



The Hunt for Microbial Dark Matter in the Deep Terrestrial Subsurface

Current interpretations of Archean carbonaceous sediments suggest that the emergence of the first forms of life, presumably the ancestors of modern Bacteria and Archaea, occurred by 3.5 billion years ago, providing ample time for genetic diversification. About 10^{30} of these predominantly unicellular organisms currently occupy every known suitable environment and metabolic niche on Earth. The great majority of bacterial and archaeal phylogenetic groups have not yet been obtained in pure culture and we have only recently become aware of their presence, mainly through cultivation-independent surveys of 16S rRNA genes. However, 16S rRNA gene sequences alone have limited capacity to reveal biological features of this so-called "Microbial Dark Matter" or MDM. The recent development of single cell genomics has enabled, for the first time, routine recovery of genomic blueprints from uncultured taxonomic groups, providing rich information about their evolutionary histories, metabolic potential and ecological

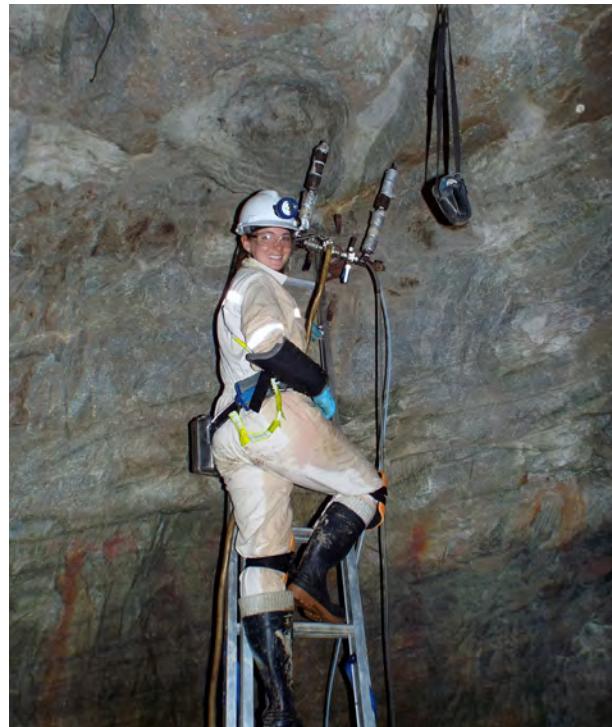


Fig. 1 - Rachel Harris successfully installs cell incubation and lipid cartridges to the front arms of the prawn at BE326-BH2 one mile beneath the surface. A methanometer is hanging next to her. Photo by: T.C. Onstott

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roles. This new capacity offers an unprecedented opportunity to fill a major knowledge gap, namely a robust reconstruction of the deep genealogy of the domains of Bacteria and Archaea.

Prof. Tullis C. Onstott *81 and his colleagues from UC Davis, the U.S. Department of Energy's Joint Genome Institute, Bigelow Laboratory for Ocean Sciences, and Desert Research Institute in Las Vegas, have recently been awarded a 5-year grant from the National Science Foundation to use single cell genomics to lay a foundation for a major overhaul of the genealogy of Bacteria

¹Cara Magnabosco's trip to Portugal was supported by NASA's Lewis and Clark Fund for Exploration and Field Research.

and Archaea and of our understanding of the early evolution of life. The project is named the Genealogy of Life Project, or "GoLife". More specifically, GoLife intends to illuminate (1) the genealogy of the two prokaryotic domains, (2) the relative timing of their origins, and (3) the role that horizontal gene transfer among distant relatives may have played in the origins of new species and novel ways of living. GoLife collaborators will continue to perform MDM sampling from unexplored subterranean environments around the world where a large proportion of MDM resides. During the summer of 2015, members of the Onstott group traveled to Portugal¹ (**Cara Magnabosco**) and South Africa (**Tullis Onstott, Maggie Lau, Rachel Harris**) to venture one mile beneath the surface to sample fracture water and to sample deep aquifers via thermal springs.

Their expedition in South Africa began at Beatrix Gold Mine, which is situated 240 km southwest of Johannesburg, in the Free State province. Geologically, the mine removes gold from Central Rand Group fluvial deposit on the southern rim of the Witwatersrand Basin, where ~2.9 billion years ago, vast networks of rivers carried elemental gold down from mountains in the north. Relative to other gold mines in South Africa, Beatrix carries out operations at fairly shallow depths – between 700 m and 2,200 m below land surface. Fifteen years ago the Onstott group discovered new archaeal lineages, which they called SAGMAs (South African Gold Mine Archaea) at a site located at 1.34 km beneath the surface. Today SAGMAs are recognized as MDM and are found globally beneath the surface of our planet. The goal of the expedition was to return to this site to capture single cells of SAGMAs.

Beatrix Gold Mine, Free State

We awoke at 3:30 a.m. in a B&B in Bloemfontein and quickly drove to the Microbiology Department at the University of the Free State to pick up our backpacks stuffed with sampling gear. By 4:30 a.m. we were speeding up the N1 to make the mine for 6 a.m. check in. Late June marks the middle of austral winter, and we felt the bite of its dry wind upon stepping out of our bakkie² at the entrance to Beatrix #3 shaft. After exchanging our clothing for standard issue coveralls, boots and helmet, watching a one half hour safety video, picking up our headlamps and emergency self-rescuer breathing packs, we carded in through several narrow, full-height turnstiles, and crammed ourselves and our

backpacks with approximately 120 other miners into a slender, 3-story, steel elevator cage that transported us down to 26 level. The drop to the bottom passed in complete darkness and silence, accompanied by the low murmur of miners' voices and the occasional jostling of the cage against its steel guide rails. Those standing along the wall of the cage were subject to a constant pelting from debris raining from the shaft outside.

Several minutes later, the elevator quickly shaved speed before coming to a halt at level 26. We had just dropped the equivalent of 4½ World Trade Center elevator rides. We were bathed in halogen light as we charged out of the cage behind the platoon of miners who quickly dispersed down the tunnels ahead of us. From that moment we had three hours to collect samples; we maximized this time by marching briskly to our field site, borehole BE326-BH2, over 1 km away. The tunnel in which BE326-BH2 is located has not been under active operation since it was created 8 years ago. As we made our way closer to the borehole, evidence of this abandonment became increasingly evident by the accumulation of rusty-orange decommissioned machinery, ducting, and cables. We then came upon a pool of standing water that covered the tunnel floor in front of us and was too deep to wade across. Reaching for anchor bolts on the tunnel wall we climbed along the wall above the pool, but not without being splashed by water and biofilms seeping through fractures in the local fault zone. Beneath us were moving rafts of thick black, white, and orange microbial mats. Even thousands of meters beneath the Earth's surface it appeared that Princeton's sphere of influence could not be avoided.

For our greenhorn subterraneanaut, **Rachel**, the borehole was easy to miss. BE326-BH2 rests in an alcove nearly 3 m above the tunnel. One of the miners accompanying us carried in a ladder and propped it against the tunnel wall beneath the borehole. He climbed up to measure any CH₄ leakage and then hung his methanometer on the rock bolt above the valve. Balancing precariously on the ladder we attached the "prawn" (Fig. 1). The "prawn" is a six-legged, stainless steel manifold fitted with high-pressure valves that had been made by our machine shop. Though certainly the stuff of plumbers' nightmares, the prawn allowed us to collect multiple sample types at once, thus maximizing our limited time underground.

