



HOOSIER GEOLOGIC RECORD

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DEPARTMENT OF GEOLOGICAL SCIENCES

Chair: Jim Brophy

Co-Editors: Arndt Schimmelmann & Jim Brophy

Graphic Design: Ruth Droppo

<http://geology.indiana.edu/>



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Executive Dean: Larry D. Singell

Executive Director of Advancement: Travis Paulin

Director of Alumni Relations: Vanessa Cloe

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Cover image: modern Lemur skeleton, part of the Paleontology teaching collection in the Department of Geological Sciences.

Greetings from the Departmental Chair

Dear Alumni,

It has been two years since the last issue of the HGR was published. Since then I have replaced Lisa Pratt as Chair who, in turn, has moved on to be Associate Executive Dean of the College. As you read through these pages I hope that you get the same sense of pride and satisfaction in our achievements that I do. Our faculty is conducting far-flung research on eight of the nine continents. (It used to be nine for nine but David Bish has not returned to Antarctica during the past two years.) Most of this research is funded by grants from government agencies or corporations.

We remain committed to providing the finest undergraduate and graduate education possible. Our best undergraduate students go to the top graduate schools in the country. All of our graduate students are finding employment in the energy and environmental industries or in academia.

The new Atmospheric Sciences program is gaining momentum every day. The Geologic Field Station is still the premier program of its kind and is witnessing record enrollments in a new curriculum that has G429 as its rock-solid linchpin.

All-in-all, life is good for our faculty, staff and students. Who could ask for more?

Happy Reading.

Jim Brophy
Departmental Chair





critical
centers of
activity

1 Global Climate and Environment

Global climate and environment are two of the most rapidly expanding areas in geosciences. Research in these areas seeks to understand the character and dynamics of Earth's habitable zone, especially the complex interactions of its biosphere, hydrosphere, atmosphere, and geosphere coupled with human-induced perturbations of these natural systems. It embraces studies of Earth's climate and its connections operating on multiple spatial and temporal scales with the hydrologic and biogeochemical cycles that are influenced by pervasive surficial processes.

Knowledge of these systems, especially their drivers and sensitivities to change, is integral to informed use of energy, mineral, water, and land resources and the environmental consequences of human activities. These advances permit understanding of paleoclimates and ancient environments from key proxies preserved in the rock record that have been verified in the modern world. The critical zone that lies as the interface of the natural and anthropogenic worlds urgently needs improved understanding. Bridges between sub-disciplines of the geosciences that focus on problems such as the role of fluids in Earth systems and controls on the movement of dissolved and suspended materials can help. Societal emphasis on resources and climate is assured in the near future, which heightens the critical need for further development of our understanding of the dynamics of present-day Earth processes at the surface, augmented by an understanding of past environments, because these insights represent the key to our and Earth's future.

Geological Sciences at Indiana University possesses research expertise in these important domains. Research that incorporates observation, analyses, experiments, and modeling has achieved critical insights into these geological and biogeochemical pathways, from molecular processes and chemical reactions, to local- and regional-scale water and sediment budgets, and ultimately to global dynamics of atmospheric composition and oceanic temperature.

The department is poised to be a key player in IU's new Integrated Program in the Environment.

Image opposite: Earth's atmospheric layers. International Space Station astronauts captured this photo of Earth's atmospheric layers on July 31, 2011, revealing the troposphere (orange-red), stratosphere and above. Credit: ISS and NASA

atmospheric sciences

Chahn Kieu, Cody Kirkpatrick, Paul Staten

The Atmospheric Sciences Program (ASP) at Indiana University is a young unit under the umbrella of the Department of Geological Sciences. After transitioning from the Department of Geography and subsequent re-structuring in 2012, the ASP has been shifting more towards observational and modeling research group with specialization in both extreme weather events as well as related climate change. The departure of the two senior faculty members in 2015 and the arrival of two new faculty members Paul Staten, who specializes in the large-scale simulations, and Chanh Kieu, who specializes in studies of mesoscale dynamics and modeling, have moved the ASP into a new phase of growth with more focus on modeling research. Given the exceptional computational resource at IU, the ASP currently attempts to re-establish itself as a premier modeling research group with a potential identity in the future as a premier unit in modeling the Earth's system at Indiana University.

Embedded within the Department of Geological Science-IUB, the atmospheric group benefits from IU's superior computational research infrastructure to explore ambitious aspects of the atmosphere. The current ASP's faculty are pursuing a number of different research directions ranging from theoretical studies of tropical cyclone development, modeling atmospheric circulations at meso-scale and large-scale, to remote sensing of clouds.

Despite being a young component within the Department of Geological Sciences, the atmospheric group is currently expanding with multidisciplinary research areas that could benefit from paleoclimate research and global climate change studies being conducted by other members of the Geological Sciences faculty. The diverse, closely-knit group of researchers gives us collective expertise in climate-atmosphere-surface interactions with the solid Earth. With the exceptional high-performance computing (HPC) infrastructure at IU with a supercomputer Big Red II that possess peak performance of one thousand trillion floating-point operations per second (1 petaFLOPS) along with a high-performance archiving and storage system of a raw tape capacity ~ 5.7PB, taking full advantage of the HPC system for modeling research and education at IU is among the highest priorities of the ASP. The fact that high-performance computing is essentially unlimited at Indiana University offers us the competitive possibility to focus more on needs and opportunities in frontier understanding of the Earth climate system.

Image: Storm cell over the southern Appalachian mountains. This storm cell photo was taken from NASA's high-altitude ER-2 aircraft on May 23, 2014, during a study aimed at gaining a better understanding of precipitation over mountainous terrain. Credit: NASA.

Paul Staten

Assistant Professor | Atmospheric Sciences

Paul is interested in understanding how the Earth's atmosphere works. Specifically, his research focuses on changes in the global circulation in the lowest 20 kilometers of the atmosphere, and the accompanying changes in cloudiness. He enjoys using both climate models and satellite data in his work. Some current and past research projects include:

Long term change from multiple satellite systems

Along with his Ph.D. student, Xuechang (Shay) Liu, Paul has been studying trends and variability in cloud types and properties, in collaboration with Brian Kahn and Mathias Schreier at JPL (Jet Propulsion Laboratory). Global cloud changes are small and highly uncertain, but the satellite record is approaching 40 years in length. If used carefully, it may be possible to use new and veteran satellites to discern the fingerprints of climate variability and change.

Modeling the mechanisms of major circulation shifts

With Thomas Reichler at the University of Utah, Jian Lu at Pacific Northwest National Laboratory, and Erol Palipane at George Mason University, Paul has been studying the widening tropics and the shifting jet streams. Observations and models agree that the tropics are widening, but the reasons behind this shift are unclear. Through repeated experiments with Global Climate models, they have made progress at discriminating some of the mechanisms behind this widening.

Of winds and warmth

Here at IU, Robert Conrick, Nathan Curtis, Cody Kirkpatrick and Paul have been looking at the relationship between lower level temperature gradients and winds in cold fronts over the NE United States, simulated by the Weather Research Forecast Model. On such scales, first guesses based on classical cyclone models only go so far.



Paul's research website: <http://pages.iu.edu/~p-wstaten/>

Chanh Kieu

Assistant Professor | Atmospheric Sciences

Atmospheric dynamics (mesoscale), nonlinear dynamical systems, tropical cyclones, ensemble data assimilation, numerical weather prediction.

Research pursued by Chanh Kieu ranges from the cloud-resolving simulations of the tropical cyclone system to theoretical analyses of dynamical behaviors behind the genesis and the rapid intensification of tropical cyclones, which could potentially lead to new understanding in the impacts of the lower stratosphere on the structure and climatology of extreme hurricanes.

Along with theoretical studies of hurricane predictability, Chanh Kieu's research group is also leading an effort to understand the structure of the most extreme hurricanes.

Using IU's Big Red II supercomputer, Kieu's group has conducted numerous simulations of the strongest hurricanes to explore their peculiar structure.



Cody Kirkpatrick

Lecturer | Atmospheric Science

From downscale regional perspective, Cody Kirkpatrick uses the advanced Weather Research and Forecasting (WRF) model to simulate convective storms and systems, and link these simulations to observations and predictability of high-impact and hazardous weather events.



Image top: Earth system modeling plays an increasingly important role in understanding past and projected evolution of the Earth, particularly the intricate interactions among various Earth spheres. Foreseeing the importance of modeling in such a frontier of scientific exploration and life applications, Indiana University-Bloomington has invested in one of the largest parallel computing infrastructures for modeling research with supercomputer Big Red II.

Image bottom: Chanh Kieu (on the left) with members of his research group, Faith Groff, Allie Downs, Madison Ferrara, Zach Moon, and Will Adam.



biogeochemistry

Simon Brassell, Erika Elswick, Lisa Pratt, Ed Ripley, Peter Sauer,
Juergen Schieber, Arndt Schimmelmann, Laura Wasylenki, Chen Zhu

Laura Wasylenki

*Associate Professor of Geological Sciences
Biogeochemistry of Metals*

Sesame Lab
(stable isotope geochemistry of metals)

Most of Sesame Lab's projects pertain to reconstruction of trace metal chemistry of the oceans throughout all of Earth history and how changes in trace metal availability have shaped the evolution of biological use of trace metals.

This year, however, Laura has landed her first major NSF grant for an environmental application of trace metal stable isotopes (Environmental Chemical Sciences Program).

Production, refinement, and industrial use of tungsten are increasing rapidly, especially for lead-free munitions, but recently this element has been implicated in leukemia clusters in several western states. Tungsten can also cause ecotoxicological harm to microbes, animals, and plants. Little is yet known about environmental transport and fate of this metal; future predictive models of tungsten's migration will require knowledge of how exactly the metal adsorbs to mineral particles in soils and aquifers and how stable the adsorbed molecules are.

Traditional methods for studying adsorption reactions do not work at field-relevant conditions for this element, so her group plans to use stable isotope geochemistry of tungsten to probe those reaction mechanisms. A promising pilot project was completed by Gus Schaefer (MS '16), including preliminary analyses of soils from Crane Naval Service Warfare Center that were contaminated by munitions testing. Further work will be conducted at the Stanford Synchrotron Radiation Lightsource, while Laura is there on sabbatical.



Laura's research website: <http://geology.indiana.edu/wasylenki/sesamelab/index.html>

Image: Mud-built homes in northern Vietnam tend to emit high concentrations of radioactive radon gas. Arndt Schimmelmann's research site.

Arndt Schimmelmann

Senior Scientist | Organic Geochemistry and Chemical Oceanography

Methane is a potent atmospheric greenhouse gas that originates mostly from agriculture and fossil fuel industry.

Arndt Schimmelmann's research group discovered that abundant subterranean porosity in Vietnamese karst mountains filters out atmospheric methane. Tropical karst represents a giant spongy biogeoreactor where 'methane-eating' microbes are thriving in humid and warm conditions. The same principle could be used in biogeo-engineered reactors where microbes selectively remove methane from industrial and agricultural point sources.

While working in rural northern Vietnam where deforestation and poverty often necessitate human habitation in 'mud houses,' Schimmelmann's team noticed that regional soil in walls and floors contains enough natural radioactivity to emit hazardous radon levels far exceeding EPA safety thresholds. Especially the radon-220 isotope with a short half-life of ca. 55 seconds poses a health hazard that cannot be mitigated by venting of room air. Radon-220 diffuses out of porous mud into room air from where inhalation and a chain of radioactive decay reactions of radon and its metallic daughter products can induce lung cancer.

This unexpected finding in mud houses is unique to living conditions in developing countries. We engage in collaborative research with Vietnamese scientists to develop affordable remediation strategies and improve public health, for example by sealing porous surfaces in mud houses with a gas-impermeable coating. Ongoing experiments in an authentic Vietnamese mud house explore the utility of inexpensive and non-toxic sodium silicate solution that soaks into the mud surface, reacts with carbon dioxide from room air, and precipitates a clear seal of silica gel. A second coat with added pigmentation of locally available limestone dust can greatly beautify the interior of a mud house and enhance acceptance of remediation measures.



Arndt's research website: <http://geology.indiana.edu/schimmelmann>

Image: Elementary school for minority ethnic students in Hà Giang province in Vietnam. Minh Schimmelmann (pictured center) distributed winter clothing and school supplies.

Outreach activities in mountain villages established personal contacts and reliable logistic support for our research.

As a third collaborative research project with Vietnam National University in Hanoi, the laminated sediment from a volcanic maar lake in central Vietnam near Pleiku is being explored as a geological archive for prehistorical monsoon strength and typhoon occurrence. The record of distinct flood layers of the past can be radiocarbon-dated and may offer a reliable statistical basis to judge the effects of climate change on modern precipitation patterns in central Vietnam.



surface processes & environmental sciences

Doug Edmonds, Laura Wasylenki, Brian Yanites, Chen Zhu

Brian Yanites

Assistant Professor of Geological Sciences | Geomorphology

The Geomorphology and Landscape Evolution group studies how climate, tectonics, and rock type influence the processes and landforms that shape the Earth's surface. Specific problems include the controls of rock strength and sediment transport on bedrock river morphology, the interaction of climate and topography during active mountain building, and the influence of landslides on river dynamics in seismically active regions. These problems are approached by integrating field and geochemical data with state-of-the-art numerical models. The implications of this work are broad, ranging from hazard mitigation and river management to the geologic evolution of a mountain system.



