



# GEOLOGY & GEOPHYSICS NEWS

## Chair's Letter

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Welcome to the Spring 2018 edition of the Geology and Geophysics newsletter! It's been a while since our last newsletter, and much has happened in the interim.

I am pleased to introduce Assistant Professor **Alan Rooney**, who joined the faculty in 2017. Alan is an isotope geochem-

ist interested in a wide spectrum of problems ranging from the history of Earth's core to the development of complex life on our planet to

the dynamics of ancient and recent ice sheets. He uses high-precision isotope measurements of platinum group metals, particularly the Re-Os system, to make breakthroughs in understanding the timing, duration, and geochemical signatures of geologic processes and events, including groundbreaking new evidence for the severe icehouse "Snowball" Earth in the Neoproterozoic, and the recent behavior of the Greenland ice sheet.



Alan Rooney, Assistant Professor

In these pages you will also read about the many exciting facets of Assistant Professor **Anjan Bhullar's** research in vertebrate paleontology which integrates evidence from genes, growth, and development using laboratory experiments and fossils to study the evolution of major vertebrate groups. For example, he has traced the origin of the bird skull through retention of the juvenile morphology of dinosaurs, and illuminated the evolutionary origin of the bird beak. His work on ancient life also captures the public's imagination, and is commonly featured in media outlets including the New York Times. This newsletter provides a fascinating glimpse into the inner workings of Anjan's laboratory operation highlighting the con-

tributions of students and postdoctoral scholars, as well as his public outreach activities with the Yale Peabody Museum of Natural History.

We continue to build our faculty and have several searches ongoing or planned. Currently, we have positions open in geochemistry and climate sciences. We have interviewed a broad spectrum of candidates for these positions and plan on bringing new faculty on board in the next year or so. And a new search in stratigraphic paleontology is being planned as well.

Herein you can also catch up on the activities and interests of faculty, students, and alums from around the globe. This includes a compelling account by G&G alum **Neil Williams G '76** of an 1840 field trip undertaken by J.D. Dana and W.B. Clarke in New South Wales, Australia.

In sad news, Geochemistry Professor **Mark Pagani**, and Emeritus Geophysics Professor **Syd Clark** passed away. You can read moving tributes to their remarkable lives, careers, and legacies in the pages of this newsletter. Each has left an indelible mark on G&G and the geosciences generally, and their contributions will live on and shape our field long into the future.

In closing, this will be my last newsletter as Chair. It has been a tremendous privilege to serve the G&G community over the past six years, and a great pleasure to get to know so many departmental friends and alumni. Please keep us posted about your activities so we can feature them in future newsletters. Best wishes for the rest of 2018!

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## FACULTY RESEARCH

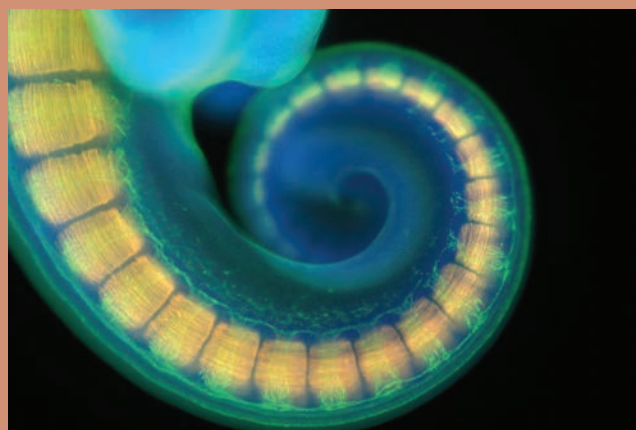
### Tracing the Deep History of Vertebrates through Earth History and Experimentally Resurrecting the Past

Bharat-Anjan Bhullar (bharat-anjan.bhullar@yale.edu)



The story of vertebrate life on Earth is immediately and perpetually interesting because it is, fundamentally, our story, and the story of our closest relatives—echoes and variations of ourselves among all the vast diversity in the biosphere. Because the vertebrate skeleton has

such high preservational potential, and because it is locked within the body and intimately associated with unpreserved soft tissues, the vertebrate fossil record records many of the transitions and transformations in body form that generated the breathtaking variety of backboned animals now on the planet. Our lab focuses on these major transformations within and outside of Vertebrata, and seeks to understand them using the rock record of their progression in combination with evidence from modern descendants, in particular the molecular and cellular mechanisms of embryonic development, which are the processes that enact the sculpting of body form anew in each generation. We are particularly interested in 3D and 4D imaging and modeling. Thus, as in many other labs in Geology & Geophysics, we are pushing the boundaries of our field by attempting, experimentally and computationally, to model the processes by which Earth system change occurs on a geologic timescale—in our case, the morphological, environmental, and genetic processes that account for long-term biospheric dynamics in the form of biotic evolution. We tend to focus on ways in which important features of the ancestors of major, instantly recognizable, vertebrate radiations were gradually assembled: the origin of mammals, of birds, of reptiles, of jawed vertebrates or vertebrates as a whole. In addition to enormous numbers of fossils, virtual and physical, from prior and current collecting efforts, we have in the lab embryos of taxa as diverse as acorn worms, amphioxus, fish, salamanders, frogs, lizards and snakes, turtles, alligators, several kinds of birds, mice, squirrels, and opossums. Our focus on diver-



Alligator embryo tail stained for muscle nerve and cell nuclei.

sity and change stands in contrast to that of other laboratories with molecular developmental capabilities, while our emphasis on experimental manipulation stands in contrast to that of other laboratories concerned with evolutionary processes on the scale of hundreds of millions of years. Major projects and initiatives include the following, many of which are in collaboration with other labs in G&G and other departments and units at Yale. Our work is also intimately tied to activities in the Yale Peabody Museum of Natural History.

#### *Developmental and Genetic Bases for Major Evolutionary Phenomena*

Broad-scale evolution sometimes involves major shifts in tempo and mode enacted by fundamental changes in developmental processes. Alterations in overall rate and timing of embryonic events can, for example, enact juvenilization or paedomorphosis within a lineage. Our previous work has suggested that juvenilization underlies many of the prominent anatomical transitions along the line to modern birds, and we continue to investigate ways in which the phenomenon impacted avian evolution. Projects involving postdoc **Adam Pritchard**, graduate student **Michael Hanson**, and



Matteo Fabbri, Elizabeth Clark, Adam Pritchard and Michael Hanson processing 3D datasets of fossils and embryos.

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several undergraduates and high school volunteers including **Adrien Gau**, **Indira Khera**, **Jane Lockery**, and **Amber Polk**, use 3D imaging of fossils and extant taxa to address anatomical aspects of juvenilization along the avian line. Complementary work, led by Human Frontier Science post-doctoral fellow **João Botelho**, includes cellular and molecular analyses of skeletal development, in vivo and in culture, to determine whether the basic growth properties of tissues differ between birds and nonavian reptiles. Projects led by Ph.D. student **Daniel Smith** deal with major rearrangements of early embryonic body structures at the origins of anatomically divergent reptile groups such as turtles and snakes.

### *History, Contingency, and Evolutionary Radiation*

In addition to the anatomical and developmental mechanisms that produce large-scale evolutionary changes in form and function, we are interested in the historical contexts that permitted the diversification of each of the disparate major clades of vertebrates and within which morphological transformations took place. Precipitous events in Earth history such as the end-Cretaceous asteroid impact preceded many, if not most, of the great vertebrate radiations, and patterns of extinction and survival as well as the fossil record of morphological evolution proximal to these events provide some insight into the effects of sudden geologic change and catastrophe upon vertebrate history. We have in the past examined the effects of the end-Cretaceous extinction on lizards and snakes, and current projects involving a number of current and former lab members concern undescribed fossils of transitional lizards and snakes record-



Bhart-Anjan Bhullar and Amber Polk examining a dinosaur fossil and its CT dataset.

ing the evolution of features in these groups soon after the extinction, as well as exceptionally preserved primitive mammal material from very early in the Cenozoic “age of mammals.”

### *Developmental and Genetic Links between the Brain and Other Tissues of the Head*

At first glance, the evolutionary history of a complex structure – and none is more complex than the vertebrate head – consists of a bewildering number of small changes within lineages, some concurrent and others spread out through geologic time. We are interested in ways in which multiple seemingly independent events might actually be nonindependent, linked by a common developmental process. In the head, which is both evolutionarily important and well-represented in the fossil record owing to a high degree of skeletal ossification, we are particularly interested in the first structure to gain distinct form in the embryo, the brain. There is evidence from biomedical fields that the brain has a primacy in the development of the head and that it is an important molecular signaling structure. Moreover, it is structurally important and, for instance, the mere physical expansion of the brain in groups like birds and mammals likely causes a number of alterations in the form of the head. Our experimental work attempts to replicate ancestral modes of brain development and to determine whether doing so can resurrect ancestral modes of skull development. Graduate student Matteo Fabbri and undergraduate interns **Anisa Iqbal** and **Arianna Lord** are studying brain expansion and skull evolution at the origin of birds. Postdoc **Macarena Faunes** and undergraduate intern **Ludivine Brunissen** are studying the same phenomena at the origin of mammals.

### *Development and Evolution of the Prime Movers and Major Spatial Occupants of the Body, the Muscles*

From the historical literature in vertebrate paleontology, one might get the idea that the history of vertebrates is that of skeletons evolving into other skeletons. Although the skeleton is an important structural component of the vertebrate body, it is only the mineralized portion of a much larger network of connective tissue that organizes and partitions spatial and functional units, and many of the spaces formed within that connective tissue are filled with muscle – hence the idea of

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### Tracing the Deep History of Vertebrates through Earth History and Experimentally Resurrecting the Past *continued from page 3*



João Botelho performing fluorescence microscopy.

the ‘musculoskeletal system.’ The intricacies of muscle evolution and development, despite the functional significance of the tissue, have been with a few exceptions largely ignored during the last several decades in comparison to those of the evolution and development of the mineralized skeleton. We are broadly interested in rectifying this insufficiency in knowledge, especially with regard to muscles of the head and neck. Ph.D. students **Michael Hanson** and **Daniel Smith**, lab volunteer **Miccaella Vergara**, and undergraduate intern **Lexis Anderson** are examining the evolution of the jaw muscles in reptiles and birds and Ph.D. student **Juri Miyamae** is studying the origin of the unique facial muscles of mammals.

#### *Origin and Development of Major Features in Reptiles*

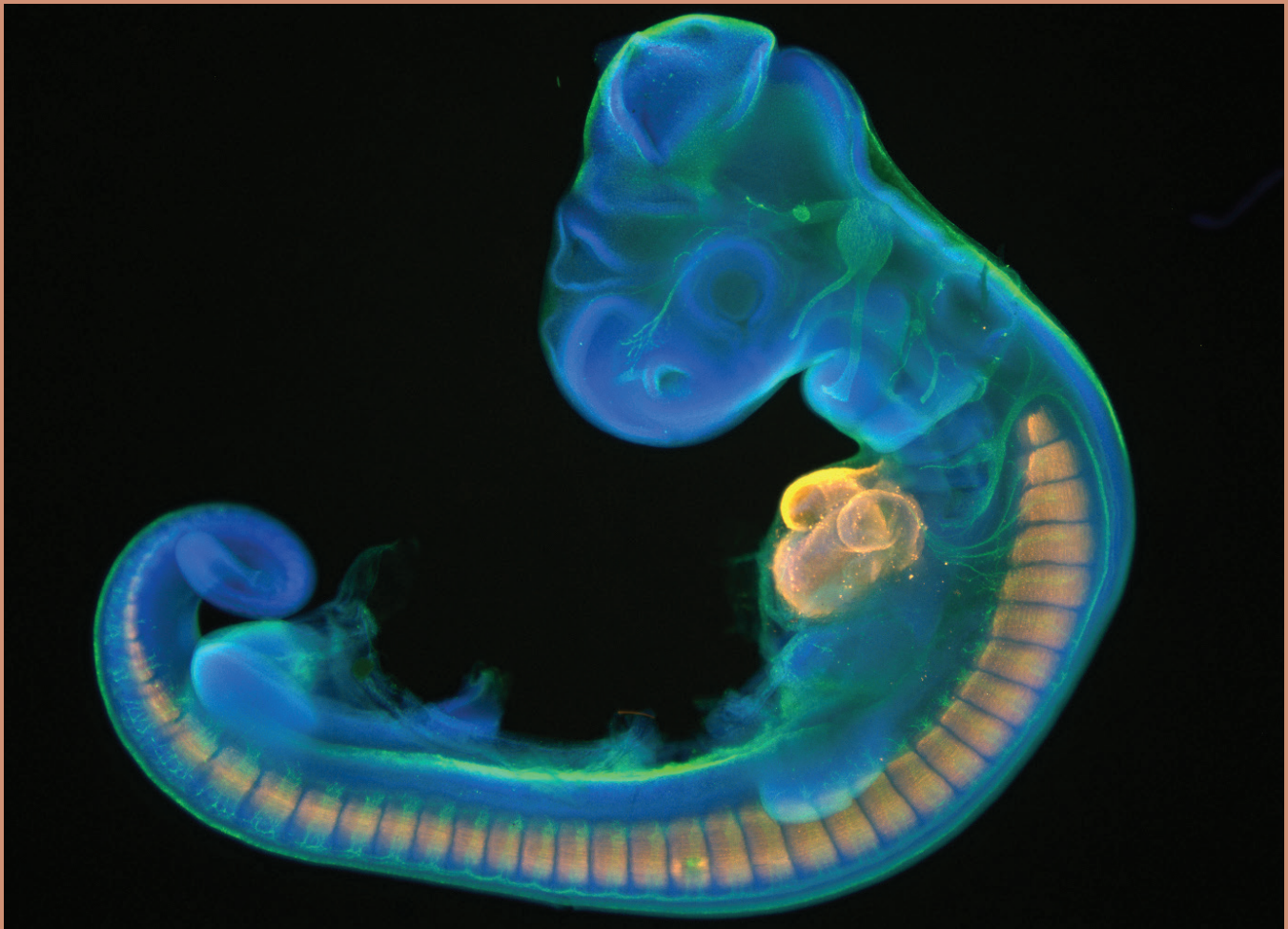
We are interested in both beginnings and endings, but for us origins hold pride of place. Among the major vertebrate clades, we focus most on the origin and diversification of groups with Reptilia. In particular, we are interested in the many transformations along the line to modern birds. Past and ongoing work currently led by postdoctoral fellow **Macarena Faunes**, but involving much of the lab, concerns the origin of the bird beak and the general evolution of the gene regulatory networks that pattern bird-specific cranial features. Recently, our resurrection of an ancestral dinosaurian snout in birds by replicating ancestral developmental patterns garnered considerable attention. We are also

pursuing the evolution and development of other distinctive parts of the bird body, including the wings, the shoulder and sternum, the pelvis, the legs, and the tail, in projects led by a number of lab members including postdoc **João Botelho**, Ph.D. student **Daniel Smith**, and visiting students **Avinash Subramanian** from Brown University and **Christopher Griffin** from Virginia Tech. Ph.D. student **Michael Hanson** has made painstaking reconstructions of some of the only three-dimensional fossils recording the transition from nonavian dinosaurs to birds, including new material of the famous “toothed birds” from the Cretaceous interior seaway of the United States. He and former postdoctoral fellow **Daniel Field**, now faculty at the University of Bath, are examining other aspects of the evolution of these transitional forms as well, including their flight apparatus. We are also attempting to illuminate the origin of the body plan and locomotion in early land-living relatives of crocodiles and in early examples of the extinct flying pterosaurs, in part based on truly exceptional undescribed specimens from the Triassic of the western United States recovered by Yale teams in the last decade. This work involves a number of lab members including postdoc **Adam Pritchard** and undergraduate **Adrien Gau**. Various lab members including undergraduates **Maya Juman** and **Katherine Walls** are also working on the origin of lizards and snakes and of reptiles as a whole, including description of new fossils pertinent to the history of the groups.