We are actively researching the mechanisms of CH₄ production and oxidation in the Witwa-

² A colloquial term in South Africa for a pick-up truck.

tersrand Basin. The $\delta^{13}\text{C}$ and $\delta^2\text{H}$ of the CH_4 indicate that much of the CH_4 encountered at less than 2 km depths is biogenic, i.e. produced by methanogenic bacteria that reduce CO_2 in the presence of H_2 . CH_4 also appears to be the primary carbon source at the base of the food web that sustains the entire microbial community, as evidenced by the greatly depleted $\delta^{13}\text{C}$ phospholipid fatty acids (constituents of cellular membranes) of the microbial biomass. At BE326-BH2 the biogenic CH_4 constitutes >70% of dissolved gases in the fluid-filled fracture. One would expect, then, that methanogens and methanotrophs (methane oxidizers) constitute a significant proportion of the microbial community, as they produce and oxidize CH_4 into readily available metabolites that sustain the rest of the microbial assemblage. Metagenomics, or the assessment of a microbial community's collective genetic composition, paints a different picture: methanogens and methanotrophs each appear to make up less than 1.5% of the total community composition at BE326-BH2. These results present a great conundrum: how can such a small population of organisms with thermodynamically limited metabolic rates sustainably support a community one hundred times their population size? The mysterious SAGMA may hold the key to resolving this mystery. To capture it and other potential MDM we attached crushed rock cartridges with various amendments and filters and opened up the valve to the borehole. The water would slowly flow through these for several weeks gathering biomass until our return to harvest them. After collecting a wide array of isotopic, gas and water samples, we put on our backpacks, hiked back to the cage and returned to the surface.

The Hot Springs of the Great Grey-Green Greasy Limpopo Province

Early the next morning, we departed Bloemfontein after having packed our bakkie full of sampling gear that we would use to sample the hot springs of the Limpopo Province, South Africa's northern most province that borders with Zimbabwe. After 4 hours on the N1, we stopped at the University of South Africa, which is located in one of the suburbs of Johannesburg. There we met Memory Tekere, a Zimbabwean microbiologist who had moved to South Africa and joined the faculty in this relatively new



Fig. 2 - Sampling team at Siloam thermal well. From left to right, Rachel Harris, Ciara Nutter, Prof. Memory Tekere of UNISA, and Maggie Lau filtering 70°C water for microbial dark matter. Photo by: T.C. Onstott

institution. During her research on the microbiology of the Limpopo springs she had found out that as much as 20% of the microorganisms could not be classified, i.e. they were MDM. We were also joined by Ciara Nutter, a Princeton undergraduate from South Africa. We then convoyed another 4 hours up the N1, arriving late at night at a traditional game lodge nestled in the woods on a mountain overlooking Louis Trichardt, the gateway to the great grey-green greasy Limpopo River watershed.

We all embarked from the lodge the next morning following the N1 as it snaked its way around the valley and ridges of the Soutpansberg. This mountain range is composed of Mesozoic sandstones and shale deposited in a failed-rift that formed with Gondwana split. The ancient rift valley marked the northern border of the Archean Kaapvaal Craton. Numerous mafic dikes intruded the basin and marked the locations where meteoric water that had infiltrated from the mountains tops and traveled kilometers down into the basin upwelled to the surface. We turned right off the highway and followed one of the roads down into a semi-lush valley with Baobab trees and several miles later turned onto a dirt road that led to a small village. Greeting us there was Ernest Shiba, who was the hydrologist studying the 15 hot springs located in the Limpopo. Ernest was Northern Sotho or Pedi and knew the tribal elders at our first stop, Siloam, home to the hottest hot spring in South Africa. After Ernest negotiated with the

tribal elder he took us to the small farm on which our target was located. The 70°C water of the Siloam hot spring had been captured by a well and was the hot water supply for washing clothes and dishes in the village. We had apparently arrived on washday as many locals were surrounding the drainpipes that flowed out from the property. After wresting our generator to the well, we inserted sterile tubing as far down into the artesian well as possible hoping to get away from air contamination. Then we turned on the peristaltic pump and started filtering the water. Each of us was in charge of a specific task, yet it took several hours to filter enough water to provide adequate biomass for genomic analyses as well as decent samples for gas and isotopic analyses (Fig. 2). Siloam had not disappointed us. It was 68°C and a pH of 9 with low dissolved O₂. This made it very similar to the composition of the deepest fracture water we had sampled in the mines of the Kaapvaal Craton. But would the water contain similar microorganisms? That was the question. After several days of sampling in the Limpopo we drove back to Bloemfontein and returned underground at Beatrix the following day to check on our experiment and collect more gas.

Hot Springs of the Cape Fold Belt

Immediately upon our return from the second visit to the Beatrix mine, we re-packed the sampling gear so that we would be ready for a 7-day trip sampling the hot springs in the mountains of the western and southern Cape Province. This 1,000 km long valley and ridge mountain range borders the southern margin of the Kaapvaal Province. It was formed during the late Paleozoic Era and then uplifted during the late Mesozoic Era. The 1 to 2 km high mountain ranges made of quartzite are separated by valley floors comprised of shale. In the valley floors along fault zones, which are seismically active, lie over a dozen thermal springs. This should be prime hunting ground for subsurface MDM.

The next morning, we flew to Johannesburg where we met Tom Kieft, a microbiologist from New Mexico Institute of Technology and a long time partner in the discovery of deep biosphere, who had just flown in from the U.S. We arrived at Cape Town and met Chris Hartnady at his consulting company UVMOTO Africa at Muizenberg. Chris was on the faculty at the University of Cape Town and a former recipient of the Hess Fellowship. Now Chris applies his knowledge in structural geology and hydrogeology to sustainable development. The international field team also included Steve Richardson, a isotopic geochemist and geochronologist of the University of Cape Town; Esta

van Heerden, a biochemist from the University of the Free State; Ramganesh Selvarajan, a microbiologist from the University of South Africa; and Michael Hartnady, Chris' son, who is also a geologist with the Namibia Geological Survey.

After a few hours of sleep, the team met at 6:30 a.m. and got breakfast from a local bakery before hitting the road. We drove along the shoreline of False Bay as the sun slowly rose above the horizon. The first site was Brandvlei, the hottest spring in the Cape Province (~60°C) (Fig. 3). This scenic hot spring looks typical as those in tourism magazines - steam hovering above the clear water, but it is located within the Brandvlei Correction Centre (formerly Brandvlei Prison). Gas bubbled out from around the spring basin, which had a radius of 3-4 meters. Tom tied a stone to the end of the sampling tube and threw it to the center in order to reach the hot water directly fed from the underground and turned on the peristaltic pump. Since the cell concentrations in the water were anticipated to be low, we concentrated the cells by filtration. Unlike the other sites, some fine, white particles of amorphous silica severely clogged the membrane quickly. With persistence we filtered for 7 hours (the long hours paid off because later we successfully extracted DNA from the filters, which will be used to determine the percentage of MDM).

