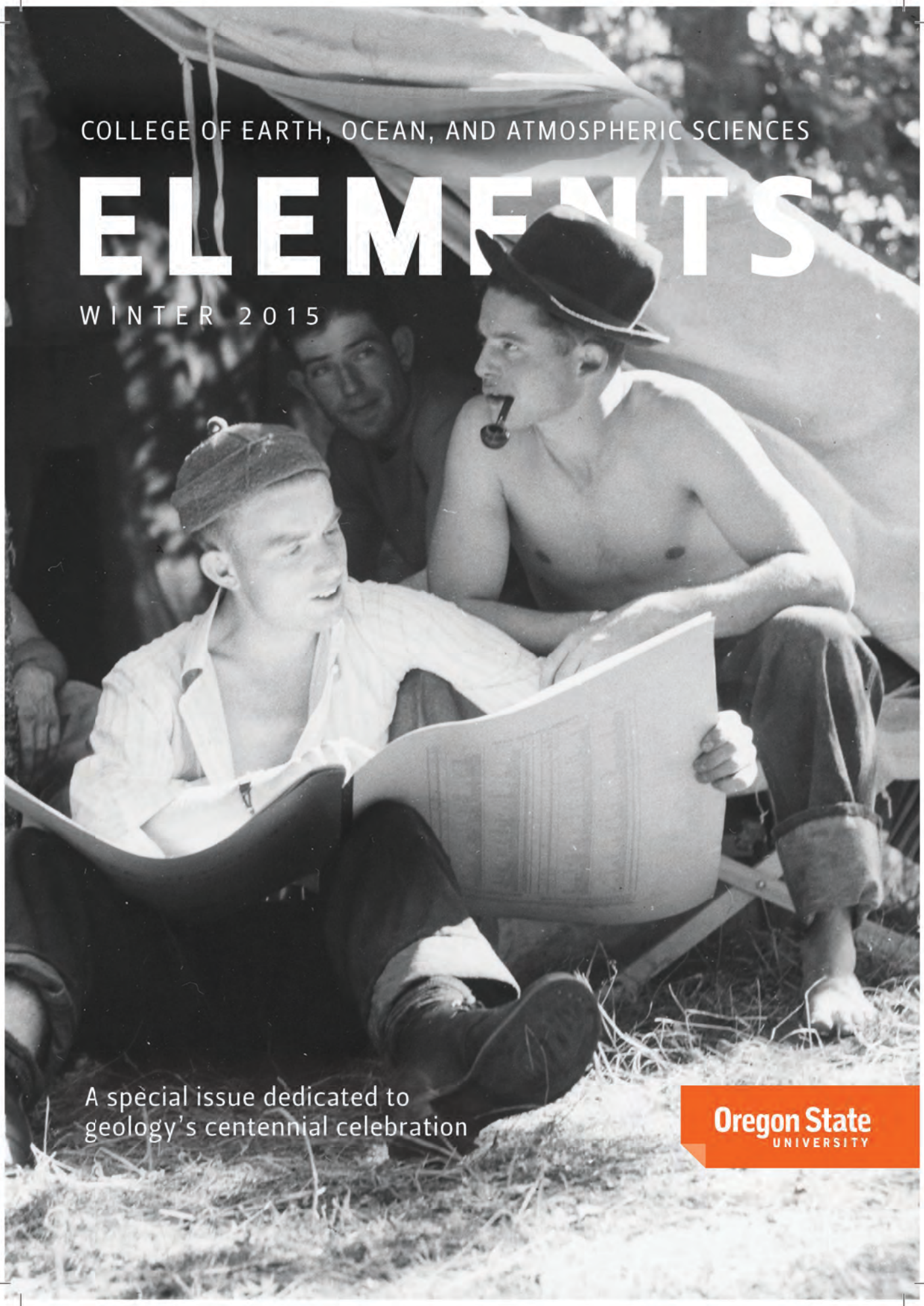

COLLEGE OF EARTH, OCEAN, AND ATMOSPHERIC SCIENCES

ELEMENTS

WINTER 2015

A special issue dedicated to geology's centennial celebration

Oregon State UNIVERSITY

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About the College

The College of Earth, Ocean, and Atmospheric Sciences (CEOAS) is internationally recognized as a leader in the study of the Earth as an integrated system. With more than 100 faculty, and about 200 graduate and 600 undergraduate students, the college has an annual budget of more than $50 million, with much of the research support coming from the National Science Foundation, National Oceanic and Atmospheric Administration, National Aeronautics and Space Administration and other federal agencies.

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CELEBRATING 100 YEARS OF GEOLOGY AT OREGON STATE

"Geology is the science of the Earth. Some knowledge and appreciation of the Earth on which we live is essential for those who wish to face intelligently the problems of modern life."