#### *Origin and Development of Major Features in Mammals*

There is an intrinsic fascination for us in the deep history of humanity, and there are few more compelling stories in vertebrate evolution than the long march from reptile-like ancestral amniotes to modern mammals. Several current and former lab members, including the PI, have abiding interests in this series of transformations and are working on a combined paleontological and developmental approach to understanding the story of mammalian origins. Notably, postdoc **Macarena Faunes**, Ph.D. student **Juri Miyamae**, undergraduate intern **Ludivine Brunissen**, and high school interns **Alice Li** and **Evelyn Fabian** are working on aspects of head and body evolution and development in Mammalia. We also are pursuing advanced 3D x-ray cinematographic studies of feeding in primi-

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Alligator embryo stained for muscle nerve and cell nuclei—Federation of American Societies for Experimental Biology BioArt Competition Winner.

tive living mammals in combination with morphological analysis of teeth and throats in order to understand the origin of the uniquely mammalian system of chewing and swallowing food.

#### *Deep Origins and Development of Vertebrate Form and Function*

Recently, postdocs **João Botelho** and **Macarena Faunes** have begun to culture the primitive chordate *Branchiostoma* (amphioxus) in our lab. This diminutive marine organism sheds light on the very earliest evolution of chordate features, and we are examining the development of its simple muscular architecture and proto-skeleton, as well as its nervous system, to better understand the origin of backboned animals as a whole. Stepping even further outside of Vertebrata proper, work in collaboration with Briggs Lab student **Elizabeth Clark** focuses on form and function in the sister

taxon to the chordate lineage, Echinodermata, which includes starfish, crinoids, urchins, sea cucumbers, and brittle stars, and nature of the deuterostome common ancestor.

#### *Fieldwork*

Yale paleontology has a long tradition of fossil collection and discovery. Students and staff from G&G and the Peabody Museum continue to go into the field every summer, currently focusing on the Triassic and Jurassic of the western United States, time periods during which many of the origin events on which our lab focuses took place. We have discovered exceptionally preserved fossils pertaining to the origin of the major reptile groups and of mammals, several of which are new and are subjects of intensive current research. Our core fieldwork is organized and led by Peabody preparator **Marilyn Fox**.

## IN MEMORIAM

**Sydney P. Clark, Jr.** (1929-2016)



Syd driving the lunar vehicle. He earned a Lunar Vehicles Driver License (#118) from the Bendix Corporation.

**Sydney P. Clark, Jr.** passed away quietly in his sleep on Dec. 24, 2016. He was born in Philadelphia on July 26, 1929. He is survived by his wife of 54 years Elizabeth (Dibbie) Frey Clark and by children Edward (Ted) of Canton CT, Jordan (wife Dorothy Pak) of Santa Barbara CA, Elizabeth (Lisa) of Brookfield CT, and Christie (husband Michael O'Hare) of New York City, NY, and nine grandchildren.

In 1947, he graduated from Pomfret School (where he served as a Trustee) and later received both his B.S. ('51) and Ph.D. ('55) in the Department of Geology (later renamed Earth & Planetary Sciences) from Harvard University. His thesis title is *Terrestrial Heat Flow in the Swiss Alps*, which was supervised by Francis Birch. After a brief period at the Carnegie Geophysical Laboratory in Washington, DC, he became the Sidney J. Weinberg Professor of Geophysics at Yale University in 1963, a position he held until his retirement in 1988. Syd moved to New Haven when the Kline Geology Building opened in 1963 after finishing a Fulbright Fellowship at the Australian National University where he collaborated with A. Edward "Ted" Ringwood and John C. Jaeger.

Syd was one of the pioneers of geophysics. He is known for his early work on mineral physical chemistry and the uplift rates of the Alps using heat flow and radioactive geochronometry, as well as theories of planetary formation that he

conducted with his Yale colleague, Karl K. Turekian, and their graduate student, Lawrence Grossman. This later work led to a lunar experiment conducted during three Apollo missions. Syd authored numerous papers and three books: *Handbook of Physical Constants* (1966), *The Structure of the Earth* (1972), and *Processes in Continental Lithospheric Deformation* (1988).

My early memories of my father are different. I was aware of his lunar drill because there was a photograph of him riding the lunar rover or "moon buggy" on a wall above our TV. My uncle, Peter Bell, took me to see the drill at the Smithsonian Air and Space Museum, when I visited him in high school. There was another photograph that was in my father's office at the Woodbridge family home. It showed a group of geologists standing on and next to a monument showing the location of the equator in Africa. It was taken during a field trip that stretched from the gold fields near Johannesburg to equatorial Africa (which, I believe, was sponsored by NSF in 1969). When he was awarded the Pomfret School Alumni of the year, my father decided to speak about this trip because he saw it as a highlight of his career in geology.

While I was attending Yale as a major in Geology & Geophysics, my father taught the only required class: Mineralogy. The class of 1988 was small and consisted of three majors: Daniel Schrag, Wendy Goldsmith, and myself. The

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sequencing of classes was such that majors from each class year took Mineralogy together. So the year I took Mineralogy, there were only three enrolled students. Nevertheless, my father's lecturing style remained the same even if I were the only student present, which was not uncommon given the early scheduled time of the class, the relatively long walk to Kline from the residential colleges, and frequent cold mornings after Halloween. His style of lecturing appealed to me because he stressed the origin of mineral names and their crystal structure. I remember in graduate school speaking with a student who was the TA for mineralogy and was having trouble with the symmetry of wooden blocks. At that point I could still help him.

As I expect many of the old-time Yale faculty remember, my parents hosted numerous parties. The amount of time and effort that my mother spent preparing for these events was substantial. As I grew older, I would join these joyous occasions and found the Yale faculty and their families to be very collegial. These impressions reinforced my earliest memories of the Fall Departmental Picnic at Chatfield Hollow State Park where a faculty member was always willing to lead a walk to examine the Indian Caves.

After retiring from Yale in 1988, my parents moved to the Island of Bermuda. While living there, they became active in a number of garden clubs. I remember learning once that my father had led a group on a 'Geologic Tour of Bermuda.' It appeared that he did not enjoy the opportunity. Apparently, a number of the participants wished to learn more about the different types of coral outcrop, a subject that he knew little about and did not find very interesting, as opposed to Darwin's theory of atoll formation.

My parents traveled frequently in retirement. They often traveled to geologically interesting areas. My wife and I have often discussed to what extent were these trips for my father or for my mother? For instance, did they go to Iceland to purchase Loppi wool for my mother or did they go to see the fascinating geology of the island nation? Knowing my parents, they decided on where to go together, a trait that ensured a happy 54 year marriage.

**Jordan Clark '88**



## MEMORIES OF MARK PAGANI

By Some of His Students, Postdocs and Friends

*I write with great sadness to let you know that Mark Pagani, Professor of Geology and Geophysics, has passed away after a courageous battle with cancer. He was surrounded by the love of his family when he left this world, and we send out our deepest condolences to them during this time of such great loss.*

*Mark got his B.A. degree at the University of Colorado, Boulder, and his Ph.D. at Penn State. He was a Postdoctoral Researcher and Research Fellow at UC Santa Cruz for a number of years before joining the Yale faculty as an Assistant Professor in 2002.*

*And he has the distinction of probably being the only geochemist who was a professional rock musician before he came to the field.*

*Mark was a pioneer in organic geochemistry, leading the way in using isotopic proxies to better understand climate and climate variations back through Earth's long history. Some of his group's accomplishments include reconstruction of Earth's atmospheric carbon dioxide content over the past 60 million years, unraveling the drivers of extreme climate variations such as the Paleocene-Eocene thermal maximum, and deducing ancient temporal and spatial variations in sea-surface temperatures and how they relate to climate phenomena such as El Niño and La Niña. For these and many other groundbreaking contributions, Mark was honored as a Kavli Fellow and as a Fellow of the American Geophysical Union.*

*One of Mark's great themes was that if we are to come to grips with anthropogenic climate change today, we need to understand natural processes and how they have influenced climate variability in the past. With his estimates of atmo-*

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spheric carbon dioxide across geologic time, he argued that the levels we experience today are similar to those about 4 million years ago, when there was little to no ice on Greenland and sea level was some 65 feet higher than now. And if things continue as they are, sometime in the next century carbon dioxide levels will be similar to what they were around 50 million years ago, when there was little or no polar ice, sea level was over 200 feet higher than today, and crocodiles lived comfortably in polar regions. His thought-provoking op-ed on these issues in CNN online is well worth reading.

Mark was a highly engaged teacher, mentor, and member of the scientific community. He served as the Director of Graduate Studies in G&G, productively restructuring the way advising committees interact with Ph.D. students in the years following the qualifying exam. He played a fundamental role in the creation of the Yale Climate and Energy Institute (YCEI), and served as the Institute's Director from 2012–15. He was an inspirational mentor and advisor to a wide spectrum of undergraduates, Ph.D. students, and postdocs who have now gone on to forge distinguished careers of their own. He served on many national and international scientific committees, and was a frequent organizer and Chair of geochemical sessions at conferences across the globe.

When Mark first arrived in the department, his office was down the hall from mine. And I quickly realized that he liked music. Loud music. Really loud music. One time he was playing “Black Dog” from Led Zeppelin IV so loudly that the pencils were rattling on my desk. We had similar tastes in music and it was fascinating to learn of people in the Boston music scene that he was once a part of, including Mark Sandman, another creative genius who left far too soon.

But early on, as my pencils were rattling, I confess that I remember thinking to myself: “What did we get ourselves into by hiring this guy?” Well, what we got was unquestionably a visionary leader in paleoclimate research—at the top of the field worldwide. And quite a personality too. He was frank. Sometimes abrasively so (well, maybe more than just sometimes...). But his honesty and unvarnished sense of humor were refreshing. He was a loyal friend who would stick by you in the good times, and the bad. He cared deeply about his family and loved talking about what his kids

were up to. There was true joy in his eyes when he spoke of them. These were all facets of his personality honed on the streets of New York City where he grew up, and were part of what made him unforgettable.

I am from the Midwest. Detroit actually. We don't hug each other too much there. But with Mark it was a different story. When really good things happened, or really bad things, Mark and I would clasp hands and put our arms around each other's shoulders. We didn't have to say anything. We just knew.

G&G has now lost three great geochemists in about as many years—Karl Turekian, Bob Berner, and now Mark. We must and will rebuild. And as we do so, we will keep the examples that these luminaries set for us foremost in our minds.

Mark's time was cut short, but he accomplished more than most ever will. Rock on.