The next day we drove north to sample water from an artesian well located at the back of a citrus farm at Blikhuis, and visited the potential sampling sites at Citrusdal (The Bath). As we traveled on the hilly road along the north-south Cederberg Mountains and through the west-east Hex River Mountains of the Table Mountain Group, it was interesting to see different features that clearly marked surface displacement due to recent earthquakes. "It is not a good idea to have geologists drive about in this area as they easily get distracted," Chris joked in the bakki. He wasn't wrong; at one point he suddenly pulled over at an early Devonian outcrop and we hunted for fossil trilobites on the side of the road. The rest of the sampling trip at the central Cape went smoothly, partly because of the easy access to the outlet for electricity to power our peristaltic pump. We returned from South Africa with a total of ten sets of isotopic, gas, and natural and pre-concentrated water samples for MDM. ■

The Hot Springs of Northern Portugal

In the northern hemisphere, **Cara Magnabosco** traveled solo to northern Portugal to sample a series of thermal springs. The first set of thermal springs sampled were in the thermal region of São Pedro do Sul, which is located approximately 230 km northeast of Lisbon. She sampled four thermal springs emitting water between 66°C and 67°C. These springs arise within two distinct mineral water producing areas ~1.2 km apart that are referred to as the "spa" and "vau" sectors. In the spa sector, an artesian well dating back to the Roman Empire and a well that samples water from 500-m depth were sampled. In the vau sector, a small mineral spring and well naturally pumping water from a depth of 216-m were sampled. All of the thermal springs in São Pedro do Sul are associated with the Verin-Régua-Penacova Fault that cuts through Paleozoic Era granites. While in São Pedro do Sul, **Cara** also led a short course on astrobiology for 25 tenth graders at the local high school. Following the course, these students participated in fieldwork at two thermal springs located in Termas, São Pedro do Sul. Their task was to analyze the water coming out of different springs in the thermal area using the same CheMet-kits, pH probe, and microscopes we use in the field. The day ended with all students receiving some NASA swag (astrobiology books and stickers) and ice cream from a local café (Fig. 4).

Later that week, **Cara** traveled to the Longroiva to sample with scientists from the Universidade da Beira Interior. The thermal waters were located in northeast Portugal along the Vilariça Fault. The region is characterized by a local mountain range (average altitude of 750-m) extending NNE-SSW from Trancoso to Longroiva. Several springs arise in this region, three of which were known to be rich in sulfur. **Cara** targeted those three sulfur-rich spring sources, which were hosted in granitoids. Although the temperatures of these waters are more moderate (18 to 45°C), the Portuguese scientists believe that the water originates from 1200 meters depth and we suspect they will host MDM's. The coolest spring (18°C), reachable only by foot in the Portuguese backcountry, has been used for medicinal purposes since Roman times and is home to a species of frogs believed to be endemic to the spring.

On the final field trip, two thermal wells were sampled in Caldas de Aregos—a town located along the beautiful Duoro River. The Duoro River is the highway that transports grapes into Porto for that delicious Portuguese port wine. Like the thermal waters of São Pedro do Sul, the thermal waters at Caldas de Aregos are also associated with the Verin-Régua-Penacova Fault. The thermal waters in Caldas de Aregos were slightly cooler (60°C and 64°C) with a reported pH of 9.2. **Cara** returned with her thermal spring samples and will be extracting DNA from the filters this fall to determine what fraction of the microbial communities are MDM.

With all these samples, we will elucidate the mysterious MDM by separating them out of the total biomass using novel cell sorting techniques and performing single cell genomics. Unlike metagenomics, which, for a given taxon, pieces together an "average" genome from a community pool of DNA fragments, single cell genomics isolates and amplifies the genomic content of an individual cell, thus eliminating the risk of assembling a genome with ambiguous or redundant DNA fragments that may actually belong to other organisms. Furthermore, single cell genomics will allow us to study subsurface microbial evolution, such that we can identify variability within a core genome across numerous individuals taxonomically assigned as the same species. This second advantage, in particular, will aid us in identifying horizontal gene transfer at Beatrix, but also what role it may have played in the ability to produce and oxidize CH_4 at the scale we observed it. ■



Fig. 4. - Cara Magnabosco running an astrobiology field trip to the thermal well of São Pedro do Sul for 25 students from the local high school. Photo by: A. Bandeira

Fieldwork in the Columbia River Basalt



Joshua Murray collects a sedimentary sample underlying a Grande Ronde Basalt flow near Halfway, OR. Photo by: J. Kasbohm

Following the extinction of the dinosaurs 66 million years ago, atmospheric CO_2 and global temperatures are thought to have declined over the Cenozoic, culminating in the relatively rapid glacial and interglacial episodes that characterize the Pleistocene. However, 16 million years ago there was a departure from this cooling trend during a period known as the Mid-Miocene Climate Optimum, when atmospheric CO_2 appears to have risen above pre-industrial levels for the last time before anthropogenic input. The cause of this warming event is controversial, but many point to the eruption of the Columbia River Basalt and its release of volcanicogenic CO_2 . Implicating this massive volcanic event in the observed climate disturbance requires precise time constraints that correlate climate records from sedimentary rocks with eruption of the basalts.

In August 2015, graduate student **Jennifer Kasbohm** and sophomore GEO major **Joshua Murray** spent

three weeks doing fieldwork in the Columbia River Basalt of Washington, Oregon, and Idaho. Under the supervision of **Prof. Blair Schoene**, who accompanied them for part of the trip, **Kasbohm** and **Murray** were seeking to collect volcanic ashes containing zircons, suitable for analysis by high-precision U-Pb geochronology. Their trip took them 5000 miles in three different loops originating from Seattle, WA, and going as far as New Princeton, OR!

Funded by a combination of sources, including the National Science Foundation, **Department of Geosciences**, and **Princeton Environmental Institute**, **Kasbohm**, **Murray**, and **Schoene** are seeking to better understand the eruptive

chronology of the Columbia River Basalt. While this flood basalt is less voluminous compared to other large igneous provinces, like the Deccan Traps, it may have had a profound impact on the climate of the mid-Miocene depending



Joshua Murray and Prof. Blair Schoene collect a potential ashbed under a massive Wanapum Basalt flow near Frenchman Coulee, WA. Photo by: J. Kasbohm



Jennifer Kasbohm admires the view at Palouse Falls State Park, WA. Photo by: J. Murray

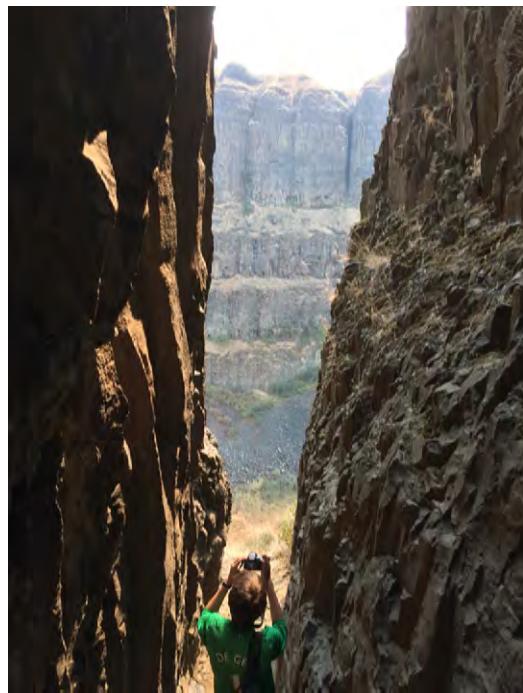
on its rate of eruption. However, prior attempts to date the province with Ar-Ar geochronology have been insufficient to resolve the precise timing and duration of different magmatic pulses.