Oregon State's 1951 catalog featured those words about its geology program, which began in 1914. As we celebrate 100 years of the discipline at OSU, we reflect on the nearly 2,000 students who have lived by that creed. Indeed they have addressed many pressing problems, whether through the discovery of earth resources, through recognition and mitigation of natural hazards, or through environmental remediation of human impacts.

This issue of *Elements* is dedicated to the people who have shaped this legacy program — and the untold number who will carry it forward during the next century. It also recognizes our important relationship with geography, environmental sciences, oceanography and other disciplines. Together with our colleagues across the College of Earth, Ocean, and Atmospheric Sciences, geology research and academic programs have expanded to encompass the Earth as an integrated system.

You can read about the many ways we are advancing Earth system sciences, whether it's Peter Clark and his work to connect past conditions of the Antarctic Ice Sheet and future climate scenarios, or Kim Bernard and her effort to understand how fluctuating sea ice impacts krill populations, and subsequently, the foraging behavior of Adélie penguins. You can learn about John Dilles and his perspective on the changing, yet fundamental nature of geology at Oregon State. The students who spent four days conducting research on Oregon State's research vessel *Oceanus* also improve our grasp of ocean ecology and coastal science. Finally, you can browse historical highlights of the geology program or read about the many alumni who joined us during the Geo@100 event in June.

With 100 years behind us, we are poised to educate the next generation of students and help them face intelligently the problems of modern life. Thank you for all your support along the way.

Mark Abbott
Dean

Jack Barth
Associate Dean for Research

Anita Grunder
Associate Dean for Academic Programs

OREGON STATE GEOLOGY PROGRAM TURNS 100

Alumni from across the state and nation gathered in Corvallis in June to celebrate 100 years of geology at Oregon State University. The four-day Geo@100 event featured lab tours, mini-courses, field trips and a host of other activities that honored the program's long-standing history and significance to the profession.

Recent graduates and seasoned professionals alike learned about the program's roots, which date back to the late 1800s when the first geology courses were offered. The program officially launched in 1914 and has since evolved to include studies in paleoclimatology, geophysics, volcanology and other areas.

The event also provided opportunities to learn about advances in the geological sciences. Mini-courses covered topics such as glaciers and earthquakes in Cascadia, while tours showcased cutting-edge research in labs such as the ice core lab and the W.M. Keck Collaboratory for Plasma Spectrometry.

Cathie Stumpenhaus, a 1974 graduate who came to the event from Portland, said much of the sophisticated lab equipment on display had yet to be invented when she attended Oregon State. Even so, her geology degree equipped her for a fruitful, 30-year career as an environmental geologist. "My degree in geology is the bedrock of my career," she said, pun intended.

For Robert Rosé, who earned his geology bachelor's in 1964 and master's in 1967, the gathering was a learning experience and a chance to connect with former classmates. "I've talked with some people here who I haven't seen in 30 years," he said.

CEOAS Dean Mark Abbott said the geology program has a century-long track record of providing meaningful learning experiences for students. "The program has a lot to be proud of in terms of engaging students in research. It really is an outstanding program," he said.

Anita Grunder, associate dean for academic programs and the event's organizer, thanked attendees for supporting the centennial celebration and laying the groundwork for the next 100 years. "It is so touching to see all these people who have done great things with their lives and whose roots are with us," she said. "It has made this century so meaningful, and I hope we build programs that do this for another century."

ANTARCTIC ICE SHEET
UNSTABLE AT THE END OF THE LAST ICE AGE

A new study has found that the Antarctic Ice Sheet began melting after the last ice age — about 5,000 years earlier than previously thought — and shrinkage of the vast ice sheet accelerated during eight distinct episodes, causing rapid sea level rise.

The international study, funded in part by the National Science Foundation, is particularly important coming on the heels of recent studies that suggest destabilization of part of the West Antarctic Ice Sheet has begun.

The researchers examined two sediment cores from the Scotia Sea between Antarctica and South America. These cores contained "iceberg-rafted debris" that had been scraped off Antarctica by moving. As the icebergs melted, they dropped the rock debris into the seafloor sediments, giving scientists a glimpse at the past behavior of the Antarctic Ice Sheet.

Periods of rapid increases in iceberg-rafted debris suggest that more icebergs were being released by the Antarctic Ice Sheet. The researchers discovered increased amounts of debris during eight separate episodes beginning as early as 20,000 years ago, and continuing until 9,000 years ago.

The research also provides the first solid evidence that the Antarctic Ice Sheet contributed to what is known as meltwater pulse 1A, a period of very rapid sea level rise that began some 14,500 years ago, according to Peter Clark, an Oregon State University paleoclimatologist and co-author of the study.

