GEOSCIENCE NEWS

for alumni and friends of the
Department of Geological Sciences
The University of Michigan, Ann Arbor, Michigan

July 1996

Lake Nyos, Cameroon

"Limnic Eruptions" of carbon dioxide from Lake Nyos explained by Youxue Zhang. (Photo by G. Kling)

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In this Issue:

Greetings from the Chair

Dear Friends of the Department,

We have had an active winter and spring season in Ann Arbor. The written report of our external review committee was submitted to the College of LS&A at the end of last year. The review committee found us to be a department in excellent health and one that has improved markedly over the past decade. The committee was impressed by the wide range of research and teaching efforts and by the collegiality of atmosphere. They particularly noted the sophisticated nature of the department's geochemical and isotopic analytical laboratories which, they said, put us in the forefront of all U.S. academic institutions in this area. We were urged not to rest on our laurels but to begin planning for the next decade in terms of what kind of a department we want to be at the end of the faculty turnover that will occur at the start of the next century. In fact, we have already started on this effort.

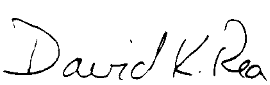
Last March the magazine *U.S. News and World Report* published its latest rankings of graduate programs around the country. We were delighted to find Michigan ranked fifth among all geology departments. In the different specialties *USN&WR* found us to be second in geochemistry, fourth in paleontology and third in sedimentology-stratigraphy. As programs are judged by results, and the generosity of our alumni/ae enable us to do many small and not so small things for our students to make our program better, the praise from *USN&WR* is for all Michigan geologists, not just those now in Ann Arbor.

In news from and about C.C. Little, the renovations continue. This summer it is the third floor that is getting most attention from the contractors. About 25 people including five faculty have been moved to temporary quarters, mostly on the second floor, while the third floor offices are remodeled and air conditioned. We hope that the third floor work will be finished early in the fall. Renovation of some of the former biology teaching laboratories on the second floor to make them suitable for our introductory level teaching labs is also scheduled for this summer.

This past year the department has searched for a new geophysicist to replace Kenji Satake. The search committee, chaired by Rob Van der Voo, received applications from about 80 people. The quality of the applicant pool was remarkably strong. We interviewed six candidates and ultimately selected Dr. Peter van Keken as our choice. Peter has been in our department for two years filling a temporary geophysics replacement position. During that time he has developed a strong teaching record along with his exciting research efforts in mantle dynamics. We are looking forward to having him as a member of our tenure-track faculty.

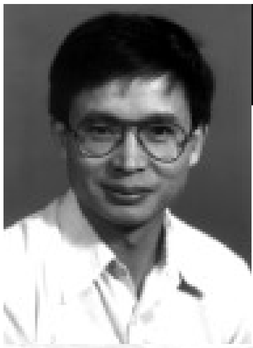
This fall the Geological Society of America meeting returns to Denver. As always, the Department has reserved a hospitality room for the Monday night reception for all of our alumni/ae and friends. I hope to see you there. Remember also that if your travels bring you in this direction we are always happy to have friends of the department drop in for a visit.

Sincerely,



David K. Rea
Chair

Cracking the Killer Lakes of Cameroon



Youxue Zhang describes advances in our understanding of Lake Nyos shown below after the 1988 disaster. (Photo by G. Kling)

Gas-driven eruptions are powerful, destructive, and not uncommon. The more familiar type is the violent volcanic eruptions powered by the exsolution of H_2O gas initially dissolved in magma, including the 1991 eruption of Pinatubo that devastated Clark Air Force Base in the Philippines, the 1980 eruption of Mt. St. Helens that killed 57 people and reduced the height of the volcano by 400 meters, and the 79 AD eruption of Vesuvius that buried the Roman City of Pompeii.

Limnic Eruptions

A new type of eruption has been recently recognized. On the evening of August 21, 1986, a massive CO_2-rich cloud, released from Lake Nyos in Cameroon (above), swept down the valleys and brought devastation to a densely populated area. The death toll was estimated to be more than 1700. Cattle and animals, some of them at hills 120 meters above the lake surface, were also killed but vegetation was largely unaffected. A similar though smaller event occurred at Lake Monoun (also in Cameroon) on August 15, 1984, killing about 40 people. In the aftermath of the Lake Nyos disaster, many countries not only offered humanitarian assistance, but also sent teams of scientists to investigate the cause of the disaster. The Cameroon Ministry of Higher Education and Scientific Research organized a conference in Yaoundé (the capital of Cameroon) in March 1987 on the cause of the Lake Nyos disaster. Two hypotheses emerged from the conference about the origin of the massive CO_2 gas releases. One can be referred to as the volcanic hypothesis. The other as the limnic hypothesis. Scientists advancing the volcanic hypothesis cited the violent and localized nature of the process plus some other anecdotal evidence regarding smell of the gas, color of the lake, etc. However, a survey of the lake and surroundings failed to discover fresh volcanic rock, a volcanic vent or disturbed sediments. In the limnic hypothesis, the process was often referred to as a lake overturn. In retrospect, the choice of the term "lake overturn" probably hindered the acceptance of this hypothesis because many people have the notion that a lake overturn is nonviolent and is whole-lake-wide. In the Yaoundé Conference, a group of French scientists led by J.C. Sabroux coined the term "limnic eruption" to describe the internal lake process that released massive amount of CO_2 gas. The limnic hypothesis was based on both the high concentrations of CO_2 in deep lake water and the absence of clear evidence for a volcanic eruption. The limnic hypothesis gradually evolved to provide a clear picture for the process. In the context of the hypothesis as it now stands, the gas release was due to the degassing of lake water that was nearly saturated with CO_2 prior to the initiation of the eruption. If this hypothesis is correct, similar events can be prevented in the future by controlled degassing of lake bottom water. If the volcanic eruption hypothesis is correct, similar events cannot be prevented. Therefore, the resolution of the scientific argument has direct socioeconomic consequences on how to prevent (or whether it is possible to prevent) such events in the future. Considerable progress has been made since the Yaoundé Conference in both monitoring lake-water composition (especially the gas concentrations) and in the theoretical understanding of CO_2-driven lake eruptions. Most workers now agree that the CO_2 gas releases

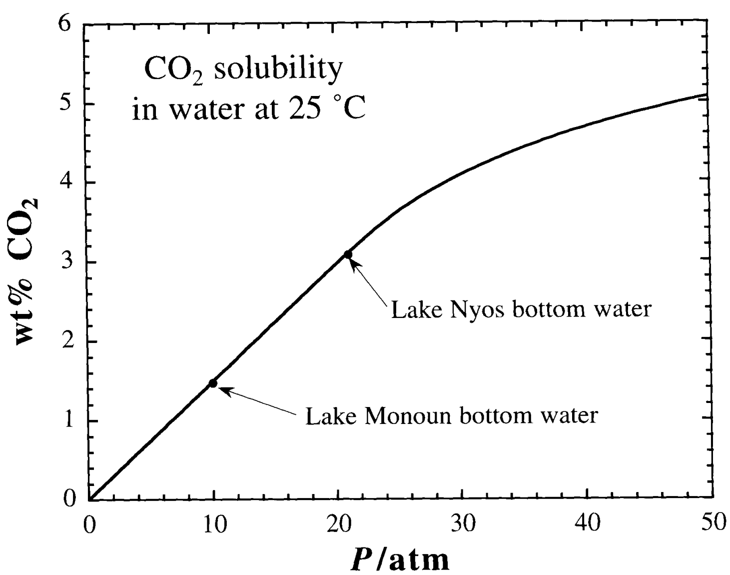


Figure 2. Solubility of CO_2 in water as a function of pressure at 22 °C. The pressure of Lake Nyos and Lake Monoun bottom water and the CO_2 content at saturation are indicated.

represent water eruptions due to the rapid exsolution of CO_2 gas bubbles from a supersaturated CO_2aqueous solution. Plans to pump out and degas lake bottom water are being carried out.

Solubility of CO_2 in Cameroon Lakes

The solubility of CO_2 in water has been studied experimentally and is well known. It increases with increasing pressure and decreases with increasing temperature. At 25 °C (77 °F), the solubility of CO_2 in water is 0.15 wt% at one atmosphere pressure. But at 21 atmospheres it is 3.0 wt% as shown in Figure 2. This roughly corresponds to the conditions at the bottom of Lake Nyos. If the amount of CO_2 which is dissolved in water is more than the solubility at the given pressure, CO_2 exsolves from the water to form a gas phase, creating bubbles. A research team led by Dr. **George W. Kling** of the University of Michigan (Department of Biology) monitored the change of the water composition of Lakes Nyos and Monoun since the 1986 eruption. Both lakes contain high concentrations of dissolved CO_2 which increases with depth and time (Figure 3). The increase is inferred to be due to leakage of CO_2 into the lake from below, probably a magmatic source along the Cameroon line (a 1600 km long volcanic chain). At the present rate of CO_2 concentration increase, saturation of CO_2 at lake bottom could be reached on a time scale of 8 years for Lake Monoun and 30 years for Lake Nyos. Water with dissolved CO_2 is denser than pure water. Therefore, before saturation, the lake is stable and is stratified. However, as the CO_2 increases, the water at the lake bottom becomes increasingly unstable. A small perturbation due to a landslide, sinking of cold rain water, an internal wave, a small volcanic injection, or a heavy flood of water might move the water up sufficiently to reach oversaturation (partial pressure of CO_2 is greater than the hydrostatic pressure).

Once a part of the lake water becomes oversaturated, disaster strikes. CO_2 gas exsolves through bubble nucleation and growth. The volume of the bubbly system expands. The bubbly water is less dense than the surrounding water and rises. As it rises, the surrounding pressure becomes less, and more bubbles grow. The density decreases further and the bubbly water rises with increasing speed. Therefore, there is a strong positive-feedback element to this process. As the vesicularity of the bubbly water increases to a threshold (roughly 70%), the water film on the bubble walls ruptures and the flow fragments into a gas flow carrying water droplets. As the flow exits the surface, the larger droplets rain down near the eruption vent and the finer droplets are carried further away. The exact location of the eruption conduit (or conduits) depends on the nature of the trigger. Once an eruption conduit forms, it can sustain itself by drawing more saturated water into it through suction. Therefore CO_2-driven lake eruptions are expected to be localized.

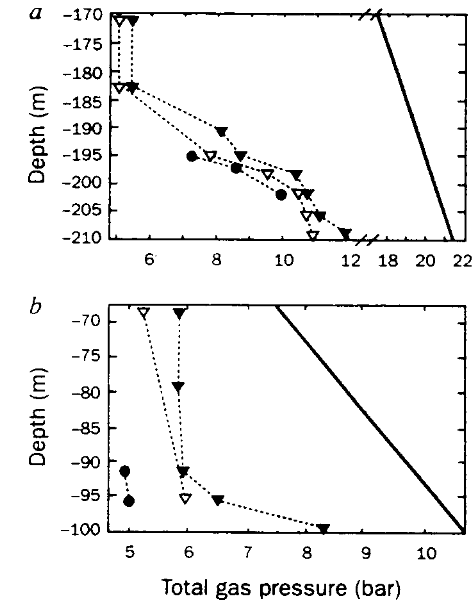


Figure 3. Total gas pressure (largely due to dissolved CO_2) measured in situ by probe in Lake Nyos (a) and Lake Monoun (b). The heavy solid line to the right represent the hydrostatic pressure. When gas pressure exceeds the hydrostatic pressure, the water is oversaturated with the gas. The measurements were made during three periods. Filled circles: December 1989; open triangles, September 1990; filled triangles: March 1992. (Kling et al., 1994)

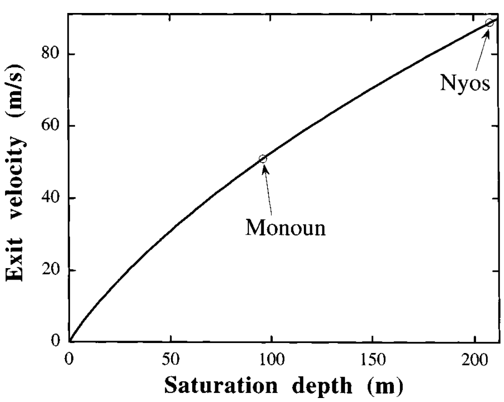


Figure 4. Calculated maximum exit velocity or erupting CO_2-water mixture as a function of initial saturation depth (Zhang, 1996)

New Eruption Simulations

Youxue Zhang and coworkers have pioneered experimental simulations of CO_2-driven water eruptions in the laboratory in so-called Champagne-type (or Coke-type) experiments. The experimental apparatus consists of a test cell that exhausts upward into a tank that can be evacuated. The tank and the test cell are separated by an aluminum foil diaphragm. During an experiment, the test cell is partially filled with CO_2-saturated H_2O (~1.0 wt% CO_2 in water). Rapidly accelerating flow is initiated by cutting the diaphragm with a pneumatically driven knife blade inside the tank. The process is recorded by high speed motion picture photography at up to 4000 frames per second. The films are then examined frame by frame using an analysis movie projector. The basic questions to be addressed are whether limnic eruptions can be violent, and the conditions for and the dynamics of a violent gas-driven eruption (including volcanic and limnic eruptions). The results have provided clear confirmation of the limnic hypothesis.

The CO_2-driven water eruptions are similar to H_2O-driven violent volcanic eruptions in that both are triggered and sustained by the exsolution of a gas component from an initial solution that is roughly saturated with the gas component. Bubble growth plays a critical role in both volcanic and limnic eruptions. The role of buoyancy, however, is different. For a CO_2-driven water eruption through a lake, the flow rises due to buoyancy because the surrounding water can deform and flow into the lower pressure region. For an H_2O-driven volcanic eruption, if the wall rock surrounding the conduit is cold and rigid, the rocks cannot deform on the time scale of an eruption, and the eruption is not due to buoyancy but due to volume expansion.