Brian's research website: <http://geology.indiana.edu/yanites/geomorphology>

Chen Zhu

*Professor of Geological Sciences | Adjunct Professor, Environmental Science
Adjunct Professor, Environmental Health*

Chen is pleased with the recent successes of his students and the publications of their papers. In June, Guanru Zhang successfully defended his dissertation on modeling the CO₂ plume development at Sleipner in Norway, the world's first industrial scale carbon storage project to abate the global warming trend. His work was published in the *International Journal of Greenhouse Gas Technology, Energy & Fuels*, and the *International Journal of Energy Research*. In July, Yilun Zhang successfully passed the qualifying exam. After years of development, a new strain of research employing the use of nonconventional isotopes to study reaction kinetics has come to fruition. Chemists have known since 1884, via J. H. van't Hoff that, at equilibrium, reactions do not stop; the rates of forward and backward reactions are equal. But how than can one measure rates at equilibrium when concentrations are constant? Post-doc Zhaoyun Liu spiked a rare Si isotope into solutions at equilibrium with quartz and observed isotope changes with time. That allowed one to calculate the quartz reaction rates at equilibrium. These results, published in the new journal *Geochemical Perspective Letters*, have far reaching significance because it tested the range of applicability of the principle of detailed balance, something often assumed but not verified in many models for society's mega-environmental projects. This innovative experimental method shows great promises to use a number of other isotopes Ca, Mg, Fe in kinetics studies of carbonates, sulfides, and oxides.



Chen's research website: <http://www.indiana.edu/~hydrogeo>

Image: A river in Wutai Township in Southern Taiwan. The river is subject to high rates of tectonically driven uplift and extreme erosive conditions associated with strong typhoons that frequently cross the island. The current alluvium covering the bed is a result of Super Typhoon Morakot that hit the island in 2009 and caused extensive landsliding, flooding, and loss of life.

2 Energy Resources and Sustainability

Finding new ways to exploit energy has reached a critical point in the 21st Century, as has the need to exploit them in a sustainable manner. The need for resources, whether they are energy, mineral, water, or soil, will never end, so how do we optimize to reduce negative impacts?

We are addressing the challenges facing humanity: Are there innovative new ways to conceptualize sustainability? Are there new ways to locate and harness resources? We have expertise in a range of topics within energy and resources.

Schieber is a leader in shale gas exploitation; the Indiana Geological Survey has expertise in coal and carbon capture and storage; Edmonds and Zhu in water resources; Ripley and Li in mineral resources. This diverse, closely-knit group of researchers gives us collective expertise in climate-atmosphere-surface interactions with the solid Earth.

We also have expertise in remote sensing, which is a potential unifying theme around which we can develop unique remote sensing platforms and methods of data analysis focused on the themes of energy, resources and sustainability. The fact that high performance computing is essentially unlimited at Indiana University offers us the competitive possibility to focus more on needs and opportunities in an experimental forum.

mineralogy & petrology

Dave Bish, Jim Brophy, Chusi Li, Ed Ripley, Juergen Schieber, Bob Wintsch

Dave Bish

Professor and Haydn Murray Chair of Applied Clay Mineralogy

Dave continues with his terrestrial and extra-terrestrial clay mineralogic research. He was named one of two new international Honorary Fellows in the Italian Society of Mineralogy and Petrology, September, 2015.

In a slight departure from clay mineralogy, Dave recently co-authored a paper studying the process of dolomitization. He recently attended a field trip on the island of Ischia in the Gulf of Naples, Italy, where he studied sub-aerial and sub-aqueous alteration of the potassic alkali trachyte Green Tuff on Monte Epomeo.

Dave continues to hold down the fort teaching G221, Introductory Mineralogy.

Jim Brophy

Professor of Geological Sciences | Chair, Department of Geological Sciences

Jim's primary research interest centers around the chemical and physical processes involved in magmatic differentiation.

Jim continues to try to melt rocks in his high-pressure laboratory (with only moderate success) with the long-term goal of nailing down the behavior of various trace elements during the partial melting of lower island arc crust amphibolite.

He recently graduated an M.S. student (Zach Osborne) who will be starting a Ph.D. program in experimental petrology at Syracuse University.

Jim has spent one month each of the past three summers at Olduvai Gorge in Tanzania, Africa, co-teaching (with Jackson Njau) a field course in field geology and paleo-anthropology.

Jim recently took over the reins of departmental Chair from Lisa Pratt and plans to hold down that position for the next four years.

Image: Rainbow over the Stillwater Mining Company. This is a palladium and platinum mining company with headquarters located at Billings, Montana, United States. It is the only palladium and platinum producer in the USA. Ed Ripley's research area.

Ed Ripley

Professor of Geological Sciences | Geochemistry, Economic Geology

Ed's research interests include the genesis of metallic ore deposits and the application of stable isotopic geochemistry to petrologic problems.

Ed Ripley and Chusi Li are a dynamic duo whose largely (but not always) collaborative work ranges from Ni-Cu-PGE mineralization, through sulfur mobility in country rocks, S isotope studies in the Sudbury and, finally, the interpretation (or re-interpretation) of trace element discrimination diagrams.

Their work has taken them from Minnesota (mid-continent rift system), Alaska (Duke Island Complex), to various metallic ore deposits in China and Vietnam. In the past two years they published 13 papers, four of which were co-authored by recent graduate students. Ed recently co-authored an important review paper on siderophile and chalcophile elements in magmatic ore deposits published in the *Geochemical Society and Mineralogical Society of America Reviews in Mineralogy and Geochemistry*.

Current grad students have or will be presenting their work at various international conferences including a Penrose Conference on Layered Intrusions held in Red Lodge Mont (Ed Ripley – Co-convenor) and the International Ni-Cu-PGE Symposium in Perth, Western Australia.

Chusi Li

Senior Scientist and Director, Microprobe Lab | Mineral Deposit Systems, Geochemistry

Chusi's research, conducted through detailed fieldwork and careful laboratory investigation, currently focuses on world-class magmatic Ni-Cu-PGE (platinum-group elements) deposits, the tectonic setting in which they occur, petrogenesis of associated mafic-ultramafic rocks, causes of sulfide saturation in mafic magma, concentration of immiscible sulfide liquids in magma plumbing systems, controls on the compositions of base metals and PGE in sulfide ores, and models that can be used to assist in exploration targeting.

Bob Wintsch

Professor of Geological Sciences | Metamorphic Petrology, Structural Petrology, Tectonics, Geochronology

The research of Wintsch and students working with him spans several aspects of metamorphic geology, from diagenesis and low grade metamorphism in slaty rocks to high grade metamorphism and partial melting.

On a very exciting note, Bob was recently elected as a prestigious fellow of the Mineral Society of America, the largest mineralogical society in the world. Congratulations are in order. He spends a lot of time in China these days but continues to oversee a bevy of graduate students who help him in his ongoing research into mineralogical controls and feedbacks in ductile deformation with recent emphasis on fault rheology. One graduate student, Bryan Wathen, earned a six-week internship this past summer with the USGS in Reston working in a geochronology lab.

This fall Bob will be giving two invited addresses at the Asia Oceania Geosciences Society. As with Dave Bish, Bob continues to hold down the fort teaching G222, Introductory Petrology, as well as offer his annual G420 field trips. The 2016 trip had 12 student participants and took place in northern Michigan and Ontario. The focus of the trip was on the differences between processes operating ~2 billion years ago with those actively occurring today.

sedimentation & stratigraphy

Simon Brassell, Doug Edmonds, Lisa Pratt, Juergen Schieber, Bob Wintsch

Juergen Schieber

Professor of Geological Sciences | Sedimentary Geology

Juergen's main research interest is the geology of shales and mudstones.

These fine-grained rocks constitute approximately two thirds of the sedimentary column, and are nonetheless the least understood sedimentary rock type. Although still only a footnote in most soft rock curricula, there are a number of very good reasons to study shales and mudstones, such as their importance as a recorder of geologic history, their role as hydrocarbon source rocks, and their sealing properties that keep hydrocarbons in their reservoirs, protect groundwater resources, and contain hazardous waste. In the context of mudstone sedimentology, Juergen is also working on features produced by microbial mats that colonize sandy and muddy substrates, and how one might identify mat deposits in the terrigenous clastic rock record. The convergence of these research themes has led to work on the sedimentology of layered rocks on Mars, the study of microbial preservation in Mars analog studies, and participation in the Mars Science Lab mission (launched in 2009).

His research is characterized by a holistic approach to shales, and consists of an integration of field studies (facies, stratigraphy) and lab studies (thin sections, electron microscopy, geochemistry) in order to understand the various factors that are involved in the formation of shales. Shales that have been studied with this approach range in age from Proterozoic to Eocene and come from the Proterozoic Belt Supergroup of Montana, the Cambrian Wheeler Shale of Utah, the Ordovician Athens Shale of Alabama, the Devonian Chattanooga Shale of Tennessee, the Triassic Moenkopi Formation of Utah, the Posidonia Shale of Germany, the Mancos Shale of Utah, and the Green River Formation of Wyoming. In addition to his broad interest in shales, Juergen is also curious about the formation of sedimentary mineral deposits and the diagenesis of sediments.



Juergen's research site: <http://www.shale-mudstone-research-schieber.indiana.edu>

Image: Migrating mud ripples in a flume (i.e. an oval-shaped racetrack circulating mud and water operated by Juergen Schieber) viewed from below through a transparent bottom. The water flows in the opposite direction of the arrow."

Doug Edmonds

Assistant Professor of Geological Sciences
Sedimentology | Malcom and Sylvia Boyce Chair in Geological Sciences

During this past year two new and exciting research projects have been initiated.

In March, Doug traveled to White Sands National Monument in New Mexico with two graduate students and a former undergraduate to measure wind velocities over the gypsum dune field (IMG_3910). They deployed two Light Detection and Ranging instruments to measure atmospheric wind velocities from the ground level to 100s of meters in the air. Their research goal is to test theories for sand movement in dune fields and link that to dust emission events, like the one pictured upper left. The field campaign was a great success.

In May, Doug started a project at the Indiana University Judson Mead Geologic Field Station to monitor gravel clasts as they move through river systems. Doug and his students collected 1000 gravel clasts from the Jefferson River (bottom image) into which they will drill and implant a passive integrated transponder that, when charged by a magnetic field via a hand-held wand, emits a unique identifier and allows them to record its position. This technology is also used extensively in tracking animal movement. They plan to use this to understand how gravel moves through river systems.



Doug's research site: <http://geology.indiana.edu/edmonds/sedSystems>

Image top: Gypsum sand dunes in White Sands National Monument looking west to the San Andres Mountains. The sand dunes migrate when gypsum sand is transported during strong wind events like the one pictured here.

Image bottom: Students Matt Wanker (left), Rebecca Caldwell (middle), Scott David (right), deploying a wind-based LiDAR unit that uses the Doppler shift from laser light to measure wind speed during sediment transport events.



The Indiana Geological Survey

The Indiana Geological Survey (IGS) has served the people of Indiana since 1837. Established in Indiana Statute in 1993 as an institution of Indiana University, and under the direction of the Office of the Vice Provost for Research, the IGS is committed to providing unbiased and reliable Earth science information through directed research, service, and education.



Through its numerous activities, the IGS assists the public and private sectors by providing technical information for locating and evaluating mineral and energy resources throughout the State, reducing environmental risks to the land, water, and air of the state, assisting in the reclamation of land that has been mined, and identifying areas susceptible to natural geologic hazards. Staff of the IGS provide information essential to the natural resource industries, which contribute more than \$2.3 billion annually to Indiana's economy.

In performing these activities, the IGS employs professional scientists along with technical and support staff. The activities of the institution are primarily funded by an annual state appropriation, and numerous contracts and grants, from state and federal agencies, as well as private organizations.

The IGS staff actively participate in numerous education and public outreach activities. As an entity of Indiana University, it plays an active role in preparing the next generation of Earth scientists by advising and by providing practical work experience.

In recent years, the IGS has relied increasingly on information technology to develop and maintain publically accessible databases, geographic information systems, and digital publications. Additionally, it maintains a robust website, which it utilizes as the major means of outreach.



The Indiana Geological Survey experienced a number of personnel changes during the past year. Todd A. Thompson, Ph.D., a 1987 graduate of the department, is the new Director and 16th State Geologist, replacing John C. Steinmetz. Also joining the Survey as stratigrapher is Pat McLaughlin, Ph.D.; Polly Sturgeon is the new education outreach coordinator; Bob Autio, also a department graduate, is the new environmental geologist; Jayson Eldridge was hired as field and laboratory assistant for petroleum records; and José Luis Antinao, Ph.D., begins in August 2016 as a new research geologist.

The IGS continued its mapping excellence in the state with the release of Indiana—a new 1:500,000-scale state map that features the latest high-resolution LiDAR elevation data. Staff hydrogeologists created two new state-wide-scale maps that show the relative risk of Indiana's aquifers to contamination and identify the locations where water, and therefore, potential contaminants applied at or near the ground surface, are expected to rapidly infiltrate into the subsurface, as well as two maps that show the elevation of the bedrock surface and the thickness of unconsolidated deposits overlying the bedrock.