Working in **Schoene's Radiogenic Isotopes**

Lab, Kasbohm will obtain the ages of zircons extracted from the ashes. The ages' anticipated precision of 10 kyr would be two orders of magnitude improved over prior work. These ages can be compared to sedimentary climate records and incorporated into atmospheric models. Using these data, **Profs. John Higgins** and **Stephan Fueglister** will be collaborating in a joint initiative to better understand the effect of Columbia River volcanism on the Earth system.

Although **Kasbohm** and **Murray** knew of only a few locations with possible ashes when they

began, they were thrilled to find 95 samples in road cuts as they drove across the three states. The first high-precision ages for the Columbia River Basalt are currently being obtained! The group is already looking forward to a return visit in 2016, ideally with fewer forest fires and temperatures cooler than 108°F. ■



Columbia River basalt flows are exposed dramatically at Palouse Falls State Park, WA; Joshua Murray pauses for a photo in a slot canyon. Photo by: J. Kasbohm

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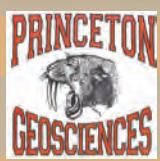
The Department of Geosciences is offering the purchase of Princeton Geosciences t-shirts through the mail for \$25 each. There are small, medium, large, and extra large shirts in three different color selections available. Each shirt features a vintage 1970s department illustration of the Smilodon and traditional Princeton varsity lettering. To order fill out the coupon specifying quantity, size, and colors, and send along with a check or money order to the address provided.

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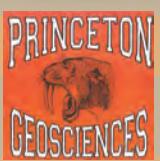
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Fieldwork in the Abisko National Park



Lapporten mountain gate or Goose valley taken from the top of Njulla Mountain at 3835 feet (1169 m). This gate is a 2 km wide U-shaped valley created during the last glaciation. The Lapporten Gate is considered to be the gateway to Lappland in Sweden. Photo by: Paul Gauthier

In Summer 2015, postdoctoral fellow **Paul Gauthier** and undergraduates **Olivia Trase '17 (EEB)** and **Joseph Redmond '18 (CBE)** spent several weeks doing fieldwork in Abisko National Park in the region of Lake Torneträsk in Sweden. The group stayed at Abisko Scientific Research Station (ANS). This station is a facility of the Royal Swedish Academy of Sciences but managed by the Swedish Infrastructure for Ecosystem Science (SITES). The station is located 200 km north of the Arctic Circle in the upper part of the subalpine birch belt. The team collected data and samples for understanding the physiological and metabolic adaptations of mountain birches to the harsh Arctic weather. The results will help us understand the response of Arctic ecosystems to climate change.

Funded by a combination of sources, including **Princeton Environmental Institute Grand Challenges**, The Carbon Mitigation Initiative, and the **Department of Geosciences**, Gauthier is seeking to better understand how continuous daylight in the summertime at high latitudes influences net ecosystem productivity. Net ecosystem productivity is the difference between the uptake of CO₂ by photosynthesis, and the release of CO₂ by respiration. In order to predict

the impact of climate change on the productivity of arctic ecosystems, a better mechanistic understanding of photosynthesis and respiration is required. Past studies have shown that the rate of respiration in leaves during the day is lower than the rate at night. It is still unclear why plants respiration more in the dark, and there may be several causes. At high latitude, in the summer, several weeks pass when there is no darkness. Plants may have developed specific physiological and metabolic adaptations to thrive under those conditions. Understanding these adaptations could help improve the modeling of net ecosystem productivity at high latitude.

Gauthier also worked in Sweden in July 2014, with undergraduates **Atleigh Forden '16 (GEO)** and **Jacob Eisenberg '16 (ORFE)**. During the second week of this 2014 trip, the average temperature was as high as 30°C (86°F), and

precipitation was very low. In summer 2015, over 6 weeks of fieldwork, the average temperature was 7°C (45°F) with much higher precipitation. Our observations thus span weather extremes at the study site. The group is now working on implementing their data into local ecosystem models to evaluate the consequence of large temperature excursions on net ecosystem productivity for the subalpine birch belt. ■



Undergraduates Joe Redmond '18 (Left) and Olivia Trase '17 (right) at the field site in Stordalen National Reserve, Sweden. Photo by: Paul Gauthier



Undergraduate Olivia Trase '17 (left) and Postdoctoral Research Associate Paul Gauthier (right) setting up gas exchange measurements on arctic birch's leaves in Stordalen National Park. Photos by: J. Redmond

The field research described on pages 6-9 were partly supported by the newly established **GGRF** and **GSRF**. These expeditions brilliantly exemplify the kind of special experiences and exciting and cutting edge research that are such essential parts of graduate and undergraduate education in Geosciences at Princeton. Most field research is supported by faculty research grants, which derive mainly from federal agencies. Across the sciences, however, federal funding has declined in recent years, while restrictions on spending have reduced flexibility in supporting new projects. At the same time, we appreciate the expressed desire of our alumni, faculty, parents and friends of the department to contribute to the life and mission of the department. Therefore the establishment of these new funds is very timely and greatly appreciated.

In addition to field trips associated with individual student projects, some members of the department have expressed interest in a departmental field trip, which would allow undergraduates, graduate students and faculty to visit special sites of broad interdisciplinary interest. Increasing costs and fund restrictions have precluded such trips in recent years. Although we have no designated funds for a departmental field trip, at the request of a group of enthusiastic undergraduate GEO majors, we have been able to "save up" some funds and hope to be able to offset part of the costs for a trip this year. Stay tuned for developments! ■

FROM THE CHAIR

Announcing Two New Funds for Geosciences Student Research

Two new funds have been established to enhance student research in the **Department of Geosciences**. Both funds are open to contributions from all donors, will be administered by the **Department of Geosciences**, and are restricted to student use. These new funds arose from the desire of alumni and faculty to contribute to the support of students in the department. They were formally established in 2014 as a result of planning by the Development Committee within the department, but the inspiration for them came from alumni interests over many years. We especially acknowledge the initiative of Prof. Alan Smith in instigating the establishment of these new funds. The department is very grateful for the support from our alumni, parents and other friends. We appreciate their commitment and generosity in providing opportunities for our students. We have ensured that the funds will be managed entirely by the department in accordance with the wishes of the donors.

The **Geosciences Student Research Fund (GSRF)** was announced in the *Smilodon* in May 2015. The **GSRF** will support both graduate and



Bess Ward

undergraduate research opportunities in the **Department of Geosciences**. These funds will allow students to pursue research topics that are of most interest to them, independent of the availability of federal grant funding. The **GSRF** will help students to investigate the most promising avenues of science and undertake entirely new, and unproven, areas of research that may be too speculative to receive government funding. This support might also supplement grant funding by serving as seed money to pursue related new ideas and proposals. Students may apply to use the funds for purposes that include, but are not limited to, field research, ocean voyages, Arctic/Antarctic research trips, lab analysis and computational studies.