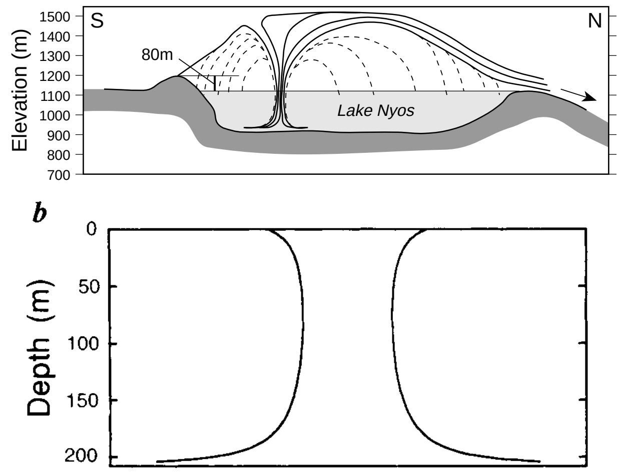


Figure 5. (a) Schematic south-north cross-section of Lake Nyos showing probable movement of gas cloud (solid curves) and water droplets (dashed curves) during a CO_2-driven lake eruption. The trajectory of water droplets depends on their size; larger droplets rain down closer to the conduit. The horizontal scale is the same as the vertical scale. (b) Close-up view of the shape of the idealized erupting conduit, calculated by assuming that the mass flux is constant. The conduit diameter depends on the mass flux into it (hence no horizontal scale is given) and reaches a minimum at a depth of 77 meters. (Zhang, 1996)

Fast Eruptions

With understanding of the physical process gained from experimental studies and from comparison with gas-driven volcanic eruptions, Zhang modeled the dynamics of CO_2-driven lake eruptions. Figure 4 shows the calculated exit velocity of the erupting gas flow carrying water droplets as the flow exits the lake surface as a function of initial saturation depth. For Lake Nyos with a depth of 208 meters, if bottom water was erupted, the exit velocity can reach 90 meters per second (200 miles per hour). At this exit velocity, the erupting cloud can rise to a height of 400 meters if the entrainment of air is ignored, consistent with dead cattle at 120 meters above lake surface. If the initial saturation depth was 96 meters (for Lake Monoun, or for an eruption initiated at mid-depth in Lake Nyos), the maximum exit velocity would be 50 meters per second (110 miles per hour). The erupting column would rise to a height of 130 meters. Because CO_2-rich gas is denser than air, the gas cloud eventually collapses down and becomes a ground-hugging density flow (Figure 5). This CO_2 flow carrying water droplets at ambient temperatures has been termed ambioructic (combination of ambient and eruct) flow by analogy to pyroclastic flow. The density flow is the killing agent for people and animals on its path through asphyxiation.

The Lake Near You?

You may wonder whether the lake next to your home may erupt tomorrow. Four conditions must be met for a violent lake eruption to occur. One is that the lake must be deep. A ten-meter deep lake would not be able to erupt violently. The deeper the lake, the more potential there is for a violent eruption. The second condition is a continuous source of gases supplied to the bottom of the lake so that bottom water gradually becomes supersaturated. The gas supply often comes from escaped volcanic gas from a deep-seated magma chamber. The third is that the gas supplied into the bottom water must have a high solubility. The erupting power is proportional to the solubility coefficient (solubility at a specific pressure). The greater the solubility coefficient, the more violent the eruption can be. The solubility coefficient of CO_2 in water is 45 times that of air. Therefore, energy obtained from the exsolution of air from water will be less than that obtained from the exsolution of CO_2 from water by the appropriate factor. The fourth is that the gas must accumulate at the lake bottom. That is, the surface and bottom water of the lake must not mix every year. Due to seasonal temperature variations, most lakes mix every year due to the sinking of surface water as the surface temperature becomes 4 °C (where pure water reaches its highest density). Therefore, the annual temperature variation must be small for gas-driven lake eruptions. These conditions mean that gas-driven lake eruptions are most likely to occur in deep equatorial lakes near volcanic zones where CO_2 leaks from deep magma chambers into rocks and lakes. Bottom waters from Crater Lake and Lake Tahoe were collected some years ago and no high concentrations of CO_2 found.

Further reading:

Kling G. W., Clark M. A., Compton H. R., Devine J. D., Evans W. C., Humphrey A. M., Koenigsberg E. J., Lockwood J. P., Tuttle M. L., and Wagner G. N. (1987) The 1986 Lake Nyos gas disaster in Cameroon, West Africa. Science 236, 169-175.

Kling G. W., Evans W. C., Tuttle M. L., and Tanyileke G. (1994) Degassing of Lake Nyos. Nature 368, 405-406.

Mader H. M., Zhang Y., Phillips J. C., Sparks R. S. J., Sturtevant B., and Stolper E. M. (1994) Experimental simulations of explosive degassing of magma. Nature 372, 85-888.

Sigvaldason G. E. (1989) International Conference on Lake Nyos Disaster, Yaoundé, Cameroon 16-20 March, 1987: Conclusions and recommendations. J. Volcanol. Geotherm. Res. 39, 97-107.

Tazieff H. (1989) Mechanisms of the Nyos carbon dioxide disaster and of so-called phreatic steam eruptions. J. Volcanol. Geotherm. Res. 39, 10-116.

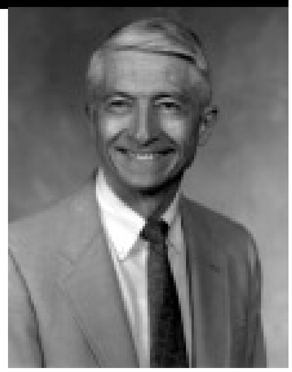
Zhang Y., Sturtevant B., Stolper E. M., and Pyle D. (1992) Gas-powered volcanic eruptions. I. Preliminary results of experimental simulations on initiation of eruption, front advance, and bubble growth. Eos, 73, Fall Meeting Suppl., 628.

Zhang Y. (1996) Dynamics of CO_2-driven lake eruptions. Nature 379, 57-59.

Earl E. Brabb wins GSA History of Geology Division Award

We were pleased to hear that **Earl Brabb** (BS '50, MS '51) has been awarded a medal by the Research Institute for Hydrogeological Protection at an awards ceremony in Perugia, Italy, on November 29th.

Robert H. Dott, Jr. wins GSA History of Geology Division Award



We were delighted to learn that **Bob Dott** (BS '50, MS '51) is the recipient of the GSA History of Geology Division Award. The citation was given by Joanne Bourgeois of the University of Washington. We are grateful to her and the editors of GSA Today for allowing us to reprint portions of the citation here.

Bob has a long and distinguished career both in the geological sciences and in history of the geological sciences, and has earned respect and admiration in both geology and history of science communities. A short summary of his contributions in history of geology includes:

Significant scholarly research in history of geology, including two edited books, some 20 journal articles, and numerous book reviews and editorials;

Outstanding contributions to teaching history of geology, both as a separate subject and within geology courses, particularly through his pioneering and influential text, Evolution of the Earth;

Thoughtful perspectives on the history of science, and on its place in geological and general science education;

Important service to various history of geology organizations.

Bob Dott is the son of an eminent geologist (Robert H. Dott, Sr.), and academic offspring of a renowned stratigrapher, Marshall Kay (Columbia University). Raised in Oklahoma, Bob graduated from the University of Michigan, where he met and married **Nancy Robertson** (BS '51), beginning a strong partnership and a large, scholarly family. The Dotts have also become extended family to many geology graduate students, including a number who are active in history of geology. Bob also served ably as a member of the U-M Geological Science Advisory Board from 1990-1994.

Receiving his Ph.D. in 1955, and after a brief stint in the petroleum industry, Bob began his academic career in 1958 at the University of Wisconsin as a sedimentary geologist. In the mid-1960s he revived the "History of Geological Thought" course taught before him by Stanley A. Tyler and also began research in the history of geology, publishing his first paper in the field, on James Hutton, in 1969. He has maintained strong ties with history of science faculty at Wisconsin, in particular with Robert Siegfried, with whom he has published work on Humphry Davy.

Bob's research in history of geology has focused on mountain building and on late-19th-century American geology. He has called attention to unique contributions from the American geological community, and to the influence of these ideas in Europe. Several of his papers treat the history of geosynclinal theory in America, as well as other aspects of the history of tectonics, of cratonic studies, and of eustasy. This latter interest led him to organize the highly successful 1990 GSA History of Geology symposium, "The Ups and Downs of Eustasy," the papers from which have been collected in a GSA Special Paper. Throughout this work, Bob has exemplified a non-Whiggish internal historian, bringing critical insight to bear on histories of geological investigations.

Probably Bob's most far-reaching contribution to history of geology is through his undergraduate Earth history text, Evolution of the Earth, published in five editions since 1971 (co-authored with Roger Batten, and most recently with Donald Prothero).

Bob's philosophy of education, also reflected in articles and editorials over the years, is well expressed in the preface to the first edition:

Our experience indicates that students are stimulated greatly by . . . exposure to scientific controversies, occasional spicy personal feuds or an amusing faux pas. The student also needs to become a partner in the endless process of hypothesis testing . . .

The historic elaboration of the development of basic principles for interpreting earth history . . . provides a proxy for the reader's actually recapitulating discoveries and interpretations accomplished by past generations that make up the fabric of geologic principles. Secondly, it helps to make clear that . . . science is a human activity, and that the quest for the understanding of nature is an on-going . . . process in which the reader . . . could participate. Finally, the historical approach reveals the cultural relationships of the science, which are unusually rich in the case of geology.

As a scientist, historian, scholar, and educator, Bob Dott is a worthy recipient of the 1995 GSA History of Geology Division Award.

Frank H.T. Rhodes wins Clark Kerr Award

Frank Rhodes, former Professor in our Department ('68–'77), and renowned for his abilities as a scholar, teacher, and leader in education is the recipient of the Clark Kerr Award of the Academic Senate of the University of California at Berkeley. Frank was Dean of the College of Literature, Science and Arts ('71–'74) and Vice President for Academic Affairs ('76–'77) at the University of Michigan before taking on the Presidency at Cornell University until his retirement last year. The prestigious award, granted in recognition of an "extraordinary and distinguished contribution to the advancement of higher education", has been presented periodically since 1968.

Department is 5th in U.S. News & World Report Nationwide Rankings

Geological Sciences at the University of Michigan ranked 5th in the 1996 nationwide assessment of America's best graduate schools, conducted by *U.S. News & World Report*. This is the second set of rankings of science programs undertaken by *U.S. News*; the first was published in 1993, and in that ranking we were placed 6th. The current assessment also gives sub-group rankings, in which our geochemistry program ranks 2nd, stratigraphy/sedimentary geology 3rd, and paleontology 4th. This strong showing by Geological Sciences gives credence to the report prepared last November by our external review committee, who commented that the Department had once again achieved national prominence. The ranking of Geological Sciences was the highest of all U-M science departments in the *U.S. News* assessment.

Alumni News

1930's

Allen George Ehlers (BS '36) still spends some time as a consulting geologist and stock market consultant. His hobbies are collecting art, travel, and hunting and fishing. On a sad note, his wife passed away in May 1995.

1940's

Harold (Hal) Kaufman (BS '47) writes that his children are all very busy. Son Pieter resumed his world travels and is currently in Bangkok; daughter Nina is in dance Master's Program at UCLA; Anya will start Master's Program in Geriatric Social Work at USC; Lisa and her husband will be owners of a music store in Barrington IL.

Nelson Sullivan (BS '47) is still fishing albacore out of Murro Bay CA.

1950's

William W. Easton (MS '52) and his wife enjoyed three weeks in December on Margarita Island, also known as Nueva Esparta, one of the states of Venezuela. It is located northeast of Caracas and appears to be a product of volcanic action. The Spanish occupied it during the 16th century and many of their old forts and churches are still there. The beaches were outstanding, the food excellent, the scenery wonderful, the climate great, and the people friendly. Bill lives in Manitou Springs, CO.

David G. Hardy (BS '51, MS '52) and **Ann (Tobin) Hardy** (BS '51) are retired and living in Mesa, Arizona, and are enjoying life in a retirement community which affords many opportunities for continuing hobbies. They have traveled to a number of countries, mostly with groups of Michigan Alumni. They hope to join them again this summer on their Swiss-Alpine adventure. It will be their fifth time hiking with them under the leadership of Bob Foreman, the past director of the Michigan Alumni Association.

James O. Bemis (BS '53) writes from Corpus Christi TX that 1995 has been an excellent year. In the spring of '96, he will visit southern Italy, Greece, and part of Turkey.

Chesley Coleman Herndon (MA ’52) has been involved in an intensive exploratory and leasing program in the Antrim/New Albany of northeastern Indiana and southern Indiana for the past five years. Also, he serves as a Regent at the University of Science and Arts of Oklahoma.

Stewart Raynor Wallace (MS ’48, PhD ’53) of Littleton, CO, recently finished a manuscript on the classification of molybdenite stockwork deposits — primarily about the genesis of the climax-type deposits of which there are only four (all in Colorado). He is now busy trying to practice being a real “goof-off,” but he has three more short papers in mind, one of which is about “geo-circular” features.

Arthur Ronald Watts (BS ’57) writes from Flushing MI that he retired from teaching sciences in high school in 1989. He spends his summers in Michigan and winters in San Benito TX. His activities include reading and doing cross-word puzzles, playing bridge brilliantly (HA!), salt and fresh water fishing, and taking care of business (rental properties). Arthur visits his daughters in Traverse City MI (a Pharmaceutical Tech) and Austin TX (an accountant with LBJ business concerns), and his parents in Fort Myers FL.