### JAY AGUE



Mark Pagani

Mark was a wonderful friend and colleague—he had great insight and a sense of mischief that made doing science with him fun. Paul Koch (UC Santa Cruz) summed him up superbly in a recent FB post commenting “he was a funny bastard with a ferocious intellect.” Shortly after my sabbatical at Yale, I invited Mark over to a meeting on CO<sub>2</sub> and plants at the Royal Society's Kavli Centre—a rather grand country house near Bletchley Park (of WW2 code breaking/Alan Turing fame). Mark gave a typically



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*brilliant talk on plants and CO<sub>2</sub> starvation and the last night held court in the local pub reducing us all to tears of laughter. Now he has reduced us to tears again. He is sorely missed.*

### DAVID BEERLING

*We were astonished and shocked to learn about the passing—last week—of our close friend and colleague, Mark Pagani. We were aware that Mark was fighting to overcome cancer but were not prepared to now learn of his sudden demise.*

*Everything about Mark was exceptional and outstanding. His research, teaching, creativity, drive, music, and above all, his friendship.*

*We (staff, postdocs, PhD, MSc and BSc students at our research group in Utrecht) have known Mark for many years, working together in our common quest to unravel the extreme climates of the Cenozoic geological era. Indeed, Mark leaves a legacy of innovative and creative hard-core science helping to understand climate dynamics in the past... and future. His contribution was not limited to publishing impactful papers. In particular, we will remember him as a driver of open discussion which he conducted characteristically: sharp, provocative, challenging, and open-minded.*

*Not in the least, he has contributed to the current and future generation of paleoclimatologists through his long-standing participation and driving force behind the series of Urbino Summer Schools in Paleoclimatology (USSP) in the heart of his beloved Italy. He was an ambassador-par-excellence of the USSP spirit, drive and inspiration for the almost 1,000 students so far.*

*It is hard to believe and accept that we cannot do more than to miss him dearly.*

*We wish Teresa, Ruben and Kayla, and all involved, all the strength to move on.*

*On behalf of the Marine Palynology and Paleooceanography group, Department of Earth Sciences, Utrecht University, the Netherlands,*

### HENK BRINKHUIS AND APPY SLUIJS

*I am still grateful for all the support and comfort that I received from Mark, when my mom was first diagnosed with breast cancer in China, and I was scrambling for help from the department (he was the DGS back then). His support made my time much easier during those hectic days. Later in our occasional encounters, I could always feel the genuine care that he showed towards me, one of the many grad students in G&G. For me, he was an exemplary of how supportive the G&G community is during my PhD study at Yale.*

*I am very sad that I never got an opportunity to say goodbye to him. Yet his spirit shall be as inspiring as ever!*

*Lastly, my condolences to everyone who has admired Mark and benefited from his supervision. Be strong and rock on.*

*RIP, Mark!*

### XIAOJUN CHEN

*Mark was my PhD advisor from 2007 to 2013. When I first learned that Mark was ill, about 18 months ago, I was in the middle of my postdoc and only had a couple of chances to see him since graduating from Yale. I really valued my time spent with Mark, and I was looking forward to spending more time with him as a peer, and continuing our conversations about science and life, but without the anxiety of being a PhD student trying to finish up and find my place in the world. When I moved to Montreal this summer, I kept thinking how great it would be to invite Mark up to give a talk, when he was feeling better, and to explore the city together. Now, like all of us, I'm feeling very sad that Mark won't be there at the next conference or for a phone call, and for the missed opportunities to spend time with him.*

*Mark was an excellent advisor. It took time to realize this because he had a well-cultivated tough exterior, and I think like all students who worked with him I was intimidated at first. But behind this tough exterior was one of the most loyal and supportive supervisors I think anyone could hope to have. I remember sitting down to tell him that my wife and I were expecting a second child, about a year before I was going to run out of funding. He definitely looked at me like I was crazy, but also with an extreme depth of support and empathy. He had been that crazy person before, and he told*

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me about his experiences finishing his PhD as a new dad. He assured me that I would get it done, and that assurance gave me a real shot of strength in a moment of deep uncertainty.

My dissertation focused on how climate change affected the ancient Maya civilization, which was pretty far removed from Mark's previous work, and it was invigorating to watch Mark engage with a new discipline. I think he really enjoyed the human dimension of this research, just as he relished the policy-related work that came with directing the Yale climate institute. As always, Mark was a constant source of new ideas. Some, like the "Maya Misery Index," made the archaeologists cringe. But I also remember sitting in a geoarchaeology seminar with him and watching as he used his geochemical knowledge to develop a very elegant explanation for how the ancient Maya were able to avoid sulfate toxicity in their crops. Mark was incredibly creative, and one of the many tragedies of his passing is the loss of the ideas he would have come up with over the years to come.

I feel very sad for Mark's family. I only saw glimpses of his life outside of Yale, but when I did meet his children and wife, I could tell how intense his love for them was. Mark clearly had a very rich life outside of science, as a musician and an artist, as a father, as someone who developed deep friendships. I think this is the aspect of Mark's life that inspires me the most. I don't know much about Mark's spirituality, but I know he had a strong interest in religion and mysticism, in part because he had a huge mural of three Hindu gods put up on the wall of his lab. I think this was partly for fun, but it was also an expression of his interest in fundamental questions that, ultimately, science can only hint at. I'm not sure what Mark's thoughts were on an afterlife, but I do know that at the least he will continue on as a beautiful memory, and as an example to us, to keep questioning our assumptions and beliefs, to keep thinking of new ideas to explain our observations, and to enthusiastically embrace every opportunity that comes our way.

**PETER DOUGLAS, G '14**

Mark was one of the few professors with whom I connected on a personal level during my time at Yale. He was down to Earth, had a sense of humor,

and loved playing and writing music. He helped me realize that I could, and should, shape my career and my future by the things I am passionate about and that bring me joy, rather than chasing the ever elusive idea of 'success.' I will always be grateful for the time I spent with Mark and the lessons he taught me, just by being his genuine self. My sincere condolences to his family.

**ABBY EURICH, '14**

Mark's style of science made a strong impression on anyone who interacted with him. In my case, as someone who uses organic biomarkers to investigate past climates, Mark provided a compelling body of work that I followed closely right up to his untimely passing.

I first met Mark when he made a presentation as a postdoc at Santa Cruz on the boron isotope system as a paleo-pH proxy to a bunch of us somewhat more senior scientists. Thinking back, the talk already had hallmarks of Mark's way of presenting things: intense, alternately humorous and pessimistic and very frank about both the promise and the potential downfalls to what he was working on. Mark had a way of selling you on the excitement of what he was doing while at the same time reminding you that our work can rest in a rather fragile way on crucial assumptions.

As it turned out, Mark turned from the boron-based method to produce an amazingly influential body of work to reconstruct past levels of CO<sub>2</sub> in Cenozoic time through his carbon isotopic analysis of marine biomolecules known as alkenones. It's perhaps fitting that this work produced some of the most definitive evidence in support of the late Robert Berner's contention that major features of the last 100 Myr of climate were dictated by changing levels of carbon dioxide in the atmosphere. The evidence that Mark generated for strikingly higher CO<sub>2</sub> levels in the warm Paleocene and Eocene epochs will undoubtedly stand the test of time, and have entered into textbooks and classroom teaching. My feeling is that the conclusions he drew from the more equivocal data on Earth's recent past will need to be revised, but that's in the nature of science at the cutting edge.

Mark energized every meeting in which he took part. He would challenge and provoke, but also save the day by letting everyone know that he

## IN MEMORIAM

*enjoyed stirring the drink. I never imagined that we would lose him so soon. I send my sincere condolences to Mark's Yale family.*

### TIM HERBERT

*He was a great mentor and a friend who inspired me to always reach higher and I plan to eventually return to grad school to pursue a PhD in climate studies/geochemistry. There was never a dull moment in his class! He will be missed.*

### IVETTE LOPEZ, '16

*I knew Mark as the only professor at Yale who started lecturing while lying barefoot and prostrate on the floor. I also knew him as the mentor who sent me to Italy, Croatia, and France, who talked me through most of the major decisions I made in my final years of school, and who, when I chose not to continue pursuing paleoclimatology research, continued to support me as a mentor and a friend. I will miss sending him Christmas cookies for Solstice (his Winter holiday of choice).*

*The celebration of Mark's life at the Outer Space was a strange mix of sorrow and joy. What I didn't fully appreciate until this remembrance was that literally HUNDREDS of people cherished Mark as a mentor, friend, collaborator, or family member, and that he had enough to give some of himself to all of them. My heart goes out to Mark's family. He was taken too soon, and will be remembered not just by them but by all those whose lives he touched at Yale, in Urbino, and beyond.*

### ELI MITCHELL-LARSON, '13

*Mark and I met just as we were starting our PhDs. We both lost our voices to laryngitis while discussing stable isotope theory on a 24-hour road trip to the Florida Keys. We debated whether Leonard Cohen's songs were better as originals or covers. I wrecked his car on the way back. And then paid him back by hauling manure around for his garden that summer. Good times.*

*After five years at Penn State (and in Kate, a supervisor with near saintly tolerance) we both flew off to our postdoctoral careers and beyond.*

*But even when far apart and only seeing each other at conferences, his presence as a friend, colleague, collaborator and... character was persistent and always inspiring.*

*And now that he is gone I sometimes miss him so much it hurts. Because even if you did not see him often or agree with him when you did, it was reassuring in this time of post-truth BS and political mendacity that there were people like Mark who always spoke their mind, did it loudly and did not care about the consequences.*

*I think many of us will always remember 'Conference-Mark' the most—the guy who would arrive at Urbino with fanfare or greet you at AGU with a completely unexpected and kind of weird but surprisingly necessary shoulder massage if you sat in the back row of the conference hall. He laughed and he made us laugh. His wit could be sharp but also self-deprecating and quite often ridiculous. He liked the stage and we loved his energy. But of course, Mark's relationship with that reputation was ambivalent. He was passionate about his science and that is what he wanted to be known for, and indeed he drove palaeoclimate science forward and made great contributions to the field through perseverance, intelligence and creativity. He was willing to pour his heart and soul into science—because he poured his heart and soul into everything.*

*Some of my favorite memories of Mark are from the Fridays at AGU or Goldschmidt. The last day, with energy waning and the debates and talks and plenaries largely over. We'd grab a quiet lunch or coffee and we'd talk about our families. He'd catch me up on what Theresa, Kyla and Ruben were doing—even though I only met Ruben once and even though Kyla must have only been two years old when she left State College. He loved his wife so much and was so proud of his kids, and you could tell that as much as he might have loved the science and attention, what he really wanted was to be back home with his family.*

*Mark taught us that it was not enough to do science well but you had to do it bravely. And that good science is important—deeply and profoundly important—but it is not the only thing that is important. Those lessons are more important than ever.*

### RICH PANCOST

## IN MEMORIAM



Italy 2007: Brett Tipple, Simone Galeotti (University of Urbino), and Mark.

Mark had just started his new position at Yale when I agreed to join him as his first graduate student in 2003. Once I committed, Mark encouraged me to come to New Haven before the start of the academic year and begin working with him to reconstruct carbon dioxide concentrations during the Eocene and Oligocene. When I arrived that July, I found that much of Mark's lab was not yet operational, with many of the items still in their shipping containers. During that summer, Mark and I spent countless hours together, putting together his laboratory, and analyzing a few initial samples on his new instruments. That summer I learned a tremendous amount from Mark about analytical chemistry and the technical aspects of starting and running an isotope laboratory—many of those skills I still apply every day in my current position. And, those first few samples that we analyzed, well, they happened to show a rapid decrease in carbon dioxide levels during a period of major ice sheet development on Antarctica. Those CO<sub>2</sub> reconstructions, based on the carbon isotope values of compounds produced by ancient algae, were published in *Science* magazine. Mark's record was not only the first of its kind, but it also had major implications to our understanding

about ancient climate and the evolution of terrestrial ecosystems during the last 45 Myr. The results of those first few samples became the foundation of my dissertation research and much of my career today.

I feel that my first few months with Mark demonstrated the true caliber of the teacher, scientist, and mentor that he was. During that time, Mark generated a transformative scientific contribution, and all the while, he was teaching a novice graduate student the ins-and-outs of how to analyze the carbon isotopes of organic compounds.

I am deeply saddened by Mark's passing. He left us way too soon and will be greatly missed by his students and colleagues.

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**BRETT TIPPLE, G '09**

After Leo Hickey died in early February 2013 I came up to Yale for the funeral service. New Haven had just had a record snowfall. Leo's funeral was at St. Thomas More and Mark walked down from Kline for the service. After the service was over several of us were standing on the front steps. Mark could see how sad I was, so he came over to offer sympathy. We chatted for a little and then Mark said he had to head back up to the department. He gave me a couple of wonderful hugs, then turned and headed down the steps. He must have sensed the hugs weren't quite enough. As I continued standing there I heard him call out from the sidewalk "Hey, Scott!!". I looked up, and saw a big, fluffy white snowball coming hurtling at me. I got a spray of snow on the side and down into my jacket pocket. Mark got a huge grin—obviously very pleased at his aim. He said: "I thought you could use that. I'll see you soon." Then he walked off, leaving me laughing for the first time all day. He was so right, and I realized later it was a very Mark thing to do—really thinking about the sorrow and how someone else felt, but at the same time giving a reminder that sometimes you just have to enjoy and laugh and play because life is short. He was right about that. We all know brilliant colleagues. We all know people who are extraordinarily sensitive to how others feel. We all know people with a special joie de vivre. Mark had all three in spades.

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**SCOTT L. WING**

## IN MEMORIAM

November 16th, 2016 (Guam Time). I was about to write an email to Mark. It's been a few days since I last wrote to him. He was too weak to respond to emails, but one of his best friends, Eric, who also lives in New Haven said Mark read my previous emails and was pleased. So as I boarded the research vessel JOIDES Resolution as a shipboard scientist, I started to write to him by emailing or texting (when we had cell phone reception). Today I was going to write "when you are well again, don't ever sign up as an organic geochemist to sail on the JR. The organic geochemist's job is mostly sediment crushing and weighing, but we never get the exciting findings as the paleontologists do." Then, I received an email from Mark's student Hui, and James a couple of minutes later, saying "Mark passed away this afternoon."

I pretended that it was ok. I pretended that we knew it's going to happen. I tried to stay calm and wrote to Eric asking if there's anything I can do for Mark and his family. Very quickly I got the reply with two words "Be famous." The moment I saw this I burst into tears. It's him! It's Mark! It must be him! His voice was in my head again: "you will be famous, Yige." For many times, we joked about that I would become a famous guy in China, so when he visits the country, he would be welcomed by red carpets and referred to as "the old friend of the Chinese people"—the highest recognition that only the revolutionary leaders such as Castro were called. We were joking but we were also serious.

I know that as an advisor, Mark wanted to see every one of his students be successful. I know as a student, I want to make my advisor proud. I felt really bad since I would never have the chance to pay him back.

Mark was known to be blunt, and abrasive in some cases. I told him he shouldn't show up at the graduate student recruiting weekend because he often scares people away. I teased him by saying that after I interviewed at Yale, I thought he was a horrible person and he should totally thank the other professors who made me want to stay. As I often say, it doesn't matter where you come from, anyone who just starts to deal with Mark would have a "culture shock." Yes, I believe he had his own culture that might come from another planet. But he could be very sweet, although he tried really hard not to show that. One day I dealt with some really, really rude people and I was very upset. I closed the door of my office and barri-

caded myself for hours. He knocked, opened the door and asked me what was going on. Then, he invited me to come to his office, treated me with the best from his secret stash of liquor (not sure if any university codes were violated), and explained the neighborhood he grew up where "you leave a donut outside, people would take it," and how I should deal with nasty people and big bullies. We spent the entire afternoon together, just drinking and chatting. In September 2014, I was about to defend my thesis and also had my newborn son. I worked at home for a month. One day he texted me and asked me to come in. He treated me to a nice meal in a small restaurant on Willow St., we had a good chat, and then he came to my apartment to meet my son. We took a photo together, one of the few that we ever took (he hated photos). Mark's friend Pam said he is a "pussycat." Nobody believed her, but I tend to agree with that.