"During that time, the sea level on a global basis rose about 50 feet in just 350 years — or about 20 times faster than sea level rise over the last century," noted Clark. "We don't yet know what triggered these eight episodes or pulses, but it appears that once the melting of the ice sheet began, it was amplified by physical processes. Our new results suggest that the Antarctic Ice Sheet is more unstable than previously considered."

TYLER SCHLIEDER

Continental Volcanism

Tyler Schlieder recently graduated from Oregon State, where he worked with Robert Duncan to study the timing and composition of continental volcanism in western Saudi Arabia. A former member of the National Society of Collegiate Scholars, a CEOAS undergraduate ambassador and three-time winner of the CEOAS award for excellence in geology, Schlieder is now studying igneous petrology and geochemistry as a graduate student at Northern Arizona University.

TIMELESS AND TRANSFORMING:
JOHN DILLES REFLECTS ON THE EVOLUTION OF THE GEOLOGY PROGRAM

Geology Professor John Dilles rolls out a map of a mineral deposit site he charted as a student in the late 1960s and early 1970s. Colorful veins of yellow and rust mark faults and ore deposits — revealing the origins and locations of the Earth's buried treasure.

Once, such maps were created by hand. Early instruments could analyze rock samples down to just 1 part per million, letting mining operations know how much of a mineral existed, and whether it was worth extracting. For reference, 1 part per million is comparable to one inch in 16 miles or one second in 11.5 days.

Today, sophisticated equipment and computers do a lot of the work. GIS software captures and analyzes layers of geographical data. A plasma spectrometer at Oregon State's W.M. Keck Collaboratory can detect the chemical composition of minerals down to 1 part per billion — 1,000 times more sensitive than the instruments Dilles used as a student.

With the advent of new technologies and a shifting global landscape, the geology discipline has changed over the years. Yet, as they say, some things stay the same.

"A lot of geology is still fundamental. Whether you're trying to find a mineral deposit or water, or you need to figure out where to put power or gas lines, you need geologists to predict what's down below," Dilles said.

Dilles should know. He has been with Oregon State for almost 30 years, and his research in mineral geology has kept him aware of industry demand and the continued need for field research.

He has also seen the political, economic and environmental drivers that have influenced mineral geology, particularly copper mining. While copper was once relatively easy to extract, a growing awareness of mining's ecological impact and diminishing stores have complicated the process.

"The problem is, easy-to-access deposits have mostly been used up, so now it's down to the hard-to-get stuff," he said. "Copper mines run roughly half to one percent copper, so 99 percent of the stuff they grind up ends up as waste rock."

In addition, copper demand is on the rise, particularly in China and India. "The world today is using about 18 million metric tons of copper per year. If you put that into pounds, it would be about 40 billion pounds of copper, and the average American uses about 12 pounds of copper per year."

Oregon State's geology program has adapted to these global complexities. From a strong emphasis in mining geology in the early days, geology expanded to support petroleum resource development, and it has recently grown to include natural hazards and a wide range of environmental concerns.

Dilles noted that the program once hired more sedimentology professors in the 50s, 60s and early 70s when the oil industry was booming. Since then, disciplinary threads in glaciation, climate change and geomorphology have taken hold, along with sophisticated instruments that provide new information about our Earth.

But Dilles circles back to the one thing that may never change, the bedrock of geology at Oregon State: people.

"It still takes the people," he said. "Geologists can still pick up a rock and tell you something about that rock. That part is really important, and we've tried to preserve that in the geology degree."

ELLEN SVADLENAK

Trace Metal Zoning

University Honors College student Ellen Svadlenak is working with Professor John Dilles to analyze trace metal zoning in Colombian emeralds and their host rocks, in an attempt to understand how those trace metal concentrations evolved during emerald growth. Her work is part of the Research Experience for Undergraduates program, and she was recently honored with an Excellence in Earth Science award.

John Dilles (left), looks at a mineral deposit map with colleagues during a field exploration in Namibia.

A brief history of **Geology** at Oregon State

The Geology Department got its start in 1914 at what was then Oregon Agricultural College, one year after the Oregon Legislature approved the establishment of the School of Mines, which had four departments, including geology. But geology courses were offered through various programs long before that. Alice E. Biddle, the first woman to graduate from what was then Corvallis College, did quite well according to her 1870 transcript.

1926: Students wearing "mines breathers."

CORVALLIS COLLEGE.

"Labor omnia vincit."