1960’s

Phil Bjork (BS ’63, PhD ’68) was a leading figure portrayed in the article “Digging the Badlands” which appeared in the April 1996 issue of Natural History magazine. The article described how a family from New York City spent a summer in the South Dakota Badlands, searching for Tertiary fossils under Phil’s tutelage. Phil is a professor at the South Dakota School of Mines in Rapid City, and director of that institute’s Museum of Geology.

1970’s

Gary (BS ’76, MS ’78) and **Lisa Finiol** (BS ’78) would like to announce the birth of Jackson George Finiol, born Dec. 21, 1995, who joins brother Hayden, 6-1/2, and sister Laura, 3-1/2. Lisa is deep into her dissertation research on migmatites in the central Colorado Front Range, helped by the whole family — Hayden can recognize and evaluate migmatite outcrops. They’ve all been enjoying geyser studies on yearly trips to Yellowstone and Tetons.

Howard J. Scherzer (MS ’77) and his wife had a wonderful son, Max, in 1993. Howard has expanded his business (Expand Corp. of New York City) to include western style shirts, vests, and jackets and added about 2,500 accounts. Particularly of note are many stores in geologically interesting areas such as Jackson WY, Aspen CO, Sun Valley, and Livonia, MI (Scott Colburn’s Saddlery).

Gordon Daniel Wood (MS ’73, PhD ’77) drove to San Antonio from his home in Katy, TX, to watch U of M in the Alamo Bowl this winter.

1980’s

Christina Behr-Andres (BS ’84) started a tenure-track position in 1994 at the University of Alaska-Fairbanks in the Civil & Environmental Engineering Dept. (and has a couple of graduate students with BS degrees in geology). She had her second child, Zachary Luke, in November 1995, weighing in at 10 lbs. 3 oz.

The Colorado School of Mines Department of Geology and Geological Engineering has named **Neil F. Hurley** (PhD ’86), former senior geologist with Marathon Oil Company in Littleton CO, as the Charles Boettcher Distinguished Chair in Petroleum Geology. Congratulations Neil!

Michael G. Wiedenbeck (BS ’82) became the manager of the University of New Mexico/Sandia National Laboratory Ion Microprobe Facility in May. He will also serve as senior research scientist in the Institute of Meteoritics, Department of Earth and Planetary Sciences. Wiedenbeck’s recent work at Oak Ridge National Laboratory included a project to design, build, and evaluate a high-precision ion microprobe for light-stable isotopes.

1990’s

John Encarnación (PhD ’94) was in Antarctica from mid-November 1995 to early January 1996 for fieldwork as part of his post-doc work at Byrd Polar Research Center in Columbus, OH. This was his third trip to “the ice.” He is trying to understand the early history of the Ross orogen in the Transantarctic Mountains, as well as shed light on the timing of Ferrar and Karoo flood basalt magmatism and their relationship to the breakup of Gondwanaland. John says he will keep doing research as long as it is enjoyable. He will be taking a tenure-track Assistant Professorship at St. Louis University beginning January 1997 but will continue to be interested in Antarctic geology and will continue to work on his “first love” — ophiolites and the tectonic evolution of the western Pacific region.

Plant Invasions: Which are Significant?

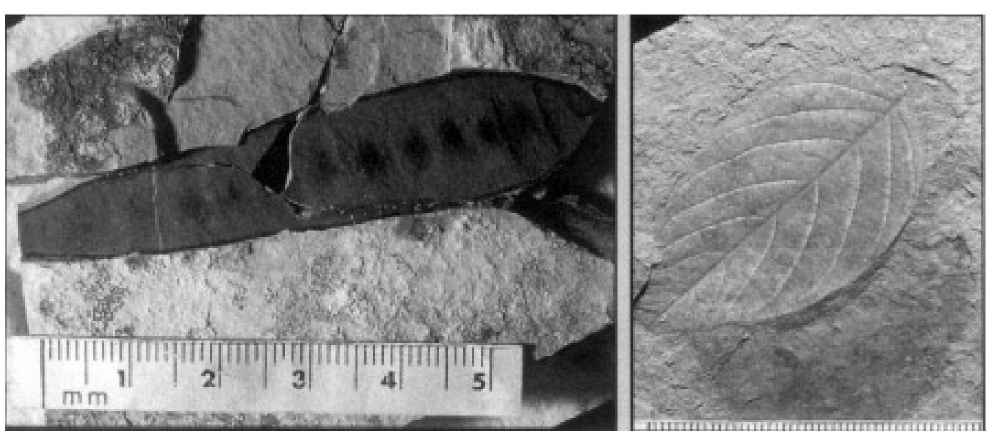
by Robyn J. Burnham
Museum of Paleontology

Yet another exotic plant is sighted in an otherwise "unchanged" natural area. Local naturalists wring their hands and develop management strategies to maintain the species composition as it was when the natural area was established. Are we fighting a losing battle, and should we be fighting this battle at all? Species composition in communities changes over time, whether the time involved is on the order of ten, one hundred, or one million years. Plant communities respond to physical conditions that are not static, and so the communities are not static: they are dynamically changing. If communities are constantly in change, does the designation of a natural area as a specific ecological community to be preserved make sense?

Plant ecologists studying modern ecosystems or paleoecosystems are intent on explaining the processes responsible for the turnover of species. Both public and academic attention has been focused on plant **invasions** as an indicator of floristic change. Why invasions? Probably because the idea of an invasion is exciting, the struggle for existence is embodied in the very word. The implication is that some floristic realm is conquered by competitively superior plants carrying an arsenal of botanical weapons. Today, plants that were resident prior to human occupation are considered "natives" and those that came with or after humans are considered "invasive." This arbitrary cut-off is clearly a barrier to understanding long-term plant compositional change, particularly when the invasions we can observe first-hand are only those predefined as being caused by "bad" or "weedy" species. Still, public attention is focused on plant invasions because the changes appear to be accelerated by human activities.

An invasion can be defined as a hostile take-over of a foreign land by elements not native to that land. We tend to view exotic plant invasions as the conquering of local, relatively fragile species by aggressive species from other states or foreign countries. The hypothesis of invasion via competitive interactions allows an explanation as well as a scapegoat. We simply identify a resource over which the organisms can compete and we have an explanation for the observations. The exotic plant is the root cause of the unpleasant interaction.

A more balanced look at invasions taken by community ecologists in recent years views them as one step of a process that may start with disturbance, loss of species richness, or lack of predators. Perturbations of many types initiate a change in community structure by unraveling the complex biotic interactions in communities. These interactions include mycorrhizal associations, pollination systems, dispersal systems, and other mutualistic associations, as well as herbivory and predation. These interactions likely contribute to ecological locking and possibly even paleoecological incumbency. Once the integration of an ecosystem is weakened by the effect of disturbance, the community is open to replacement of species by exotics that can tolerate the lack of community integration. Invasion is not the result of intrinsic fallibility of the native species occupying the community. Rather, invasion is the result of a number of ecological factors, including chance. It is the response of specific communities to these factors that appears to hold the most promise for future research. Neoecologists articulate well the many avenues that invasions may take, decoupling the link between



What labels a plant an exotic or native? This legume fruit was collected from the Cuenca Basin of Ecuador. (left) The study of a leaf from the Nabon Basin may reveal clues about plant invasions. (right) species replacement and competition. Still, however, explanations for long-term species change can revert to the simplistic view that stronger replaces weaker, ignoring many of the experimental approaches that are being taken. Fusion of paleoecology with experimental approaches on persistence, constancy, and disturbance in plant ecosystems holds promise for interpreting recurring patters in species change over long periods of time. The recurring changes are those that are most logically integrated into management plans.

The relatively dry climate, coupled with the high elevation (about 7,000 feet) in the Nabon Basin of Ecuador, has led to innovative land use.

Appearance and success of new plant taxa need not depend on competitive interactions as an explanation unless interference and one-for-one replacement is documented. A couple of decades of research on tree species composition in eastern United States forests has shown the relationship between climate and species presence to be quite strong. The predator-escape hypothesis also provides a mechanism by which plants can establish successful populations. The absence of a co-evolved predator is proposed to promote the spread of an exotic species in a new area. The link to competitive superiority has not been made in this case. Paleoecological studies suggest that some ecosystems are not species-saturated and thus the spread of new species to island chains or island continents does not require competition between members of communities brought into close proximity.

These arguments do not deny the importance of competition in communities, they only release us from the strict interpretation that an exotic must have "conquered" another species to have been successful in its invasion. The unfortunate tendency to characterize change in paleocommunities in terms of changes in proportions of species draws attention to inverse relationships between species and allows unnecessary leaps to competitive arguments.

Both the characteristics of plant communities and of colonists are critical to the success of invasion and the impact of a successful colonist. Data from fossil plant communities must have the following strengths to address invasions.

First, the **preinvasion** community is well-preserved, allowing detailed documentation. The preinvasion community has been a stumbling block for analysis of the plant macrofossil record at the Cretaceous-Tertiary boundary, where usually only one side or the other of the boundary is represented by macrofossils.

Second, adequate dating of the invasion sequence is important. To correlate biotic changes with climatic or other physical events requires the potential for isolating the sequence of interest temporally.

Third, a record from which paleoecological information can be retrieved is mandatory. The relative importance, life-form, and habitat preferences of each taxon are some of the community-level parameters that should be evaluated in assessing the rate and extent of turnover observed. Paleoecological studies rarely report this level of detail.

Fourth, not only must the community picture be accurate, but the taxonomic composition must be well-resolved. Depending on the scale at which the question if posed, taxonomic resolution provided by a particular plant organ (leaves, pollen, fruits, wood) may be most appropriate.

Finally, an ability to reconstruct the physical events that occurred before, during and after the invasion process is critical. Climate, paleogeography, paleotopography and depositional environment of the ecosystems are all factors that may influence the rate and style of floristic turnover.

Interactions across the Panamanian Isthmus: a test of ecological hypotheses. The emergence of the isthmus of Panama about three million years ago, connecting South and North America, provided paleontologists with an ideal site to evaluate invasions via the fossil record. The efforts of vertebrate paleontologists have established a geochronology for South America that has been refined by magnetostratigraphy and isotopic dating. South America was an island continent during the late Cretaceous and Tertiary. Island chains have been proposed prior to the Pliocene, but few mammals crossed these chains until at least the late Oligocene, when evidence for primates are first found in South America. Until the connection of the two continents in the Pliocene little exchange is documented. Architects of the America Interchange Hypothesis propose that there was a disproportionate exchange of mammalian groups following the emergence of the isthmus during the Pliocene. Many North American mammal species spread south and diversified, while relatively fewer South American mammals spread north. The basis for an interpretation involving competitive replacement has been questioned recently by Elizabeth Vrba. She believes that changing climate, coupled with the geographic positions of South and North America at the time of interchange would encourage a southward migration toward warmer climates by North American natives. The same climatic and geographic conditions would be unlikely to encourage a northward migration by South American natives, who would have to enter areas of cooler climates and less hospitable environmental conditions to do so.

South American mammalian interchange has been the subject of intense scrutiny since the 1940's, yet little or no evidence on plants has been evaluated in light of the same or alternative hypotheses. Habitats occupied by South American fossil mammals have been reconstructed based on dentition and analogy with environments in which modern relatives of the Miocene and Pliocene mammals are found. Pollen records indicate that vegetational change was slow over this period. No large interruptions and relatively few northern invaders are seen in South America until quite late in the Pliocene.

Should we expect the land bridge to have similar effects on plant and animal communities? Were plant communities in South America more invasible than their northern counterparts, as shown by mammalian communities? The most recent review of the taxonomy and floristic composition of Miocene floras of northern South America was completed in 1941 by E. E. Berry, whose contributions to the Tertiary floras of South America are impressive yet stand almost completely alone. Even his reports are based on few specimens from two valleys in southern Ecuador. Recent explorations in the Miocene volcanic valleys of Ecuador have turned up a number of new plant macrofossil localities. These excellent floras are notable for their high quality preservation, potential for ecological reconstruction, and their proximity to well-dated deposits of mammals and invertebrates. These provide the important pre-contact flora that has not been available from northern South America up to this point. If we are to understand the long-term implications of invasions on world floras, we must understand the vegetation that existed before the contact. Recent palynological results on the Amazon Basin have provided a clear view of the taxa present after the contact. We are now closing the loop with paleoecological data from the pre-contact floras.

The above article first appeared in modified form in Geotimes (vol. 40, no. 8, p.16-18) and is reproduced with kind permission of the editors.

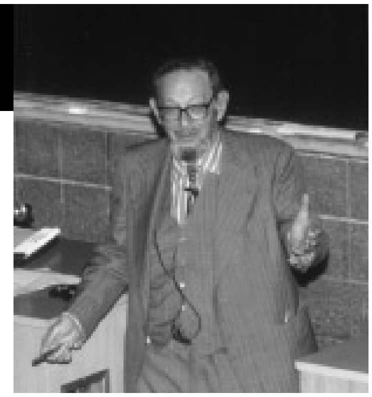
A bit of history: Israel C. Russell

The University of Michigan leads the nation in the volume of federally sponsored research activities, and over the past decade the Department of Geological Sciences has ranked in the top ten Earth Science departments in terms of funding from the National Science Foundation. What may not be so well known is the fact that U-M geology has a long tradition of external funding for research reaching back more than a century. The very first research grant made by the National Geographic Society 106 years ago went to U-M geology professor **Israel C. Russell**. National Geographic had assembled contributions from 27 donors to help finance Russell's expedition to Mt. St. Elias in Alaska, where his team measured glaciers, gathered samples, and made sketches for National Geographic Magazine.