I met Mark Pagani in December 2008, San Francisco, CA. He was wearing glasses with a black frame, and a leather jacket. I saw Mark Pagani the very last time in April 2016, Cambridge, MA. He was wearing glasses with a black frame, and a leather jacket. It seems nothing had changed. I know that at this very moment, he must have the same appearance in the other world. He might be reading "New York Times" on his Macintosh, or painting in a studio, or building a shed—I'm not sure. But I feel lucky that I met him, had him as my advisor and my friend for the last eight years.

YIGE ZHANG, G '14

## ALUMNI IN MEMORIAM



A. Lee McAlester

**A. Lee McAlester** died on December 27, 2016, in Tyler Texas. Lee received a M.S. (1957) and Ph.D. (1960) from Yale and then joined the faculty of the Department of Geology, where he served until 1974, leaving to join the faculty of SMU to assume the post of Dean of Humanities and Sciences.

## RECENT AWARDS AND HONORS FOR 2016-17: FACULTY



Jay Ague

**Jay Ague** (jay.ague@yale.edu) has been named a Fellow of the Mineralogical Society of America and a Fellow of the Geological Society of America. He is recognized for his outstanding contributions to the fields of igneous and metamorphic geology, including recognition and quantification of exhumation depths

in ancient magmatic arcs, thermal pulse durations, petrologic indicators of ultra-high pressure/temperature metamorphic conditions, and fluid and carbon fluxes in orogens and subduction systems. He is also commended for exceptional training of young geologists.

**Mark Brandon** (mark.brandon@yale.edu) was appointed the Allan Cox Visiting Professor for Fall, 2017 at Stanford. His host was Professor George Hilley. The visit provided many opportunities to interact and work with researchers at Stanford on problems related to active tectonics of western North America.



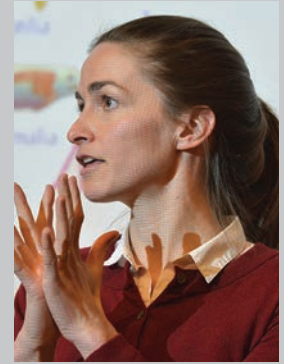
Mark Brandon

**Derek Briggs** (derek.briggs@yale.edu) has received the 2017 Graduate Mentor Award in Natural Sciences from the Yale Graduate School. This award recognizes graduate mentors for their “exceptional support of the professional, scholarly and personal development of their students.”

The selection committee receives scores of nominations from graduate students across the FAS, but only three awards are given each year—one each in Natural Sciences, Social Sciences, and Humanities.

**Pincelli Hull** (pincelli.hull@yale.edu) has been selected as a 2017 Sloan Foundation Research Fellow. From the Foundation’s website: “These 126 early-career scholars represent the most promising scientific researchers working today. Their achievements and potential place them among the next generation of scientific leaders in the U.S. and Canada.”

Celli is being recognized for her groundbreaking work understanding environmental, ecosystem, and evolutionary dynamics during and after times of great change in the geologic record, including mass extinctions and large swings in climate. This research of course has profound implications for what might happen in the future in a warming world as well.



Pincelli Hull



Shun Karato

**Shun Karato** (shun-ichiro.karato@yale.edu) won the 2016 Inge Lehmann medal of the American Geophysical Union (AGU). The AGU was established in 1919 by the National Research Council, and has grown to be the largest and most influential geophysical organization in the world with 62,000 members. The Lehmann medal

has been awarded to only a handful of the world’s greatest geophysicists—true giants of the field. It recognizes “outstanding contributions to the understanding of the structure, composition, and dynamics of the Earth’s mantle and core.” From the AGU website:

*“Established in 1995, the Lehmann Medal is named in honor of Inge Lehmann, who made many contributions to our understanding of the Earth’s deep interior, including her discovery of the Earth’s inner core in 1936.”*

**Maureen Long** (maureen.long@yale.edu) is a winner of the 2016 Macelwane medal of the American Geophysical Union. The AGU was established in 1919 by the National Research Council, and has grown to be the largest and most influential geophysical or-

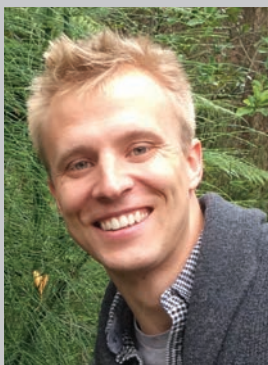
## RECENT AWARDS AND HONORS: FACULTY



Maureen Long

ganization in the world with 62,000 members. The Macelwane medal is one of the top few international prizes recognizing the accomplishments of young geoscientists, and is one of only two Union-wide awards. It is for “significant contributions to the geophysical sciences by an outstanding early career scientist.” From the AGU website: “Established in 1961, the Macelwane Medal was renamed in 1986 in honor of former AGU president James B. Macelwane (1953–1956). Renowned for his contributions to geophysics, Macelwane was deeply interested in teaching and encouraging young scientists.”

Maureen was also named an EarthScope Distinguished Speaker for 2016–2017. The EarthScope Speaker Series is part of the larger EarthScope Education and Outreach program and seeks to present the scientific results of EarthScope researchers to faculty and students in departmental seminars at colleges and universities. Speakers are selected based on their outstanding research accomplishments involving EarthScope as well as their abilities to engage a variety of audiences.



Noah Planavsky

**Noah Planavsky** (noah.planavsky@yale.edu) was awarded a 2016 Packard Fellowship for Science and Engineering to study how life in Earth’s oceans has changed over billions of years. Planavsky’s research focuses on the history and effects of Earth’s oxygenation. He studies connections between the evolution of Earth-system processes, biological innovation, and ecosystem change, primarily in Earth’s early history.

The David and Lucile Packard Foundation established the fellowships in 1988. Each year, the foundation invites 50 universities to nominate two faculty members for consideration in the following disciplines—physics, chemistry, mathematics, biology, astronomy, computer science, Earth science, ocean science, and all branches of engineering.

The program “invests in future leaders who have the freedom to take risks, explore new frontiers in their fields of study, and follow uncharted paths that may lead to groundbreaking discoveries.”

Noah is also among 126 U.S. and Canadian researchers who were awarded a \$50,000 Sloan Research Fellowship to advance their work. The fellowship program honors early-career scientists and scholars whose achievements and potential identify them as rising stars—part of the next generation of scientific leaders. The fellowships are awarded in eight scientific and technical fields: chemistry, computer science, economics, mathematics, computational and evolutionary molecular biology, neuroscience, ocean sciences, and physics.



Brian Skinner

**Brian Skinner** (brian.skinner@yale.edu) received the William C. DeVane Medal for emeritus faculty from the Yale chapter of Phi Beta Kappa. From their website, the DeVane Medal is conferred “on members of the faculty who have distinguished themselves as teachers of undergraduates in Yale College and as scholars in their fields.”



Ellen Thomas

**Ellen Thomas** (ellen.thomas@yale.edu) received the Brady Medal from the Micropalaeontological Society. The Brady Medal is widely recognized in the Micropalaeontological community as an award of excellence as evidenced by the calibre of previous recipients. This award is being made because of the widely recognized and appreciated contribution Ellen has made to micropalaeontology internationally. This has included communicating to an extremely broad audience fascinating, impactful and often thought-provoking research. As Dr. F. John Gregory, President The Micropalaeontological Society states, “Also, equally important, has been Ellen’s academic encouragement of students and peers over the years with her generosity of time in a very busy and successful career.”

## RECENT AWARDS &amp; HONORS: STUDENTS



Ross Anderson



Srikanth Toppaladoddi

**Ross Anderson** and **Srikanth Toppaladoddi** were elected to junior research fellowships at All Souls College in Oxford.

For those who are unfamiliar with such fellowships, they are peculiar to Oxford and Cambridge (with the Harvard Society of Fellows trying to mimic them). The competition is extremely stiff with many hundreds of applications for a few positions. Those elected become full members of the governing bodies of their colleges, with lunch and dinner at high-table, housing, and stipend (in this case the position is for 5 years), and they will also have an affiliation with a department. Ross and Srikanth are among the five fellows elected at All Souls College.

**David Auerbach** was awarded a Yale Institute for Biospheric Studies Doctoral Dissertation Improvement Grant. The topic of the study that was funded is *“Understanding the evolution of the Patagonian rain shadow through the Cenozoic.”*



David Auerbach



Janet Burke

**Janet Burke** was awarded a Martin Fellowship from Naturalis Biodiversity Centre in The Netherlands. She also received the Mid-American Paleontology Society (MAPS) Outstanding Research Award, which is awarded to the top 3 applicants for Paleo Society grants. The title of the research project for both awards is *“Planktonic Foraminiferal Morphology Across a Period of Global Cooling”* in which she will be attempting to gain a better understanding of the causes of the extinctions of planktonic foraminifera in the Middle to Late Eocene. She also received a Yale Institute for Biospheric Studies Doctoral Pilot Grant.



## RECENT AWARDS & HONORS: STUDENTS

**Devon Cole** has been awarded a National Geographic Young Explorers grant. Devon will join a group of roughly 15 archaeologists, anthropologists, astronomers, conservationists, ecologists, geographers, geologists, marine scientists, adventurers, storytellers, and pioneers that are “*passionate, creative individuals with great ideas.*”



Devon Cole

The award will allow Devon to continue to explore the links between Earth’s oxygenation and the rise and early diversification of early animals.



Neala Creasy

**Neala Creasy** has been awarded a Graduate Research Fellowship by the National Science Foundation. The NSF Graduate Research Fellowship Program recognizes and supports outstanding graduate students in NSF-supported science, technology, engineering, and mathematics disciplines.

**Nicole Shibley** has been awarded a National Defense Science and Engineering Graduate (NDSEG) Fellowship. This is a three-year graduate fellowship awarded “*...to individuals who have demonstrated the ability and special aptitude for advanced training in science and engineering.*”



Nicole Shibley



Jack Shaw

**Jack Shaw** is one of the winners of the Geological Society of America Geobiology and Geomicrobiology Student Presentation awards for his talk: *Planktonic Foraminiferal Bleaching during Early Eocene Hyperthermal Events.*

## STUDENT NEWS

**Seniors who graduated in the Class of 2016****Chris Bowman**

“A High Resolution Stable Isotope Analysis of Middle Eocene Planktonic Foraminifera”

**Advisor:** Pincelli Hull

**Paige Breen**

“Creating an Extensive, Multi-species Planktonic Isotope Record at an Eocene-Oligocene High Latitude Site”

**Advisor:** Pincelli Hull

**Luke Cartwright**

“Reversing the Effects of the Patagonian Ice Sheet on the Southern Andes”

**Advisor:** Mark Brandon

**Martha Cosgrove**

“A Paleoelevation History of the Southern Patagonian Andes from Hydrated Volcanic Glass”

**Advisor:** Mark Brandon

**Eric Fein**

“SKS and SKKS Splitting Beneath Alaska: Evidence for Anisotropy in the Lower Mantle”

**Advisor:** Maureen Long

**Matthew Goldklang**

“Carbonate Clumped Isotope Thermometry of Bulk Planktonic Foraminifera”

**Advisors:** Pincelli Hull and Mark Pagani

**Sara Kahanamoku-Snellings**

“Sizing up Community Structure: Exploring Latitudinal Gradients in Eastern Pacific Patellogastropoda (Mollusca, Gastropoda) Body Size with High-throughput Morphometric Imaging”

**Advisor:** Pincelli Hull

**Parker Liautaud**

“Isotopic Composition of Near-Surface Snow Across Antarctica”

**Advisor:** Ron Smith

**Samantha Lichtin**

“Variance in Orca Basin Compound-specific GDGT  $\delta^{13}C$ : Implications for Source, Sink, and Paleoclimate Interpretations”

**Advisors:** Pincelli Hull and Mark Pagani

**Ivette López**

“Seismic Anisotropy Beneath the Northeastern United States: An Investigation of SKS Splitting at Long-running Seismic Stations”

**Advisor:** Maureen Long

**Tess Maggio**

“Old and New Climate Proxies with Foraminifera: Providing Geochemical Evidence for Porosity as a Proxy for Metabolism, and Investigating the Validity of I/Ca as a New Redox Proxy”

**Advisor:** Pincelli Hull

**Maya Midzik**

“Monitoring Harmful Algal Blooms in Lake Champlain with MODIS and Landsat 8 OLI Remote Sensing Data”

**Advisor:** Ron Smith

**Viktor Nesheim**

“Mineral Carbon Sequestration and Theoretical Constraints on CO<sub>2</sub> Removal”

**Advisor:** David Bercovici

**Astrid Pacini**

“The Relationship of Water Isotopes to Orographic Precipitation and Regional Climate”

**Advisor:** Mark Brandon

## STUDENT NEWS

**Gabriel Roy Liguori**

“An Analysis on the Influence of a Horizontal Axis Wind Turbine on the Ambient Electric Field”

**Advisor:** Ron Smith

**Jane Smyth**

“Responses of the Hydrological Cycle to Solar Forcings”

**Advisor:** Trude Storelvmo

**Christine Tsai**

“Cloud Thermodynamic Phase in the Radiation Budget and its Determination Using Remote Sensing Technology”

**Advisor:** Ron Smith

**Rain Tsong**

“Re-examination of Li Isotopic Ratios as a Weathering Proxy: a Core-top Calibration”

**Advisors:** Pincelli Hull and Noah Planavsky

**Olivia Walker**

“Refining the Paleomagnetism of the Congo Craton, Northern Namibia”