Report of Scholarship and Deportment of

Miss Alice E. Biddle

For ..... April 1870

Reading,	Polit'l Text Book,
Orthography,	Mechanics, 90
Writing,	Astronomy, 90
Geography,	Rhetoric,
Grammar,	Botany, 95
Arithmetic,	History, 95
Elocution,	Criticism, 95
Physiology,	Eng. Literature,
Algebra,	Political Economy,
Geometry,	Chemistry, 98
Trigonometry,	Classical Literature,
Book-Keeping,	Latin,
Navigation,	Greek,
Surveying,	Music,
Analytics,	Composition, 95
Nat. Philosophy,	Declamation,
Philosophy,	Deportment, 100
Philosophy,	

100 is the ma

A. FINLEY

EMERY

1905: Early geology-related classes were held in the Paleontology Building, now the Women's Center.

1910: Lab for Mineralogy 101.

1913: Mines Building, now Batcheller Hall, was home to geology classes until 1939.

1928: School of Mines faculty at the beach.

1939: The first female geology graduate, Jean Bowman Clark, was housed at a ranch house in Mitchell, Oregon, rather than at the nearby camp with her male classmates.

1940: Following the closure of the School of Mines, the Department of Geology moved to Education Hall.

Geology courses in Chemistry and Pharmacy

Geology courses in Engineering and Mechanical Arts

Department of Geology in the School of Mines

Department of Geology in School of Science

• *Geology as a major emerges*

1900 1910 1920 1930 1940 1950

1958: Geology field camp with W.D. "Doc" Wilkinson (center).

1981: Field work in Eastern Oregon.

1973: Wilkinson Hall became the new home for geology and geography. It was named in tribute to W.D. "Doc" Wilkinson, who served the department for 34 years.

2011: The Department of Geology joins the College of Earth, Ocean, and Atmospheric Sciences.

2012: Geo Club in Muktinath, Nepal.

1978: Chow line at geology camp. The site near Mitchell in Oregon was purchased in 1979, and a permanent structure designed by Ed Taylor was built in 1983. Geology camp has been an Oregon State tradition since 1934.

2014: Sherm Bloomer confers with Peter Clark at the Geo@100 celebration; 80 undergraduate and 40 graduate students are in the geology program.

For a more detailed pictorial history of geology at Oregon State, see the Geo@100 posters:

ceoas.oregonstate.edu/GeologyAtOneHundred/timeline1.pdf

ceoas.oregonstate.edu/GeologyAtOneHundred/timeline2.pdf

• School of Science becomes College of Science

• First doctoral degree in geology is conferred

Department of Geosciences in the College of Science

Geology and Geophysics discipline in CEOAS

1960 1970 1980 1990 2000 2010

FORAGING FOR TRUTH

KIM BERNARD
PHOTO BY: HANK STATSCEWICH

The population of Adélie penguins in the Western Antarctic Peninsula have been steadily declining for the past 30 years, and Kim Bernard wants to know why.

Climate change, fluctuations in sea ice and unpredictable ocean conditions may be connected culprits. To find out more, the assistant professor in high-latitude oceanography at Oregon State University travels every year to Antarctica's freezing fringe. There, she studies the patterns in nearshore density and distribution of Antarctic krill — the primary food source for Adélies — and the environmental conditions that might explain the decline.

Bernard's work is part of a broader, multi-university research project called CONVERGE that explores the complex interplay between physical ocean processes and ecology, particularly whether tidal currents impact krill populations and in turn, the foraging behavior of Adélie penguins. Because krill are an important food source for other predators in the region, including whales, seals and seabirds, learning

the drivers of change to their distribution patterns and total biomass will provide a broader understanding of the Antarctic ecosystem.

Bernard's role in the CONVERGE project involves sampling krill from a Zodiac inflatable boat using a Biosonics DT-X single frequency echo sounder. It works by converting electrical energy to sound, which is then transmitted through water. Objects with a different density than water reflect back sound, giving her an idea of what is beneath the surface.

"Krill form dense aggregations, like schooling fish, that are easily distinguishable on the echo sounder," Bernard said.

Bernard's data will be coupled with real-time surface current maps generated from a series of High-Frequency Radar systems (HFR). The maps will help researchers identify regions of convergence — or strong ocean currents that often result in outbreaks of high biological productivity. Bernard can then confirm these biological hot spots with additional acoustic krill sampling.

"The combination of the real-time surface convergence maps with adaptive in-situ sampling will allow us to rigorously and efficiently test the influence of local tidal processes on top predator foraging ecology," she said.

Bernard has so far observed links between tides and nearshore densities of krill. The tides in the region oscillate between diurnal (one high, one low tide per 24-hour period) and semi-diurnal (two high, two low tides per 24-hour period). Bernard has recorded greatest krill densities during diurnal tides.