Russell was a respected educator, researcher and explorer, an early student of the geology of the Great Basin, a specialist on glaciers, author of 122 scholarly papers, and of five books aimed at a scientifically educated lay audience. During his career, Russell's research took him from New Zealand to the Antarctic to the Italian Alps, and brought him positions with the pioneering government-sponsored Wheeler Survey of 1878 that examined the geology of the USA west of the 100th meridian, as well as with the USGS Great Basin surveys of 1880-83. It was during the latter that he became acquainted with **Grove Karl Gilbert** who provided guidance for Russell's investigations of glacial lakes of the western states, including Lake Bonneville. However, Russell labored in the Department as the lone Geology professor, for much of that time without even an assistant, and it is safe to say that his productivity must have been somewhat impeded. In 1906 he was elected president of the then still young Geological Society of America. But he was not the first Michigan professor to reach the GSA presidency. Another U-M geologist, **Alexander Winchell**, had already served as the third President of GSA in 1891. Russell's death in 1906 led to the appointment of **William Herbert Hobbs** as his replacement, and thus began a new era in the history of the Department.

This note was prepared by Henry Pollack and Rob Cox, with contributions and insights from Paul Komar (MS '65).

Grand Opening for Extension to RIGL



Jerry Wasserburg explains why the evidence for high initial ^{182}Hf in the early solar system, discovered last year using MC-ICPMS, is critical to models of the supernovae that contributed to the solar nebula.

The Radiogenic Isotope Geochemistry Laboratory celebrated the new extensions to its capabilities with a ceremony on April 22nd. The lab was officially opened by Professor Homer Neal, Vice President for Research and interim President of the University of Michigan, and Professor Edie Goldenberg, the Dean of the College of Literature, Science and Arts (LS&A). To celebrate the occasion Professor Gerald J. Wasserburg gave a lecture entitled "Flavors of supernovae, ^{182}Hf, ^{107}Pd, PGEs and planetary cores with some of the waters". The ceremony was attended by a variety of individuals who visited the Department for the occasion. The mass spectrometry lab, built in 1987, has doubled in size with the creation of a noble gas geochemistry lab and the installation and commissioning of a new kind of instrument - a multiple collector magnetic sector inductively-coupled plasma mass spectrometer (MC-ICPMS). Both areas of mass spectrometry represent exciting new areas of expansion. The noble gas lab is already making He isotopic measurements on mantle-derived samples and crustal fluids. The MC-ICPMS is the first of its kind in North America. The technique has already achieved some important goals by using a prototype housed in the Chemistry Department, while the production instrument was under development and the lab was being constructed. These accomplishments include the measurement of W isotopic compositions in silicates by which the timing of terrestrial core formation may be deduced (published last year in *Nature*) and the first high precision measurements of Sr isotopic compositions *in situ* in a rock sample (published last year in *Earth and Planetary Science Letters*) .

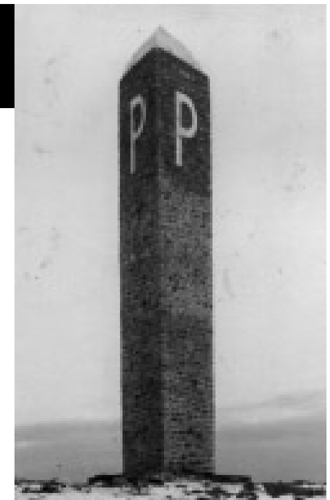
Homer Neal underlines the importance of investment in scientific research.

Funds to pay for the construction of the laboratory extension were provided by the Department and LS&A. The new mass spectrometers were funded by the National Science Foundation, the Department of Energy, the College of Engineering, the College of LS&A, the Office of the Vice President for Research, and the Departments of Geological Sciences and Nuclear Engineering. Additional funds have recently been added by NSF, DOE, NASA and LS&A.

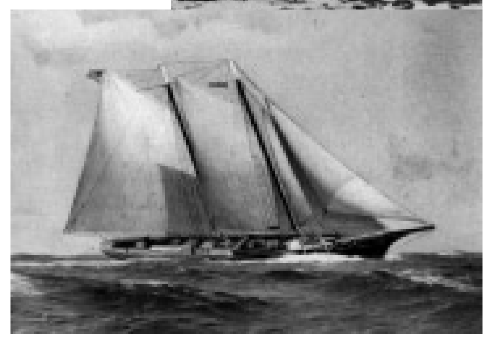
Edie Goldenberg highlights the collective efforts made by so many at Michigan in expanding RIGL.

Alex Halliday explains the principles of MC-ICPMS to visitors.

U-M Greenland Expeditions Recalled



The Department co-hosted a 70th anniversary retrospective of the five U-M expeditions to Greenland spanning the years 1926-1932. The event, held at the Bentley Historical Library on March 28, was conceived by **Catherine Belknap** (AB '29), widow of Prof. **Ralph Belknap** (BS '23, AM '24, SCD '29, faculty until 1961), in honor of her late husband. Prof. Belknap, along with **W. H. Hobbs**, was an organizer of and participant in these expeditions, the purposes of which included installation of a network of meteorological stations in Greenland. In the 1920's and 30's basic high latitude meteorological information was essential to the safe navigation of trans-Atlantic flights between North America and Europe, an endeavor then in its infancy. In addition to Belknap and Hobbs, other notable U-M participants included **William Carlson** (PhD '38) and **Larry Gould** (MA '23, SCD '25, LLD '54), who later joined Admiral Byrd at Little America in Antarctica.



The remembrance began with a short lecture by Prof. **Kacey Lohmann** on the history and purposes of the Greenland expeditions. Dr. **John E. Belknap**, son of Professor and Mrs. Belknap, recounted anecdotes about the expedition vessel, the *Effie M. Morrissey*, and its extraordinary skipper Captain Bob Bartlett. Recollections of the construction of the Admiral Robert E. Peary Monument at Cape York (near Thule in northern Greenland) were provided by Comdr. **Edward Peary Stafford**, grandson of **Admiral Peary**, who as a young teenager had accompanied the expedition to construct the memorial. Closing remarks were given by Catherine Belknap, who on behalf of the Belknap family announced the donation of Ralph Belknap's recently restored dog-sled to the U-M Natural History Museum where it will be on display. The formal program was followed by refreshments and the leisurely perusal of mementos, documents, and items of equipment related to the expeditions.

Comments on Gould, Siple, Byrd and Hobbs

Our tribute to Larry Gould, published in the last issue generated a lot of interest and some comments about William H. Hobbs who was appointed Professor of Geology at U-M in 1906. The following two comments were particularly interesting.

Ruth Siple of the Antarctican Society, who helped us with our article on Gould, writes..."Paul A. Siple was an Antarctic veteran. He went first in 1928-30 as the Boy Scout with Admiral Richard E. Byrd on the First Byrd Antarctic Expedition; in 1933-35 on the Second Byrd Antarctic Expedition; in 1939-41 on the U.S. Antarctic Service Expedition, during which he formulated the wind-chill equation, so he is the "Father of Wind-chill"; and then in 1957 at the South Pole, first time men wintered over at the Pole. He was co-leader with Jack Tuck, U.S. Navy. While Siple was living in Boston the summer and fall of 1939 and before he went on the U.S. Antarctic Service Expedition, Dr. William H. Hobbs (LL.D. '39) had dinner with Siple and his wife and signed their guest book."

James O. Bemis (BS '53) writes about knowing Professor William H. Hobbs slightly back in the late forties, when Hobbs was a very old man. "On a cold and snowy January day students had made a slide on the sidewalk outside of the geology building. Professor Hobbs walked by, stopped and scratched his chin — we were watching from a window — then he walked to one end of the slide, ran a few steps, and slid the entire length of the slide. One of our classmates said, "My God, he"s going to fall and bust his ______." Well, Hobbs kept his balance and did not "bust his ______." When he came into the building, we all clapped our hands and cheered. I'll bet that man, in his younger days, was a real "bear."

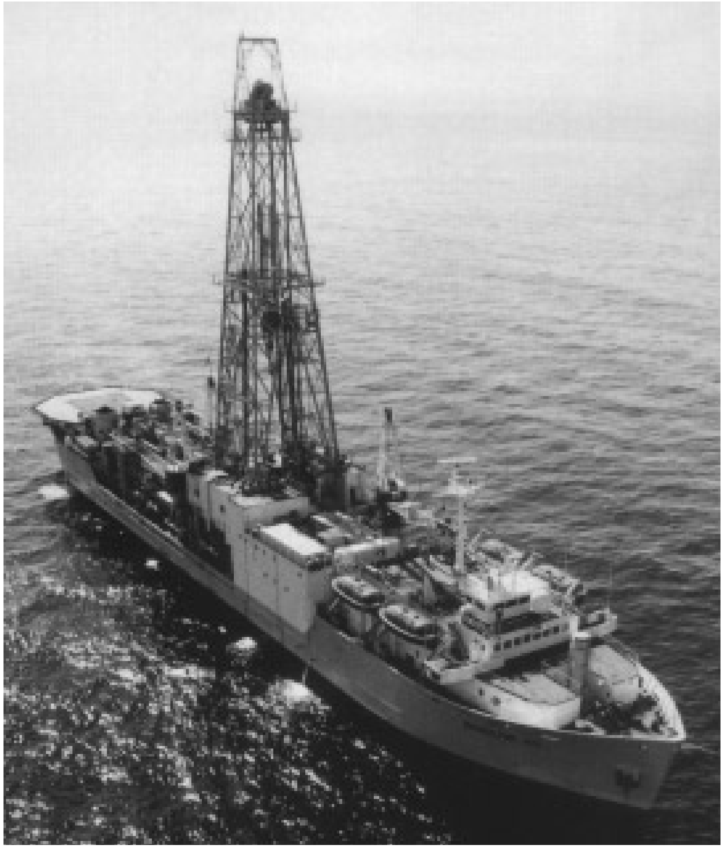
"Survival is a Good Crew"

Damon Teagle recounts the tale of the ill-fated ODP Leg 163
Southeast Greenland Margin
September-October 1995

Early on the morning of the 7th of September, 1995 the Ocean Drilling Program research vessel JOIDES Resolution slipped its berth and proceeded out to sea past the austere sky-line of Reykjavik, Iceland; the angular edifice of the city's cathedral reflecting in the weak northern sunshine. This was the beginning of Leg 163, the second of two 8 week drilling cruises to investigate the causes and mechanisms of continental break-up and the initiation of large ocean basins, by coring the volcanic rifted margin that forms a submerged shelf along the east coast of Greenland. It would prove to be an eventful voyage. Before the end of the cruise, the need for major structural repairs to the drilling equipment would require a return to Reykjavik , and approximately a month later a battered JOIDES Resolution would limp under escort into Halifax Nova Scotia, three weeks before the scheduled termination date.

Leg 163 was planned to be a high profile cruise, following on from the highly successful Leg 152 (Sept-Nov, 1993) which had drilled on a shelf to ocean transect at 63°N on the Southeast Greenland margin. An experienced scientific party had been assembled with most scientists having previous shipboard experience and many being actively involved in field work on Greenland and Iceland. In times of shrinking budgets, a high public profile is essential for the continuation of costly scientific endeavors such as the Ocean Drilling Program. In addition to the normal complement of seamen, technicians and scientists, the sea-going party also included a reporter from the Dallas Morning Star and the ODP publicity coordinator, the latter hoping to acquire footage for a Discovery channel television documentary about the Program.

Volcanic rifted margins are the most common style of divergent margin in the Atlantic and perhaps world-wide. The Southeast Greenland Margin is a type example of a volcanic rifted margin and is characterized by a broad Seaward Dipping Reflector Sequence (SDRS) that onlaps continental (mainly Precambrian) crust to the west and terminates eastwards in oceanic crust of early Tertiary age. The rifted structure of the Southeast Greenland Margin is structurally simple, with a well understood plate kinematic history. Break-up took place within cratonic lithosphere, forming two conjugate margins, Southeast Greenland and the Rockall-Hatton margin. The Leg 163 cruise plan was to occupy a number of sites on two transects at latitudes 63°N and 66°N off Southeast Greenland in order to constrain the magmatic and tectonic processes associated with the rifting of this continental margin, and in particular to assess the impact of the Iceland mantle plume on this break-up and early spreading.



JOIDES Resolution (registered as SEDCO/BP 471) is one of the world's most advanced drilling vessels, and is perhaps the flagship of marine geological research. Built in Halifax, Canada in 1978, the ship previously worked as an oil-exploration vessel before being converted in 1984 for scientific purposes. The sheer size and technological abilities of the ship are impressive; 470 feet in length and 70 feet at the beam, the profile of the ship is dominated by the 202 foot high, centrally-mounted drilling derrick. The hull has been ice-strengthened for operations at high latitudes. Site location during drilling is

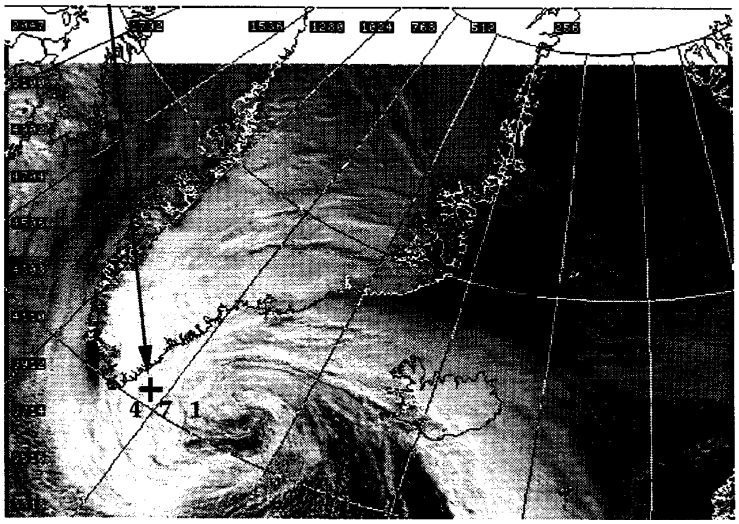
By evening a new forecast from the DMI had upwardly revised their predictions, indicating the development of a full storm

maintained using a computer-controlled dynamic positioning system, supported by 12 powerful thrusters and the two main shafts. This system can keep the ship over a specific location to within 0.1 % of the ocean depth, in waters up to 8000 m deep, making feasible the drilling of deep holes (> 2000 m) into both sediments as well as the basaltic ocean basement. The scientific party normally numbers about 25 and comprises geologists and other specialists from the 19 member countries of the ODP consortium. All tolled, the ship's total complement numbers about 110 to 120.

