*, Engineering on shaky ground: The MIT Press.
- Robertson, W.R., D. B. Kluver, J. T. Allen, and E. J. Anderson, 2022, The hydrologic response to a meteotsunami in an isolated wetland: Beaver Island in Lake Michigan, USA: *Journal of Geophysical Research Oceans*, 9, <https://doi.org/10.1029/2022JC018611>.
- Saldaña-Tejeda, A., X. Pérez-Campos, E. Reddy, 2022, Seismic noise to public health signal: Investigating the effects of pandemic guidance in Mexico: *Tapuya: Latin American Science, Technology and Society*, 5, no. 1, 2086446, <https://doi.org/10.1080/25729861.2022.2086446>.
- Schippkus, S., R. Snieder, and C. Hadziioannou, 2022, Seismic interferometry in the presence of an isolated noise source: *Seismica*, 1, no. 1, <https://doi.org/10.26443/seismica.v1i1.195>.
- Schumann, H., and G. Jin, 2022, Inferring hydraulic connectivity of induced fractures in the near-wellbore region using distributed acoustic sensing-recorded tube waves excited by perforation shots: *Geophysics*, 87, no. 3, D101-D109, <https://doi.org/10.1190/geo2021-0276.1>.
- Singh, S., and I. Tsvankin, 2022, Sensitivity analysis of elastic full-waveform inversion for orthorhombic media: *Journal of Seismic Exploration*, 31, no. 2, 105-130.
- Singh, S., I. Tsvankin, and E. Zabihi Naeini, 2022, Facies prediction with Bayesian inference: Application of supervised and semisupervised deep learning: *Interpretation*, 10, no. 2, <https://doi.org/10.1190/INT-2021-0104.1>.
- Singley, J.S., K. Singha, M. N. Gooseff, R. González-Pinzón, T. P. Covino, A. S. Ward, J. Dorley, E. S. Hinckley, 2022, Identification of hyporheic extent and functional zonation during seasonal streamflow recession by unsupervised clustering of time-lapse electrical resistivity models: *Hydrological Processes*, 36, no. 10, <https://doi.org/10.1002/hyp.14713>.
- Snieder, R., and M.B. Wakin, 2022, When randomness helps in undersampling: *SIAM Review*, 64, 1062-1080, <https://doi.org/10.1137/21M1441006>.
- Staněk, F., G. Jin, and J. Simmons, 2022, Fracture imaging using DAS-recorded microseismic events: *Front Earth Science*, 10, <https://doi.org/10.3389/feart.2022.907749>.
- Titov, A., G. Jin, G. Binder, and A. Tura, 2022, Distributed acoustic sensing time-lapse vertical seismic profiling during zipper-fracturing operations: Observations, modeling, and interpretation: *Geophysics*, 87, no. 6, B329-B336, <https://doi.org/10.1190/geo2021-0758.1>.
- Underwood, M. B., B. Dugan, and S. Cardona, 2022, How clay mineral assemblages affect instability on the upper slope of the Hikurangi subduction zone, New Zealand: *Geophysical Research Letters*, 49, no. 21, <https://doi.org/10.1029/2022GL100529>.
- Wilson, G., J. Conrad, J. Anderson, A. Swidinsky, and J. Shragge, 2022, Developing a low-cost frequency-domain electromagnetic induction instrument: *Geoscientific Instrumentation, Methods and Data Systems*, 11, no. 2, 279-291, <https://doi.org/10.5194/gi-11-279-2022>, 2022.
- Wolf, J., D. A. Frost, M. D. Long, E. Garnero, A. O. Aderoju, N. Creasy, E. Bozdağ, 2022, Observations of mantle seismic anisotropy using array techniques: shear-wave splitting of beamformed SmKS phases: *Journal of Geophysical Research-Solid Earth*, <https://doi.org/10.1029/2022JB025556>.
- Yang, J., J. Shragge, and G. Jin, 2022, Filtering strategies for deformation-rate distributed acoustic sensing: *Sensors*, 22, no. 22, 8777, <https://doi.org/10.3390/s22228777>.
- Zhu, X., and G. Jin, 2022, Hydraulic fracture propagation in Denver-Julesburg Basin constrained by cross-well distributed strain measurements: *SPE Measurements*, 27, no. 6, 3446-3454, <https://doi.org/10.2118/210582-PA>.



COLORADO SCHOOL OF
MINES
@ 150 | 1874-2024

1500 ILLINOIS ST.
GOLDEN, CO 80401-1887
GEOPHYSICS.MINES.EDU

SUPPORT GEOPHYSICS

The Department of Geophysics is grateful for gifts and support from alumni, friends of the Department, and corporate partners. Your support helps us deliver many of the programs from which our students benefit, including graduate and undergraduate fellowships and scholarships, opportunities for students to engage in professional development activities, computing upgrades, department initiatives, and Field Camp.

If you are interested in making a gift to the Geophysics Department or sponsoring one of its programs, please contact the Mines Foundation (303-273-3275) or <https://weare.mines.edu/supportgeophysics>