However, her analysis of new data suggests that this might not always be the case, and that sea ice may also play a role. Because krill depend on sea ice for food and shelter, their numbers vary depending on conditions. Favorable conditions with large krill numbers may buffer the effects of a semi-diurnal tide and provide enough nearby food so the penguins don't have to travel far while hunting. But a year with less sea ice means lower krill numbers, which may also increase the tidal influence enough to force the penguins to travel offshore and expend more energy while foraging for food.

"Traveling offshore to forage is a huge energy cost for the Adélies, and if sea ice conditions worsen with climate change and result in consistently smaller krill populations in the future, there will likely be an impact on the penguins," Bernard said.

Such findings are providing important insights that contribute to our understanding of the local survival of Adélie penguins in the north of the Western Antarctic Peninsula. Yet, collecting samples off the world's most frigid continent poses challenges. Bernard spends seven hours a day in a Zodiac on icy waters, routinely wearing two layers of thermal underwear, fleece pants, a down jacket, a waterproof coverall called a sailing bib, a mustang coat, a wool hat, a neck gaiter and three pairs of gloves that she switches between as they get wet — just to do her acoustic sampling.

Installing the HFRs can also be dangerous with unpredictable sea ice. Too much, and researchers won't be able to navigate the Zodiac and land on the island. If they do reach the island, the ice could suddenly increase and strand the researchers.

"There are a number of risks involved, but the reward will be very high," she said.

Bernard hopes to soon determine the finer details of small-scale, coastal oceanographic variability and its impact on krill distribution patterns and Adélie penguin foraging. That quest lures her back to the most remote — and perhaps the most remarkable — place on our planet.

"It might seem crazy, but I wouldn't want to be anywhere else."

APRIL ABBOTT

Rare Earth Elements

April Abbott is a Ph.D. student in ocean ecology and biogeochemistry working with faculty researchers Brian Haley and James McManus. Her research explores the rich interactions between the water column, sediment and porewater and the resulting effect on rare earth elements that are important tracers for biogeochemical pathways. While at Oregon State, she has received the teaching assistant excellence award and the CEOAS student research fellowship.

OCEANOGRAPHY BOOT CAMP

Students take the science helm in Oregon Coast research cruise

If they had come home early, you wouldn't have been surprised. Half of them got seasick. Equipment failed. And the weather changed unexpectedly. But last April, 11 Oregon college students from three institutions — Oregon State University, the University of Oregon and Clatsop Community College — stuck it out for four days at sea on Oregon State's research vessel *Oceanus* and learned what it's like to run their own oceanographic research cruise. They returned with respect for the difficulties of doing science on a rolling ocean and a better understanding of what stirs beneath Oregon's coastal waters.

The students deployed and piloted two autonomous underwater gliders, captured underwater video, collected data on water chemistry and phytoplankton and monitored currents as well as upwelling and downwelling events. Unfortunately, oxygen sensors on the ship's ocean sampler failed, and some sensors secured to a mooring were lost in heavy seas.

When the unexpected happened, the two Oregon State students who served as chief scientists — Alejandra Sanchez and Rosie Gradoville — had to make rapid adjustments, said Angelicque White, one of the organizers and an assistant professor in the College of Earth, Ocean, and Atmospheric Sciences. To compensate, the students collected extra water samples and relied heavily on the glider measurements.

OSU oceanographer Angelicque White helps students deploy equipment into the waters off Cape Perpetua. (Photo: Molly O'Neill)

"They had a profound lesson in doing real oceanography," added Kipp Shearman, a CEOAS associate professor. "It was particularly exciting for me to see how they grappled with a lot of the same things that I do now as a scientist."

The students were tackling an oceanographic conundrum: what underlies occasionally rapid and drastic changes to underwater habitats. They zeroed in on a hot spot along the central Oregon coast, the Cape Perpetua Marine Reserve. In past years, this area has seen abnormally low oxygen conditions — leading to what has been called a hypoxia dead zone.

The students looked at the factors that might cause extreme low oxygen conditions to arise. They also considered how those factors might affect fish, crabs and other sea life. The issue is particularly important now because fishing restrictions in the reserve went into effect in 2013, and scientists want to know whether future ecosystem changes are due to natural variability or to changes in fishing.

Lives on the Line

The students' results are providing scientists with useful data about the reserve, but the experience of planning and carrying out experiments was life changing.

"The thing that surprised me the most was the amount of foresight and planning that is required for a successful cruise," wrote Molly O'Neill, a student from the University of Oregon, in an email. "Even for just a four-day cruise, the principal investigators expend an enormous amount of time and energy planning every hour of every day. From the loading dock to the university, there is so much that needs to be accounted for. The logistics need to be thought through in such extreme detail because time, money and people's lives are on the line. It was a tremendous learning experience that will stay with us forever."