There was only a short transit from Reykjavik to the first drilling site at 66°N, slightly north of Ammassalik, Greenland and some 30 miles off the coast. It was perhaps ominous that geophyscial site survey and drilling operations were delayed until a large iceberg cleared the location. We were met on-site by the Gadus Atlantica, a small ice support vessel that had been hired for the entire leg to scout for sea ice and to move small pieces of floating ice from the vicinity of the JOIDES Resolution when the ship was drilling. From this site the rugged mountains and glaciers that form the forbidding eastern coastline of Greenland were clearly visible. Icebergs proved to be a constant hazard, in what turns out to be one of the worst years in recorded history for ice, with the currents of the North Atlantic sweeping bergs down from the north along the coast of Greenland through the Denmark Strait. This resulted in numerous interruptions in the drilling operations, while the drill pipe was withdrawn from the hole, and the ship offset from the site to allow the huge icebergs, some over 60 meters high above the waterline and weighing millions of tons, to slowly drift by with majestic arrogance, oblivious and unperturbed by our presence. Even smaller chunks of floating ice, "growlers" (<1 m above sea level and <20 m2) and "bergie bits" (1-5 m above sea level and <300 m2), could have caused major damage to the ship especially to the thruster systems and required constant monitoring day and night.

Iceberg and the Gladus Atlantica off the coast of Greenland.

After only about 30 hours of drilling at the first site and 27 meters of penetration into submerged sub-aerial lavas flows the drill bit became firmly stuck. While working the stuck pipe in an attempt to free the drill string, a joint of pipe some 135 m beneath the rig floor parted. The recoil resulting from the pipe failing under tension caused major damage to the mountings that secure the top drive, the large electric motor that turns the drill string when coring. The whole ship, which had been effectively anchored by the stuck pipe to the seafloor 260 meters below, rebounded from the sea like a 500 foot long cork. The mountings of the top drive are made of 1.5 inch thick hardened steel and were torn apart like paper. Fortunately there were no injuries, and while the drilling equpment was seriously damaged, the 60 ton motor remained more or less in position and didn't hurtle down onto the rig floor and on through the moonpool in the middle of the ship.



Satellite image showing the location of the ship during the storm.

Better to dodge icebergs than fight the storm and drown like rats. . .

The damage was such that operations had to be abandoned and in order to repair the top drive frame we returned to Reykjavik.

The JOIDES Resolution is on long-term lease to the Ocean Drilling Program but is still a commercial venture with maritime and drilling operations the responsibility of SEDCO. Operators in the oil industry can not allow large pieces of hardware to be idle for long and by the time we returned to Reykjavik the damaged equipment was dismantled ready for repair on shore. Within 6 days we were back on site, the most serious damage to ever occur aboard the JOIDES Resolution fixed and recertified, so that operations could continue with only minimal disruptions to the proposed scientific objectives.

Permission for drilling in shallow waters was retracted however, while operational procedures were assessed and until extra equipment that might prevent a repeat of the accident could be ferried to the ship. The ship returned to the coast of Greenland, but to 63°N, to complete the more southerly transect of drill holes that had been started on Leg 152. Inclement weather and ice bergs continued to delay operations and forced the postponement of one site for a slightly more seaward location. These interruptions were frustrating to both the ship's crew as well as the scientific party, especially as when core was being retrieved the recovery rate was exceptionally high for marine hard rock drilling, commonly over 95%. Long, continuous pieces of basalt allowed the description of magmatic structures and quantification of secondary alteration rather than just providing un-oriented samples for the "crush and boil" geochemists to analyze and create innumerable scatter diagrams or spurious correlations.

Drilling operations continued at two sites on the 63°N transect until the 24th of September when conditions developed to storm Force 10, with wind gusts as high as 70 mph and 20-30 foot seas, for 12 hours or so. While trying to secure equipment near the moon-pool a crew member suffered a dislocated shoulder and torn ligaments when hit by a wave which swept across the lower rig deck. The gunwales are only a few meters above the waterline at this point of the ship. A medivac helicopter arrived the next day, in clear, calm conditions and transported the crewman to Ammassalik, Greenland, from where he was flown to Iceland for medical treatment. This incident broke a string of 1368 days without a time-lost accident aboard the JOIDES Resolution .

Aerials, weather stations, and searchlights had been swept away

Forecasts from the Danish Meteorological Institute indicated that gale force conditions were to be expected from the morning of the 29th September through to the 1st of October, with a maximum sustained wind speed of approximately 55 mph. Through the 29th of September, the north-north easterly winds gradually increased and the seas rose to 20 feet. By evening a new forecast from the DMI had upwardly revised their predictions, indicating the development of a full storm, expected to persist for approximately 48 hours. The heavy seas caused drilling operations to be suspended and the drill pipe was pulled from the current hole to 140 m below sealevel until the storm blew over. At this time the ODP technicians secured the numerous computers and analytical equipment to avoid potential damage; the scientific computer networks were shut down in order to divert as much power as possible to the propulsion systems.

Those of us on the night shift felt the weather develop during the early morning of the 30th September. Winds strengthened to over hurricane force, sustained at over 80 mph and gusting to peg the wind-speed indicator at its maximum reading of 100 knots (>115 mph). Seas continued to build to greater than 70 feet, with occasional rogue waves estimated to exceed 100 feet. The ship was pitching 14° and rolling in excess of 18° on a very short frequency. The wave period was very short (8 to 10 seconds) and the ship's stern was coming out of the water with every wave causing the propellers to clear the water and overspeed, raising the fear that the main drive shafts could overheat or suffer bearing failure. 14° pitch doesn't sound extreme but on a 470 foot long ship that translates to a vertical motion of the bow or stern of 115 feet every 8 to 10 seconds. Even in the accommodations/ laboratory stack the vertical motion was probably greater than 60 feet.

Like most of the scientific party I was blissfully unaware of the seriousness of our predicament. . .

A heading was maintained into the storm but even with engines and thrusters running at 120% of rated power the ship was being driven backwards at a rate of 3 to 4 knots, the drilling derrick acting as a huge sail in the strong winds. The coast of Greenland was only 35 miles astern, but the abundance of icebergs in this region made the potential shelter of the Greenland coast a less than agreeable option. Lookouts were lashed to the deck beneath the exposed fantail at the stern of the ship to scout for icebergs that we might overtake during our rearwards progress. The violence of the ship's motions were such that Captain Ed Oonk decided that it was futile to attempt to hold position because of the pounding the ship was enduring. The 12 dynamic positioning thruster units were used to maintain the ship's heading but were being run in the most extreme conditions, far beyond their normal operating tolerances. In particular, it was feared that, should the bow thruster fail, it would be nearly impossible to maintain heading into the storm and the combination of huge waves and the wind beating against the flat edifice of the 7 storey laboratory block would cause the ship to roll over. The power to the main screws was reduced and the ship was allowed to fall back with the storm, while the thrusters were used to maintain heading; better to dodge icebergs than fight the storm and drown like rats. With the decision to give ground to the storm, the vessel's motions became less violent but weather conditions continued to deteriorate. About this time the wind direction changed to a more northerly heading still pushing the ship backwards subparallel to the coast of Greenland rather than back into the iceberg-infested inland waters. High seas (60-70 feet) and hurricane strength winds (> 80 mph) would be maintained for more than 24 hours.

With rapid vertical motions and waves continuously raking the decks of the ship, the members of the scientific party were restricted indoors, in case their overly inquisitive minds compelled them to go stand at the prow and get the full nautical experience! There are no forward looking windows or portholes on the JOIDES Resolution except those on the bridge and the dynamic positioning cabin directly above it. With the crew struggling to keep heading, this was not a good time for social visits to the control centers of the ship. From the library, which is directly below the bridge, one could just about see forward through the side windows, and observe the interminable procession of 60 to 70 foot waves crashing onto the bow of the ship at regular 8 second intervals. It was early afternoon on Saturday, while I was looking out the port window of the library, pretending to research the conditions of formation of various zeolite minerals, that an enormous wave struck the ship. A loud crash made the whole ship shudder and most oddly, water started to pour through the ceiling of the library.

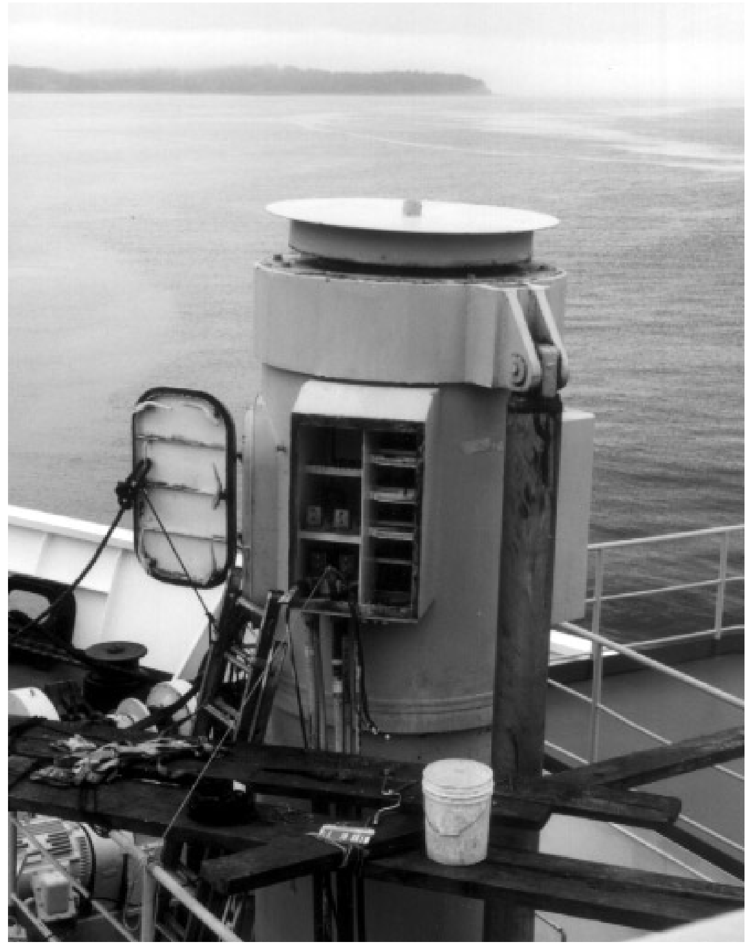
The third mate had been standing at the port side of the bridge as the body of an enormous wave struck the face of the bridge. As the mate dived for cover beneath the radar console, the portmost window caved in and the force of water punched the brass clear-view, that had been mounted in that window, through a bulkhead wall at the rear of the bridge. A large volume of green water entered the bridge, flooding both radar sets and narrowly missing the dynamic positioning computer controls. Had the latter been disabled maintaining heading in these conditions would have required steaming directly into the storm in order to allow the rudders to steer effectively, but greatly increasing the force at which waves were hitting the front of the ship. Aerials, weather stations, and searchlights that had been mounted outside, around and above the bridge had gone, swept away by the wave that had engulfed the ship. Radar and communications systems were now disabled and radio contact with the Gadus Atlantica severed.

After flooding the bridge knee-deep with water, a two foot wave rushed aft down the corridor into the forecastle, dissipating through electrical cableways and air ducts to the decks below. Sleeping technicians and crew were shocked awake by huge volumes of salty water pouring onto their bunks. Startled occupants of darkened cabins staggered sodden into the gangways still trying to evaluate the situation; were we sinking? were we still upright? what the .... was going on? This was a good time to have been awake. The thought of being woken in a pitch black windowless cabin by a torrent of seawater seems terrifying and could just have necessitated a scream or two! Surprisingly people were startled yet remarkably calm. The danger had not passed.

Another colossal wave submerged the ship, dislodging the patch on the bridge window and again flooding the bridge and cabins

With winds gusting at over 100 knots, members of the crew and ODP technicians worked frantically on deck in freezing conditions to patch the broken window and prevent more water entering the bridge

Most oddly, water started to pour through the ceiling of the library


Damage after the storm

and further damaging the equipment essential to the safety of the ship. Time was too short to follow the correct procedures and lash those working outside to the ship. This was truly heroic and selfless action by many members of the crew and their prompt response to this crisis probably saved the lives of the 110 people aboard the ship. Had another wave raked the bridge, those outside would have been crushed by the weight of water and undoubtedly washed overboard into the freezing turbulent sea.