All of these maps are now part of the collective suite of IndianaMap and IGSMAP digital products. A cooperatively funded project between the IGS and USGS continues IGS mapping efforts northward from Lawrence and Monroe counties through Morgan County to join completed mapping in Marion County.



Indiana Geological Survey website: <https://igs.indiana.edu/index.cfm>

Images: IGS staff field trip, May 2015. Todd Thompson (pictured in the yellow vest) became the Director of the IGS in July, 2016.

3 Origin and Evolution of Life

The National Research Council (NRC) highlighted new challenges related to the Origin and Evolution of Life. Among the challenges identified as most pertinent are how biological systems adapt to physical and geochemical conditions during and after transitions in Earth systems, and how biodiversity adapts to greenhouse worlds. The construction of an explanatory narrative of the interactions of Earth's climate, environment, and evolving life was urged. Recently the National Science Foundation instituted a new Earth-Life transitions track within the Sedimentary Geology and Paleobiology program to help meet these challenges. Our strengths leave us poised to address this NSF-prioritized area, and our group has already received one grant from the program to study the impact of climatic change on fossil mammal ecosystems.

David Polly's research on vertebrate paleontology focuses on changing climates and geographies in Earth history. His work includes quantitative trait-based studies of community responses to environmental change, geometric morphometric analysis of evolution and morphology, phylogenetics, biogeography, and speciation.

Claudia Johnson's research on evolutionary paleoecology investigates biotic processes in the temperate and tropical realms. Her studies explore biotic evolution within the encompassing environments and in the larger geological landscape.

Jackson Njau's research investigates the origin of humans during the late Cenozoic to the recent time. His work includes investigation on the role of climate-modulated environmental change to the evolution of early hominins, making use of the unparalleled resource of Olduvai Gorge in the East African Rift Valley, one of the hotspots of human origins research.

Gary Motz is focusing much of his research at IU on generating good workflows for the generation of digital data from the vast treasure trove of knowledge stored in IU's natural history collections. He works with high performance and high throughput computing to optimize algorithms for automated handwritten text recognition, optical character recognition, 3D scanning of fossils, and community-driven web portals to access and contribute to our understanding of the richness of the IU Paleo Collection.

National Academy member David Dilcher (paleobotany), Twenhofel and Paleontological Society Medal Awardee Erle G. Kauffman, and James A. Hopson (biology and anatomy of extinct reptiles and mammals) add prominence and prestige to our activities in evolution.

The present research is focused on coral reefs, vertebrate evolution, the evolution of early humans, early angiosperms, and Cretaceous marine faunas. Specific projects include the study of evolutionary paleontology, paleoecology, paleoclimates, phylogeny, functional morphology, taphonomy, biostratigraphy and biogeography. Research in progress by graduate students and faculty includes coral species extinction, paleoecology of Cretaceous faunas, reef ecosystem evolution and the relation of reefs to tropical paleoclimatology and paleoceanography, evolution and paleocommunity dynamics in mammalian carnivores and ungulates, Pleistocene mammal faunas, dinosaur diversity, climatic factors in the evolution of snakes, and evolution of the earliest flowering plants.

Alex Zimmermann (ancient marine ecosystems and climate change), Spencer Hellert (evolution of modularity in dinosaurs and birds), John Kearney (depositional environments and tephra stratigraphy of *H. erectus*-bearing strata), Silvia Ascari (functional morphology of dinosaurs), Allison Bormet (functional morphology of ungulate mammals), Blaire Hensley-Marschand (paleoecology of early hominin sites in China).



geobiology, geoarchaeology, paleontology

Simon Brassell, Erika Elswick, Ed Herrmann, Claudia Johnson, Gary Motz, Jackson Njau, David Polly, Lisa Pratt

Claudia C. Johnson

Associate Professor of Geological Sciences | Geobiology

Claudia enjoys working on reefs – from the stories unfolding in their evolutionary history, to the power of resilience in times of climate change. Her research question has always been: How does a healthy reef ecosystem function? She addresses this multi-faceted investigation through examination of the rock record for Mesozoic reefs, and through analysis of coral and water quality data for modern reefs. Her ultimate research goal is to write the history of Caribbean reef evolution.

To uncover details of corals' environmental envelope, Claudia has recently joined forces with colleagues to address coral disease and reef health. Together they integrate millions of data points of coral species, disease, and temperature records over a 40-year span and let the data drive the hypotheses. Their work was presented in 2016 at the 13th International Coral Reef Symposium in Hawaii, and has been accepted for the annual Geological Society of America Meeting in Denver, and the 6th International Workshop on Climate Informatics in Boulder, Colorado, hosted at the National Center for Atmospheric Research.

In recent years Claudia has been invited to participate in the research coring project in Tanzania at Olduvai Gorge with departmental colleague Jackson Njau, and Stone Age Institute colleagues Nick Toth and Kathy Schick. Together with D. Van Damme of Ghent University, Belgium, they published the very first paper on macroinvertebrates from Olduvai Gorge, highlighting the fact that macroinvertebrate paleoecology can certainly enhance knowledge of paleolandscape evolution at a site renowned for its hominin and stone tool remains. For their work, they examined the ecology of recent *Chambardia wahlbergi* freshwater bivalves, added stratigraphic and sedimentologic data, and suggested the aquatic environment during Olduvai Bed III and Bed IV times should be reconstructed as a periodically dessicated floodplain bordering a river channel with permanent running water and marked seasonal fluctuations.

Claudia's reef interests expand each spring as she teaches G341, the Natural History of Coral Reefs, to upper division undergraduates from diverse majors across the College and university. This work keeps her current on the literature, and allows students to gain integrated knowledge on reef ecosystem evolution, resilience through time, and ocean/climate dynamics. The other mainstay of her teaching profession is G114 Dinosaurs and Their Relatives, the success of which is achieved largely through the cooperation of wonderful AIs - associate instructors who are truly dedicated to helping students learn skills of data acquisition, interpretation, and critical thinking.

Image: Olduvai Castle, Olduvai Gorge, Tanzania.

Ed Herrmann

Research Scientist | Geoarchaeology

Ed is a geoarchaeologist focused on understanding how geomorphological change affects the preservation of archaeological sites. My research is multidisciplinary in nature. I am particularly interested in how fluvial and colluvial systems influence site burial, erosion and preservation.

This information is important to understand because it can lead to more accurate predictive modeling of buried archaeological site locations. Although his long-term research focus is largely Paleoindian (the first inhabitants of the Western Hemisphere), his current research attempts to locate buried, and therefore preserved, bison bonebeds associated with prehistoric bison hunting on northwestern Plains in Montana and Wyoming. This work is on the Crow reservation and is an archaeological field school for Crow students working for the Crow Tribal Historic Preservation Office.

Because archaeological excavation is inherently destructive, geoarchaeologists use coring, geophysical and GIS methods to understand stratigraphy, sedimentation and paleoenvironments in a non-invasive fashion. These methods are also useful in understanding archaeological mound construction methods, site locations, chronologies and taphonomic alterations.

Another interest is prehistoric lithic technology and identification. Over the past few years, Ed has helped maintain a lithic raw material comparative collection at the Glenn A. Black Laboratory of Archaeology at Indiana University. He is a flintknapper with an interest in experimental archaeology. Ed has been involved in archaeological projects in Germany, Wyoming, Montana, Ohio, Mississippi, Wisconsin and Indiana.

Gary Motz

Research Associate | Paleontology

Project Coordinator Center for Biological Research Collections

Gary is focusing much of his research at IU on generating good workflows for the generation of digital data from the vast treasure trove of knowledge stored in IU's natural history collections.

He works with high performance and high throughput computing to optimize algorithms for automated handwritten text recognition, optical character recognition, 3D scanning of fossils, and community-driven web portals to access and contribute to our understanding of the richness of the IU Paleo Collection. Gary's work with crowd-sourced and citizen science platforms is proving to be an excellent way to share the collection with the scientific community and well beyond, plus getting a little bit of help in doing it! Visit the fossil collections at www.notesfromnature.org to see some of our own collections in action.



<https://www.notesfromnature.org/>

Jackson K. Njau

Assistant Professor, Geological Sciences | Paleoanthropology Research Associate, The Stone Age Institute and the Center for Research into the Anthropological Foundations of Technology (CRAFT), Bloomington, Indiana.

Adjunct Professor, Department of Anthropology, Indiana University

Jackson's research seeks to understand the relationship between paleolandscapes and paleoenvironmental contexts of hominin evolution.

His research combines a broad range of paleoanthropological approaches, including archaeology, paleontology, taphonomy and occasionally actualistic studies of predators in natural environments. The primary interest of his research is to determine ecological conditions that influenced hominin adaptations and behavior.

Over the last ten years his research has focused on the impact of crocodile predation on hominin behavior at a site in Olduvai Gorge that is perhaps the most famous of all archaeological sites informing on human evolution.

Jackson's research integrates taphonomy, ecology, archaeology and geology with the goal of understanding the paleoenvironmental contexts of hominin evolution.

P. David Polly

Professor, Geological Sciences

Adjunct Professor, Departments of Biology and Anthropology

Director, Center for Biological Research Collections

Research Curator, IU Paleontology Collection

Affiliate Member, Integrated Program in the Environment

Research Associate, Department of Zoology, The Field Museum, Chicago

Polly's research on vertebrate paleontology focuses on changing climates and geographies in Earth history. The work in his group includes quantitative trait-based studies of community responses to environmental change, geometric morphometric analysis of evolution and morphology, phylogenetics, biogeography, and speciation.

Recent graduates include Michelle Lawing, who is now an assistant professor at Texas A&M University, and Rich Bykowski, who is now at Georgia Southern University.

From 2016-2018, Polly is serving as President of the Society of Vertebrate Paleontology.



Polly Lab website: <http://mypage.iu.edu/~pdpolly/>



The 1.3 million fossils in the Indiana University Paleontology Collection are once again part of the department's research activity after a seven-year program to reorganize, inventory, and rehouse them. The Collection is a public trust research repository operated by the department that documents past research projects and serves as a resource for new synthetic research on stratigraphy, paleoecology, evolution, and the biotic component of Earth system change.

The IU Paleontology Collection

This year we celebrated the completion a new research-focused Collection facility on the 5th floor of the Geology Building with a gala Open House on April 30, 2016. About 150 people attended, including many alums, to browse the Collection, hear about the latest paleontological research, see the products of our new 3D digitizing program, and reconnect with each other and with the department. IU Alum William Ausich of Ohio State University delivered a keynote address titled "*Biosphere Collapse and Recovery - Lessons from the Paleozoic Crinoids*" - his career-long research on one of the most diverse groups of the Paleozoic that he started as a graduate student of Gary Lane's.

Once ranked among the top 20 paleontological research collections in North America, the renovation program has been aimed at reestablishing the Collection's prominence in the field. A \$475k grant from the US National Science Foundation's Division of Biological Infrastructure (DBI-0846697) was awarded in 2009 to reorganize the fossil material into a stratigraphic format, inventory it, and to move it into secure, climate controlled research space in the Geology Building.

The project was led by faculty Claudia Johnson, David Polly, and Erika Elswick and by graduate students Robin Green and Devin Swander, who served as project managers during the phases of moving everything to the basement, sorting boxes and drawers in those hot and cramped quarters, and moving them up again into the new space. With 1.3 million fossils, many hours were put in by a team of more than 20 undergraduate and graduate students, several of whom are now alums themselves.

To culminate the project, the first designated collection manager was appointed since Alan Horowitz's retirement in 1996. Gary J. Motz, a paleontologist trained at University of Cincinnati whose specialties are in evolution of bivalves and digital methods for analyzing morphology, is now the Collections Manager.

Collection Personnel

Gary Motz
(Collections Manager)
phone: 812-856-3500
email: garymotz@indiana.edu

David Polly
(Faculty Research Curator)
phone: 812-855-7994
e-mail: pdpolly@indiana.edu

Claudia Johnson
(Faculty Research Curator)
phone: 812-855-0646
e-mail: claudia@indiana.edu

Jackson Njau
(Faculty Research Curator)
phone: 812-856-3170
email: jknjau@indiana.edu

Image: IU's new Paleontology Collection manager, Gary J. Motz. Gary is an expert in bivalve evolution and also serves as the lead Project Manager for IU's Center for Biological Research Collections.

Society's most challenging questions will be answered by the Earth Sciences. How will climate change affect environments and biotas? Where will tomorrow's energy resources be found? More than ever, research requires large-scale analyses of past organisms and their environments to understand the dynamics of changing climate, biotas, and Earth systems. The Paleontology Collection, as a member of the international network of research repositories, provides the deep-time data needed to answer these questions. As the NSF report on Future Research Directions in Paleontology stated, "never before has the study of past life been as exciting and as urgent".

about the Collection

Each of the 1.3 million fossils in the Paleontology Collection is a carefully documented data point used to reconstruct the history of life. Unlike personal collections or gem and mineral shows, fossils are curated into the research repository because they answer specific research questions. How did the Earth's first mass extinction unfold? How did organisms partition resources during peaks of species diversity? How intense were storm systems when the Earth was hotter than today?