For Sanchez, an Oregon State graduate student, the trip was worth the problems the students encountered. "I always get seasick in research ships, sometimes worse than others, but I really enjoy going out and doing it anyway," she said. "It's the adventure that attracts me. You are out there trying to find something, and you are using all this equipment to find it, so I feel like an explorer. Sometimes you find what you are looking for, and sometimes you find something else, but you always learn something new."

The level of teamwork also provided an important lesson. "One of my favorite things about the cruise was the opportunity to work on a tight-knit team, aligned toward the same goal," wrote O'Neill. "Everyone had a job, but we all relied on each other for support and morale. Perhaps the most important thing we learned was how to safely work aboard a pitching and rolling vessel on the high seas."

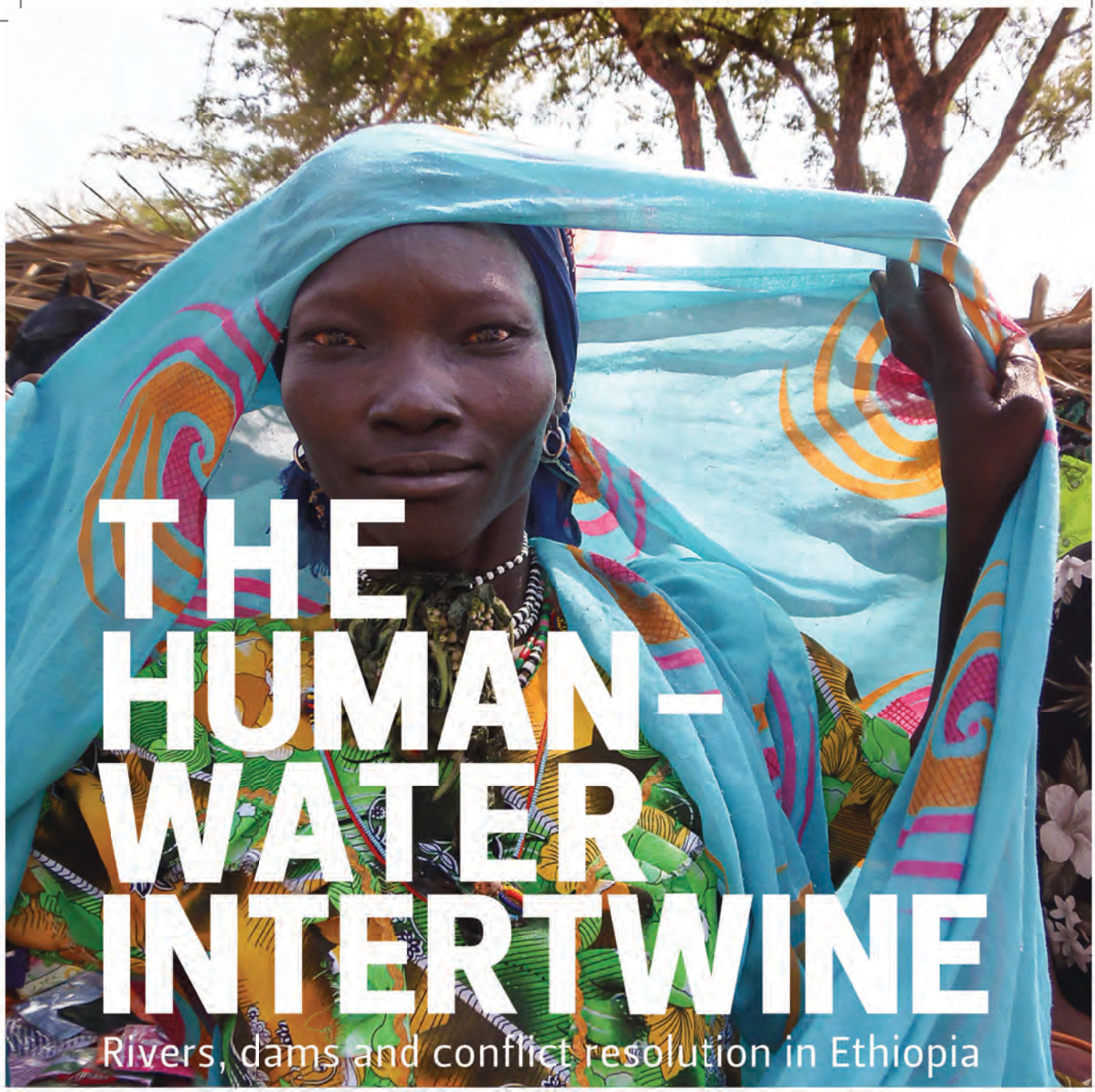
Shearman, White and their CEOAS colleague Laurie Juranek applied for financial support for the trip through what may be a unique program in the United States. In 2013, the state legislature created a $300,000 fund at Oregon State University for oceanographic research. State agencies and Oregon University System faculty and students are eligible to apply for funding. A Research Vessel Council chaired by Jack Barth, professor and associate dean for research, reviews grant requests.