This was perhaps the critical moment of the cruise; the shattered window was patched and held firm and almost imperceptibly the winds began to decrease. The barometer, that had bottomed out at 979 mbar, slowly began to rise. At 10 pm on Saturday night the Chief Engineer was sighted going to bed. This was taken as a good sign that perhaps the worst was over; 12 hours previously he had called the ship's senior personnel to his office and predicted that we would probably have to take to the life boats in less than a hour! Assuming that the lifeboats could have been actually launched, in abandoning the ship in a hurricane in Arctic conditions we would have had a low probability of survival.

Peace was not to be had though. At 2 am on the Sunday, another colossal wave submerged the ship, dislodging the patch on the bridge window and again flooding the bridge and cabins with green water. I was asleep at this time, finally getting some rest after listening to the waves bang the huge anchors against the hull on the outside of my cabin. While some scientists grabbed their survival suits and rushed to find out the situation I merely rolled over and tried to get back to sleep, too exhausted to be concerned any more. Luckily the damage to the navigational equipment was minimal and the situation was soon back under control.


Heading into an eighty-foot wave. (Photo courtesy Ocean Drilling Program)

At 7:20 am on Sunday morning the bow thruster finally failed, joining the majority of the other 12 thrusters that had either flooded or burned out during the storm. The failure of the bow thruster only hours before could have been disastrous, but with the seas reduced to only 40 to 50 feet and the winds abating, it was still possible to maintain control of the ship by using the main screws and the remaining 4 thrusters.

By Sunday afternoon the storm was greatly reduced in strength, but it was apparent the ship was no longer in an operational condition and that Leg 163 would have to be abandoned to allow major repairs. This eliminated Reykjavik as a potential destination and required us to make the long transit to Halifax, Nova Scotia. In the calmer seas, the 140 meter long drillstring that had been hanging beneath the ship through out the storm was finally retrieved and the remaining thrusters were used to bring the ship about to commence the 1900 mile journey to Halifax.

Dartmouth is a port town, and it didn't take too long to find a bar

During the storm the Gadus Atlantica had steamed north and whilst contact with that vessel had been lost she had ridden out the storm in better condition than JOIDES Resolution. As the storm abated she returned to our position to accompany us and provide radar surveillance of the transit path to Canada.

The nature of people's experiences throughout the storm greatly depended on their responsibilities, whether they were seasick or not, and most importantly on how much information they had about the condition of the ship and the dangers we were facing. For me the experience was exhilarating, though like most of the scientific party I was blissfully unaware of the seriousness of our predicament and the extent to which the storm was crippling the ship. Factors concerning the ship's survival were beyond our control, and it was a matter of maintaining faith that the officers and crew of the JOIDES Resolution were capable of handling any emergency. Black humor was bantered around and those of us with more macabre inclinations watched Bob Ballard's "Search for the Titanic" documentary or enjoyed the vicarious distraction from the sound of water gushing along the gangways and decks outside with Arnie in Terminator II (the directors cut!). Some planned elaborate escape routes in case the ship turned turtle and others practised donning their survival suits.

Those of us who could eat dined well on T-bone steaks, or dared any latent queasiness with ham and pea soup. The 18° roll and 14° pitch of the ship meant that only diners over 300 pounds remained sedentary. The rest of us skated around the mess on our chairs, our random paths occasionally returning us to our places so we could stab another mouthful of food from our plates! Others remained in their bunks. One of my roommates was not a good sailor and remained in his bunk for at least 5 days.

Perhaps the most disturbing situation I encountered was actually after the worst of the storm had passed, when there was a power outage in the laboratory stack. After a month at sea, silence suddenly replacing the ambient noise of fans and pumps was quite unnerving; the only sound being the waves outside and the distant ringing of an alarm bell. Most of the scientists slowly congregated in the SEDCO lounge on one of the upper decks, some in their hard hats and lifejackets with their survival suits near to hand. Conversation was stilted and I found myself mindlessly twirling my handlens on a shoelace around my fingers, while we sat through the oppressive quietness.

Resolution docked at Dartmouth harbor in Halifax on the 7th of October, to be met by a host of ODP representatives, eager to debrief the senior personnel and to minimize any possible repercussions from the near disaster. However in their haste somehow the traditional dockside beers for the shipboard party had been forgotten and the proffered packets of M&Ms (small) distributed by the shipping agent seemed vaguely inappropriate. Dartmouth is a port town though, and it didn't take too long to find a bar!

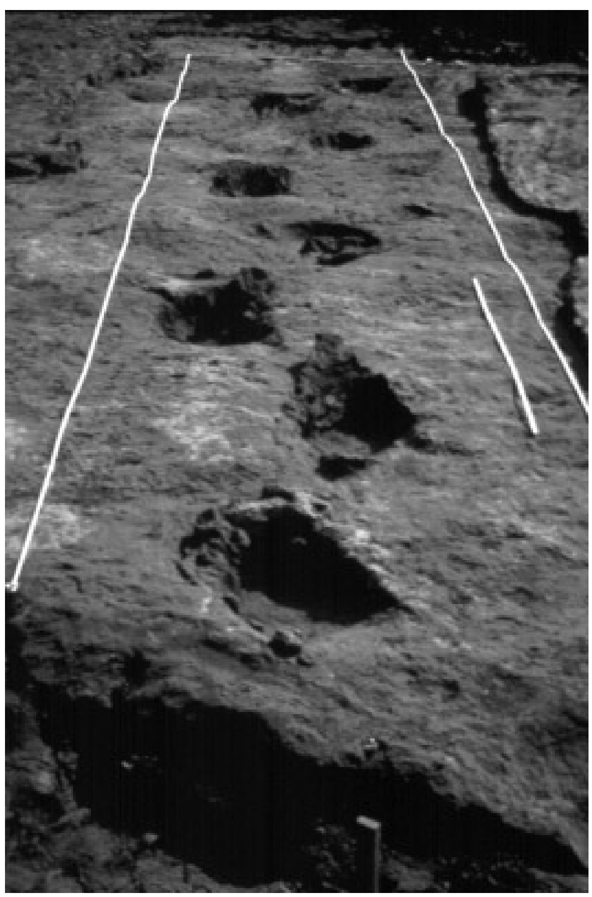
The banner headline of The Mail-Star, the Halifax evening paper, proclaimed "Faith, Heroism pull crew through stormy seas." We had survived and possibly cheated the odds. Halifax is a dour Scottish city; it has a maritime history and is used to tragedy. It was here that the survivors of the Titanic were brought ashore and many of the less fortunate passengers are buried in the town's cemetery. It is also the site of the largest non-atomic man-made explosion, which occurred during the First World War when a munitions ship exploded in the harbor, vaporizing the docks and devastating the downtown killing thousands of civilians. Plaques to these generally forgotten tragedies can be found in Halifax; perhaps there may have been another to record the loss of the Leg 163 party and the end of the Ocean Drilling Program. Those of us who sailed as scientists on that voyage will always be grateful to Captain Ed Oonk, his crew and the ODP technicians whose experience, bravery and calmness during crises undoubtedly saved the ship and returned us all safely to shore.

Damon Teagle is a Research Fellow in the Department of Geological Sciences and is presently researching fluid-rock interaction in mid-ocean ridge hydrothermal systems. He was educated at the University of Otago, New Zealand and Cambridge University, England. He is returning to sea on the JOIDES Resolution in August, 1996 for two months of drilling on the Juan de Fuca Ridge .

Faculty, Research Staff, and Student News

In January **Jeff Alt** and post-doc **Damon Teagle** traveled to Hobart, Tasmania, to attend the post-cruise science meeting for Ocean Drilling Program Leg 158. Jeff was a shipboard scientist on this cruise to drill the TAG hydrothermal mound, an actively forming massive sulfide deposit on the Mid-Atlantic Ridge, and he and Damon are studying the mineralogy and Sr and stable isotope geochemisty of the deposit and stockwork feeder zone. They also participated in a week-long field trip to visit volcanogenic massive sulfide deposits on the west coast of Tasmania, including going underground in two of the mines. Damon took the opportunity to spend some time back home in New Zealand, and after a few days sightseeing in Sydney, Jeff returned to Ann Arbor for a month to get some lab work done before he departed for the Universite Louis Pasteur in Strasbourg, France, where he is currently a Visiting Professor for six months.

Eric Essene again participated with **Sam Mukasa** and other faculty in helping to prepare another NSF proposal for a Cameca 6f SIMS that would be housed in the Electron Microbeam Analytical Laboratory. This machine would offer trace element capabilities in a manner somewhat analogous to those of the electron microprobe, which is limited to major and minor elements. Eric is convinced that the SIMS will be the standard microanalytical tool of the 21st Century for trace elements. Eric's field plans this summer include a trip to the Carthage-Colton line in the NW Adirondacks with **Meg Streepey** (MS student) and **Ben van der Pluijm** to the Wind Rivers Mountains in Wyoming with **Steve Keane** (Msc student), and to komatiite localities of N. Ontario with **Tim Grove** of MIT. Eric would also like to visit kimberlite localities of the Canadian Arctic with **Donggao Zhao** (PhD student) and **Youxue Zhang**, but that may not transpire until next year. **Peter Tropper** (PhD student) continues his research on Alpine eclogites and is currently undertaking experiments on glaucophane stability with **Craig Manning** of UCLA. **Liping Wang** (PhD student) continues research with Eric and Youxue on garnet xenocrysts from Four Corners kimberlites, including work on a new Cr-Ti oxide mineral from this locality with **Roland Rouse** (PhD '72) and **Don Peacor**. **Teri Boundy** (PhD '95) has just submitted the last two of her chapters for publication with Eric and other co-authors, one to EPSL and one to Lithos. **Grigore Simon** (PhD student) and Eric have just submitted a paper on Se fugacities of various selenide ore deposits to Economic Geology. This paper is the logical extension of analogous works on Te fugacities completed in 1988 with **Aboud Afifi** (PhD '90) and **Bill Kelly**. Eric's review paper with Don on the fallacies of clay mineral thermometry finally appeared in the November-December issue of Clays & Clay Minerals (43, 728-745).



Bill Farrand is still avoiding the noise and confusion in the C. C. Little Building by taking refuge in the Exhibit Museum as much as possible. As Museum Director he is giving increasing attention to fundraising in order to mitigate decreasing funding from the College. To this end the Exhibit Museum has recently hired a development officer to seek out donors, large, small, and corporate. (You, too, can become a Friend of the Exhibit Museum, wherever you live!)

This year has also seen lots of activity with the American Quaternary Association (AMQUA), in preparation for its biennial meeting in Flagstaff in May. This meeting marked the end of Bill's presidency of AMQUA, freeing up some of his time, which will, alas, be absorbed by his new role as Chair of the U.S. National Committee for the International Quaternary Association (INQUA). The next INQUA Congress will be in Durban, South Africa, in 1999. Then, perhaps, Bill can retire.

Dan Fisher is pleased to report that the 12-meter long cast of the Brennan mastodon trackways (shown at left) is now installed in a display area overlooking the Hall of Evolution, in the Exhibit Museum. Explanatory materials presenting some of the background and interpretation of the trackways still need to be added, but a large, suspended structure supporting the cast itself is complete. Another new twist on the Pleistocene front is the suggestion, emerging from work on the recently excavated St. Johns mastodon, that Paleoindian meat caching involved not only carcass parts of animals that were hunted in the autumn, but also scavenged heads from mid- to late-winter natural deaths. So why did heads merit such attention? Cached heads that show evidence of utilization all have their braincases opened, and the brain is one of the last and best reservoirs of fat and cholesterol (nutritionally important in cold climates and "brain food" for a developing fetus or young child) in winter-stressed animals. Head scavenging and caching thus secured an important resource, but it also adds to our knowledge of the background of natural mortality, against which the impact of hunting must be evaluated. When not busy probing things that stink, or used to, Dan has been pursuing his interest in use of stratigraphic data in phylogenetic inference. This winter's offering of Geology 622 has focused on such issues, and a number of intriguing projects are now under way. Among others, Lindsey Leighton, Jonathon Bloch, and Mark Uhen are doing interesting case studies on brachiopods, carpolestid primates, and archaeocete whales, respectively; **Brian Bodenbender** and **Will Clyde** are both wrapping up projects with Dan, dealing, respectively, with blastoid echinoderms and a reanalysis of twenty-nine published data sets; and **David Fox** is investigating the relative success of cladistics and stratocladistics at reconstructing relationships generated artificially by a computer model of evolutionary change. This diversification of effort promises to greatly accelerate exploration and development of a role for temporal data.