Rigorous paleontological science requires that each fossil be linked to detailed contextual information and that those details be available to researchers. How old is it? With what other organisms was it associated? What were the properties of the sediments in which it was buried? Curation and access distinguish research repositories from personal collections, because without careful contextual record-keeping, the scientific power of a fossil is severely diminished. Rigorous science also requires repeated access to the same specimen by many researchers, both to critically reevaluate older work and to collect new data, often with next-generation technologies, to address emerging areas of research.

Collection Location

Department of Geological Sciences
Indiana University
1001 E. 10th St. Room GY518
Bloomington, IN 47405



IU Paleontology Collection website: <http://go.iu.edu/1cHc>

Our earliest fossils were collected by David Dale Owen of New Harmony, Indiana during his geological survey of Wisconsin, Iowa, and Minnesota (1846-1848). Most of Owen's material is now in the Smithsonian Institution, but a small selection is retained at IU.

unique segments of the Collection

Earth's first mass extinction occurred at 440-450 million years ago when 70% of species disappeared because of climatic and oceanographic upheavals. IU paleontologist Edgar Cumings conducted one of the first systematic studies of turnover in species caused by this event. He collected material from the entire length of the Ordovician-Silurian boundary in Indiana, including a remarkable series from a long railway cut at Tanner's Creek.

JJ Galloway was a pioneer in micropaleontology, the fossilized remains of microscopic organisms like foraminifera and coccolithophores. Microfossils provide evidence for telling geological time, exploring for petroleum, and reconstructing the Earth's climatic history. Galloway taught the first micropaleontology course in the US and published the field's seminal textbook. Our Collection holds extensive microfossil material, including Galloway's original specimens.

Conodonts are one of the first vertebrate groups, tiny eel-like creatures that swarmed the seas of the early Paleozoic. Their tooth-like denticles are common in marine rocks. Conodonts provide evidence of not only age, but depth of burial of rocks because their color changes in response to heat. We have an extensive collection of conodonts from the research of Carl Rexroad, one of the world's foremost experts.

The N. Gary Lane Memorial Fund

The momentum of paleontological research at IU has its foundation in the Paleontology Collection. With more than 1.3 million fossils from Precambrian to present – each with detailed taxonomic, stratigraphic, and geographic data – it places IU ahead of our peers.

Nobody recognized the fundamental connection between repositories and research more than Gary Lane. His work on the extraordinary crinoid fauna of Crawfordsville, Indiana synthesized data from repositories around the world. Today, few collections rival IU's for research on this important group because of Gary's contributions.

To support the financial costs of the collection's infrastructure, curation, and staffing now and in the future, we launched the N. Gary Lane Paleontology Collection Fund.

Your generous donations to the N. Gary Lane Memorial Fund will ensure that this research collection remains world-class. Please consider giving to help us maintain this momentum into the future.



Olduvai Gorge Coring Project

Indiana University has developed a very strong research presence in the world famous Olduvai Gorge located in Tanzania Africa. The main players are Jackson Njau and Nick Toth and Kathy Schick of the Stone Age Institute.

For several years now it has been recognized that future research into the origin and evolution of the Olduvai sedimentary system and associated hominid evolution could benefit immensely from fresh sedimentary rocks in lieu of the largely weathered sediments exposed in the side of the gorge. To that end the Olduvai Gorge Coring Project (OGCP), which is led by Jackson Njau, Kathy Schick, Nick Toth and Olduvai geologist Ian Stanistreet (University of Liverpool) organized and carried out a drilling campaign which, during the summer of 2015, drilled four boreholes at three selected localities. The drilling project, along with a parallel seismic study of the region being conducted by three seismologists from the King Abdullah University for Science and Technology in Saudi Arabia itself was entirely funded through the Stone Age Institute. The result is nearly 600 cumulative meters of core with a quality and resolution that are simply astonishing.

To date, twenty-five scientists from eight different countries have been working on the cores, focusing on different aspects of the overall research including sedimentology/stratigraphy, argon-argon dating, paleomagnetism, x-ray diffraction, tuff and lava chemistry and correlation, limestone analysis, carbon and oxygen isotopes, lipids, pollen, macro-plant remains, phytoliths, diatoms, ostracods, and mollusks.

Other Department of Geological Sciences faculty that have been involved in the Olduvai coring project include Simon Brassell and Claudia Johnson, as well as graduate students Devon Colcord, Andrea Shilling, and John Kearney. IU alum Kate Freeman (Penn State) is also on the team.

There is little doubt that these investigations, in conjunction with the on-going shallow level seismic surveys of the Olduvai basin, have the potential for rewriting the geologic history of the Olduvai system. These are truly exciting times in both Bloomington and Tanzania.

Image: Drill rig at Olduvai Gorge.

The First Drilling and Seismic Surveys in the Cradle of Humankind, Olduvai Gorge, Tanzania

Olduvai Gorge is an exceptionally rich paleoanthropological site preserving one of the best records of human history spanning the Pleistocene period. The site, which is regarded as the cradle of humankind, is located on the shoulder of the East African Rift System (EARS) in northern Tanzania.

Over four hominin (early human forms or the taxonomic tribe which includes *Homo sapiens* and our close fossil relatives from the last 6 Ma) species including two holotypes *Australopithecus boisei* (aka *Zinjanthropus*) and the first species in our genus *Homo* (*H. habilis*) have been discovered at the site. The fossil record shows the evolutionary transition from *H. habilis* to *H. erectus* and subsequently to anatomically modern *H. sapiens*. Stone tool technology evolved from the Oldowan (characterized by simple core-and-flake stone technology) to the Acheulean (composed of hand axes and cleavers), to stone arrowheads, blades and micro-blades. Fossils, archaeological and associated paleoenvironmental records provide an unsurpassed dataset for testing the most debated hypotheses of human evolution.

Climate & Tectonic Hypotheses of Human Evolution

Few scientific subjects fascinate the public interest as much as human evolution and climate change. Understanding this relationship requires interdisciplinary approaches across the Earth sciences and paleoanthropology. For more than a century scientists have speculated about why and how we evolved and what conditions drove biological and cultural changes. More recently, climate change and tectonic forcing have been hypothesized as primary drivers of human evolution. The premise of this idea is that major evolutionary events such as hominin speciation, innovation, and dispersal were associated with African climate change during the Pliocene and Quaternary. Deep-sea core records of continental dust flux indicate global climatic shifts at time intervals that appear to coincide with the timing of key evolutionary milestones in the history of our ancestors such as: the first appearance of robust australopithecines (e.g., *Australopithecus boisei*), the origins of an enlarged brain (genus *Homo*), the emergence of *H. erectus* and subsequently *H. sapiens*, and the extinction of australopithecine forms.

The link between Earth system history and human evolution however, face many challenges, especially when we seek to answer the following fundamental questions: When and how did climate and environmental forces influence adaptation during the critical times of human evolution? Do changes

in morphology and innovation reflect changes in the local environment affecting habitat, food, refuge trees, predation pressure, raw materials (rocks for tool making) and other resources? To answer these questions we have to turn to sedimentary core records from continuous paleolake beds that are in proximity to fossil sites.

Olduvai Gorge Drilling Project (OGDP)

In order to address this paleoanthropological problem and transform the scientific debate we developed Olduvai Gorge Drilling Project (OGDP) in 2014. This collaborative effort between Department of Geological Sciences and Stone Age Institute researchers succeeded in launching the first drilling at the site that obtained long and continuous lacustrine sediment cores in close proximity to archaeological sites. Drill cores from fine-grained paleolake beds circumvent outcrop sample problems such as degradation from weathering, discontinuous stratigraphic records, and limitations to continuous measurement for key paleoenvironmental variables.

Subsequent reflection and refraction seismic surveys were conducted to obtain subsurface images of the bedrock and the basin structure, so far only inferred from outcrop studies. The seismic data were useful in determining buried faults, their geometry at depth, and current micro-seismic activity. This allowed for correlating geophysical information to the local lithology obtained from drill cores.

Image: Drilling and seismic crew - IU participants include Jackson Njau (center, in green shirt) and Nick Toth and Kathy Schick of the Stone Age Institute (far right).



The First Core from Olduvai Site

Over 612 m of continuous drill cores were acquired from four boreholes drilled into Olduvai basin depocenters, covering all geological beds. This constitutes approximately 30% of all cores from East African paleolake and hominin sites (including Kenya and Ethiopia). However, the Olduvai cores are exceptional because (1) the cores were drilled within only a short distance to well-known archaeological sites, bearing rich fauna and hominin material; (2) the exceptional core recovery (>94%) provides an almost continuous high-resolution record; (3) the high lithological variability allows for direct identification of base level changes linked to lake level fluctuations; and (4) the Olduvai record covers time periods that document the evolution of *H. habilis* to *H. erectus* (~1.7 Ma) and early *H. sapiens* (~0.5 Ma) and the extinction of *Australopithecus boisei* (~1 Ma). Cores thus deliver an unsurpassed link between environmental history and the fossil record at high resolution.

New Interpretation of Olduvai Sequence and Hominin History

New paleogeographic models of the lake-centered basin are emerging. The initial results indicate that the Paleolake Olduvai basin: 1) has a much older depositional history than previously extrapolated from outcrops, 2) contained a lake longer-lived, deeper, and more extensive than previously thought, and 3) was strongly affected by influxes of variable volcanic and volcanoclastic materials from the adjacent Ngorongoro volcanoes, altering the lake configuration and influencing hominin palaeolandscapes through time.

This new information changes the longstanding view of the hominin record at Olduvai and environments in which they evolved. It provides a detailed and continuous record upon which environmental and tectonic forcing hypotheses can be tested.

In this endeavor the synergy between the Earth science and paleoanthropology communities is growing globally and has stimulated research frontiers in archaeology, paleobiology, geochemistry, organic geochemistry, stratigraphy, sedimentology, geochronology and geophysics. A number of graduate and undergraduate students and faculty in the IU Department of Geological Sciences are actively engaged in various aspects of the project in order to relate events and trends in the hominin and archaeological records to the core records. This project is opening up a new research direction in the northern Tanzanian rift system.

Drilling for Scientific Research in Africa

To conduct any scientific drilling or seismic research in Africa is a very challenging endeavor. The 2014 drilling operation at Olduvai was executed within a window of 8 days but required more than a year of massive logistical preparations both in the US and in Tanzania. It included two semesters of bi-weekly organizational meetings in Njau's lab, hosting an international concept workshop with 25 partic-

ipants at the Stone Age Institute, raising over half a million dollars in research funds for the project (mostly from private donors) and contracting with five companies (drilling, scientific oversight, down-hole logging, core packing and air shipping, University of Minnesota's LacCore field and lab support and core storage) as well as contracting with the Tanzanian government research authorities, and meeting with local Maasai communities to address environmental and conservation issues and raise public awareness about the benefit of this new approach in archaeological research.

Image: Jackson Njau evaluating cores at University of Minnesota LacCore support facility.



4 Solid Earth Dynamics

In the field of solid Earth geodynamics, we are at the forefront in a new observational revolution—one that takes advantage of great technical breakthroughs in geophysics, petrology, and structural geology—to observe characteristics of Earth structure and dynamics at scales that have never before been possible. The ultimate goal of these studies is a unified physical and chemical theory that can explain both the evolution and deformation of our dynamic planet. This necessarily requires the combined efforts of geophysicists, structural geologists, igneous and metamorphic petrologists, mineralogists and geochemists.

The greatest advances in the near future will undoubtedly rely on those interdisciplinary studies that can integrate observational (i.e. field and analytical data collection and interpretation), theoretical (including analytical and numerical modeling) and experimental work.

Our current faculty strengths emphasize observational aspects of geophysics, petrology, and structural geology (Hamburger, Pavlis and Johnson in seismology, Wintsch, Brophy and Bish in mineralogy/petrology, Wintsch, Johnson, and Douglas in structural geology, Yanites in geomorphology). The addition of recent faculty hires in sedimentary geology offers the opportunity to link these deep Earth processes with those affecting Earth's surface and its resources and hazards.

The scientific frontiers are wide open in this field, especially with the ongoing deployment of the Earthscope facilities (www.earthscope.org). Our program also has a strong field component with ongoing projects in China, Taiwan, Philippines, South America, and Alaska. M.S. students from our program are strongly recruited by the petroleum industry, while Ph.D. students have found positions in other industries and academia.



geophysics, structural geology, tectonics

Bruce Douglas, Michael Hamburger, Kaj Johnson, Gary Pavlis,
Bob Wintsch, Brian Yanites

Michael Hamburger

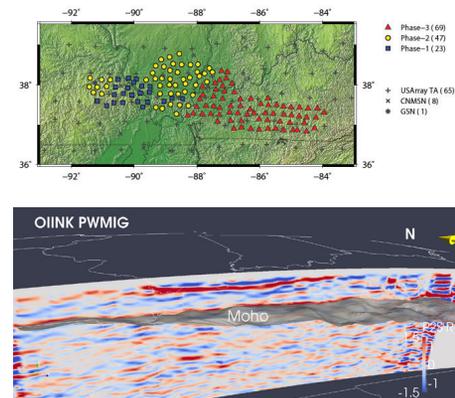
Professor of Geological Sciences | Geophysics, Seismology, and Tectonics

Michael Hamburger continues his collaboration with the US Geological Survey's Geologic Hazards Center on earthquake-induced landslides.