**Advisor:** David Evans

**XinXin Xu**

“Paleomagnetism of Mesoproterozoic Lavas in the Barby Formation of the Sinclair region, southern Namibia”

**Advisor:** David Evans

**Seniors who graduated in the Class of 2017****Juan Aragon**

“SKS Splitting and Seismic Anisotropy Beneath the Mid-Atlantic Appalachians using Data from the MAGIC FlexArray Experiment”

**Advisor:** Maureen Long

**Derek Brown**

“Hydraulic Fracturing and its Impact on Renewable Energy Development”

**Advisor:** Michael Oristaglio

**Annie Bui**

“The Feasibility of Implementing Carbon Capture and Storage at Yale”

**Advisor:** Michael Oristaglio

**Khalid Cannon**

“Reviewing Crude Oil Extraction Methods and Investigating Innovative Improvements”

**Advisor:** Jay Ague

**Adrienne Gau**

“Structure and Evolution of the Unique Pseudosuchian Auricular Region from the Late Triassic to the Present”

**Advisor:** Bhart-Anjan Bhullar

**Lily Hahn**

“Impact of Cloud Phase Composition on the Climate Response to Obliquity Forcing”

**Advisor:** Trude Storelvmo

**John McNamara**

“A Fluid Dynamics Approach to Planetesimal Formation”

**Advisor:** David Bercovici

## STUDENT NEWS

**Torren Peebles**

“Development of Hubbert’s Peak Oil Theory and Analysis of its Continued Validity for U.S. Crude Oil Production”

**Advisor:** Jay Ague

**Adam Sokol**

“Aerosols, Ice Supersaturation, and Cirrus Clouds in the Southern Hemisphere: Comparison of Aircraft Observations with Two Global Climate Models”

**Advisor:** Trude Storelvmo

**Jordan Vargas**

“Mars: A Primer on Modern Research and the Martian Past”

**Advisor:** Jun Korenaga

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**Ph.D. Degrees awarded in December 2015**
**Xu Chu**

“Metamorphic Phase Equilibria and Diffusion Kinetics, and Applications to the Taconic-Acadian Orogenic Belts in New England”

**Advisor:** Jay Ague

*Chu is an Assistant Professor at the University of Toronto.*

**Zhixue Du**

“Melting and Rheology of (Mg,Fe)O Ferropericlaase at High Pressures”

**Advisor:** Kanani Lee

*Zhixue is a postdoc in the Geophysical Lab at the Carnegie Institution of Washington.*

**Colton Lynner**

“Seismic Anisotropy from the Core-Mantle Boundary to the Surface”

**Advisor:** Maureen Long

*Colton is a postdoc at University of Arizona working with Susan Beck.*

**Victoria McCoy**

“The Formation of Concretions and their Role in Fossilization”

**Advisor:** Derek Briggs  
*Victoria is a Postdoctoral Researcher at the Steinmann Institute of Geology, Mineralogy and Paleontology, University of Bonn.*

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**Ph.D. Degrees awarded in May 2016**
**Chris Thissen**

“Deformation Processes in Orogenic Wedges: New Methods and Application to Northwestern Washington State”

**Advisor:** Mark Brandon

*Chris is a Senior Research Scientist at Boston Fusion in Boston MA.*

**Meng Tian**

“Compaction-Driven Fluid Flow During Metamorphism: Its Impacts on Carbon Dioxide Transfer, Thermal Advection, and Its Competition with Porous Convection”

**Advisor:** Jay Ague

*Meng is a Newton International Postdoctoral Fellow at Oxford University working with Rich Katz.*

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**Ph.D. Degrees awarded in December 2016**
**Matthew Davis**

“North American Megafaunal Functional Diversity During the Last 50,000 Years”

**Advisor:** Jacques Gauthier

*Matt is a Carlsberg Foundation Semper Ardens Postdoctoral Fellow in the Department of Bioscience at Aarhus University, Aarhus, Denmark.*

## STUDENT NEWS

**Daniel Field**

“Macroevolutionary Patterns in Total-Clade Avialae: The Complex Evolution of Avian Biogeography, and the Origin of Avian Flight”

**Advisor:** Jacques Gauthie

*Daniel is an Assistant Professor at the University of Bath.*

**Emma Locatelli**

“The Roles of Decay and Mineralization in Leaf Preservation: Implications for the Fossil Record”

**Advisor:** Derek Briggs

*Emma is an AAAS Science and Technology Fellow working in science policy, Washington DC.*

**Ivy Tan**

“On the Climatic Impact of Thermodynamic Phase Partitioning of Mixed-Phase Clouds”

**Advisor:** Trude Storelvmo

*Ivy is a Postdoctoral Fellow at NASA.*

**H. Patrick Young**

“The Contribution of Metasomatized Lithospheric Mantle to Arc Magmatism”

**Advisor:** Mark Brandon

*Patrick is an Data Scientist at Yale-New Haven Hospital, in New Haven CT.*

**Ph.D. Degrees awarded in May 2017****Jennifer Axler**

“New Indicators of Ultrahigh Temperature Metamorphism and their Petrogenetic Implications for the New England Appalachians”

**Advisor:** Jay Ague

*Jennifer is a Lecturer at Tufts University.*

**Elizabeth Christeleit**

Advisor: Mark Brandon

“Integrated Analysis of Geologic Data and Landscape Evolution, with Applications to the Patagonian Andes, Olympics Mountains, and Messinian Salinity Crisis”

*Elizabeth is a Developer at Sitka Technology Group.*

**Ph.D. Degrees awarded in December 2017****Ross Anderson**

“The Rise of Eukaryotes: Environmental Controls During the Neoproterozoic–Paleozoic Transition”

**Advisor:** Derek Briggs

*Ross is a Postdoctoral Research Fellow at All Souls College, University of Oxford.*

**Xiaojun Chen**

“New Perspectives on Earth’s Lateral Heterogeneities through Normal Modes”

**Advisor:** Jeffrey Park

*Xiaojun is a Quantitative Analyst at a financial firm in New York City.*

**Zhen Liu**

“Imaging Crustal and Mantle Seismic Interfaces Using Multi-Taper Receiver Functions”

**Advisor:** Jeffrey Park

**Srikanth Toppaladoddi**

“The Statistical Physics, Fluid Mechanics, and the Climatology of Arctic Sea Ice”

**Advisor:** John Wettlaufer

*Srikanth is a Postdoctoral Research Fellow at All Souls College, University of Oxford.*

## STUDENT NEWS

### Shuang Zhang

“Case Studies in Tracking and Modeling the Global Carbon Cycle”

**Advisor:** Pincelli Hull, Noah Planavsky, Jay Ague  
*Shuang is a Postdoctoral Associate in the Department of Geology & Geophysics at Yale University working with Noah Planavsky.*

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### Department of Geology & Geophysics Prize Recipients

#### Undergraduate Prizes

Hammer Prize for excellence in the oral presentation of the Senior Thesis.

#### 2016

Eva Hoffman  
Maya Midzik  
Jane Smyth

#### 2017

Juan Aragon  
Adam Sokol

Belknap Prize to a Senior for excellence in geological studies (awarded to senior with highest grade point average).

#### 2016

Maya Midzik  
Astrid Pacini

#### 2017

Lily Hahn

Samuel Lewis Penfield Prize for proficiency in mineralogy.

#### 2016

XinXin Xu

#### 2017

Peter Mahony

Pat Wilde Prize for excellence in marine geology and oceanography.

#### 2016

Paige Breen  
Jane Smyth

#### 2017

Adam Sokol

#### Graduate Prizes

The Phillip M. Orville Prize in recognition of outstanding research and scholarship in the Earth Sciences which is awarded to the most outstanding graduate student.

#### 2016

Xu Chu  
Daniel Field

#### 2017

Ross Anderson  
Srikanth Toppaladoddi

The William E. Ford Prize is given for excellence in mineralogical studies.

#### 2016

Jennifer Axler  
Anwar Mohiuddin

#### 2017

Kierstin Daviau

The Elias Loomis Prize for excellence in studies of physics of the Earth, usually manifested in outstanding effort on thesis research.

#### 2016

Azusa Takeishi

#### 2017

Yana Bebieva  
Christopher Kruse

## STUDENT NEWS

The Hammer prize is given to an outstanding geology graduate student(s).

### 2016

Devon Cole  
Zhen Liu  
Emma Locatelli

### 2017

Neala Creasy  
Elizabeth Clark  
Jie Deng

Karl K. Turekian Prize for excellence in studies of geochemistry.

### 2017

Elizabeth Christeleit  
Shuang Zhang

The Excellence in Teaching Prize. This award is given in recognition of the student's outstanding contribution to the teaching process at the Department of Geology and Geophysics.

### 2016

Jennifer Axler  
Ross Anderson

### 2017

Yana Bebieva

## COMMENCEMENT



**CLASS OF 2016:** Mark Brandon, Zhixue Du, Colton Lynner, Chris Thissen, Maureen Long.



**CLASS OF 2017:** H. Patrick Young, Jennifer Axler, Elizabeth Christeleit, Daniel Field.

## VISITORS

**Zhi-Gang Chen**, Researcher, College of Ocean and Earth Sciences, Xiamen University. Dr. Chen collaborated as a Laboratory Associate, from August 2016 thru September 2017, with Ruth Blake tracing the cycling of phosphorus in the environment (sea water) by the oxygen isotope composition of phosphate.

**Rene Garreaud** is a Professor at the Department of Geophysics, University of Chile in Santiago. Professor Garreaud was the Richard Foster Flint Visiting Professor in the Spring of 2016. He is a leading expert on climatology of South America. While at Yale, he collaborated with Ron Smith's group on mountain meteorology and with Mark Brandon's group on glacial erosion and water isotopes.

**Tangao Hu** is a Visiting Fellow, from 2017 thru 2018, working with Ron Smith on spatial-temporal evolution of urban LULC based high-resolution remote sensing and mapping and analysis of flood areas. Dr. Hu is an Associate Professor in the Institute of Remote Sensing and Earth Sciences at Hangzhou Normal University in China.

**Lei Jiang** is a Visiting Associate Professor, during 2017-2018, from the Institute of Geology and Geophysics at the Chinese Academy of Sciences, working with Noah Planavsky. Dr. Jiang Lei's research interests include sedimentology, geochemistry, and diagenesis of ancient carbonates and petroleum reservoirs. His central research theme has been trying to evaluate the impact of diagenesis on carbonate reservoir formation. While visiting Yale he is working with the Peabody Museum collection to acquire a set of well-preserved brachiopods across the Phanerozoic and generating novel isotope records from this sample set.

Professor **Bijaya Karki** was a Visiting Fellow in the fall of 2017, collaborating with Shun Karato on computational techniques to investigate transport properties of mantle materials under high pressure-temperature conditions. Dr. Karki is Professor and Chair of Computer Science and Engineering at Louisiana State University.

Professor **Charles Merguerian** was a Visiting Fellow in 2015, working with Jay Ague on geological samples from western Connecticut and eastern New York in an effort to learn more about ancient mountain building events in the region. Before retiring, Dr. Merguerian was a Professor of Geology at Hofstra University.

Dr. **Francesca Piccoli** was a Visiting Associate in Research in the Ague Lab (2016-17) working on carbon cycling in subduction zones. She is now a postdoc at the University of Bern, Switzerland.

Professor **Roy Plotnick** of the University of Illinois at Chicago served as an Edward P. Bass Distinguished Visiting Environmental Scholar in the Spring of 2017. He enjoyed conversations with Yale paleontologists as part of his research for a book designed to introduce lay readers to the methods, goals, and practitioners of paleontology and to explain the discipline as a scientific enterprise. He also investigated fossils from the famous Mazon Creek deposits (~300 million years old) which include soft-bodied relatives of modern anemones and jelly fish and are well represented in the collections of the Yale Peabody Museum.



## VISITORS

Professor **Maureen Raymo**, from the Lamont-Doherty Earth Observatory at Columbia University, was our Richard Foster Flint Lecturer in November 2017. Professor Raymo gave three lectures: *Tectonic Forcing of Climate and Some Mysteries of the Carbon Cycle*; *Paleoclimate, CO<sub>2</sub>, and Sea Level: Past is Prologue*; and *Orbital Forcing of Pleistocene Climate: Puzzles to Ponder*.

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**Andrew Shao**, was a Laboratory Associate in 2017, collaborating with Mary-Louise Timmermans' research group developing and validating coupled climate models including representation of Arctic sea-ice. Dr. Shao is a postdoc at Princeton University.

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**Jun Shen** is a Visiting Fellow, from 2016 thru 2018, working with Noah Planavsky on reconstruction of the oceanic environmental changes during the Permian-Triassic, Ordovician-Silurian and Guadalupian-Lopingian transitions, based on non-conventional stable isotopes. Dr. Shen is a Lecturer in the State Key Laboratory of Geological Processes and Mineral Resources at the China University of Geosciences.

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**John Slack** was a Visiting Fellow in 2016, collaborating with Noah Planavsky in geological research on black shales and black shale-hosted mineral deposits, using samples in his field collections from Maine, Arizona, Alaska, and Montana. The research included microscopic and SEM imaging of minerals and textures. Before his retirement, Dr. Slack was employed by the US Geological Survey in both California and Virginia.

Professor **Grae Worster** was the Edward Bass Distinguished Environmental Fellow for the 2016-2017 academic year. He collaborated with John Wettlaufer on colloidal suspensions and poroelastic media, which surround us in the natural environment and have broad implications for a wide range of phenomena including frost heave, plant respiration, and the physical behavior of water-saturated soils. Professor Worster is at the Department of Applied Mathematics and Theoretical Physics at Cambridge University, and is a Fellow of Trinity College, Cambridge.

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**Chi Zhang** was a Lab Associate in 2017, collaborating with Ruth Blake on the use of two model organophosphorus pesticides (glyphosate, phosphonoacetic acid) to investigate the oxygen isotope signatures of biodegradation pathways. Dr. Zhang is a lab technician in the department of Environmental Engineering, at the University of Science and Technology in Beijing.