A second fund, the **Geosciences Graduate Research Fund (GGRF)** will support graduate student research with an emphasis on field work, including graduate student led group expeditions. At least 50% of the funds allocated every year will be committed to field work, unless the applications for field work support do not reach that level.

Administration of the GGRF and GSRF

The **GSRF** and **GGRF** will be administered by a subcommittee of the **Department of Geosciences** faculty, representing the diversity of research areas within the department. Proposals to the funds will be submitted annually by graduate and undergraduate students, but special requests will also be considered outside of the annual call if warranted. Several alumni have proposed that the **GGRF** be named in honor of **Harry Hess**, one of the founding fathers of the unifying theory of plate tectonics and one of our most admired and respected former faculty members. **Hess** is already honored by an existing endowed fund in the department, the "**Harry Hess Senior Fellow Fund**", which was established in 1978 and is used to support distinguished visitors, including seminar speakers. In addition, we have established, using other funds, the "**Harry Hess Honorable PostDoctoral Fellow Program**", which allows us to bring outstanding junior scientists to the department on a competitive basis. Because of the existence of these programs, the new funds have been given general names. However, if they wish, donors can designate that their contributions are made in honor of a former faculty member, such as Professor Hess, and this designation will be noted and reported in the Smilodon when the funds are awarded.

The **GSRF** and **GGRF** are term gift funds, rather than endowments, at least initially. Spending will be managed in order to provide for continual availability of funds, by ensuring that a residual (at least \$10,000 or 25% of the total amount) is carried over from year to year.

For further information, please contact Nora Zelizer (nzelizer@princeton.edu) or Bess Ward (bbw@princeton.edu). The fund will be administered and managed by and used to benefit solely the **Department of Geosciences students**. ■



A Note from Rick Vierbuchen *79

Graduate alumni on last fall's field trip to New Mexico represented over fifty years of Geoscience classes. In spite of the range in ages and interests, we held in common fondly remembered years of intense intellectual excitement and growth while studying at Princeton, experiences that helped launch our careers. That same feeling exists in the Department today but is becoming more difficult to maintain because of reduced government funding, restrictions on endowed funds, and other challenges. That's why the **GGRF** and **GSRF** are important. They provide a simple, direct means of encouraging students to develop and pursue their own research ideas, which strengthens the creative spirit that is a hallmark of Princeton Geoscience. By contributing to these funds we help preserve the inspiring intellectual environment that benefitted all Princeton Geoscience graduates.

Rick Vierbuchen is a graduate alumnus of the Department of Geosciences

ALUMNI NEWS UNDERGRAD

Sarah Bluher '14 is working at Cornell University researching the effects of pesticides on honeybee health and colony performance.

Charlotte Conner '14 works for The Boston Consulting Group in Houston, Texas, providing management consulting for the energy and utilities industries.

Raleigh Martin '08 is wrapping up a postdoc at The UCLA Department of Atmospheric and Oceanic Sciences on aeolian sediment transport processes.

For his master's thesis at the University of Texas at Austin, **Logan West '07** worked on the formation of residual oil zones in the Permian Basin. He also spent a year as Scientist-in-Residence at a couple of Austin public schools, co-teaching AP Environmental Science and sharing with the students what it means to be a scientist (not all lab coats and bubbling flasks). He's staying at UT for his Ph.D., but switching from carbon capture to sedimentology/stratigraphy.

After graduating from Harvard Medical School, **David Bartels '06** is in his third year of residency at Massachusetts General Hospital in Boston. He specializes in critical care, anesthesiology, and pain medicine with a focus on pediatrics. He is married to Devan Darby '06, a graduate of the EEB department; it must have been something about Guyot Hall!

Maia Schweizer '04 is Chief Development Officer for Origin Energy Limited in Australia. It develops natural gas assets in Australia and abroad, and are the upstream operator for the Australia Pacific LNG project, which promotes the export of coal seam gas. Her group looks after a large chunk of the company's annual capital investments, including reservoir modeling and drilling projects.

In 2014, **Patrick Shamberger '02** was appointed as a research faculty member in Materials Science and Engineering at Texas A&M, and has recently switched over to a tenure track position.

For the past 7 years, **Emily Johnson '01** has been doing product development at various New York tech startups, and is now starting her own tutoring company. She reports that her geology skills of piecing together complex and incomplete information to tell a coherent story have served her well throughout her career.

Sarah Gaines '00 is a program specialist in the Earth Sciences and Disaster Risk Reduction Section at UNESCO headquarters in Paris, France.

After eight years as a park ranger at national parks including Yellowstone and The Badlands, **Cathy Bell '99** is now the Visual Information Specialist at Joshua Tree National Park. Joshua Tree is particularly challenged by climate change, and Cathy spends much of her time devising ways of using the park's publica-

tions, website and social media programs to combat science illiteracy. **Cathy** has an M.S. from the University of Vermont's Naturalist program, does freelance environmental writing and is currently working on a book about the impact of rat poison on wildlife. She credits the **Department** for shaping her career path, starting with her 1995 visit to Yosemite with the Active Geological Processes freshman seminar.

Bill Langin '99 works for Shell Oil as the Exploration Manager for Petroleum Development Oman (PDO), and has been living in Muscat, Oman for the past 1½ years. PDO is currently exploring for oil and gas in a good part of the geologic column in Oman, from pre-Cambrian carbonates to Paleogene clastic reservoirs. He also enjoys weekend hikes through the spectacular ophiolite sequences that are within an easy driving distance from Muscat.

Ann Marie Lavigne '98 is in the process of relocating from Singapore to the USA with Google, where she'll be the Head of Americas Strategy and Operations, Small and Medium Business; she held the same role in the Asia-Pacific region for the past three years. It's not fieldwork, but every day she uses the same problem-solving skills she developed when studying geology.

Robert Fargo '97 credits his year at Princeton on the Oxford-Princeton Engineering Exchange Program as playing a large role in his career. Today, he is a reservoir engineer with ConocoPhillips in Aberdeen, Scotland.

Since 2014, **Eric Hand '97** has been a staff reporter at *Science* magazine in Washington D.C., covering Earth and planetary science. Before that, he spent seven years as a reporter and editor at *Nature*. He enjoys seeing many familiar names and faces at the AGU meeting, and welcomes hot science news tips anytime (e.hand@aaas.org).

Adrienne Toy Saur '96 advocates and organizes enrichment and learning opportunities for children through "Kids Need Enrichment" (www.kidsneedenrichment.com). She works with students, educators, and scientists on STEM events and welcomes any alumni or faculty that would want to join in the fun!

M. Todd Henderson '93 is a professor at the University of Chicago Law School and has published his first textbook, "Securities Regulation, 13th Edition." He also just completed a draft of his first novel, in case there are any publishers or agents out there!

John Scicchitano '93 is glad to be back in Washington, D.C. area after spending several years in Chad, Central Africa, as director for the non-profit World Vision. His career has been a mix of government, non-profit, and private sector work in Africa, although he plans to stay stateside for the next few years.