Ph.D. student Anna Nowicki Jessee is working with the USGS team on developing a near real-time system to assess the likelihood of landslides triggered by earthquakes around the globe. The project has involved a global compilation of nearly thirty major earthquakes that have triggered landslides, and using that data set as "training data" to make a predictive system for future earthquakes around the globe. The system can be used for both newly occurring events, such as the recent magnitude 7.1 Kumamoto earthquake in Kyushu, Japan, as well as imaginary "scenario" earthquakes, such as anticipated large events in California and the Pacific Northwest, to discern the potential impacts of future earthquakes. One of the new directions they are pursuing is to use the system not only to detect locations of probable landslides, but also to identify the likelihood of landslide-related fatalities.

Undergraduate majors Madison Ferrara and Chris FitzGerald contributed to this component of the landslide hazard project.

It has been a busy time for the Solid Earth Dynamics group. Gary Pavlis and Michael Hamburger are at the tail end of their NSF-funded project, "Structure and Dynamics of the North American Craton- An EarthScope Swath from the Ozarks to the Grenville Front" - a five-year, \$1.2M collaboration with Purdue University, the University of Illinois, and the Indiana, Illinois, and Kentucky geological surveys. The project involved an ambitious 3-year deployment of seismographs at 140 sites throughout four Midwestern states (image top), giving rise to our project acronym "OIINK"—for Ozarks, Illinois, INdiana, and Kentucky.



The project has resulted in an unprecedented, detailed view of Earth structure associated with the enigmatic crustal structures of the Illinois Basin, Rough Creek Graben, Ozark Dome, and Grenville Front. Xiaotao Yang recently defended his dissertation "Seismic Imaging of the Lithosphere Beneath the Southern Illinois Basin and its Tectonic Implications", in which he discovered an unusually thick crust beneath the Illinois Basin, with surprising rough topography along the Moho surface. As part of his project, he "discovered" a new seismic zone associated with the Ste. Genevieve Fault Zone that marks the boundary between the Illinois Basin and the Ozark Dome. Masters students Matthew Shirley and Dante Curcio and undergraduate majors Jimmie Atterholt and Mitchell Spangler are continuing the project through studies of microseismicity, density structure, and seismic amplitude variations in the Illinois Basin and Rough Creek Graben.

Image: Students studying seismographs during an Earthquake Short Course given by Michael Hamburger and technician Terry Stigall, along with Greg Nelson and Walt Gray from the Indiana Geological Survey.

Kaj Johnson

Associate Professor of Geological Sciences

Kaj is a geophysicist who works primarily with geodetic data and numerical and analytical modeling to investigate active deformation of the lithosphere. In particular, he studies how deformation within plate boundary zones is accommodated by faulting and folding in the crust and viscous flow in the lower crust and upper mantle.

Bruce Douglas

*Senior Lecturer and Director, IU Judson Mead Geologic Field Station
Structural Geology*

Bruce Douglas has been working with colleagues from UNAVCO and other academic institutions including Mt. San Antonio College, the University of Colorado, University of California Riverside, and Idaho State University to develop teaching resources that involve various types of geodetic data (e.g. Airborne and Terrestrial LiDAR, InSAR, GRACE gravity, GPS). These resources will ultimately be added to the Geodesy Tools for Societal Issues (GETSI) teaching resources package sponsored by UNAVCO. The GETSI collaboration was an outgrowth of the incorporation of Terrestrial Laser Scanning (TLS) into the concentration week within G429. This effort led to discussions of how to include various geodetic data sets into undergraduate courses to better prepare students going on to graduate school for research that rely on geodetic data.

The UNAVCO connection also has led to the use of TLS and Post-Processing Kinematic (PPK) GPS data collection and analysis for two M.S. projects undertaken in SW Montana under Bruce's supervision. In May 2014 James Wallace completed a M.S. degree entitled - Structural Evolution of the J-Fold; a Multi-Scalar Approach to Modeling Kinematic Fold Evolution in the Cordilleran Fold-Thrust Belt, Southwestern Montana. A primary data set for this work was a TLS point cloud that James collected and used to make detailed measurement of bed thinning associated with the various phases of faulting and folding that produced the J-Fold. Donald Tripp is working on a M.S. degree that addresses the displacement history for an active normal fault that bounds the east side of the North Boulder valley. Don is analyzing nick point migration in streams that cross the normal fault to then be able to model the displacement history.

Image: Students in the G429g option are learning to use a Terrestrial Laser Scanner to capture dense point clouds that can be used to make more accurate observations and measurements of geologic features. A number of current students working with Dr. Bruce Douglas have incorporated TLS in their research.





Images: Field photos showing weight drop source (top) and land streamer (bottom) in the vicinity of the Yates shaft at SURF.



Gary Pavlis

Professor of Geological Sciences | Geophysics, Seismology, and Tectonics

Gary Pavlis and Ph.D. student Ross Caton have a collaborative project with physicists at the University of Minnesota involved in the LIGO project to directly detect gravitational waves.

The group deployed a 24 element passive array in the winter and spring of 2015 at the Homestake Mine in the Black Hills of South Dakota. The Homestake Mine is now a facility called the Sanford Underground Research Facility (SURF) funded mainly by the DOE (Department of Energy). The 24-element array uses real time telemetry with fiber optic communications to the underground sites and digital radio communications to surfaces sites, monitoring the instrumentation for problems and early data analysis. Seismic noise levels in the mine are extremely low at long periods making this likely the quietest seismic array on the planet in the traditional long-period band (periods over 20 s). Caton is exploiting this to study the interesting problem of coupling of solar free oscillations to the group through electromagnetic induction created by harmonic oscillations in the solar wind.

In September 2015 the group, with major help from Terry Stigall, fielded a series of “piggy-back” active source experiments at SURF. The active source experiments were designed to investigate three interwoven problems in seismic wave propagation in the real Earth: anisotropy, near surface scattering, and the how the Earth’s free surface actually reflects seismic waves at different frequencies.

Three different experiments were done in a 3 week period.

1. A weight drop source supplied in collaboration with Boise State University with an associated land streamer was operated on roads around the city of Lead, SD. Over 4200 shots points were collected with a 2 m shot spacing. These were well recorded by the underground array producing an outstanding data set to address the science problems defined by the project. Figures to the left show the weight drop and land streamer during that experiment.
2. Three 9-component seismic surveys were conducted in the underground at the 1.25 km (4100 ft) and 1.48 km (4850 ft) levels of the mine. These were designed to directly measure anisotropy through shear wave splitting measurements. Photos left show activities from that work.
3. An upside down reflection experiment was run on the 0.6 km (2000 ft) level of the mine using a hand pulled land streamer. 1 km of line was collected with 1 m shot intervals with the objective of imaging variations in amplitude of the free surface reflection.

Unfortunately, the hammer source used was apparently not beefy enough to produce visible returns even with 100 fold stacks. Only scattered arrivals from backfilled mine stopes were imaged.



Images right: Field shots of underground seismic work. Top shows alignment procedures. Compasses do not work in this mine so sensors were aligned with the jig shown to steel rails used for underground trains. Bottom figure shows use of airless jackhammer source in vertical and transverse directions for a nine-component survey. Radial (not shown) positioned the jackhammer on protruding rock in the drift.

5 Leadership in Field Geoscience

Our department has long maintained a strong commitment to field-based geoscience investigations and education to achieve a fundamental improvement in our understanding the Earth. This is manifested most forthrightly through the Judson Mead Geologic Field Station and its long tradition of field education and research, but also through the equally long-lived tradition of field excursions, both local, regional, and international that take place multiple times each year. This commitment permeates down to the level of our introductory courses for non-majors that provide field experiences for the students in these courses.

The primary challenge to this philosophy is the increase in the dependence on remote- and instrument-based observations coupled with computational modeling and visualization that have the tendency to minimize the importance of primary observations that come through direct field-based observations. Rather than view the rise of this digital component of the geosciences as a competitor to field research, we have chosen to find the means to integrate this into our field-based education and research efforts.

The Judson Mead Field Station is a prime example with its new classroom and geotechnology center that allows for integration of field observations with a wide array of laboratory and digital technology. We are now in a position to couple the renowned geological setting of the Field Station with an ever-widening array of instruments, technologies, and subdisciplines within the geosciences that will expand both the number of faculty members, graduate students, and undergraduate students who want to integrate a field component into their research or educational goals.

Judson Mead Geologic Field Station

The Judson Mead Geologic Field Station continues to thrive with increasing diversity of students, faculty involvement and national recognition.

Courses & Faculty

The flagship course G429 continues to draw the top students from typically 30 different schools across the country. The recent addition of GEOL X479 Geology, Hydrology and Geochemistry in the Rocky Mountains to the course offerings has expanded the range of degree programs to include those offering environmental geology degrees. It should be noted that Indiana University, in an effort to make students aware of courses that provide experiential opportunities, has created a system with an X course number to add in on-line searches. This effort initially included G429, but we were able to successfully argue that the G429 course had a national audience and that changing the course number would create serious problems.

Over the last few years our efforts to develop a stable faculty for courses offered at the Field Station has been successful. We have added Jim Handschy who is also an IUB Adjunct Professor and former chief geologist for ConocoPhillips, and Page Quinton from SUNY Potsdam to the G429 faculty. These folks join Mike Rygel (SUNY Potsdam), Mikki Osterloo (U Colorado), as well as X479 faculty Erika Elswick (IUB), and Candace Kairies-Beatty (Winona State Univ.)

In addition to those faculty involved in teaching our courses, we have had visits from a number of other IUB faculty members to assess the options for both new courses and for research opportunities. Doug Edmonds made a visit in summer 2015 and sent graduate students out in the summer of 2016 to conduct the initial fieldwork for a study on the Jefferson River as part of his ongoing research on floodplain channel networks. Cody Kirkpatrick made a visit during the summer of 2016 to view the facilities to assess for the Atmospheric Science group the options for courses and research. Cody was very enthusiastic about options for both an introductory course and an advanced course that would emphasize instrumentation. The new classroom with the computer lab and general laboratory space coupled with the field setting and access to the meteorological stations within the Willow Creek Demonstration Watershed, were all items that would greatly enhance these courses.

Other Academic Users

Other academic users of the Field Station include Hong Kong University that entered into a three-year agreement with the Field Station to run their required field course for their majors following an initial site visit in 2014. In both summer 2015 and 2016 students and faculty led by Jess King spent most of the month of June at the Field Station. During the summer of 2016, one of the new HKU faculty members was a former G429 student excited to return to the Tobacco Root Mountains! We also are continuing with hosting a number of high school groups for short stays.

Research and Short Courses

In addition to serving as a base for teaching, the Field Station continues to provide the base and logistical hub for research. At the present time one M.S. thesis has been completed, and three other projects are ongoing.

In recognition of the leading role the Field Station has played in incorporating geophysical instrumentation into the G429 curriculum, a short course offered in conjunction with UNAVCO was run this summer. It was attended by 21 faculty members and advance graduate students from across the country. All were impressed by the Field Station facilities as well as the surrounding geology. A number expressed interest in making arrangements to use the Field Station for short courses and field trips for their students. Details of the curriculum have been reported elsewhere in this publication.

Scholarships

Two new scholarships were awarded for the first time this summer. The George M. Nev-ers Memorial Field Station Scholarship and the Class of 2013 Katharine E. Compton Memorial Field Station Scholarship. The latter was initiated by her classmates, and joined by her family, in memory of the death of Katharine E. Compton, a recent G429 student.



<http://www.indiana.edu/~iugfs/index.html>

Image: Field Station viewed from a high point along the South Boulder River.

Olduvai Gorge Summer Field Study

First offered in 2014, the summer field course in Field Geology and Paleoanthropology at Olduvai Gorge (X377) is going strong with 2015 and 2016 enrollments of 11 and 10 students, respectively.

X377 (Formerly G349) Field Geology and Paleoanthropology

The course is designed to provide students with a unique opportunity to learn the basics of field geology and paleoanthropology in one of the world's most famous anthropological sites. Not only is it a unique educational experience but an unparalleled cultural experience as well. Instructors Jackson Njau and Jim Brophy are excited to see the course starting to attract students from outside IU which is a sign that it is starting to gain some attention. This past summer there was one student from University of Ohio, two students from the University of Witwatersrand, South Africa and one home-grown student from University of Dar Es Salaam, Tanzania.

2016 VIP tours of the research and teaching sites

Of special note this past summer were two separate VIP tours. Early in the summer Larry Singell (Executive Dean of the College), Jean Robinson (Associate Executive Dean of the College) and her husband Jack Bielasiak (Professor of Political Science) joined the course for a 3-day fact finding mission before going on a personal safari in the Serengeti.

They attended the same lectures, climbed the same slopes, made the same stone tools, butchered the same goat and took the same "solar" showers as the students and the faculty. Word has it that they had a blast and were very impressed with the program.

Later in the summer an IU alumni group consisting of Mark Leonard (M.S., Geol Sci), Jim Farnsworth (B.S., Geol Sci), Elizabeth Balt (B.A., Fine Arts), Gary Covenor (B.S., Physics) and his wife Sharon made a similar visit but this time joined the students for a 3-day Serengeti safari. The purpose of their visit was to act as very willing guinea pigs on a "dry run" for a potential IU Alumni College that would be offered every summer after the formal field course is over. Based on their experience it looks like the Alumni College could "be a go." Stay tuned.