# JAPAN FIELD TRIP 2017



Seeing meter-long tourmaline crystals and other mineralogical delights, Ishikawa.

In June 2017, a group of 12 G&G graduate students and faculty visited the geologic highlights of Japan, following up on the Spring 2017 “Regional Perspectives on Global Geoscience” seminar class. The trip was planned by G&G students Duncan Keller, Katelyn Gray, and Yoshi Miyazaki, and the faculty leaders for the trip were Maureen Long and Noah Planavsky. Our two-week adventure ranged across the islands of Honshu, Awaji, and Shikoku and covered a huge range of geologic, geophysical, oceanographic, and climatological features. Highlights included visits to several geologic and fossil museums, a day exploring the Sendai Plain to see features from the 2011 great earthquake and tsunami, a stop to see a Ryoke Belt pegmatite that featured meter-long tourmaline crystals, a view of a spectacular pyroclastic flow deposit on the Sea of Japan, a

visit to the youngest exposed granodiorite pluton on Earth, a stop to see an exposure of the Median Tectonic Line, an exploration of the famous Kiso River bedded cherts, a museum stop that featured a preserved 5 meter fault offset from the 1891 Nobi earthquake, a hike up Mount Ibuki, which has some of the heaviest orographic precipitation on Earth, a boat trip to see the Naruto Whirlpools up close, a hike to see blueschists and eclogites of the Sanbagawa Belt, and a hike to Hoei Crater on Mount Fuji. We had a day off for sightseeing in Kyoto and even felt an earthquake (well, some of us did)—a shallow magnitude 5.2 in Nagano Prefecture.



Neala Creasy searching for the Takadani Granodiorite near Mount Yake.



Yoshi Miyazaki and Sarah Arveson finding Devonian fossils, Takayama.



Mount Ibuki, Maureen Long.

## CANADA FIELD TRIP 2017

Yale G&G faculty member Noah Planavsky and Paul Hoffman (emeritus faculty Harvard University) lead a group of 10 Yale students to see an exceptional carbonate succession exposed along the shores of the Great Slave Lake in Northwest Territories, Canada. The eastern reaches of the Great Slave lake are home to the anomalously well-preserved, beautifully exposed, 420 m thick, Paleoproterozoic (1.9 billion year old) Pethei Group. The succession was deposited on the south-eastern Slave Craton margin in a wedge-shaped foreland basin during northward subduction. Collision of the Slave and Rae Cratons compressed the sequence into a series of thrust sheets.

The Pethei Group is unique in preserving a complete platform to deeper basinal facies transect dominated by carbonates that formed at the seafloor (instead of in the surface oceans as is typically the case). The Pethei provides a unique opportunity to walk from a paleo-shoreline to the



The 'Pethei group' in front of air dried fish on the fishing boat.



Martha Longely (G&G 2018) holding an example of a deep water stromatolite.



The 'Pethei group' standing on top of massive branching microbial mediated carbonates—stromatolites.

kilometer deep deposits in an almost 2 billion year old basin. The Pethei Group has an impressive array of abiogenic and microbially mediated benthic carbonates—but is dominated by stromatolites and abiogenic seafloor cements. This distribution of volumetrically important in situ carbonate precipitation across a platform and into deeper waters is unusual compared to Phanerozoic platforms and provides a means to measure in situ seawater conditions on a broad range of paleo-water depths.

The students spent a little under three weeks logging several kilometres of sections and working out the structural relationships in Pethei Group rocks while traversing along the East Arm of the Great Slave Lake in an old fishing boat. Besides becoming experts in carbonate sedimentology most of the students also picked up skills in prepping and cooking fish—given that the captain of the boat was able to get a fresh fish haul most days.

The students were also able to examine iron formations and seafloor (pillow) basalts. For some of the students this was their first camping experience and for most of the students the first time they saw bears, mink, moose, and faint sunlight at midnight.

This is one of several trips made possible by a generous donation of Joe Greenberg '83 that is helping us ensure that students are learning about the geology the best way possible—through field geology!

## DANA AND CLARKE'S EXPLORATION OF THE ILLAWARRA DISTRICT

***J.D. DANA and W.B. CLARKE and their pioneering geological exploration of the Illawarra District, New South Wales, in January 1840***

by Neil Williams, G' 76

Since retiring as CEO of Geoscience Australia in 2010 and accepting the position of Honorary Professorial Fellow at the University of Wollongong I have taken the opportunity to learn more about the historically important geological expedition that Yale's James D. Dana and the pioneer Australian geologist, the Rev. William Clarke, undertook in January 1840. Together the two geologists examined the geology of the area surrounding Wollongong to the south of Sydney known as the Illawarra District.

Dana and Clarke's geological expedition interests me not only because I'm a member of the Dana Club, but also because as CEO of Geoscience Australia I was the Australian Chief Government Geologist, a role first fulfilled in a casual capacity by the Rev. Clarke in Colonial New South Wales. Dana served with distinction as the geologist on the famous U.S. Exploring Expedition that, between 1838 and 1842, explored the Pacific Ocean and adjacent land masses and islands, as well as part of the Antarctic coast. The Expedition was led by the United States Navy Lieutenant Charles Wilkes, and today the expedition is commonly referred to as the Wilkes Expedition. After exploring the west coast of South America and many of the Pacific Islands, the Expedition reached Sydney, Australia, then with a population of ~25,000, on November 29, 1839. Here Wilkes oversaw the repair and re-supplying of the fleet

of ships under his command ahead of the most dangerous stage of the Expedition – the charting of part of the Antarctic coast. Wilkes chose not to include the Expedition's civilian scientists (including Dana) on the journey to and from the Antarctic and ordered them to go ashore in Sydney and do whatever natural history science they could for two months. They were told to then sail to New Zealand where they were to re-join the expeditionary fleet after it had left the dangerous Southern Ocean.

As fate would have it, the Revered Clarke had arrived in Sydney from England 6 months before Dana set foot in Australia.<sup>1</sup> Clarke had studied at Cambridge University where he took a course in geology given by one of the UK's geological pioneers, the Rev. Adam Sedgwick. Clarke, like Sedgwick, chose the church as a career and was successful in his application to become the Chaplain of the fledgling Colony of New South Wales. His first appointments in New South Wales were to be the headmaster of the King's School in Parramatta, some 12 miles inland from Sydney, and minister to a number of rural congregations in settlements to the north of Parramatta. Fulfilling these two roles involved a lot of horse-back travel for Clarke and his passion for rocks soon found him exploring the local geology as he went about his pastoral duties. As a prominent clergyman in the Sydney district Clarke was introduced to the Chaplain on the Wilkes Expedition, the Rev. Elliot, soon after the expeditionary fleet arrived in Sydney<sup>2</sup>. It is assumed that their association led to Clarke meeting Dana in Sydney on December 18, 1839. By this time Dana had already spent



**Figure 1.** Aerial view, looking south, of Wollongong Harbour and Flagstaff Hill with its prominent lighthouse. Dana and Clarke spent January 3, 1840 studying the geology on the cliffs and wave platforms around the harbour and hill. (Photo provided courtesy of the University of Wollongong)

## DANA AND CLARKE'S EXPLORATION OF THE ILLAWARRA DISTRICT

two weeks exploring the geology of the Hunter River valley some 80 miles to the north of Sydney, including the Newcastle coal mines near the mouth of the Hunter River.

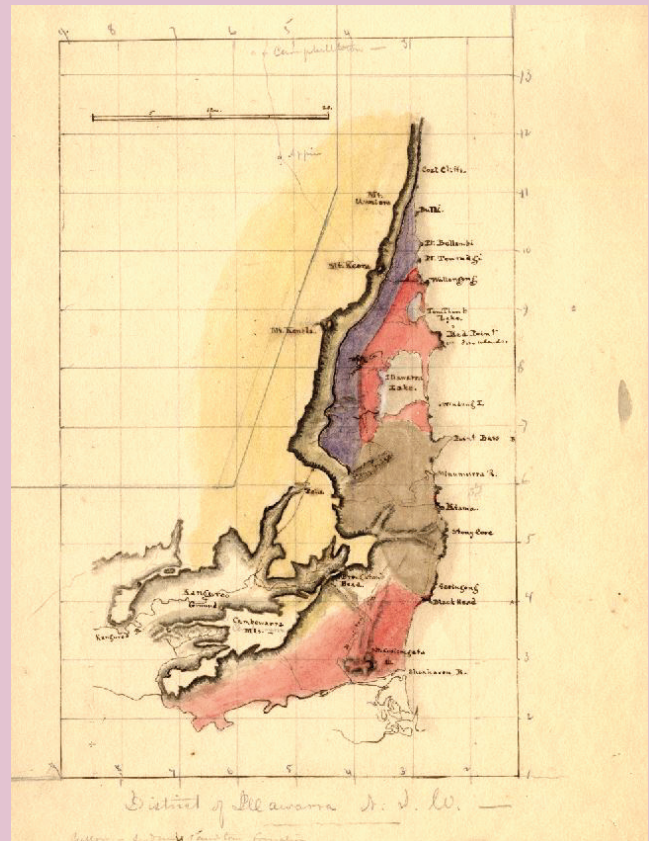
Dana and Clarke next met some 42 miles south of Sydney in coastal Wollongong on the evening of January 2, 1840. They both stayed at a hotel that once stood near Wollongong Harbour and the adjacent Flagstaff Hill (*Figure 1*). The following day the pair explored the sandstone outcrops along the cliffs and wave platforms surrounding Flagstaff Hill and Wollongong Harbour. Dana collected many fossils and other samples that day and his descriptions of these can be found in his official Wilkes Expedition geology report<sup>2, 3</sup>.

On January 6, 1840, Dana and Clarke and a local guide left Wollongong on horseback and spent 5 days exploring the geology of the region to the south and west of Wollongong. The explorers returned to Wollongong on January 9 and the next day Clarke set off for home while Dana remained in Wollongong for another week, during which time he is thought to have studied the geology of the area north of the settlement, including the coal seams that outcropped in the Bulli region. Dana then traveled to Parramatta to re-join Clarke and they spent their last day together (January 17, 1840) examining a small nearby basalt quarry at Prospect that was developed to support the expanding road construction work in and around Sydney. Before leaving Australia for New Zealand to re-join Wilke's expeditionary fleet, Dana returned to the Hunter Valley to further his studies there.

The many discoveries Clarke and Dana made during their time together are described in the New South Wales chapter of Dana's official Wilkes Expedition geology report<sup>3</sup>. The chapter includes a geological map of the region Dana and Clarke explored. Importantly, the chapter is the first scientifically comprehensive geological report ever published on Australia's geology.

Most of the information researchers in Australia have used to document Dana and Clarke's pioneering work in the Illawarra comes from Clarke's personal diaries, and I wondered if more could be gleaned from Dana's papers, particularly those housed at Yale. Brian and Cathy

Skinner agreed to investigate on my behalf, and while they did not find Dana's field notes of his time in New South Wales during their search in the Yale Library, what they did find were a number of pencil drawings that Dana made during his time with Clarke, many of which were later reproduced in Dana's Wilkes Expedition report and/or in the geological texts he later published. One of the most significant finds Brian and Cathy made was a pre-publication draft of Dana's geological map of the Illawarra that was presumably drawn in early 1840, making it one of the oldest known Australian geological maps (*Figure 2*).



**Figure 2.** Pre-publication version of Dana's geological map of the Illawarra. Editorial changes noted in pencil on this map are included in the published version of the map<sup>3</sup>. Yellow—Sydney Sandstone (now the Triassic Hawkesbury Sandstone); Brown—basalt (now the Late Permian Gerringong volcanic facies); Red—Wollongong Sandstone (now the Late Permian Broughton Formation); Purple—Coal formation (now the Late Permian Illawarra Coal Measures). The dotted line shows the routes taken by Dana and Clarke.

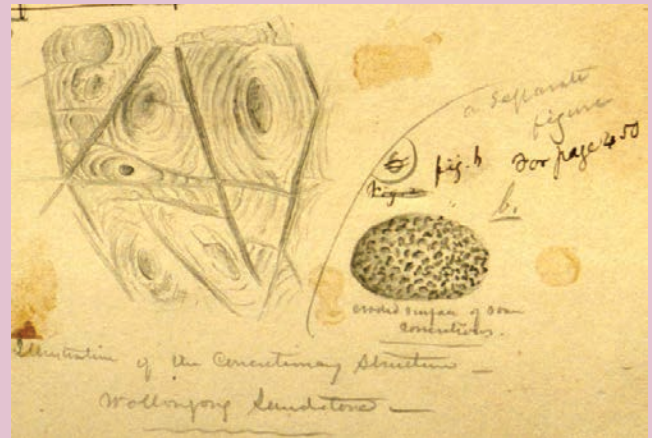
## DANA AND CLARKE'S EXPLORATION OF THE ILLAWARRA DISTRICT

The oldest known map is thought to be another one of the Illawarra that was drawn by Alexander Berry, an ex-naval surgeon who was a keen amateur geologist<sup>2,4</sup> and an early settler in the southern Illawarra near the town of Berry that is named in his honor. Another geological map of the Illawarra, and accompanying report, was published in 1845 by the Polish explorer P.E. de Strzelecki<sup>5</sup>. It predates the published version of Dana's map by 4 years. However, the Dana and Strzelecki maps appear to have been originally drawn within a few months of each other in 1840 and we will probably never be able to determine which was produced first. What is clear from this history is that the scenic and geologically diverse Illawarra district is the cradle of Australian geological studies and that Dana laid an impressive and scientifically rigorous foundation for the elucidation of Australia's geological evolution that Clarke built on as he continued to map and publish on the geology of south-eastern Australia.

The friendship that grew between Dana and Clarke as they explored the Illawarra together continued for the rest of their lives, and in a letter from Dana at Yale to Clarke, written on July 8, 1872, he says:

*"The few weeks of intercourse which I had with you in Australia were among the happiest days of my life, and I shall never forget your kindness & the scenes we enjoyed together"*<sup>6</sup>.