After a M.S. and Ph.D. in geophysics from Stanford and Univ. of British Columbia, respectively, **Christina Chan-Park '92** has gone on to earn a MIS in Information Science from the Univ. of North Texas and a

MPA from the Univ. of Houston. She is currently the science librarian at Baylor University.

Julia Shepard Stenzel '86 lives in the San Francisco Bay Area, and is a writer and consultant. She co-authored a book, "The Brand IDEA: Managing Non-profit Brands with Integrity, Democracy, and Affinity," which helps nonprofit leaders, board members, and managers understand how a brand can help an organization achieve its mission.

For 18 years, **Art Diaz '82** worked for Amoco/British Petroleum, first as a geophysicist and later (after getting an MBA from Stanford) on the financial side of the business. He was based in New Orleans, Houston, Chicago, Denver, Atlanta and London. He then changed careers, working for a Paris-based manufacturing firm before spending 10 years in Connecticut as CFO of Pomfret School, his high school alma mater, in Connecticut. This July, he has started a new job as CFO of Groton School in Massachusetts.

Sam Bull '82 runs the accredited two-year experiential college program LEAPYEAR based in Calistoga, California.

Since graduation, **Catherine McVay Hughes '82** has been working on environmental health issues, community organizing, and urban resiliency. She is the Chair of Community Board 1, which covers much of lower Manhattan and Liberty, Ellis and Governors Islands. Her engineering experience, especially in slurry wall construction, has been invaluable in recovery efforts after both the September 11, 2001 terrorist attacks and Superstorm Sandy of October 2012. **Catherine** has also been working with all levels of New York City and State government to address climate change, using a two-track approach that both presses to reverse anthropogenic climate change and also shares best practices for adapting to a warmer world. She has served on a variety of boards and committees, including the World Trade Center Scientific Technical Advisory Committee, Governor Cuomo's New York Rising, Speaker Silver's School Overcrowding Taskforce, the World Trade Center Health Program Survivors Steering Committee and the President's Council of Ceres.

Gary Rosenberg '81 is now a full professor at Drexel University in the Department of Biodiversity, Earth and Environmental Science. He remains curator of mollusks at the Academy of Natural Sciences of Philadelphia, which affiliated with Drexel in 2012. Drexel is building its geoscience curriculum, and this fall **Gary** is scheduled to teach invertebrate paleontology, after digging out his notes from when he took the course with **Ida Thompson** (Faculty 1974-80) and **Doug Jones *80**.

After 21 years at the Australian National University in Canberra, **Charlotte Allen '79** is now Senior Research Fellow at the Queensland University of Technology in Brisbane. The main focus of her research

involves the accuracy and applications of Laser Ablation Inductively Coupled Mass Spectroscopy.

This fall, **Wayne Lau '79** will be re-commencing his Ph.D. work at the Engineering Department of Cambridge University after a "short" break of nearly 30 years. His research will be on rural infrastructure development, and will reflect work that he has been doing in Cameroon. His interest was kindled by his Marshall Fellowship, his work for the Board of the Association of Marshall Scholars and his Masters thesis in solar energy. Wayne has also been pursuing experimental projects in endangered species conservation, which led to his work in rural development in Cameroon.

Joseph J. Perkins '76 has practiced natural resources law in Alaska for more than 35 years, most recently as a partner in the Anchorage office of Stoel Rives, LLP since 2008. In 2007, he taught oil and gas law at the University of Wyoming College of Law, and in 2014 he returned to YBRA (the first time since his 1974 field course) to give a talk on "Land, Law, and Resources of the Last Frontier" at the annual YBRA Industry Day.

Bern Hinckley '75 continues his Laramie, Wyoming consulting practice in water resources management and water rights. He is an expert witness in the US Supreme Court Montana vs. Wyoming lawsuit over the Yellowstone River Compact, after working for 13 years on the similar Nebraska vs. Wyoming lawsuit over the North Platte River Decree. His work also includes assisting the Wyoming State Engineer's Office in the administration of conjunctive water rights and in monitoring the impact of rural residential development on groundwater quality in Laramie. **Bern** has served several terms as the Governor's public interest representative on the Wyoming Enhanced Oil Recovery Commission.

Trevor Ford '74 is now based in Indiantown, Florida and has acquired a boat, First Nanny, which he will make available for research use for water testing in Florida and the Caribbean.

Carol Molina '74 is on the Board of Directors at a horse rescue clinic, and works as a feeder, exerciser, and grant writer. She also sews adaptive clothing for wounded soldiers.

Susan Petty '73 has been working on advanced geothermal technology with the aim of replacing coal fired power generation and helping meet President Obama's Clean Power Plan. Her company, AltaRock Energy, Inc., has purchased the Blue Mountain geothermal project in Nevada, and will be improving its energy output using stimulation technology on hot but low permeability wells. AltaRock is one of five finalists vying for selection as the Department of Energy's Frontier Observatory for Research in Geothermal Energy (FORGE). **Susan's** husband Rick Adair is an energy journalist. Last year, **Susan** became a member of our **Department of Geoscience's** recently reinstated Advisory Council.

The July 4 edition of "The Economist" highlights work by Humboldt State professor **Harvey Kelsey '71**

whose international research team has documented evidence for 11-13 tsunamis that have hit the Sumatran province of Aceh over the past 8,000 years. In addition to work on areas affected by the powerful tsunami-generating Indonesian earthquake of 2004, Harvey is a leader in the field of neo-tectonics and paleo-seismology, with much of his work focusing on the Pacific Northwest and Japan.

Jerry R. Fish '71 is a partner in the Portland, Oregon law firm of Stoel Rives, LLP, with a focus on the western states and the District of Columbia. He has practiced natural resources law for more than 30 years, and plans to retire at the end of 2015.

This past January, **Geoff Feiss '65** retired for the second time, this time leaving his position as President of the Geological Society of America Foundation. He remains active with the Foundation on some of their long-term fund-raising initiatives, but strictly as a volunteer. **Geoff** and wife **Nancy West '79** are moving from Fort Collins, Colorado to coastal Maine, but also keep their off-the-grid cabin in the Colorado foothills on the margin of the Virginia Dale ring dike complex.

After 41 years of providing geotechnical engineering services, **Zavis "Zip" Zavodni '64** has retired as Chief Advisor-Geotechnical for Rio Tinto Kennecott. Over the years he has enjoyed the mining business, travelling the world and specializing in open pit slope engineering, tailings embankment design, underground rock mechanics, and waste dump design. He plans to remain based in Salt Lake City, Utah and set up a one-man consultancy.

This year, **John DeYoung '64** retired from the USGS after 40+ years of service. In 2014, he received a Distinguished Service Award from the Survey, and is still affiliated as "Scientist Emeritus." He continues to volunteer on several projects, including the publications of the National Minerals Information Center. Outside of the office, he is active in youth sports, coaches lacrosse and baseball, and is in the last stages of recovering from a hamstring tear after a nasty fall on the ice!

Charles (Bill) Brown '57 and wife Winnie are thriving in North Carolina and enjoying their 11 great grandchildren.