<http://geology.indiana.edu/njau/tanzania/index.html>

Image: Top - Students explore a carbonatite lava flow on the flanks of Oldoinyo Lengai volcano. Second from Top - Members of the VIP tour. From left to right are Jim Brophy, Jim Farnsworth, Mark Leonard, Gary Covenor and his wife Sharon. Missing is Elizabeth Balt. Bottom Three - Nick Toth demonstrates the technique of "stone knapping." Larry Singell and Jean Robinson try their hand at it and are then accompanied by the rest of the students.



6 News about Faculty, Students, Department, and Alumni

The following sections contain news and information about our graduate students and faculty members, construction and upgrade projects in the department, a few stories from Emeriti and Alumni, and a list of our esteemed benefactors.

student careers

Our best undergraduates are sought by the top graduate programs in the U.S. We place three or four students per year in the most highly competitive programs and about 10 additional students in moderately competitive programs. Our M.S. students are recruited by the top Ph.D. programs in the U.S. Conversely, we are able to draw students from top programs into both our M.S. and Ph.D. programs. Our graduate students are annually recruited by two major and several mid-sized oil companies. Service companies also conduct on-campus interviews each year.

jobs & internships 2016-2017

- 1** MOHAMMAD ALROWAIE, Ph.D. candidate
Scholarship from Saudi Aramco Advanced Degree Program.
- 2** ANTHONY FRUSHOUR M.S. candidate
2016 - Vatican Observatory Summer School in Castel Gandolfo, Italy.
- 3** CARLEY GASAWAY, M.S. 2016
Full-time position with Devon Energy.
- 4** JOEL LEONARD, Ph.D. 2016
Ph.D. candidate, Arizona State University.
- 5** RYAN MCALEER, Ph.D. 2016
Full-time position with USGS.
- 6** ZACH OSBORNE, M.S. 2016
Ph.D. candidate, Syracuse University.
- 7** ELLEN REAT, M.S. 2016
Ph.D. candidate, University of Utah Department of Geology and Geophysics.
- 8** CAMERON STEWART M.S. candidate
Summer 2016 Internship with Whiting Petroleum Corp. Denver, CO.
- 9** LIN WEI, Ph.D. 2016 PetroChina in Beijing
- 10** MOLLY WILLIAMS, M.S. 2016
Ph.D. candidate, ETH Zurich, Switzerland.
- 11** QIAN ZHANG, Ph.D. 2016
Full-time position with Gradient Environmental Consulting.



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faculty news

Michael Hamburger

Michael Hamburger has been away from the department for the past year—representing Indiana University in our nation's capital. Last spring, Hamburger was selected to take part in the National Academy of Science's Jefferson Science Fellowship program, the first IUB faculty member to take part in this prestigious program. Each year, the fellowship brings a dozen scientists and engineers to Washington to serve as foreign policy advisors to the U.S. Department of State and the Agency for International Development. Hamburger landed an unusual posting, as a Senior Advisor in the State Department's Office of Religion and Global Affairs.

The Office, created by Secretary John Kerry in 2013, is something of a policy think-tank, focusing on the role of religious dynamics in all of the major global issues that play a role U.S. foreign policy. As the only scientist in the office, Hamburger's work has focused on a variety of global environmental issues, including climate change, public health, wildlife trafficking, and natural disasters. His office's work with religious groups both domestically and internationally contributed to the successful negotiation of the landmark climate agreement at the COP-21 conference in Paris.

Through Hamburger's work with the State Department, he has initiated a number of projects engaging religious groups in disaster risk reduction.

One of the most exciting of these is a project, developed in collaboration with the U.S. Embassy in Islamabad, Pakistan, involves collaboration between U.S. and Pakistani scientists and engineers to develop a training program for religious leaders and madrasa (religious school) instructors in earthquake-threat-

ened areas of Pakistan. As a separate initiative that occupied his last month in the Fellowship program, Hamburger served as an Embassy Science Fellow in Kathmandu, Nepal, where he will be working with the USAID office of Disaster Risk Reduction, Resilience, and Reconstruction (or "DR4" as they call it) on a multi-hazard risk assessment for the areas affected by the devastating 2015 Nepal earthquake.

The project is intended to help train Nepali geologists and engineers in the challenging hazard assessments involved in return or relocation of the 20,000+ Nepali citizens displaced by last year's devastating earthquake. Hamburger hopes to bring some of the project work back to IU for student-based research projects.

One initial product of Hamburger's Washington work: IU is now a charter institution in the State Department's *Diplomacy Lab* program, which will bring IU faculty and students as participants in State Department research projects, starting in fall of 2016.

Lisa Pratt

Lisa Pratt is finishing up her research project in Greenland and mentoring two Ph.D. students (Mohammad Alrowale and Patrick Cavanagh). She is currently a member of NASA's Return Sample Science Board for the Mars 2020 mission.

Lisa served as Chair of the Department of Geological Sciences from 2011 to 2016. In July, 2016 she took on a broad leadership role as Associate Executive Dean for the College of Arts and Sciences at IU Bloomington.



department news

new fellowships & scholarships

Don & Margie Hattin Special Field Course Fund

This Fund is intended to support IU geology undergraduate students planning to participate in high-quality, rigorous field camp programs. Students who are planning to participate in the Olduvai Gorge field course are encouraged to apply. This fund provides up to \$1000 to help pay expenses associated with the field course.

Olduvai Gorge Field School Scholarship

Scholarships of up to \$2,000 each are awarded to successful applicants. The scholarship, which is open to all participants including non-IU students is intended to help pay expenses associated with participation in the Olduvai Gorge field course. The financial support for these scholarships is provided by generous donors, who are committed to increasing paleoanthropological and geological field training opportunities in Africa for dedicated students.

African Ambassador Scholarship

This award supports undergraduate and graduate students studying in African Universities to participate in the Olduvai Gorge field course. The scholarship fund provides up to \$6,000 each to successful applicant. This financial support is provided by generous donors, who are committed to increasing support to dedicated African students to participate in high-quality, international educational programs.

George M. Nevers Memorial Field Station Scholarship

The George M. Nevers Memorial Field Station Scholarship was established by William R. Kersten and Timothy K. Driggers to honor the memory of their dear friend Dr. George M. Nevers and his love of the Judson Mead Geologic Field Station. Dr. Nevers earned his MA at Indiana University in 1957, attended field camp in 1956 and is remembered as “being a great leader, wonderful person and even better friend.” Recipients are not required to be students at Indiana University, but preference will be given to those students who are degree-seeking at Indiana University.

Class of 2013 Katharine E. Compton Memorial Field Station Scholarship

The IUGFS Class of 2013 and Compton family established an endowment in memory of Katharine E. Compton, an enthusiastic young woman with a profound interest in field geology. This scholarship will be awarded to students on the basis of scholarship and service. The recipients' application should provide evidence of their campus and community involvement, leadership qualities and academic preparedness. The funds are to be used to provide one or more scholarships, to be awarded to student(s) attending G429.

Margaret C. and Anne Marie Kuzmitz Scholarship/Fellowship

Anne Marie Kuzmitz has irrevocably given to the department a gift to be used to support scholarships and fellowships for undergraduate and graduate students in need of financial assistance who are pursuing a degree in Geological Sciences. Preference will be given to a female student. The number, amount, and recipients will be determined by the scholarship committee of the department. Margaret Clare Kuzmitz received her B.A. from the department in 1938.

Mary Iverson Graduate Fellowship

This fellowship was established to support graduate fellowships for students who are pursuing an M.S. or Ph.D. in Geological Sciences and need an additional semester of support to finish writing their thesis or dissertation.

Peter S. and Susan M. Dahl Graduate Fellowship

This gift is used to support graduate fellowships in the Department of Geological Sciences.

Frank D. and Shirley A. Pruett Undergraduate Scholarship

This gift is used to support undergraduate scholarships for students majoring in Geological Sciences and who hold an academic standing of junior or senior status and a grade point average of 3.0 and above.

James Rockford Orgill Endowment

Income from this gift is used to support undergraduate scholarships and/or graduate fellowships in the Department of Geological Sciences. Recipients of the scholarships and fellowships may include full-time IU students attending the IU Judson Mead Geologic Field Station in Montana. Preference will be given to students with demonstrated financial need.

new fellowships & scholarships

Parke Graduate Fellowship in Geological Sciences

The income from this gift is used to support fellowships for graduate students in the Department of Geological Sciences within the College of Arts and Sciences who are entering their final year of study. The fellowships should be awarded to students who are no longer eligible for regular department support but who, in the estimation of the Fellowship Committee, have demonstrated good progress toward degree completion. The fellowship is not renewable.

Norman R. King Graduate Field Research Fellowship

The income from this gift is used to support fellowships for M.S. or Ph.D. students in the Department of Geological Sciences who are conducting field studies in the area of soft-rock geology including stratigraphy, sedimentology, and paleontology. The fellowship may be renewable at the discretion of the Chair of the department.

Sheldon Turner Geological Science Scholarship

Income from this gift is used to support scholarships for undergraduate students in the Department of Geological Sciences. The scholarship may be renewable.

John and A-Lan Reynolds Undergraduate Research Travel Award

The income from this gift is used to support travel awards for undergraduate students to conduct field-based research. Recipients of these awards shall include, but not be limited to, students planning to conduct their research at the Judson Mead Geologic Field Station. The award shall be given to undergraduate students pursuing a major in Geological Sciences with records of academic excellence as demonstrated by a minimum GPA of 3.0 on a 4.0 point scale.

Van Benschoten-Rapoport Scholarship

Income from this gift is used to support undergraduate and graduate scholarships for field study at the Judson Mead Geologic Field Station. The recipients shall be registered at Indiana University and enrolled in field courses offered through the Indiana University Department of Geological Sciences. Preference will be given to students from the State University of New York College at Oneonta who meet the academic guidelines and admission criteria for field study at the Judson Mead Geological Field Station, as defined by the Scholarship Committee. Preference will be given to students who express financial need.

If you would like to donate to any of the funds that support the department, please visit <https://www.myiu.org/one-time-gift> and select your preference from the drop-down list.

department staff

Staff members work in a variety of occupations to enhance the presence and function of the department on campus.

- Pam Christenberry: Administrative and Fiscal Officer.
- Amanda Coats: IUGFS Accounting Associate.
- Megan Divine: Contracts and Grant Accounting Associate.
- Ruth Droppo: Graphic and web design and development.
- Dianne Dupree: Administrative Secretary, Chair's Assistant.
- Tammi Duzan: Graduate Services Coordinator.
- Kristie Flanders: Building Assistant for MSBII.
- John Hettle: Facilities Administrator, Geology Building
- Mary Iverson: Alumni Secretary.
- Erica Kendall: Purchasing and Travel Representative.
- Jian Liu: Geosciences Librarian.
- Terry Stigall: Geophysics Electronics Technician.
- Mark Toensing: IU Geologic Field Station Resident Manager.
- Ben Underwood: Manager, Stable Isotope Research Facility.
- John Walker: IT Technical Specialist.

building updates

Recent improvements to the Geology building include redesign of the first and fifth-floor display cases into museum-quality displays (see right).

This is part of a building-wide restoration of the cabinets that will culminate in a joint project with the IGS as a museum tour of both the Geology and Survey buildings.

Some of the materials in the displays will incorporate AR (augmented reality) software so viewers can use mobile devices to connect with online databases and view more information about the specimens.



donor wall

In October of 2016 we dedicated a Donor Wall to honor our benefactors. The modern wood and Plexiglass structure is installed in the building lobby. It contains the names of people who have made substantial donations to the department and are listed in “Presidents Circle,” “Arbutus Society,” and “Major Gifts” by the University Development Office.

On a separate plaque is written: *Since 1886, the Department of Geological Sciences has successfully carried out its mission of teaching, research and service to both the profession and the community. The continued generosity of our alumni and friends has made this possible. The donor wall recognizes those who have contributed significantly to the Department over the years. We are forever grateful for the legacy of philanthropic support from all of our benefactors.*



2011-2015 Benefactors

Cole Abel & Jean Brown-Abel
Richard & Marsha Adams
Keith Adkins & Yvonne Oropeza
Jeannie L. Alexander
Harry & Deborah Allen
Garry & Janice Anderson
Phillip & Linda Asher
M. D. Babb
Kate H. Baker
Jack & Carolyn Baker
Joseph B. Balta
Lawrence H. Balthasar
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Abhijit & Ilora Basu
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Chusi Li
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Joe J. Litehiser
Xin Liu
Peng Lu & Xiaouu Sun
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Joseph L. Manson

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 Evan R. Zeller

Greg Olyphant

So I retired in July 2014 and now I am able to spend more time in the Sangre de Cristo Mountains of northern New Mexico. The picture of me and Cindi was taken on a trail in the mountains just a 20 minute drive from our house in Las Vegas. I still have the urge to teach so I always stop (with guests) at the outcrop shown in the other picture and it becomes a discussion point concerning the geologic history of the region, as do the



many truncated pediments, stepped canyons, cirques, rock glaciers and moraines we encounter on our drives and hikes in the area.