"State funding for an educational expedition like this is huge," said White. "We are so grateful to the legislators for making this possible for the students."

LINDSAY CARROLL

Communicating Coastal Science

Lindsay Carroll is a master's student in the Marine Resource Management Program, where she studies sand dune conservation using effective science communication and data interpretation. Carroll spent her summer profiling and sampling various dune transects along the Oregon and Washington coastlines, with the beaches of the Pacific Ocean serving as her office.



THE HUMAN-WATER INTERTWINE

Rivers, dams and conflict resolution in Ethiopia

Two years ago, the online newspaper *Aljazeera* ran a stark headline: Almost half of humanity will face water scarcity by 2030. Similar stories have splashed the front pages of major newspapers for nearly 20 years, with many predicting global water wars.

Jennifer Veilleux sees a different picture. The recent Ph.D. graduate from Oregon State's geography program studied the human dimensions of dam development on international rivers. Her work explored the complex intertwine between people and water, and how resource sharing can serve as a platform for peace rather than conflict.

"Water is needed and shared by every sector of human society and the ecosystem. It shapes the physical and human landscape," she said. "I wanted to explore how different communities of people fit in when water is shared between countries and cultures, while examining how resource use can be cooperative."

Veilleux's research took her to Ethiopia's Blue Nile River, where she spent five months interviewing urban Ethiopians, as well as rural communities who will be displaced by a controversial capital improvement project — the Grand Ethiopian Renaissance Dam.

The dam presents both enormous opportunities and challenges for Ethiopia. On one hand, it will provide reliable power. "Only about 40 percent of Ethiopia has electricity. When complete, the massive, 6,000-megawatt Renaissance Dam will be the largest hydroelectric power plant in Africa, expanding electricity coverage in Ethiopia and neighboring countries," Veilleux said.

It's also a source of pride for Ethiopians, who are eager to shed the perception of being a famine-plagued and donor country rather than an African leader with a middle-class economy.

"Dams are really big power symbols, not just for their capacity to harness energy, but as symbols of modernity and identity," she said.

Yet, the dam means something else for the 20,000 people who will be displaced by the project. The vast majority of these are the Gumuz people, a little-studied subsistence culture found mostly along the Blue Nile in Ethiopia and Sudan. Local Gumuz have important traditional knowledge about the region's natural resources and depend on the Blue Nile for their livelihood and identity. The river is a vital source for water, food and artisanal gold mining that allows for economic trade with nearby communities.

While the Ethiopian government has a comprehensive resettlement program, Veilleux's research raises many important — and unanswered — questions: What will replace gold as a currency in a cash economy? How will farming change without seasonal flooding? Will malaria rates increase with a stagnant reservoir? How will it change the fish stocks and equipment needed to catch them? How will the Gumuz stay connected to other villages when the now-navigable river becomes an expansive lake? Will moving to an urban area lead to increased social problems related to modern life, such as a loss of cultural identity?

Veilleux also made an unexpected find that went against prevailing predictions of water wars: Despite the dam's threat to uproot the Gumuz and their subsistence culture, study participants showed flexibility, resolve and general acceptance.

"I think people had a very keen sense of being river people, meaning they are very adamant about staying near the water because it's their everything, their life. But I was surprised at how flexible they were about moving," she said.

One possible explanation is that the project may benefit the Gumuz in certain respects. "If done correctly, the Ethiopian government can greatly improve some of the challenges that the Gumuz communities face due to malnutrition, disease or lack of access to secondary or higher education. Resource sharing will also improve the lives of Ethiopians who benefit from expanded electricity," Veilleux said.

But she cautioned that the cultural costs should not be ignored. "More attention needs to be spent on identifying the vulnerabilities and strengths of local communities, to buffer possible threats to these areas and to make sure that the benefits outweigh the costs."

Using her qualitative data from the Gumuz people, as well as a similar comparison study in Laos on the Xayaburi Dam, Veilleux developed a Human Security Measurement Key that will help identify security vulnerabilities in complex resource-dependent systems. The key provides a platform to compare disparate data sources across multiple geographic and time scales, and it has been integrated into the Transboundary Freshwater Dispute Database (TFDD), a comprehensive set of water data that aids in understanding water conflict and cooperation.