David P. Phillips '56 retired in 2012 after serving 42 years as the Executive Director of the Rocky Mountain Mineral Law Foundation, a non-profit professional educational organization dedicated to the study of the law and regulations relating to mining, oil and gas, water resources, public lands, energy, and environmental protection. He and wife Annie continue to live in Boulder, Colorado.

GRAD/POSTDOC

Kelly Kearney '13 has started a new position as a research scientist at the University of Washington JISAO/NOAA Alaska Fisheries Science Center.

Hejun Zhu *13 is now an assistant professor of geophysics in the **Department of Geosciences** at The University of Texas at Dallas.

After a postdoc stint in Lausanne, France **Suki Dorfman *12** is an assistant professor in the Department of Geological Sciences at Michigan State University.

Makoto Suwa '07 is back in Washington, D.C. after several years in Rwanda, Japan, Switzerland and Kenya. His work for the World Bank supports countries in Africa, Asia and the Caribbean in their efforts to provide weather, climate and hydrological services that will mitigate adverse impacts of extreme weather events, and better inform planning and development of sectors sensitive to climate.

Mark Davidson '08 is a senior scientist for Geo-syntec Consultants in Pasadena, CA. He credits the broad geoscience education he received in the Department to his success as an environmental consultant. His work includes designing in situ bioremediation remedies to deal with chlorinated solvent impacts to groundwater (thanks, **Profs. Francois Morel, Bess Ward** and **Satish Myeni**); serving as a technical resource on litigation cases regarding vapor intrusion and perchlorate isotopes for source differentiation (thanks, **Prof. Tullis Onstott**); and serving as Project Manager for an above-ground bioreactor treating hexavalent chromium-laden groundwater for the high profile PG&E Hinkley site (subject of the movie "Erin Brockovich.")

Last December, **Ben Phillips '05** joined NASA as Lead of the Earth Surface and Interior (ESI) Focus Area. ESI is NASA's solid Earth research program that supports investigations on processes and properties from crust to core.

Alex Fournier '04 is a professor of geophysics at the Institut de Physique du Globe de Paris (IPGP), France.

Meredith Hastings '04 has been promoted to associate professor at Brown University in Providence, RI. She was awarded AGU's 2014 Atmospheric Sciences Ascent Award and was named one of "Insight into Diversity" magazine's top 100 Inspiring Women in STEM.

Adam Baig '03 is currently working in Kingston, Ontario for a company called ESG Solutions, looking at microseismicity (usually $M < 0$) from hydraulic fracturing, cyclic-steam injections, water floods, mining and other industrial sources. It's an exciting field, with huge amounts of data to analyze and very difficult questions to answer about the processes generating seismicity in these environments.

Maribeth Price '95 is a geology professor at the South Dakota School of Mines and Technology. She mainly teaches GIS courses, and the 7th edition of her textbook, "Mastering ArcGIS," was released last spring. With her students, she explores the use of 3D photogrammetry and unmanned aerial vehicles for documenting paleontological quarries and specimens, and is also involved in ecological and hydrological spatial analysis.

Ching-Hua Lo *90 is currently serving as president of the National Applied Research Laboratories, an independent organization affiliated with Taiwan's Ministry of Science and Technology. After a three-year term, he will be back at his position at National Taiwan University.

At the University of Utah, **Paul Jewell *89** keeps himself busy applying hydrology to problems in sedimentation, geomorphic evolution, and geochemistry of surface water environments. He collects field data through mapping and technologies such as LiDAR, and incorporates the data into models of varying sophistication. **Paul's** work is currently focused on Pleistocene Lake Bonneville in the western United States, and alluvial channels and erosion in the intermountain west.

Kabir Roy-Chowdhury (postdoc 1981-1988) remembers arriving at JFK airport to start his work with **Bob Phinney** (Faculty Emeritus). **Bob** was on vacation and requested that **Rob Hargraves** (Faculty 1961-1994) receive him, but **Rob** was also out of town. So a graduate student picked Kabir up at the airport, whisked him down the NJ Turnpike, and delivered him to Sybil Hargraves who served as a gracious host until he could move into his Hibben apartment. **Kabir** retired from the University of Utrecht in 2009, but still maintains an office there.

Mike Purucker *84 is now the chief of the Planetary Magnetospheres Laboratory at the NASA Goddard Space Flight Center. The lab builds and flies magnetometers to the planets and moons of our solar system in order to understand magnetospheres that envelop many of these bodies.

Lisa A. Rossbacher *83 is now President of Humboldt State University, CA. She previously served as president of Southern Polytechnic State University, GA.

Cathy Busby *83 has retired from UC Santa Barbara after 32 years of teaching, and is now a research scientist at UC Davis and continues to have Ph.D. students and postdocs. Her current projects include work related to IODP Expedition 350 in the Izu-Bonin arc, on which she was co-chief scientist in 2014; a Cretaceous outcrop in Baja California as an analog to the Izu-Bonin arc; and a Research Experience for Undergraduates project called "Baja Basins" in the Gulf of California rift. For this she is recruiting undergraduate participants at: cad.umkc.edu/geosciences/babajbasins.

After working at the State Department for 21 years on international water and environment issues, **Chuck Lawson *82**, in July 2008 became the Secretary of the U.S. Section of the International Joint Commission. Established by the governments of the U.S. and Canada under the 1909 Boundary Waters Treaty, the Commission helps prevent and resolve disputes involving water issues along the border by assisting the governments to monitor and implement various aspects of the treaty.

For the last 10 years, **Steve Bergman *82** has been a member of Shell's R & D Global Geology Team in Houston working mainly on the Arctic and southeast

Asia. This follows 5 years of teaching at University of Texas, Dallas and Southern Methodist University (including courses on earthquakes and volcanoes, diamonds, and the geology of wine) and 20 years at ARCO R&D's Tectonics & Basin Analysis team in Plano. He and wife Mary are enjoying their new house on Vashon Island in Puget Sound, near the Tacoma Fault, and keeping track of Mt. Rainier's waning snowfields from their deck.

Just down the road at Rider University, **Jon Husch *81** has started his tenth year as Chair of Department of Geological, Environmental, and Marine Sciences (GEMS) and 36th year of teaching. His current research projects include working on how to distinguish between dropstones and bomb sags in photographs of Earth and Mars in order to better interpret Mars rover images, and looking at the impact of winter deicing salt on surface water groundwater quality in the Delaware River Watershed. Quite a ways from his roots in igneous geochemistry! In recognition of his many years of outstanding teaching, Jon was selected as the 2015 Faculty Inductee into The Rider University School of Liberal Arts and Sciences Honor Society.

Last March, **Richard (Rick) Lee Heestand *81** retired from ExxonMobil Technical Computing Company. Over his third of a century (yes, 33 1/3 years) with Exxon and then ExxonMobil, **Rick** has worked in a number of divisions; his most recent position was with Geoscience Technology at the Seismic Imaging Center of Excellence. His career has included projects related to seismic data acquisition, velocity models for 3D depth migration, and developing high performance computing capability. **Rick** and wife April remain in Woodlands, TX and April reminds him that she typed his dissertation on the first word processor that the Department owned.