Of course, many of you know I still have unfinished business with doctoral students as well as papers in development and review. We sold our party house in Hyde Park and bought a nice little place closer to campus (a few houses down the street from Jackson Njau's). Cindi and I currently split our time between Las Vegas and Bloomington, but hope to tilt that balance in favor of New Mexico as time passes. The Las Vegas house is at the foot of the Rockies (very similar, geographically, to Boulder Colorado), so it's a great stopping place for those



heading farther west from the eastern U.S. Our guest house remodeling is almost completed and we hope to see many ex-students and faculty friends who need a free place to stay and reminisce times past in Bloomington and Cardwell, Montana.

Caption for outcrop: *Here we see the vertically oriented Pre-Cambrian metamorphic rocks sharply truncated with horizontal sandstone beds of Cretaceous Age unconformably sitting on top - and we are roughly 2000 ft above the base of the range where it meets the Great Plains sediments of Tertiary Age! How do make all that work?*

Enrique Merino

Enrique Merino traveled in early April 2016 from his base in Madrid to Switzerland to give a set of four lectures at the University of Geneva on "Mineral replacement, metasomatism dynamics, and the blind spot of geochemists."

In October 2016 he will give a summary of those four lectures at the Water-Rock Interaction meeting WRI-15 to be held at Évora, Portugal. He continues exploring the varied, subtle, and unwitting ways in which geochemists and petrologists have missed insights about the kinetics of metasomatism.

emeriti notes

John Hayes

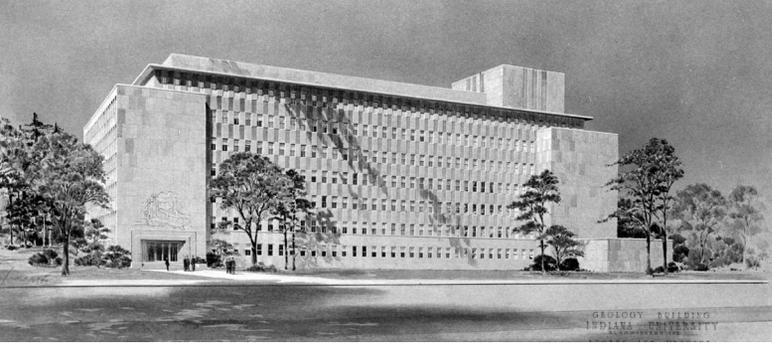
I opened my e-mail this morning and learned that I have been elected as a foreign member of the Royal Society of London. Their system is such that I had to sign a document last fall, agreeing that the information in a nomination was correct (and hilariously amplified), but I never expected that it would succeed.

Steve (Studley), for the millionth time, I thank you. This is all about results obtained in a laboratory, and you know how that happened, as do I.

Erle Kauffman

I am Erle Kauffman, or Professor Emeritus Dr. Erle G. Kauffman, and my chief interest is in Mesozoic paleobiology and ocean-climate supported ecosystems of that time.

My specialty is in Cretaceous Bivalvia (clams), especially *Inoceramidae*, a major clam group of the Jurassic-Cretaceous that lived in the nearshore with all the other molluscan members of shallow-water ecosystems, to deeper, oxygen-restricted ecosystems of which they may have been the sole or dominant member. I LOVE my paleobiology and the interpretations afforded by these fossils, as shown by my lifetime's work of several hundred publications, and the wonderful honor of being the recipient of the 2014 Paleontological Society Medal. Now that I am wheelchair-bound and 83 years of age, special arrangements have to be made, but I still do what I can do, and that's a lot! That's it from Erle. I wish you a successful, happy and profitable life. May you live as long as I have, and still be an optimist about love and life, and you'll be alright.



Left: Architect's rendering of the Geology building, 1961. Middle: Geology building under construction, 1961. Right: Geology building in 2016.

Nityananda Bhattacharya

Nityananda Bhattacharya, born in 1929 and now 86 years old, was a student of professors Thornbury and Droste and received his Ph.D. in 1960. His dissertation was entitled "Weathering products of tills in Indiana". Bhattacharya's son corresponded with Abhijit Basu to establish contact with Droste, who is living in the Bell Trace retirement community in Bloomington. Bhattacharya has photographs of Thornbury and Droste framed and hanging on a wall of his house in Delhi, India (see on the right side).

Charles Wier

An even older alumnus is Charles Eugene Wier, born in 1921. By now he must be around 95 years old. His dissertation was defended in 1955 and was entitled "Correlation of the upper part of Pennsylvanian rocks in Southwestern Indiana". Charles continues to attend social meetings in the IGS and the department.



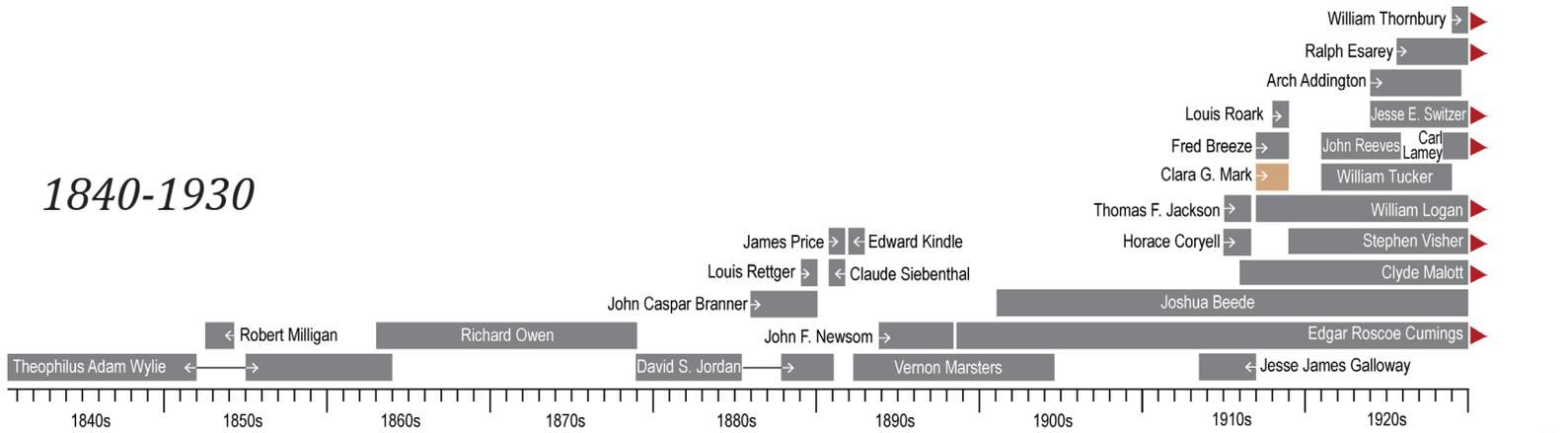
David Jarzen with Bob Dodd and Don Hattin at the Paleontology open house in April, 2016.

alumni news

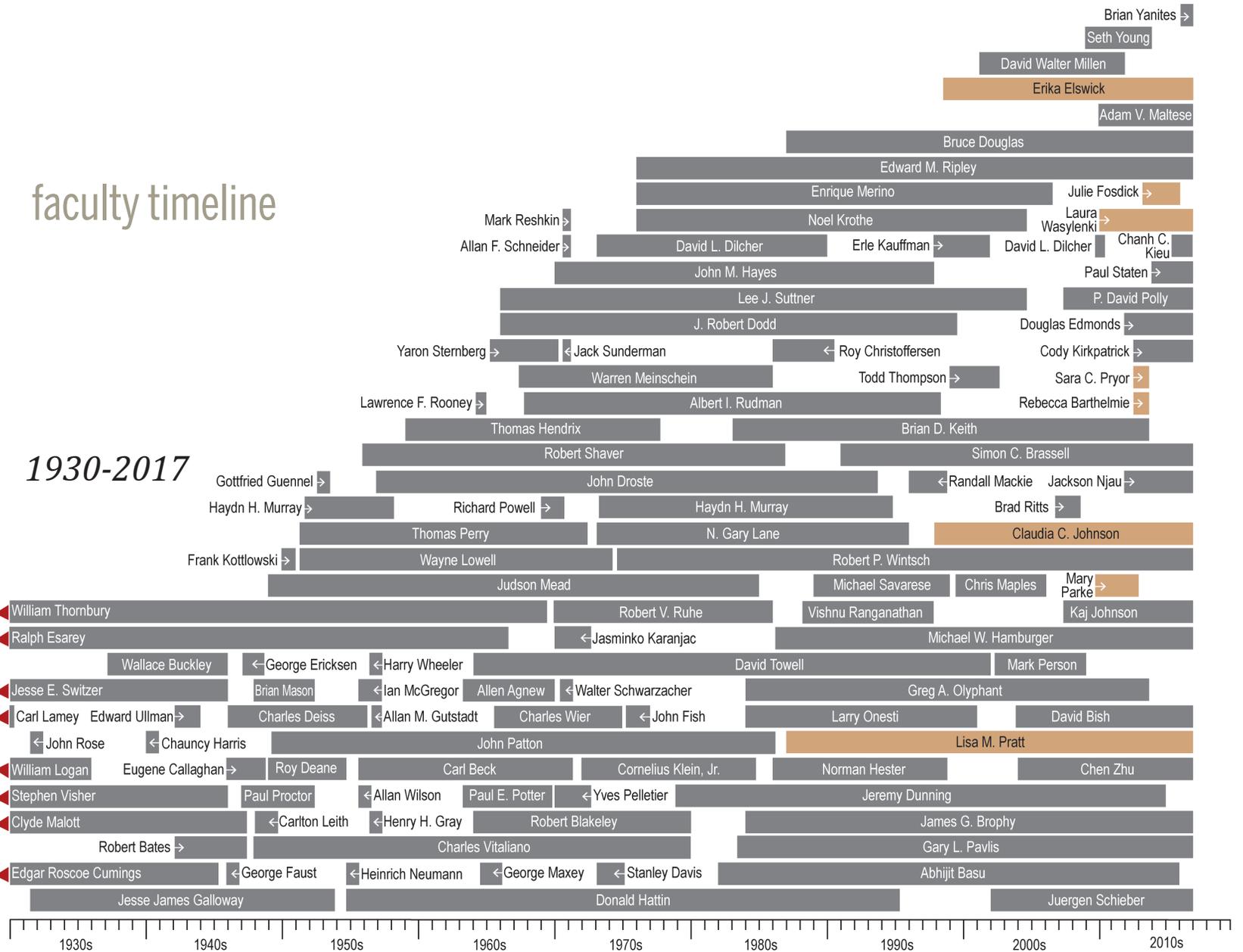
Image: 1980, left to right: Al Archer, Anne O'Connell, Mark Seelen, Chris Foel, Peggy Fisher, Doug Robbins, Marcus Johnson.



1840-1930



faculty timeline





Haydn Murray

Dr. Haydn Murray

Born: August 31, 1924

Died: February 4, 2015

Prof. Haydn H. Murray passed away peacefully on February 4, 2015 in Bloomington, IN. Many of you are familiar with Haydn's varied scientific contributions to applied clay science, and he was one of the few members of our science elected to the National Academy of Engineering in 2003. In addition, he made tremendous contributions to many aspects of Indiana University and was awarded an honorary doctorate in 2004.

Prof. Murray mentored an incredible group of graduate students including 68 M.S. and Ph.D. students, and he served on an additional 60 graduate committees. He was also instrumental in establishing the Grassmann Fellowship for clay mineralogy graduate students and the Haydn Murray Chair of Applied Clay Mineralogy in the Department of Geological Sciences at Indiana University. His presence will be missed in the Indiana University community and in the greater international mineralogical community.

A memorial service was held for Professor Murray on Saturday, February 21 in the Tudor Room at the Indiana Memorial Union 900 E. Seventh St., Bloomington, IN 47405. If you were close to Haydn or the family, Juanita, Haydn's wife of more than 70 years, would be happy to hear from you. Her address is: 901 S. Fieldcrest Ct., Bloomington, IN 47401

Dr. Haydn H. Murray, world renowned geologist and longtime professor of geology at Indiana University, died on February 4, 2015. He was born in Kewanee, Illinois, on August 31, 1924, to Ardis and Herbert Murray. He was preceded in death by his parents and his brother, Winston Murray. He attended a one-room school for eight years and graduated from Toulon High School third in his class. He was the state clarinet high school champion and was a three letter athlete. He dated his high school sweetheart, Juanita Appenheimer, from the first high school dance. He attended the University of Minnesota before leaving to serve in the Army Corps of Engineers. He served in the South Pacific in New Guinea and the Philippines. He and Juanita were married in 1944 and they celebrated their 70th wedding anniversary in December 2014. Upon his return from serving his country, Haydn attended the University of Illinois where he earned his Bachelor's, Master's and Ph.D. in Geology, specializing in Clay Mineralogy. In 1957 he became an associate professor and a clay mineralogist for the Indiana Geological Survey at Indiana University. In 1957 Haydn left Indiana University to enter industry as Director of Research for Georgia Kaolin Company in New Jersey.

At Georgia Kaolin Company Dr. Murray held several positions: Vice President; Chief Operating Officer and finally Executive Vice President. In 1973 when the owner of Georgia Kaolin died and the company was sold, Haydn was asked to return to Indiana University as Chairman of the Geology Department, a position he was happy to accept. He remained at Indiana University until he retired at age 70.