I personally owe much to Dana and Clarke having completed my formal geological training in the Yale department that Dana helped make famous, and being able to build on Clarke's pioneering mapping of Australia's geology as the CEO of Geoscience Australia. I too am inspired by the Illawarra geology and scenes that Dana and Clarke enjoyed together and would like to close this brief summary of their time together with some "then and now" images of some of these scenes (*Figures 3, 4, 5, and 6*).



**Figure 3.** Dana's concentric structures, south side of Flagstaff Hill – then and now. Dana's drawing of these structures is reproduced as Fig. 1, p. 486 in Dana (1849)<sup>5</sup>, and Fig. 85, p. 99 in Dana (1867)<sup>7</sup>.

DANA AND CLARKE'S EXPLORATION OF THE ILLAWARRA DISTRICT



**Figure 4.** Cathedral Rocks, north of Kiama, NSW—then and now.



**Figure 5.** Basaltic headland north of Kiama, NSW – then and now. Sadly the spectacular basalt columns sketched by Dana were removed by later quarrying on this headland. However, the original skyline is still more or less today as it was in 1840. Dana’s drawing of this headland appears on p. 496 in Dana (1849)<sup>3</sup>, as Fig. 975, p. 703 in Dana (1867)<sup>7</sup>, and as Fig. 12, p. 22 in Dana (1878)<sup>8</sup>.

## DANA AND CLARKE'S EXPLORATION OF THE ILLAWARRA DISTRICT



**Figure 6.** Two views from the top of the Triassic Hawkesbury Sandstone escarpment near where it was scaled by Dana and Clarke on January 6, 1840. The co-ordinates of the site on Dana's geology map (Fig. 2) are 6.3 (vertical axis) and 4.7 (horizontal axis). The top photograph is taken looking southeast along the escarpment and the lower photograph is taken looking northeast toward Lake Illawarra and Wollongong.

### Acknowledgments

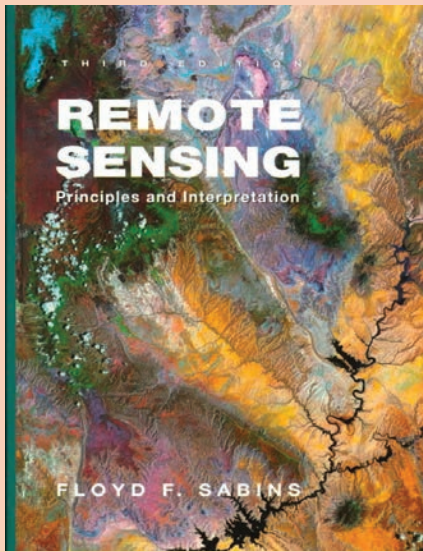
It is with pleasure that I thank the University of Wollongong's Paul Carr, Brian Jones, and Robert Middleton for sharing with me the fruits of their research into Dana and Clarke's work in the Illawarra district. I would also like to pay particular thanks to Paul Carr for guiding me around the various geological exposures which Dana sketched and reproduced in several of his publications. Thanks also go to Brian and Cathy Skinner for uncovering many of Dana's original Illawarra drawings and, in particular, the pre-publication version of his historic geological map of the Illawarra District.

### References

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4. Berry, A., 1825, On the geology of part of the coast of New South Wales. Read 1822 before the Philosophical Society of New South Wales (pp.231-254), in Barron Field (editor), *Geographical Memoirs on New South Wales*, John Murray, London, 1825, 504p.
5. Strzelecki, P.E. de., 1845, *Physical description of New South Wales and Van Diemen's Land: accompanied by a geological map, sections, and diagrams and figures of the organic remains*, Longman, Brown, Green and Longmans, London, 1845, 462p. [Reprinted 1968].
6. Moyal, A., 2003, *The Web of Science, The Scientific Correspondence of the Rev. W.B. Clarke, Australia's Pioneer Geologist*. 2 Vols. Australian Scholarly Publishing: Melbourne.
7. Dana, J.D., 1867, *Manual of geology, treating of the principles of the science with special references to American geological history*, Theodore Biss & Co., Philadelphia.



## ALUMNI NEWS



**Floyd Sabins G '55** (ffsabins@roadrunner.com): "I am writing and revising the 4th edition of my textbook *Remote Sensing—Principles and Interpretation* for my publisher Westland Press. My goal is to present the many advances in technology and applications that have occurred since the 3rd edition. The schedule is to complete the manuscript by the end of 2017 and for the book to be published in 2018."



George Devries Klein

**George Devries Klein G '60** (gdkgeo@earthlink.net) retired to Guam three years ago fully expecting to watch the sea

turtles, coconut crabs, and conches wiz by him sitting on the beach or snorkeling in a tropical lagoon. Instead, a local hydrogeologist got Klein interested in the issue of climate change. After a lot of reading and discussions with local experts, Klein was invited to present a talk at the 2016 University of Guam Island Sustainability Conference on "Some Geological Aspects Of Long- And Short-Term Climate Change." That led to two more invitations to make presentations, one at the Western Pacific Water and Environmental Research Institute, and the other at the University of Guam Marine Sciences Laboratory. The second pair of talks were longer and included a section on policy implications. A paper on the science part was published in AAPG's online journal, Search and Discovery ([http://www.searchanddiscovery.com/pdfz/documents/2016/70217klein/ndx\\_klein.pdf.html](http://www.searchanddiscovery.com/pdfz/documents/2016/70217klein/ndx_klein.pdf.html)). "Didn't think at age 83, I would still be publishing papers and giving talks."

**John P. de Neufville '61** (jpdeneufville@yahoo.com): "I am saddened to hear of the passing of Professor Syd Clark. I have some clear memories of Syd from the early 60's just before he was recruited by Yale. I was Y '61, a geology major who became a "Scholar of the House" senior year, allowing complete focus on my NSF-supported petrology project under Prof. Matt Walton and

in collaboration with then grad student Bob Tilling, based on field work near Copiapo, Chile in the contact metasomatic rocks at the edge of the Andean batholith. Miraculously I discovered a recently translated condensed monograph by Russian petrologist D. S. Korzhinsky at the Yale Co-op, which provided a much needed basis for understanding how a bed of limestone could be converted to monomineralic scapolite or adjacent andradite garnet. In any case the outcome of that work was a year-long appointment as a pre-doctoral fellow at the Geophysical Laboratory. Syd Clark took on the role of friend, mentor and collaborator for that year, sharing the mentoring role with Frank Schairer."

"I worked closely with Frank making silicate glasses on the join Diopside - Ca Tschermacks "molecule":  $\text{CaMgSi}_2\text{O}_6$  -  $\text{CaAl}_2\text{SiO}_6$ . We then ran the phase diagrams at 1 atm and 20 kbar, the former in Frank's home-made Pt-wound furnaces, the latter in Syd's solid pressure medium (talc) micro reactor. Collaborating with then Geophysical Lab postdoc (and now retired Harvard geology prof) Charlie Burnham, we refined the lattice parameters of the resulting sub-solidus high pressure phases and discovered a continuous single phase field with the diopside structure all the way to  $\text{CaAl}_2\text{SiO}_6$ . Subsequently this latter phase was discovered in a meteorite, thus qualifying it to be named a mineral: thus it's now kushiorite!"

## ALUMNI NEWS

*"Meanwhile Yale Geology was in search of new blood, recruiting from the Washington DC G&G community first Syd and, shortly thereafter, Brian and Cathy Skinner! It has provided me lifelong happy memories to have been part of that intense and welcoming DC geology community and culture so many years ago."*

*"The following fall I formally became a geology grad student at Harvard, Syd's alma mater. But after a summer internship at Bell Labs, my focus migrated to materials science, in part attracted by the opportunity to study glasses and other solids whose compositions are far away from naturally occurring atomic ratios! So now at a new company called Eutectix, we melt metal alloys in vacuum induction furnaces for applications ranging from rare Earth magnets, aerospace superalloys and alloys for solid-state hydrogen storage and compression."*

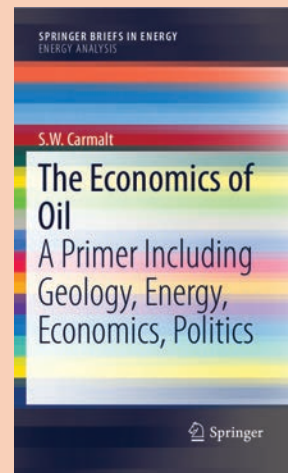
**Paul Enos G '65** (enos@ku.edu) writes: *"The cover of Yale Alumni Magazine (Mar/Apr 2017) reminded me that my advisor, John E. Sanders (1926-1999; '53 PhD) was caretaker of the official Yale bulldogs, Handsome Dan IX and X, during his time on the Yale faculty (1954-64).*



Sam Carmalt

**Sam Carmalt '66** (scarmalt@swconsult.ch): *"Since graduating, I've both practiced geology and done a variety of other interesting things such as designing databases and working for humanitarian organizations. I'm neither rich nor famous, but I've had lots of fun doing it all. Now I've circled back and am a full-time PhD student at the University of Geneva (Switzerland), again in geology, and writing a thesis to (finally, I hope) add the letters P h and D after my name."*

*"Throughout, I've known that I'm an academic at heart. The thesis explores the limits, both geologic and economic, of the Marcellus formation natural gas resource. Tangentially, Springer has just published my book The Economics of Oil. The bottom line of that is that there is plenty of reduced carbon available in the lithosphere to use for energy. But there are limits, both economic (the easy, cheap stuff is gone) and societal (primarily climate change), to*



*question whether the present global economy can survive if it continues to be fueled by fossil sunshine."*

*"Despite my poor French, I've survived in Geneva for 35 years now, and have managed to acquire Swiss citizenship. It's home. So be sure to let me know if you're in town, as I'm always ready for an end-of-day beer."*



Gary Feulner leading a field trip in the Hajar Mountains.

**Gary Feulner G '74** (grfeulner@gmail.com) has been semi-retired from the legal profession since

## ALUMNI NEWS

2010 but has remained in Dubai, United Arab Emirates, his home for more than 30 years, where he is the long-time chairman of the Dubai Natural History Group and continues to publish the results of many years of exploration and field research on local natural history topics. That includes, most recently: the flora of the Musandam peninsula; the flora of Wadi Wurayah National Park (a reserve in the Hajar Mountains encompassing two large watersheds entirely within ultrabasic bedrock); an introductory catalog of spiders of the UAE; the discovery of two butterflies new to the country; and studies of local mudskippers and a rare lizard. Most recently, he was solicited to put on his geologist's hat to consult for a local museum project.

Gary is also the founding sponsor of an English-medium primary school in the hill country of eastern Nepal, now in its fifth year, where he spends two months each year.

**Ken Rose '72** (kdrose@jhmi.edu): *"I retired in August 2016 after 36 years at Johns Hopkins University School of Medicine, where I taught human anatomy to medical, graduate, and undergraduate students. While on the faculty of the Department of Cell Biology & Anatomy, and subsequently the Center for Functional Anatomy and Evolution, I also taught mammalian evolution and diversity to graduate and undergraduate students, and supervised 14 PhD students."*

*"Following Yale, I received my PhD in geology from the Uni-*



Ken Rose

*versity of Michigan (1979), studying under fellow Yale graduate Philip Gingerich (G, '74). I went from Ann Arbor to Washington, D.C., as a postdoctoral fellow in paleobiology at the Smithsonian, working with curator Bob Emry. I joined the faculty of Johns Hopkins in 1980. Much of my research has centered on fossil mammals collected during our annual paleontological field project each summer in the early Eocene of the Bighorn Basin, Wyoming—a project I started with Tom Bown (formerly of the Yale Peabody Museum, then USGS) in 1979, which has trained scores of students and postdocs. The project has amassed more than 50,000 vertebrate fossils. Since 2001 I have also directed a multinational team (with Indian and Belgian colleagues) searching for early Eocene vertebrate fossils in open-pit lignite mines in western India. Among our discoveries are the oldest fossil primates from India, which show the most primitive skeletal features of any primates known from anywhere in the world; the sister-group*

*of perissodactyls (horses, tapirs, and rhinos), suggesting that the group originated in or near India; and the most diverse known early bat assemblage."*

*"In 2005 David Archibald and I edited The Rise of Placental Mammals: Origins and Relationships of the Major Extant Clades. A year later my book The Beginning of the Age of Mammals was published by Johns Hopkins University Press."*

*"I am now Professor Emeritus, continuing my research on early Cenozoic mammals, but also spending much more time on my recent marine mollusk collection, and bird-watching with my wife Jennie."*

**Michael Binder G '75** (coldwar@flash.net): *"I crossed the continent from New Haven to begin my brief (eight-year) geoscience career, starting with Atlantic Richfield Corporate Technology in Chatsworth, California, before transferring to the ARCO Oil & Gas Co. lab in Plano, Texas. Alas, in 1991 I*

## ALUMNI NEWS



Michael Binder

*joined several hundreds of other Dallas-area oil sector employees who did not survive the post-Desert Storm crash in oil prices. Instead of remaining in the oil business, I decided to embark on a totally new career, and began my underwhelming ten-year life as a military history consultant, working on environmental and cultural resources projects. I did get a couple of paid trips to Hawaii for field work, and traveled around the U.S. for another project. But the 'allure' of steady work prompted me to move to D.C., first for a job with the Department of Energy as a contractor document reviewer, and for the last eleven years as a federal employee with the Air Force Declassification Office, where I am currently a GS-14 Technical Advisor working out of the National Archives in College Park. Some people in the Department of the Air Force consider me the service's expert in nuclear weapons information, but I just say that I have expertise in that subject, being called on to review classified documents, brief civilian/military audiences from the Department of Defense*

*and the Intelligence Community, and make the occasional trip to the Pentagon."*

*"My wife, Sheila Etzkorn, retires this summer from her early childhood teaching career with Montgomery County Public Schools. As for me, I just got my Medicare card, but am having too much fun to consider retirement. In fact, I tell people I would do my job for free, and that is the truth."*



Jill Schneiderman, Siccar Point Scotland.