Rick Vierbuchen *79 retired from ExxonMobil in 2013 and moved from the UK to a farm in central Virginia, where he lives with his wife, **Joanna Ajudkiewicz *77**. He currently serves as chairman of the **Department's Advisory Committee**.

On June 30, **Karl W. Muessig *79** retired after 30 years with the New Jersey Geological Survey. He served as State Geologist for the last 16 years. Accomplishments of the Survey during his tenure include overseeing the merging of the NJGS with the Division of Water Supply; evaluation of geologic sources of indoor radon; evaluation of geologic formations for disposal and containment of radioactive waste; enhancements of stream, groundwater and drought monitoring; support of the state's climate change and energy initiatives; evaluation of seismic risk to NJ infrastructure; and defining offshore sand resources for beach/dune restoration following Hurricane Sandy. His successor at the survey is **Jeffery L. Hoffman *81**, a graduate of Princeton's interdepartmental Water Resources Program offered jointly by the **Departments of Geosciences** and **Civil/Environmental Engineering**.

As the Director of the USGS Earthquake Science Center, **Thomas Brocher *78** led the scientific response to last year's magnitude 6.0 South Napa earthquake, the largest to strike the San Francisco Bay Area since the 1989 Loma Prieta event. After 6 ½ years in the position, **Tom** has returned to his research position assessing seismic hazard in Washington and Oregon. Lately he's been working on a model that explains how crustal faulting in Cascadia accommodates the clockwise rotation observed in GPS and paleomagnetic data.

After eight years as Director of the Institute of Earth Science and Engineering at the University of Auckland, New Zealand, **Peter Malin *78** has relocated to Dallas, TX to give the non-conventional resources consulting and borehole seismograph manufacturing business a try. He is also completing work at The German Research Centre for Geosciences in Potsdam, co-writing a paper on best practices in shale gas frack monitoring, a project supported by the EU Parliament. Former postdoc **Peter Leary** joined him in Potsdam for several weeks, and last November both were happy to stop by Princeton to check in with their mentor **Bob Phinney** (Faculty Emeritus).

Since 1996, **Robert Kleinman *79** has been editor-in-chief of *Mine Water and the Environment*, a quarterly peer-reviewed journal published by Springer. He retired from the U.S. Dept. of Energy National Energy Technology Laboratory three years ago and is currently working part-time for CH2M HILL, an engineering and environmental consulting company, mostly on mine water remediation.

George Harlow *77 was elected vice president of the Mineralogical Society of America for 2016; he will commence his duties just prior to the GSA Meeting in Baltimore in November. He will become president of MSA (barring a write-in challenge!) for the year of 2017.

Rich Yuretich *76 retired from the University of Massachusetts last year, but only to move to Washington, D.C. and become Program Director for Surface Earth Processes in the Division of Earth Sciences of the National Science Foundation, with primary responsibility for overseeing the Critical Zone Observatories that have been established nationwide.

For the past 14 years, **Robert Wallace *75** has worked with science education programs at New York University. This includes working with graduate students who want to teach middle and high school science mostly in New York City. He also works with science teachers in Abu Dhabi through the NYU campus there. Bob finds it an interesting experience to work in a culture and environment that is so different from his own; for example, when he was in Abu Dhabi this past August temperatures were about 114°F, which made it quite a challenge to explore the local ecology! But he finds the teachers eager for these experiences, and that good science teachers are much the same everywhere.

After getting his Master's at Princeton, **Mike Mottle *72** earned his Ph.D. at Harvard, spent two post-doc years at Stanford, and then worked at Woods Hole Oceanographic Institution for nine years. Since 1986 he has been at the University of Hawaii at Manoa, where he is currently serving a second term as chair.

Tim Anderson *70 retired (early) from Chevron in 2002 and then did consultant work with them for an additional six years. Most of his work was in international oil and gas exploration in West Africa and the countries of the former Soviet Union. After leaving geology, he and wife Ursula (they met in Princeton in 1966) continue to enjoy the outdoor life, including fly fishing. **Tim** has translated a book about bamboo fly fishing rods from German into English and is now a well-recognized maker of bamboo fly rods himself! This avocation has led to many new friends and travel to, among other places, Montana, Wyoming, Idaho, Oregon, Germany, Switzerland, Austria, and New Zealand.

J. David Buckry *67 spent 28 years with the USGS working on nanoplankton biostratigraphy for the NSF Deep Sea Drilling Project. Since "retiring" in 1995 and becoming a USGS Scientist Emeritus, **Dave** has switched to studying climate change using siliceous nanoplankton (silicoflagellates) in association with the Pacific Holocene Climate Change project and the Northwest Pacific Geologic Mapping and Urban Hazards projects. These efforts have established climate change proxy species for use in core studies of the Holocene and late Pleistocene along the Pacific Coast.

Fifty years ago, "The fit of the continents around the Atlantic," by Edward Bullard, James E. Everett, and **Alan Smith *65** was published in the Philosophical Transactions of the Royal Society of London. The August 2015 issue of The Geological Society of London's Geoscientist Online contains a retrospective look at this seminal paper which described the first use of numerical methods to generate a computerized fit of the continents. Alan worked on the northern Atlantic continents, and recognized that things worked a lot better without Iceland! His recollections of this error are preserved in audio interviews for VOICES OF SCIENCE, the website of the Oral History of British Science. See www.bl.uk/voices-of-science/interviewees/alan-smith/audio/alan-smith-fitting-the-continents-back-together-with-the-help-of-a-computer

Atholl Sutherland Brown's *54 latest publications include his 2014 book "Searching for the Origins of Haida Gwaii," and a recent two-part article for the "Journal of the Canadian Aviation Historical Association" entitled "Aces and the Development of Air Combat in World War I." **Atholl** himself served as a fighter pilot in World War II. ■



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Bachelor Degrees Awarded

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Eric D. Bolton, "Parameterizing the KoK Effect: How Light Inhibition of Respiration Affects Ecosystem Carbon Budget Predictions" (D. Medvigy)

Leticia M. Bombieri, "The Importance of Volcanic Rocks and Thin Sediments on Thermal Gradient" (T. Onstott)

Joan L. Cannon, "Studying Past Atmospheric CO₂ Concentrations Using Mass Spectrometer Analysis of Foraminifera-Bound Organic Matter" (D. Sigman)

Tiffany W. Cheung, "A Mechanistic Study of CO₂ Fixation in Marine Diatoms: The Effects of Diel Cycling, Temperature & Light Intensity on *Thalassiosira weissflogii*" (F. Morel)

Preston C. Kemeny, "Seasonality in the Antarctic Ocean: Late Summer Nitrate Isotope Measurements from the Pacific Sector and A Seasonal Model of the Upper Water Column" (D. Sigman)

Trevor D. Klee, "Calculating Mass Balance per Degree for the Aleutian Crust Using a Novel Method" (B. Schoene)

Sean P. McIntee, "The Concentration and Isotopic Composition of Nitrate in the Water Column along a Cross-Basin Transect of the North Atlantic Ocean" (D. Sigman)

Yuem Park, "Constraining Deformation in the Skymo Lake Area of the North Cascades, WA: Implications for the Rapid Exhumation of Arc Middle Crust Along Strike-Slip Fault Systems" (B. Schoene)

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