During his time at Indiana University, Dr. Murray received numerous awards, published 170 articles, obtained three patents, wrote the book *Applied Clay Minerals* and was a lead editor of the book *Kaolin Genesis and Utilization*. He consulted for many companies in 54 countries so he and Juanita traveled the world extensively. He was asked by the National Research Council Office of International Affairs to be an expert consultant for U.S. Aid for

International Development Project in Egypt to evaluate bentonite clays. Between 1983 and 1986 he made several trips to Egypt which resulted in a new industry to produce drilling muds and foundry clays for Egypt and other Middle Eastern countries.

At Indiana University Dr. Murray advised 68 graduate students and was a member of 60 thesis committees. He received the Lifetime Achievement Award by Professional Geologists of Indiana, Honorary Doctor of Science Degree from Indiana University in 2004 and the Alumni Achievement Award from the Department of Geology at the University of Illinois in 2004. Other important achievements included President of the Clay Mineral Society, President of the Ceramic Association of New Jersey, Member of the Board of Directors for the University of Illinois Alumni Association, Speaker of the Year at the Indiana Academy of Science, Distinguished Service Award at Indiana University, President of the International Clay Minerals Association, President's Thomas Hart Benton Medal for Distinguished Service to Indiana University, Indiana University Alumni Association Orwig Medal for Distinguished Service to Indiana University Athletics, and an Honorary Doctorate from the Universidad Nacional del Sur. Most notably, Dr. Murray was inducted into the National Academy of Engineers. He was also elected as the faculty representative for athletics to the Big Ten Conference and the NCAA, a position that he enjoyed very much.

During his lifetime, Haydn worked hard, had a great sense of humor and was very considerate of others. His ability to connect with everyone he met or interacted with, from fishing guides, laborers, peers or high level foreign dignitaries resulted in everyone holding him in high esteem. In addition to traveling the world, often with his wife, Juanita, he spent time with his family, enjoying golfing, reunions, card games, reading, fishing and hunting. During the late 1960s until the late 1980s, Haydn and Juanita spent as much time as they were able in St. Croix. In later years he and Juanita spent winters in Bonita Springs, Florida.

Memorial contributions may be made to the Clay Mineral Society, 3635 Concorde Parkway, Suite 500, Chantilly, VA 20151.

Don Hattin



Dr. Donald Hattin

Born: 1928 in Cohasset, MA

Died: June 24, 2016

Dr. Donald E. Hattin, Professor Emeritus of Geology at Indiana University, 87, beloved husband and cherished father, passed away June 24, following an acute cerebral hemorrhage.

The son of Edward Hattin and Una W. Hattin, Don was born in 1928 in Cohasset, Massachusetts, and grew up in the neighboring seaside town of Scituate, where he maintained lifelong friendships. As a boy, Don was never at a loss for something interesting and exciting to do. During his adolescent years in Scituate, he was a very proud and active Eagle Scout, worked at a local produce farm, a small grocery store, and with lobster fishermen. These experiences provided a lifetime of skills and never ending stories. Many of them were retold in his book, *Tales of a New England Boyhood*. While in high school he met and fell head over heels in love with Marjorie Elizabeth Macy, who remained the love of his life. Last summer they celebrated their 65th wedding anniversary by dancing to "Sentimental Journey," "their song" throughout their long and happy marriage.

Don began his college studies in 1946 at the University of Massachusetts, where he soon discovered his love for geology and college high jinks! He graduated with a B.S. degree in 1950, but the highlight of the year was his marriage to Margie. In the fall of that year he and his bride headed west to Lawrence, Kansas, where he studied stratigraphy and paleontology at the University of Kansas, earning a master's degree and Ph.D. in 1954 under the tutelage of his mentor, Raymond C. Moore. During his college years and whenever he was away doing field work, he and Margie shared a loving correspondence. Don relied heavily on these letters while writing his memoir, *Pathway to a Professorship*.

In 1954, Don joined the faculty of Indiana University as an Assistant Professor of Geology. He taught for one year before being called to active duty during the Korean conflict. Serving as a Lieutenant in the US Air Force, Don was assigned to Wright-Patterson Air Force Base in Dayton, Ohio. He was later transferred to the Icing Research Establishment on Mt. Washington, New Hampshire, and eventually attained the rank of Cap-

tain. He returned to Indiana University in 1957. In 1960 he was named Associate Professor of Geology and in 1967 received tenure and became Professor of Geology. He continued teaching at IU until his retirement in 1995. As Professor Emeritus, Don continued to visit his office weekly, collaborated on papers, maintained a "Rock of the Month" display, and enjoyed Friday morning coffee with colleagues.

During his career at Indiana University, Don authored or co-authored over 100 scientific publications on numerous topics ranging widely across his fields of study. His knowledge of chalk deposits in Cretaceous strata around the world led him to be affectionately known as "Dr. Chalk." Don was involved in the naming of a fossil genus and 13 species during his career, and was also extremely honored to have a genus and five species named after him (*Cretalamna hattini*). He was the recipient of numerous teaching awards, but his students will always remember Don for his irrepressible enthusiasm for geology, which he shared in the lecture hall and while leading adventurous and challenging field courses throughout Kansas, Colorado, New Mexico, the Florida Keys, and the Bahamas. Don was especially proud of the establishment of the Donald and Marjorie Hattin Special Field Course Fund. This fund subsidizes students taking non-required geology field courses. This summer, students are utilizing these funds to study in the Great Rift Valley in Tanzania.

Even with his countless professional accomplishments, Don's family was his greatest joy. Family adventures included numerous summer camping trips. Crisscrossing the country, with pop-up camper in tow and a canoe christened "Kwitchurbelyakin" on the car roof, the Hattin family explored most of America's National Parks. Many trips were punctuated with a surprise ride on one of America's historic steam locomotives. A Dad who always had time for his kids, Don created a backyard paradise that included a playhouse with a trap door escape, a pond, large fruit and vegetable gardens, and most memorably, a giant snow-dinosaur, nicknamed "Big Bluey." Beach vacations always featured one of Don's intricate sand castles creatively carved with popsicle sticks.

Don and Margie traveled internationally as well, including a 9-month sabbatical with the family in England in 1969, and a 1985 visiting professorship in East Germany at the Ernst-Moritz-Arndt-Universität in Greifswald, where he and Margie lived for a month, four years prior to the fall of the Berlin Wall. Their frequent travels took them to over 20 countries, and as recently as 2014 they visited Denali National Park and sailed through the Panama Canal.

Don's interests were many and his energy legendary. Don was a 30-year volunteer on the French Lick West Baden and Southern Railroad, where he was the fireman on the steam locomotive #97, which he lovingly helped restore. As an active member of The Indiana Society of Mayflower Descendants and an avid genealogist, Don was extremely proud that both he and Margie were Mayflower descendants. Don was also proud of Margie's Macy ancestry, and published a biography of her grandfather, W. Ferdinand Macy, a notable painter of Nantucket seascapes.

Don's incredible zest for life touched all who knew him, from his favorite bank tellers and waiters, whose names he always knew, to the legions of former students, colleagues, and lifelong friends he leaves behind. It was frequently said that "Don Hattin could make friends with a fence post." He was a role model and mentor to all who knew him—a man whose cup was never half full; it was always overflowing. Don's outlook on life is exemplified by the title of his forthcoming book, *Living the American Dream*.

A celebration of Don's life was held on Saturday, July 23rd, 2016 in the Tudor Room of the IU Memorial Union. Memorial contributions may be made to the Donald and Marjorie Hattin Special Field Course Fund by mailing a check to the Indiana University Foundation, P.O. Box 6460, Indianapolis, Indiana, 46206-6460. The check should be payable to the I.U. Foundation with a note on the memo line indicating that the gift is for the Donald and Marjorie Hattin Special Field Course Fund.

Robert Blakely



Dr. Robert Blakely

Born: April 1, 1921

Died: September 15, 2016

Robert F. Blakely, 95, died at Landmark of Baton Rouge on September 15, 2016. Blakely was born on April 1, 1921 in Newark, New Jersey. After serving in the Army Air Force in World War 2, Blakely returned to Miami University in Oxford, Ohio, where he taught physics while earning his masters degree.

In 1949, he went to work in the Geophysics section of the Department of Geological Sciences at Indiana University in Bloomington, Indiana, where he worked for his entire career, earning his PhD degree in Geology and teaching meteorology, seismology, geophysics, and geology. He retired in 1986.

He and his wife travelled extensively throughout the United States and around the world, and he always was eager to see new places and learn new things. He never met a stranger and he loved life. In 2010, he and Rosanna moved to Baton Rouge to be close to their daughter, Linda. In accordance with his wishes, Blakely will be cremated. Burial will be in the New Antioch Cemetery, New Antioch, Ohio

Michael Hamburger noted that "it is with great sadness that I share the news of the death of a long-time friend and colleague, Robert (Bob) Blakely, who passed away September 21st at his home in Baton Rouge at the age of 95. Bob was a highly talented geophysicist who worked both with the Department of Geological Sciences and the Indiana Geological Survey from 1949 through his retirement in 1986. His broad research and teaching interests ranged from applied geophysics to earthquake hazards to potential fields and meteorology. He worked closely with geophysics faculty Al Rudman and Judson Mead on problems of mid-continent basement geophysics and was a mentor to me and Gary Pavlis early on in our careers at IU. Bob was a delightful colleague and friend, and he will be greatly missed."

Enrique Merino emphasized that Bob Blakely also "was critically helpful to me and Bob Wintsch in solving for the "speciation" of experimental high-temperature aqueous solutions. The speciation required solving systems of nonlinear algebraic equations with many unknowns, and investigating the Monte-Carlo propagation of errors through them. He was very clever and very kind."

Joann Dodd



From Bob Dodd: Most of the active faculty, except the "old timers" did not know Joann Dodd, who died on April 6 of viral encephalitis. But many former students will remember Joann. Perhaps they will recall the times when we had seminars at our house. Joann would bring down a tray of goodies, either at "half time" or after we had finished. She was always careful to make one of her special recipes (she was a very good

cook). Many former faculty members and grad students will recall parties on our lawn (or sometimes in our wonderful mid-century modern home where we lived for some 46 years).

Joann always recalled with embarrassment the time when Don Hattin raised his plate after eating a piece of her delicious cheese cake saying "more, more." She had already served all of the cake and could not comply with his request.

Don and Marge and their children traveled together or met at exotic places across the country. Perhaps the most memorable time was on Mt. Rainier when they admired the many wild flowers peaking up through the snow. Joann was one of the last from the "old school" who did not get a job after putting her husband through college at Caltech.

She devoted the rest of her life to raising her sons and doing volunteer work. She especially worked with the Red Cross (now Hoosier Hills Food Bank book sale) for every year it existed except the first. For many years it has been located in the large commercial building at the county fair grounds. You may have seen her selling "Cougar ears" for the band boosters at Bloomington North High School where our two sons were active in the Jazz Band. The money raised helped send them on tours. What wonderful memories of a wonderful lady!

Virginia Suttner



Virginia (Ginny) L. Suttner

Born: April 27, 1944

Died: July 7, 2016

Like so many alumni of Indiana University, Ginny Suttner fell in love with Montana's Tobacco Root Mountains on her very first visit to the Judson Mead Geologic Field Station. It was the summer of 1967. She was accompanied by Mrs. Judson Mead. Together they had flown out with Ginny and Lee's 14 month-old daughter, Jennifer, and one-week old son, Jim. Because the Suttner family had doubled in size by the following June, Ginny did not return that summer. But never again did she miss spending part of the summer in what she fondly called "Montana's magical mountain setting".

Ginny was diagnosed with acute myeloid leukemia in June, 2015, just days before she and Lee celebrated their 50th wedding anniversary. She ultimately lost her battle with leukemia on July 7, 2016, just 10 days after returning from her last visit to Montana. She and Lee were building a vacation home for their children and grandchildren west of McAlistler. Although the home was not yet completed, the entire family was able to stay there for a few days before pneumonia accelerated Ginny's passing. She and Lee had to return early from their last family vacation together.

In addition to being a wonderful mother to four children and grandmother to eleven, Ginny had a most successful career in teaching, elementary-education administration, and as an educational consultant for the Indianapolis Archdiocese. But she often said (not always jokingly) that one of her greatest challenges was trying to control Lee's behavior at Indiana University sporting events. She was a huge fan of any game being played by a team wearing Indiana University jerseys.

Ginny's life was celebrated at St. Charles Borromeo Catholic Church, 2222 E. Third St, Bloomington on Saturday, August 13. The Funeral Mass was conducted by Fr. Michael Keucher, who she taught in first grade.

In lieu of flowers, the family requests memorial contributions be made to the Virginia L. Suttner Legacy Fund at St. Charles School. Checks should be made out to St. Charles School with the fund designated on the memo line. They should be sent to St. Charles School, 2224 E. Third St., Bloomington, IN, 47401. Memorial contributions also can be made online at <http://conta.cc/2a3yeBd>.



Link to Virginia Suttner's obituary

hello alumni!

(we'd love to hear from you)

Are you an alumnus of the Department of Geological Sciences? Would you like to update your contact information?

If so, please click on this link  to our online form and send us some stories about your life.



Indiana University College of Arts + Sciences
2016-2017 Alumni Newsletter
of the
Department of Geological Sciences

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