Alex Halliday and his research group have been very busy over the past few months. There has been a lot of travel associated with presenting the new data from the MC-ICPMS together with the administrative responsibilities for the Geochemical Society, including trips to GSA (New Orleans), AGU (San Francisco), the Todai Symposium (Tokyo) and the Goldschmidt Conference (Heidelberg). It was nice to catch up with some of our U-M postdocs on these occasions, particularly **Shun'ichi Nakai** and **Klaus Mezger**. The MC-ICPMS and the new noble gas lab are generating exciting data and considerable interest from outsiders. There have been plenty of visitors, here for a variety of reasons, including **Don DePaolo** (Berkeley), **Tim Grove** (MIT), **Stan Hart** (Woods Hole), **Munir Humayun** (DTM), **Charlie Langmuir** (LDEO) and **Jerry** and **Naomi Wasserburg** (CalTech). Representatives of the Department of Energy (**Bill Luth** and **Paula Davidson**) and the National Science Foundation (**Russ Kelz**) visited the expanded lab operations in October. **Bill Nash** (Utah) visited on sabbatical for 8 months and deciphered the evolution of the Yellowstone hotspot with neodymium isotopes. **Chris Ballentine**, **Chris Hall** and **Dan Barfod** have been getting the "new" noble gas mass spectrometers up to speed and are now producing excellent He isotope data. **Hailiang Dong** and Chris Hall are now trying to date clays in thin sections with a laser. **Damon Teagle** has been producing a considerable amount of interesting new data for the TAG-hydrothermal field in the Atlantic. **Charlie Jones** is re-immersed in the origins of dust and is desperately trying to finish his work here before taking a faculty position at the University of North Carolina. **John Christensen** has been successfully developing Sr, Pb and Hf isotopic measurements in situ with laser ablation as well as such tricky stuff as dating sulfides and melt inclusions on the side. **Xiaozhong Luo** has been developing new techniques for U-Th disequilibrium dating by MC-ICPMS. One of the major interests of the research group these days is how the core formed, and the manner in which it has since interacted with the mantle. To this end, **Mark Rehkämper** has developed new techniques for the accurate analysis of platinum group elements in small samples. **Wen Yi** is now extending his earlier work on In and Sn to the elements Te and Cd with the most accurate measurements yet made of these elements in geological materials. **Der-Chuen Lee**'s work on Hf-W isotopic chronometry and the timing of terrestrial core formation, published in Nature in December, has generated widespread interest both from the scientists intrested in understanding the early evolution of the Earth and from those concerned with nucleosynthesis. In this respect, the lab opening ceremony with an all encompassing lecture from **Jerry Wasserburg** (entitled "Flavors of supernovae, ^{182}Hf, ^{107}Pd, PGEs and planetary cores with some of the waters") and associated celebrations at the end of April (see article elsewhere in this issue) made an enjoyable and fitting finale to the semester.

After being a postdoctoral research fellow for three years, **Shaopeng Huang** has become an Assistant Research Scientist in the Department. Shaopeng has been working with **Henry Pollack** in the areas of heat flow since he came to the USA from the Institute of Geology of the Chinese Academy of Sciences in Beijing in October 1992. They are working towards the assembly of a Global Database of Borehole Temperatures and Climate Reconstruction. This database project is sponsored by the National Science Foundation. Shaopeng and Henry have set up a special Web page for interested people to contribute their data/ information to the database. The URL address of this WWW page is "**http://www.geo.umich.edu/IHFC/btcr.html**." Shaopeng will be traveling to the Czech Republic in June to attend the 4th International Workshop on Terrestrial Heat Flow and the Structure of the Lithosphere, and to China in August to participate in the 30th International Geological Congress in Beijing.

Since the last Newsletter, **Steve Kesler** has lectured at the Geological Survey of Canada, the Prospectors and Developers meeting in Toronto, the GSA, and the University of Cincinnati. He also visited **Del Harper** of Asarco in Tennessee to go over aspects of Appalachian and mid-continent MVT deposits in preparation for final revision of the Appalachian MVT review paper. The main item on the agenda, however, was preparation for the summer field season, which will involve at least five students. Among those in residence, **Gregory Simon** will be working for Santa Fe Pacific Gold on the geochemistry of micron gold deposits, and **David Borrok** will be working for Pegasus Gold, while looking into the composition of igneous rocks related to gold-rich porphyry copper deposits. In a remarkable coincidence, they will be living in the same motel in

Winnemucca, Nevada, this summer, making field visits much easier for Steve. **Sue Duly** will be back at Copper Mountain and Afton in British Columbia, also working on porphyry copper deposits, and incoming students **Jim St. Marie** and J**ohn Fortuna** will be headed west or south depending on results of negotiations with possible host companies.

Becky Lange and her students, **Jean Tangeman** and **Fred Ochs**, are pleased to be back in their lab after being locked out by the construction crew for two months last summer. Jean has finished a project measuring the configurational heat capacities and viscosities of iron-bearing silicate melts; her long-term goal is to develop a comprehensive model for the viscosity of magmatic melts as a function of temperature and composition. Fred has completed a project in which he determined the partial molar volume of dissolved water in silicate melts (17.9 ± 0.3 cc/mole). Previous estimates in the literature ranged from 0-25 cc/mole. Fred's results are the most precise to date and have major implications for the dynamic behavior of hydrous crustal melts. This study constitutes his Masters thesis, and Fred will be staying on for a Ph.D. degree. Undergraduate **Michael Richey** is also working in the laboratory, continuing a project begun by **Robert Cooper** (who finished his Masters degree last Fall and was co-advised by **Youxue Zhang**) to measure ferric-ferrous equilibria between clinopyroxene and silicate liquids. Our other undergraduate lab assistant, **Laura Foreman**, has completed a study of ferric-ferrous equilibria in iron-bearing potassium silicate melts (to be published) and is currently an intern at the Hawaiian Volcano Observatory. She claims that romping around the Kilauean rift is almost as much fun as working in our lab!

Phil Meyers has been developing collaborative research plans with colleagues in Italy, Germany, and other U.S. institutions to study laminated Pliocene-Pleistocene sediments from the Mediterranean Sea and southern Italy. These sediments evidently record cyclical climate changes in the Mediterranean region that have occurred at 20,000 year intervals since almost 5 million years ago. In anticipation of this initiative, he had participated in Ocean Drilling Program Leg 161 (western Mediterranean) in May and June, 1995, and he met with Italian researchers at the University of Ferrara prior to the cruise.

Phil and PhD candidate **Jim Silliman** attended the 17th International Meeting on Organic Geochemistry in Donastia, Spain, in September to present results of their research. Jim is investigating records of paleoenvironmental change in Great Lakes sediments that have been deposited since the end of the Wisconsin glaciation. Phil presented some of the results from his previous Ocean Drilling Program cruise, one in the eastern Atlantic off the Portugal coast, where turbiditic sedimentation has influenced the degree of organic matter preservation and therefore a whole host of postdepositional geochemical processes.

Phil was a Visiting Professor at Kyoto University, with support from the Japanese Society for the Promotion of Science, for five weeks in the fall. The purpose of his visit was to expand on studies of climate change as recorded in lake sediments deposited over the past half million years. These studies were started during an earlier visit he made in 1990, and their preliminary results encouraged further study. The basis of these studies is that organic matter compositions of lake sediments provide a history of the types and amounts of plants that have lived around and in a lake. Climate changes impact these plant communities and consequently affect the delivery of plant residues to sedimentary records. Part of his visit was to provide a chance to sample new cores that were collected from Lake Biwa, the largest lake in Japan, in late July 1995. These cores provide opportunities to examine sedimentary records from the present to approximately 30,000 years before present, a period during which global climate peaked at maximum glacial conditions and subsequently changed to the relatively warm one that has existed since about 10,000 years ago. Lakes in Japan contain climate records that are particularly suitable for paleoclimate studies because: (1) they provide temperate-zone histories that are uninterrupted by glacial scouring, (2) they contain multiple volcanic ash layers that improve dating of the sediment horizons, and (3) they are close to marine areas, allowing coupling of the lake records of local climate change to oceanic records of global climate change. **Gabrielle Tenzer**, who finished her MS studies with Phil about two years ago, has completed a one-year Sea Grant Internship with U.S. Congressman **Frank Pallone** from New Jersey. She has accepted a full-time staff position with Representative Pallone that started in February. She has been part of his science advisory group, a role in which she has looked into the pros and cons of topics like beach replenishment and tidal marsh preservation.

Don Peacor & Co. were delighted to have several old friends visit to do TEM work on clays this last year. Alum **Ray Coveney** is working with **Gengmei Zhao** on black shales rich in metals, and among lots of other things, they've found a mixed-layered Mo-hydrocarbon compound which has amazing catalytic properties in desulfurization of hydrocarbons. **Wei-Teh Jiang** spent a couple of weeks working on some prograde sequences from China, and **Harue Masuda** had fun looking at clay diagenesis in shales of the Nankai Trench (congratulations to Harue on the recent birth of her daughter). **Dave Wiltschko** was able to spend a couple of weeks, following up on his sabbatical last year when he worked on clays associated with thrust faults, and he shared the TEM with **Dick Merriman** (on a Visiting Professorship) and **Steve Hirons** (from Birkbeck College) who were working on pelites from the British Isles. Those familiar with our old clunkers of X-ray machines will be pleased to hear that we are in the throes of buying a new automated system - a Scintag obtained with the help of **Drew Isaacs**. This is a happy time for graduating students: **Gejing Li** is finishing her PhD thesis on New Zealand pelites, **Vicki Hover** is close to putting finishing touches on her thesis on clay-water interactions (after accepting an Assistant Professor position at Colgate), **Dr. Weixin Xu** defended his thesis on rock magnetism (Weixin and Gejing are going to ASU on postdocs), and

Gengmei Zhao is putting her M.S. thesis together (on retrograde diagenesis). **Weiming Zhou** is getting some exciting results on magnetic oxides in basalt glass, and **Hailiang Dong** continues to unravel the secrets of Ar-Ar isotope systematics of clays - while working on a plethora of other research problems. We hear that **Nei-Che Ho** is doing great things in Bus. Ad. school, but he continues to help with some structure/mineralogy research.

Since his last submission to the Newsletter over a year ago, **Henry Pollack** has completed his four year stint as Chairman of the International Heat Flow Commission (IHFC), a group which operates under the auspices of the International Association of Seismology and Physics of the Earth's Interior. The passing of the gavel took place at the quadrennial meetings of the International Union of Geodesy and Geophysics (IUGG) held in Boulder, Colorado, last July. The new IHFC Chairman is **Vladimir Cermak** of the Czech Republic, with whom Henry and **David Chapman** (PhD '76) of the University of Utah have had a joint research project sponsored by the Czech-USA Cooperative Science Program. At the IUGG meeting, Henry helped organize an interdisciplinary symposium on Climate History and Forcing Over the Past Millennium.

Following the IUGG meetings, **Mike Jones** of the University of Witwatersrand in South Africa came to Ann Arbor for two weeks to analyze his South African borehole temperature profiles for evidence of climate change over the past five centuries or so. Mike's visit was part of Henry's ongoing assembly of a global database of subsurface temperature data to enable climate reconstruction on a worldwide basis. The database project is being managed by Shaopeng Huang, recently promoted to Assistant Research Scientist in the U-M Geothermal Lab, and assisted by undergraduates **Dana Hanselman** and **Rochelle Allen**.

In December, during the holiday break between the Fall and Winter terms, Henry joined the M/S Explorer naturalist and lecturing staff on a journey to the Antarctic Peninsula, with stops in the Falkland Islands, South Georgia, and the South Orkneys en route. The Explorer brings small groups of ecotourists to these extraordinary places, to experience the unique environment, landscape and wildlife. Also aboard the Explorer was **Ralph Eshelman** (PhD '74) who lectured on Antarctic history. Upon returning, Henry squeezed in a quick trip to the United Kingdom, to participate in a Geological Society Discussion Meeting

Scenes from the 1996 Spring Banquet. Top left: Henry Pollack models the latest in Mid-West Spring fashion. Top right: Tim Ku clears the floor. Above: Kelly Fuks, Tim Ku, Luke Walker, and Nate Dietrich impersonate members of Congress threatening to cut the science budget. Below: Professors Van Der Voo, Rea, Meyers, O'Neil, and Moore simulating a construction crew trying to decipher the renovation plans for C.C. Little.

The Aqueous Geochemistry Class (GS478) had a field day in the wetlands of the Huron River behind Lynn Walter's house. Above: Passing beneath the railroad on the way to the raised peat bog and the bank of the Huron River. Below: A core taken by Tim Ku and Nate Dietrich of river bottom sediments.

addressing aspects of continental breakup, and to present lectures at Imperial College and Birkbeck College, both part of the University of London.

Near the end of the winter term, Henry was invited to a meeting of the newly-formed University of Arizona Geosciences Alumni Advisory Board, to share with that group the Michigan experience with an alumni advisory board over the past fifteen years. The Geosciences Department at Arizona is chaired by **Joaquin Ruiz** (PhD '83), who coincidentally also sits on the U-M Alumni Advisory Board. During the weekend in Tucson, Henry also visited with **George Davis** (PhD '71), a former Chair of the Arizona Department and former Vice-President of U-A, and **Sue Beck** (PhD '87), a seismologist on the Arizona faculty. Henry also ran into **Dave Dettman** (MS '91) who has a research position at U-A, **John Chesley** (PhD '93) who is a post-doc there, and **Lois Roe** (MS '90) who is now pursuing a PhD at Arizona. And one great big coincidence was running into **Tom Tinker** (MS '55), a current member of U-M's Alumni Board, who was in Tucson visiting his son, Mark.

David Polly spent the Winter term teaching GS 125 "Evolution and Extinction," supervising two UROP students, and generally working on Eocene carnivores. He also spent a significant part of the semester reading **Mark Uhen**'s massive dissertation on archeocete whales. Now he is trying desperately to finish four manuscripts before getting married later this summer and moving to London. If anyone knows of any jobs there for paleontologists.....

Dave Rea's students continued their research on various aspects of the geologic history of the Earth's marine and continental environments. **Dave Dobson** has gathered annually-delimited proxy data of climate changes, such as tree-ring data, coral growth banding and sediment varving in lakes to examine the past few hundred years of climate variability. Dave is also continuing his work on the sediments of the Ceara Rise in the equatorial Atlantic as both a high-resolution and long term record of the uplift, weathering and erosion of the Amazon drainage basin. **Libby Prueher** continues her work on the detailed stratigraphy of volcanogenic and continentally derived sediment in North Pacific Ocean Drilling Program cores with the intent of refining our understanding of the events surrounding the onset of northern hemisphere glaciation. **Leah Joseph** has assembled an exciting data set consisting of grain size distribution and magnetic fabric information on turbidites from the California continental margin and on drift currents from the continental margin off Carolina and Georgia. She hopes to find a way to identify these and other sedimentary processes by using information that can be obtained from a single sample. **Holly Godsey** has finished her first year of course work and will begin a study of the sediment cores collected by Dave and **Ted Moore** on their 1995 research cruise to the Great Lakes. This summer Holly will be one of the TA's at Camp Davis and is looking forward to that experience.