**Jill Schneiderman '81**

([schneiderman@vassar.edu](mailto:schneiderman@vassar.edu)):  
*"The high points of the last two years were: watching our son graduate from high school and our daughter thrive during a high school semester in Madrid as well as attending the Autumn 2015 celebration of the Skinners upon Brian's retirement."*

**Marcus Key G '88** ([key@dickinson.edu](mailto:key@dickinson.edu)):

*"The good news is that I am still teaching in the Department of Earth Sciences at Dickinson College as the Joseph Priestley Professor of Natural Philosophy. The bad news is that I am still department chair! I continue working on the evolution of epibiosis in the bryozoans. I am currently working on a project on Miocene crabs from Iran whose carapaces are being exploited by bryozoans as viable substrates. My team consists of paleontologists and geologists from France, Austria, Slovakia, and Iran. Danny Rye would be proud of my newest project testing the effect on C and O stable isotope values of various pretreatment methods for removing organic matter from skeletal carbonate. On the home front, Maria and I only have the youngest two still at home. We have paid off the college loans of the two oldest and the middle child is graduating from college this May!"*



Marcus Key with his wife of 34 years, Maria.

## ALUMNI NEWS



Kira Jewett, far left with several of Ugandan friends as well as the other Professional Fellows, Uganda.

**Kira Jewett '94** (kirafiddle@gmail.com): *"I am currently Department Director and teaching biology and environmental science at the Paulo Freire Social Justice Charter School in Holyoke, MA. Our school is in its fourth year of existence and incorporates social justice into every aspect of education: student and family engagement, curriculum, discipline, and leadership to name a few areas. We serve primarily low-income students of color and most attend college during their senior year as part of a dual enrollment program. I also traveled recently to Uganda as part of a U.S. State Department Professional Fellowship on Tolerance and Conflict Resolution. In my spare time I am a mom of two, gardener and play Irish fiddle with a traditional Celtic band."*

**Michael Mann G '98** (mann@psu.edu) is Distinguished Professor of Atmospheric Science and Director of the Earth System Science Center at Penn State University. His research focuses on understanding climate variability and human-caused climate change. He was selected by Scientific American as one of the fifty leading visionaries in science and technology in 2002. He was organizing committee chair for the National Academy of Sciences Frontiers of Science in 2003 and contributed to the award of the 2007 Nobel Peace Prize with other IPCC lead authors. He was awarded the Hans Oeschger Medal of the European Geosciences Union in 2012 and the National Conservation Achievement Award of the National Wildlife Federation in 2013. He made Bloomberg News' list of fifty most influential people in 2013. In 2014, he received the Friend of the Planet award from the

National Center for Science Education. He is a Fellow of the American Geophysical Union, the American Meteorological Society, and the American Association for the Advancement of Science. He has authored more than 200 publications, and three books including *Dire Predictions: Understanding Climate Change*, *The Hockey Stick and the Climate Wars: Dispatches From the Front Lines*, and most recently, with *Washington Post* editorial cartoonist Tom Toles, *The Madhouse Effect: How Climate Change Denial Is Threatening Our Planet, Destroying Our Politics, and Driving Us Crazy*.



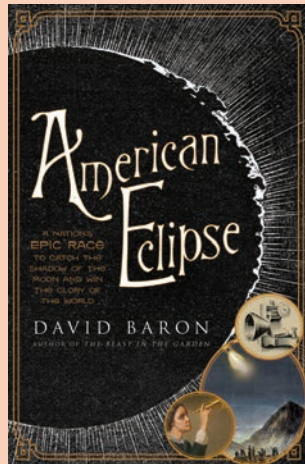
Michael Mann's visit to Sydney, Australia 2016.

## ALUMNI NEWS



David Baron

**David Baron '86** (davidhbaron@comcast.net): *"I was a G&G major as an undergrad and went on to become a science journalist for NPR. I have now turned to writing books, and my latest was published in 2017. American Eclipse tells the true story of a total solar eclipse that crossed the American West in 1878, luring many of the era's great scientists (including Thomas Edison) to the frontier and inspiring our nation's rise as a global scientific power. The book's release was timed to coincide with this past summer's total eclipse, on August 21, 2017 which will be the first in 99 years to cross the breadth of the continental United States. While my book is focused on astronomy, I should note that Yale's pioneering paleontologist O. C. Marsh makes a couple of cameo appearances. You can learn more at [www.american-eclipse.com](http://www.american-eclipse.com)."*

**Chelsea Willett '05**

(Chelsea.d.willett@gmail.com) is in her fourth year of graduate studies in the Department of Earth and Planetary Science at Berkeley, working with David Shuster. When she's not thinking about the influence of radiation damage in apatite on low-temperature thermochronology, she is running marathons and learning to rock climb in the beautiful Californian outdoors.

**Anthony Didlake '06** is an Assistant Professor in the Meteorology Department at Penn State University. While he was an undergraduate at Yale, Ron Smith served as his senior advisor. Anthony went on to receive his PhD from University of Washington, and then he was a postdoc at NASA.

**Yanping Li '09**, won the NCAR Outstanding Publication award in 2016 for her paper *Excitation of Rainfall over the Tropical Western Pacific* published in the *Journal of the Atmospheric Sciences*.



Yanping Li

Yanping is an Assistant Professor in the School of Environment and Sustainability and Global Institute for Water Security at the University of Saskatchewan.

**Eric Sperling, G '10** is currently an Assistant Professor at Stanford, was awarded a 2017 Sloan Research Fellowship.

## ALUMNI NEWS



**Chris Thissen, G '16, Karen Paczkowski G '12, Brad Foley G '14, Chao Liu, G '15 and Zhixue Du, G '15** at the "Carnegie Evening" in Washington DC. Chris, Brad, Chao and Zhixue were or are postdocs at the Carnegie Institution. Karen is doing a Congressional Fellowship with the American Association for the Advancement of Science. Brad is now an Assistant Professor at Penn State, and Chris is a Senior Research Scientist at Boston Fusion.

**Alison D. Nugent G '14** (anugent@hawaii.edu) finished her postdoc at NCAR in December 2016 and is now a tenure-track faculty member in the Department of Atmospheric Sciences at the University of Hawaii at Manoa, part of SOEST (School of Ocean and Earth Science and Technology). She is continuing to research orographic precipitation on tropical islands as well as cloud microphysical processes.



Alison Nugent in Portugal.

She is currently teaching an atmospheric instrumentation course and taking full advantage of her surroundings for teaching, research, and recreation.

**Tolulope Olugboji G' 14** (tolumorayo@gmail.com) has been selected as a Next Einstein Forum (NEF) Fellow due to strong scientific record and potential for leadership. The NEF Fellowship is a flagship program of the Next Einstein Forum, an initiative of the African Institute for Mathematical Sciences

(AIMS) in partnership with Robert Bosch Stiftung.

Tolu has also accepted an offer to be an assistant professor at the University of Rochester, in its Department of Earth and Environmental Sciences. He is currently a postdoctoral associate at the University of Maryland, where he has developed algorithms with Prof. Vedran Lekic for combining different types of earthquake-seismology data to map out the crust and lithosphere of North America. While at Yale, Tolu worked with Profs. Jeffrey Park and Shun-Ichiro Karato to elaborate and test the grain-boundary-sliding model for the seismic lithosphere-asthenosphere boundary.



Tolulope Olugboji

## ALUMNI NEWS



Matthew Davis

**Matthew Davis G' 16** won his second Digital Education Education Innovation Grant from the Rosenkranz Fund and the Online Education Committee. These grants support the creation of new and innovative education opportunities for the Yale community using digital and/or online platforms.



Caroline Eakin, Fitzroy Falls, New South Wales.

**Caroline Eakin G '15** (caroline.eakin@gmail.com): *"After a stint back in the UK as a postdoc I opted to switch up hemispheres and make a leap down under. In June 2016 I took up a faculty position at The Australian National University in the Research School of Earth Sciences. The university*

*is based in Canberra, nestled among various lakes and hills; it's known as the bush capital, located mid-way between Sydney and Melbourne. So far I've been enjoying geology field-trips along the coast with students and bush walks in the surrounding highlands. Over the next few years I'm very much looking forward to exploring more of my new continent, both above and below the surface. I'm already planning to get involved with seismic field experiments that will take me deep into the Australian outback. Hopefully my PhD training in the Andes and Amazon with Maureen Long will serve me well!"*

**Daniel Field G '16**

(danieljaredfield@gmail.com): *"I joined the Department of Biology and Biochemistry at the University of Bath in January 2017, following*



Dr. Field discusses research with close colleagues.

*a PhD in Jacques Gauthier's lab and a short postdoc with Anjan Bhullar, both in Yale G&G. Research in my lab is focused on understanding the evolutionary origin of biologically modern birds, and the impact of the Cretaceous-Paleogene mass extinction on vertebrate evolution. I'm enjoying life in southwest England, and am grateful to G&G for six great years!"*



Ivette Lopez

**Ivette Lopez '16** (Ivette.lopez@yale.edu) is currently working with the U.S. Fish and Wildlife Service working with local communities to connect them to our natural resources, green spaces, and more! Here is a link to a recently published article (first 2 paragraphs) describing what she has been up to: <http://sustainability.yale.edu/news/yale-alumna-addresses-barriers-latino-communities-face-environmental-field>.



## YALE CENTER FOR RESEARCH COMPUTING



## Center for Earth Observation Celebrates 25 years

Ellen Kan Feb 02, 2017

Staff Reporter, Yale Daily News

Courtesy of Larry Bonneau



For more than two decades, the Yale Center for Earth Observation has served as a nexus for University-wide research efforts in areas as varied as geology, epidemiology and anthropology. Now, as satellite-based remote sensing technology becomes more widespread and powerful, the YCEO is celebrating 25 years.

A research center within the Yale Institute of Biospheric Studies, the YCEO provides students and faculty with opportunities to incorporate remote sensing techniques into their research endeavors. The center, located in the School of Forestry & Environmental Studies Environmental Science Center building, was founded in 1992 by Ronald Smith, a professor in the Department of Geology and Geophysics. In establishing the YCEO, Smith said that he hoped to make satellite data more accessible for faculty and students interested in Earth science research, especially since only a few of his colleagues had experience with remote sensing technology.

Over the past quarter-century, the YCEO has continued to provide the campus with software, educational support and other tools to engage the rapidly expanding field of remote sensing.

“We were ‘riding a wave’ in a sense because new satellite sensors; faster, cheaper computers and new research problems came along very fast,” Smith said. “We had to race just to keep up. Not surprisingly, student interest grew too.”

Today, the YCEO draws students from Yale College and the University’s professional schools. According to YCEO Manager Larry Bonneau, while the majority of YCEO student researchers are affiliated with F&ES, the center also attracts undergraduate and graduate students from fields as diverse as history, architecture, public health and archaeology.

Unlike the remote sensing facilities used at other schools, the YCEO is not affiliated with a particular lab or department at Yale. F&ES professor Xuhui Lee, who recently took over as

## YALE CENTER FOR RESEARCH COMPUTING *continued*

the center's new director, said that this feature allows the YCEO to assist research efforts from all over the campus. He added that the center also focuses more on the application of remote sensing technology, rather than developing products themselves, as centers at other universities often do.

Recent advances in remote sensing are especially important today, Smith said, because this monitoring capability "comes at a time of rapid human-induced change in our planet." Over the last couple of decades, a big change in the field is that data produced by environmental satellites is now available to anybody in the world, Lee added.

"Because data are publicly available, we can monitor places we otherwise don't have access to," Lee said. "It removes legal and logistical restrictions, which is so important for environmental monitoring. If you analyze local data, it may be screened for [some] reason, but with remote sensing, it's unbiased and makes it difficult to hide problems. Everything is more open and more transparent."

According to Bonneau, one of the most worthwhile parts of managing the YCEO is seeing the impact made by students who were introduced to remote sensing at Yale. Many students have gone into careers that rely heavily on satellite imagery, while some have even established remote sensing centers at other universities, he added.

Karina Yager GRD '09, who became involved with the center while completing her Ph.D. in anthropology, said that the YCEO had a "major influence" on her academic interests, research and career. Now a professor at Stony Brook University, Yager said that she continues her remote sensing research today to monitor land cover and land use change in the Andes Mountains.

"In my opinion, I couldn't have asked for more," Yager said. "[The YCEO] was the perfect place for learning about remote sensing, connecting with others on current and interdisciplinary research and [having] access to an incredible lab and research support network."

In addition to hosting workshops to guide students through the basics of image analysis, the YCEO also offers a course every spring

semester—"Observing Earth from Space," co-taught by Lee and Bonneau. While it serves as a practical introduction to the theory and application of satellite remote sensing, the class also incorporates weekly lab exercises that challenge students to solve real-world problems in environmental science, Lee said.

Cameron Yick '17, a computer science major, said that he chose to take "Observing Earth from Space" because it offered a unique opportunity to work with data and software available only through University resources. He added that because he is interested in exploring data journalism and environmental nonprofit organizations after graduation, the class provides valuable exposure to the techniques available in the field.

"When you hear news today about the environment, so much of the data supporting the underlying claims are collected by satellite, whether it's carbon in the atmosphere or pollution in the water," Yick said. "I thought it would be cool to understand the studies that people don't usually read so that I can be a more informed person."

Looking forward to its next 25 years, the YCEO hopes to strengthen its connections with various departments on campus, Lee said. Smith added that he hopes the center's existing facilities can be supplemented with GIS activity and climate simulation tools, an expansion of the center's capabilities that could lift the University's position in environmental science.

According to Lee, the YCEO also looks forward to embracing a newer technology: drones. Although drones are limited in their range of coverage, they can provide on-demand image acquisition, leading to the creation of localized, detailed surveys that complement global coverage obtained from satellites, he said.

The Yale Center for Earth Observation was designated a NASA Center of Excellence in 1997.



**Alumni Please Note:**

**We would especially like to hear from you. Please send your news to [rebecca.pocock@yale.edu](mailto:rebecca.pocock@yale.edu).**

# GEOLOGY & GEOPHYSICS NEWS

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