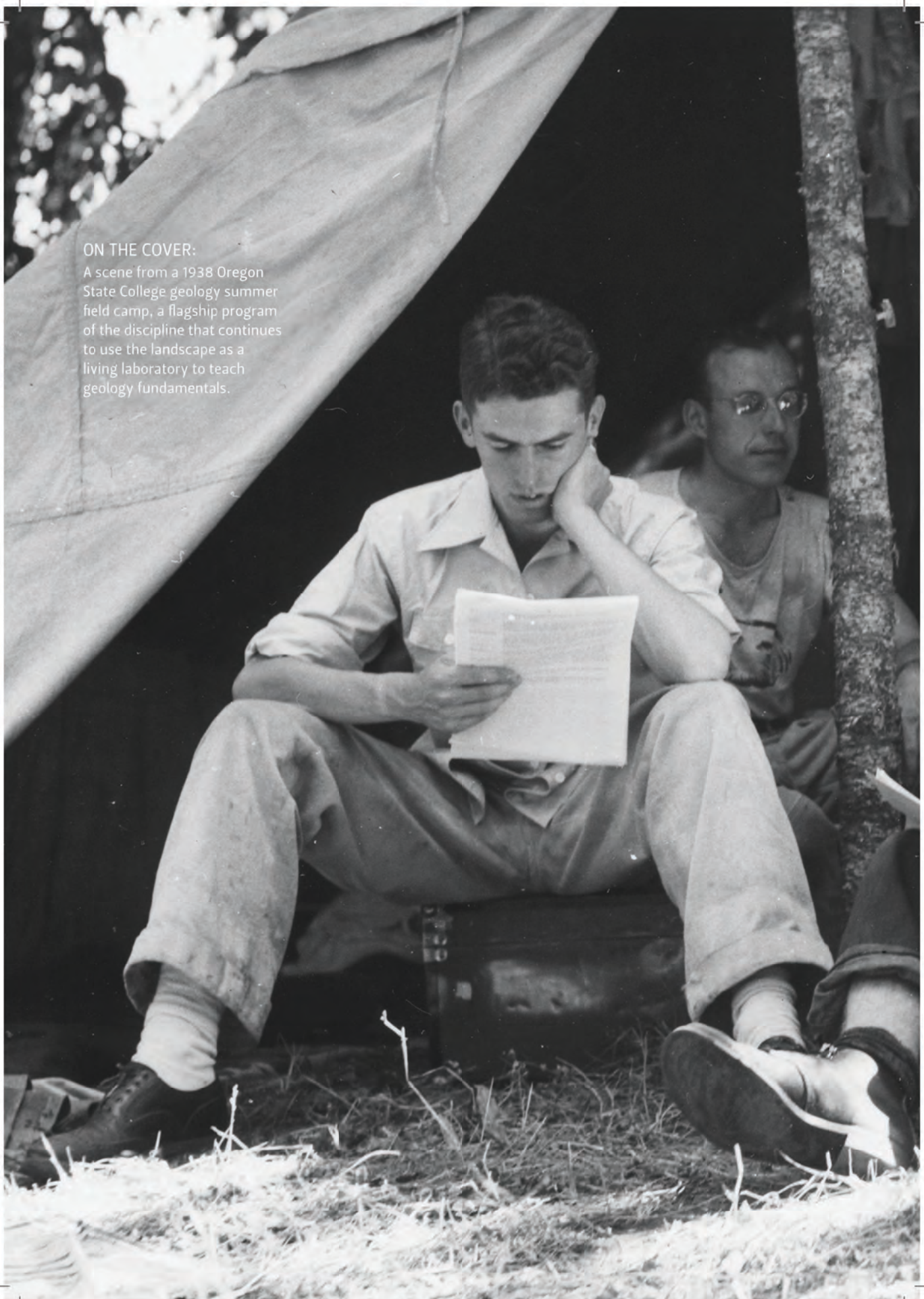
ABOUT JENNIFER VEILLEUX

Major: Geography (Ph.D., 2014)

Advisor: Aaron Wolf, Professor of Geography and Water Resources

Most interesting job: Live sound mixing for the Smithsonian Folklife Festival in Washington, D.C. or writer for E/Environmental Magazine

Major accomplishments: Recipient of the Gray Family Fund for Geographers Award; National Security Education Program/Boren Fellow, Visiting Fellow at Central European University; Visiting Fellow at the Hungarian Academy of Sciences, United States Geospatial Intelligence Foundation Scholar; Visiting Scholar at the International Management of Watersheds Institute in Addis Ababa, Ethiopia; Visiting Researcher at the Naga House in Vientiane, Laos



ON THE COVER:
A scene from a 1938 Oregon State College geology summer field camp, a flagship program of the discipline that continues to use the landscape as a living laboratory to teach geology fundamentals.