Structure and Tectonics saw some personnel changes this year, reports **Ben van der Pluijm**. This Winter, **Jay Busch** completed his Ph.D. on Grenville extension along the Robertson Lake shear zone (with **Eric Essene** and **Chris Hall**) and left for a post-doctoral position at Boston University. Not wasting any time in the rapidly evolving workplace, he will move to Exxon in Houston later this Spring. **Meg Streepey** will now carry the Grenville baton and is working on the Carthage-Colton shear zone of the Adirondacks in northern New York. **Liz Meyers**, who worked with **Rob Van der Voo** and Ben on Silurian rocks in the northern Appalachians, accepted a position at the Cranbrook Institute of Bloomfield Hills; only some finishing touches on her thesis remain. Until the arrival of new graduate student **Allen McNamara** this Fall, the Appalachian project is headed by post-doctoral fellow **Conall Mac Niocaill**, who is working on a detailed paleogeographic analysis that is primarily based on paleomagnetic data and faunal provinciality. Meanwhile, **John Harris** is working on his M.S. study of calcite strain in the Hudson Valley fold-and-thrust belt of the Appalachians, where has been able to characterize distinct strain events (he recently presented his results at the NE GSA). Reports on other projects and people in PaSTeL can be found elsewhere. Ben's quest to work with each faculty member of the Department now also includes oceanography (with David Rea) in Leah Joseph's project on the characterization of sedimentary environments in ocean sediments using grain size distributions and anisotropy of magnetic susceptibility.

However, most of the term was filled with teaching-related efforts (both classroom and administrative work). One very satisfying effort was a web publishing project as part of Michigan's First-Year Seminar series. The undergraduate students in the class wrote chapters for an illustrated (cyber)text that starts with the 'Big Bang' and ends with a 'Sustainable Earth.' Check out their wonderful fruits at **http://www.umich.edu/~gs265/cybertext.htm**. With the summer approaching, Ben is planning several fieldtrips and work on a couple of manuscripts from the X-ray goniometry project with **Don Peacor**, as well as preparing for a series of new courses in the Fall (a hands-on environmental class with Lynn Walter and a class on mechanics in Earth and environmental science for graduate students with Richard Nolen-Hoeksema). Not ignoring life's real priorities and neighborhood pressures, Ben has started to teach his kids baseball (some of you will likely shudder at the mere thought), but he promises to move to soccer as soon as possible.

With the arrival of Spring weather, summer travel plans of **Rob Van der Voo** have come into view: two meetings (EGS in the Hague and AGU in Baltimore), two weeks of vacation near Montpellier, France, and a stint of teaching in Geol. 440 at Camp Davis. The plan is to reintroduce some geophysics in that course, notably gravity in Star Valley and magnetics in the mapping exercise at Atlantic City, as used to be done several years ago. The group of paleomagnetism and tectonics people is presenting seven talks at the AGU meeting this year: **Arlo Weil** will talk on the Precambrian Supercontinent Rodinia; **Liz Meyers** on Silurian paleomagnetic studies in Maine and New Brunswick; **Don Cederquist** on two topics, one dealing with fabric and paleomagnetic studies of Pennsylvania rocks, and the other with a Bingham statistical approach to the definition of apparent polar wander paths, **Maria Marcano** is presenting an assessment of true polar wander as a possibility during the Permo-Triassic; postdoc **Conall Mac Niocaill** will present new results from a latest Precambrian suite of red beds and volcanics from coastal New Brunswick, and undergraduate student **Brian Trent** will present results from the Triassic red beds at Red Hills near Jackson, Wyoming. At the EGS meeting, Rob will talk about the results obtained with **Weixin Xu**, who has now graduated with the Ph.D., and with Professor **Donald Peacor**, in studies of the electron microscopy of paleomagnetically relevant materials. Some of the rocks studied by Weixin include ocean-floor basalts of various ages, and we have found that it is likely that the magnetism of the ocean floor decays with age because of alteration of the magnetic carriers to non-magnetic materials in the course of some tens of millions of years. Another project involved the Precambrian Stillwater Complex in Montana in collaboration with **John Geissman** (M.Sc. '76, Ph.D. '80), and allowed us to correlate some secondary magnetizations carried by chromian magnetite in this complex with mineralizing events.

The geodynamically oriented part of the geology department can relish the use of a new instrument as an addition to the increasing computational facilities. **Henry Pollack**, **Peter van Keken**, and **Debra Tjoa** can now, through a gracious donation of **Bruce Wilkinson**, study processes of mass and heat transport using the analogue approach of a genuine, 70's-style lava lamp. Although the rheological and thermodynamical properties are slightly off from what is expected to govern mantle convection and plate tectonics, this tool will no doubt help to establish the quality of the numerical simulation techniques that have been used until now as the preferred research tool.

Jim Walker has been developing computer simulations for use in introductory earth science classes, as well as computer simulations of the structure and composition of Michigan Lakes for use in paleoclimate research.

Lynn Walter and **Joyce Budai** and their research associates (**Anna Martini**, **Tim Ku**, **John Hansen**, **Ted Huston**) have been expanding the Antrim Shale gas project into the southern part of the Michigan basin and into the Illinois basin as additional drilling in these areas has been successful. The Gas Research Institute support for the project ends at the close of 1996, but already some major oil companies have expressed interest in continuing the work. They consider the Michigan Basin as a type section in which to explore the rate of shallow biogenic gas formation.

The Antrim Gas project was also greatly assisted by the generous support of one of Michigan's alumni. With this support, the EAGL lab has acquired a state-of-the-art gas chromatograph for doing rapid and complete gas chemical analyses. Due to the constraints of lab space, additional room is being provided for EAGL activities on the first floor of CC Little.

Research into the geochemistry of carbonate sediments continues as well. Lynn, Anna, Tim, and **Ruth Blake** spent two weeks in the Florida Keys in January sampling sediment pore waters. Tim and Anna are working on the sulfur system and the oxygen isotope composition of sulfate in pore waters. Ruth is working on the phosphate system, exploring interactions between carbonate minerals and the abundant phosphate released during organic matter decay within the sediment.

One of the EAGL members is leaving us to join the faculty at Rutgers University, Newark Campus! **Vicky Hover** landed an excellent start up package to continue her work on aluminosilicate/carbonate diagenesis in coastal sediments in New Jersey. Also, her position is joint with the department of civil and environmental engineering because they noted her significant skills in environment geochemistry and marine pollution studies. She will be defending her dissertation and leaving Ann Arbor in August.

Finally, the Water and Watersheds NSF/EPA Program finally committed firm funding for the Walter/Budai plus Engineering, Biology, and School of Natural Resources interdisciplinary study of carbon flow in the Cheboygan watershed of northern Michigan. We will begin characterizing the hydrogeology and surface/subsurface stratigraphy this summer to plan sampling well emplacement for next spring. **Tim Ku** and **Anna Martini** will be key players in this research effort, with able assistance from **John Hansen** in the field.

1995-96 Undergraduate Research Opportunity Program Activities in the Department

Faculty members of the Department have participated in the Undergraduate Research Opportunity Program (UROP) since its initiation in 1988. A major goal of the program has been to engage beginning students at The University of Michigan in the wealth of research activities of this institution. First-year and second-year students collaborate with faculty members in actual research projects and thereby learn firsthand about the pleasures and perils of research. During the 1995-1996 academic year, 800 students participated in a variety of projects across campus that spanned a wide range of disciplines.

Seven UROP students worked with five faculty members of the Department in the past academic year. **Brian Trent**, a sophomore from Ohio in the College of Engineering, worked with **Rob Van Der Voo**. Brian participated in an ongoing project to study rotations and remagnetizations in Jurassic and Triassic rocks of the Idaho-Wyoming overthrust belt. He will present his results in a poster, “Rotations of Remagnetized Triassic Redbeds in the Gros Venture Range, Wyoming,” at the spring AGU meeting in Baltimore. **David Cohen**, a freshman from New Jersey, and Georgina Hirschler, a sophomore from California, worked on “The Evolution of Early Carnivores: Phylogeny and Variability in Viverravidae (Carnivora, Mammalia)” with **David Polly** in the Museum of Paleontology. These students used measurements of fossil teeth collected in Eocene deposits in the Bighorn Basin to determine the gender and species distributions of these extinct carnivores. **Suzanne Schaefer**, a freshman oceanography major from Michigan, worked with **Ted Moore** and **Dave Rea** on “Lake Level Fluctuations of Lake Michigan.” She integrated seismic profiles with radiocarbon dates of sediment cores to identify the absolute times of latest Pleistocene glacial advances and retreats in the Lake Michigan region. Three students worked with **Phil Meyers**. **Sandra Hong**, a sophomore from Michigan, measured amounts and types of sedimentary organic matter in her study, “Paleoceanography of Mediterranean Sapropel Layers.” The results of her research confirm the theory that periodic freshening of the surface waters of this sea during the Plio-Pleistocene contributed to Sapropel deposition. **Sean Ryan**, from New Jersey, and **Luis Martinez**, from Puerto Rico, are two freshman who worked as a team on “Records of Environmental Change in Freshwater Sediments.” They studied the contents of a sediment core that provides a 5,000-year record of organic matter accumulation in Seneca Lake, New York, and they identified evidence of modern enhanced nutrient delivery to this lake.

The students presented the results of their research in the annual UROP symposium on April 15, which consisted of several hundred poster displays, a few dozen talks, and lots of discussion. Several of the UROP participants from previous years have discovered the attractions of geology and have become concentrators in the Department. One of the most important elements of the program remains, however; exposure of non-science students to real-life research experience.

Degrees Granted

PhD

Theresa Boundy "Metamorphic, Geochronologic and Tectonic Evolution of Deep Crustal Rocks Within the Caledonian Orogen, Western Norway"

Jay Busch "Terrane Accretion and Orogenic Extension Along the Robertson Lake Shear Zone, Grenville Orogen, Canada"

Tracy Frank "Petrographic, Geochemical and Isotopic aspects of Carbonate Diagenesis"

Jean Johnson "Asperity Distribution of Alaskan-Aleutian Earthquakes from Inversion of Tsunami Waveforms"

Cassi Paslick "A Geochemical Study of Volcanism Associated with the Early Stages of Continental Rifting in Northern Tanzania"

William P. Patterson "Stable Isotopic Record of Climatic and Environmental Change in Continental Settings"

Hilde Snoeckx "Late Pleistocene History of Ocean-Atmosphere Interaction in the Eastern Equatorial Pacific"

Yuichiro Tanioka "Seismotectonics of Northern Japan as Inferred from Analysis of Large Earthquakes"

Mark Uhen "Form, Function, and Phylogenetic Relationships of Dorudon atrox (Mammalia, Cetacea) From the Late Middle Eocene of Egypt"

Weixin Xu "Electron Microscopic and Rock Magnetic Studies of Magnetic Minerals in Mafic and Carbonate Rocks"

MS

Jonathan Bloch "Systematics and Cranial Anatomy of Late Paleocene Carpolestes (Mammalia, Proprimates)"

Robert Cooper "Determination of Ferric-Ferrous Equilibria Between Clinopyroxene and Silicate Liquid: A New Technique"

David Fox "Growth Increments in Gomphotherium Tusks and Implications for Miocene Climate Change"

BS

Jason Anderson
Joey Barker
Mark Ferguson
Suzanne Havach
Anne Hellie
Joylyn Keil
Anne Rauscher
Andrew Rieth
Elise Shelton

In Memoriam

John E. Nafe (BS '38), a physicist who originated significant seismological concepts over nearly three decades as a teacher and researcher at Columbia University, died on April 6 at his home in Vancouver, British Columbia. He was 81 and had lived at the university's earth sciences campus in Palisades, N.Y., until his retirement in 1980.

Dr. Nafe was a professor of geophysics who did much of his work sailing the high seas on far-flung cruises, often aboard Columbia's research vessels, the Vema and the Robert D. Conrad. He was the chief scientist on oceanographic voyages from 1951 to 1962 and then served for three years as chairman of the department of geography.

His base was the Lamont-Doherty Earth Observatory in Palisades. In the 1940's and 1950's he and fellow Lamont researchers began to profile the earth"s crust, an effort that opened the way for the tectonic plate theory of continental movement.

In 1958 Dr. Nafe was first in demonstrating that sound waves could girdle the globe through the ocean. With a colleague, Dr. Charles L. Drake, he developed the Nafe-Drake Curve, which relates the speed with which sound travels through rock to the rock's density.

Much of his work at sea employed a technique known as seismic refraction, in which echoes from explosive charges set off in the ocean are monitored at varying distances. The purpose is to gauge the composition of the seafloor crust and the depth to the earth's mantle beneath.

Born in Seattle, Dr. Nafe graduated from the University of Michigan in 1938 and earned an M.S. at Washington University in St. Louis in 1940, and a Ph.D. in physics at Columbia in 1948.

He taught at Columbia and the University of Minnesota early in his career, returning to Columbia as a researcher at its Hudson Laboratories in Dobbs Ferry.

Dr. Nafe is survived by his wife of 55 years, Sarah Underhill Nafe; two daughters, Mary M. Chase of Vancouver, and Katharine E. Kenah of Granville, Ohio, and six grandchildren.

Peter Harker (PhD '51) of Ottawa, Canada, passed away on December 16, 1995. He was employed by the Geological Survey of Canada for 32 years until his retirement. Born in England, he served for six years in the British Army during WWII. He very much enjoyed his time at U-M and kept up with many of his associates and professors.