



# GEOSCIENCE NEWS

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

December 1994



## **C. C. Little Renovation**

*A new mechanical tower in the courtyard extends above the roof of C. C. Little. Renovation of the building will be an ongoing project over the coming years.*

## **In This Issue:**

|   |    |
|---|----|
| Greetings from the Chair .....  | 2  |
| Kenji Satake and Michigan Geophysicists Called in to Evaluate Tsunami Disasters ..... | 3  |
| Two New Faces at Michigan .....   | 4  |
| Awards:   |    |
| James Rogers .....  | 4  |
| Steven Henry .....  | 4  |
| Gabrielle Tenzer .....  | 4  |
| Henry Pollack .....   | 5  |
| Youxue Zhang .....  | 5  |
| Alumni News .....   | 6  |
| Kelly Retirement .....  | 8  |
| Quaternary Paleoclimatology of the Great Lakes .....                                  | 8  |
| Faculty, Research Staff, and Student News .....                                       | 9  |
| Contributors to Geological Sciences Campaign for Michigan .....                       | 10 |
| Degrees Granted .....   | 19 |
| In Memoriam .....   | 19 |

DEPARTMENT OF GEOLOGICAL SCIENCES  
The University of Michigan  
1006 C. C. Little Building  
Ann Arbor, MI 48109-1063

First Class

Address Correction Requested

## Greetings from the Chair

Autumn is upon us and the pace again has quickened on campus as tens of thousands of students arrived on or returned to campus. The trees are turning red, brown and yellow as they always do when I write the Fall Newsletter Greetings. There must be a correlation. The unscientific conclusion: my writing causes the leaves to fall.

The news from the Department continues to be dominated by the chaotic and noisy C.C. Little renovation which is now well underway. It is so disruptive that the leaves were falling even in Spring and Summer, no matter what anyone wrote. As mentioned before, this infrastructure improvement (1994-1996) includes new windows, heating, air-conditioning machinery, plumbing and electrical renovations, and a new elevator. Parts of the first, third and fifth floor are also included in this renovation, but the main structure (and money-sink!) is a central tower (see the cover of this issue) in the former courtyard that will house storage areas for Geology on the first floor, and major mechanical equipment in the upper floors.

The Department learned with much regret this past summer that Mike Foote had decided to accept a position in paleontology at the University of Chicago. We wish him well in his new situation. We have just received authorization from the College to fill Mike's position with a new hire. In the meantime the Department has been able to appoint temporary assistant professors who will help carry the flag in paleontology (David Polly, Dan McShea, and Brian Bodenbender), and Peter Van Keken will be with us for two years to teach Geodynamics to undergraduates and graduate students, replacing Mike Gurnis who left in Fall 1993 for a faculty position at CalTech.

As mentioned in the last Newsletter, an external review of the Department has been planned for 1995, and we are now busy gathering data and information about who and what we are, and where we have been, for the self-study that will form the first component of this review. Undoubtedly some graphs and diagrams will be deemed worthy of dissemination to our alumni in this or future newsletters, so watch for these to appear. This Fall the departmental committee in charge of the self-study will be writing the text to accompany the tables and figures, and in the Winter our report should be completed. We anticipate the external review team (yet to be appointed) to visit the Department next Fall.

The last Newsletter contained a broad-ranging appeal for alumni donations; since then, alumni who attended Camp Davis in years past have received a letter asking for financial help to assure that Camp Davis remains a first-class educational facility. Many have already sent in a contribution, some large, some small, but all are equally appreciated. However, we need more! I want to re-emphasize not only the importance of your gift to future student generations, but also the fact that considerable leverage is attained by your gifts; your employer may match your tax-deductible contribution, and the College of Literature, Science, and the Arts will also provide a matching contribution, above and beyond the regular annual budget for Camp Davis. I look forward to hearing from you; let them checks fall like leaves!

Sincerely,



Rob Van Der Voo  
Chairman

## Degrees Granted

### M.S.

**James S. Cureton** "Late orogenic normal faulting along the Mooroton shear zone, Grenville Province, Ontario, Canada"

**Andrew J. Mughannam** "Stable isotope constraints on the origin of a zoned plutonic sequence, Tuolumne Intrusive Suite, central Sierra Nevada, California"

**Sean M. Todaro** "Near-Laurentian paleogeography and accretionary history of the Lawrence Head Volcanics of central Newfoundland, northern Appalachians"

### Ph.D.

**Brian Eugene Bodenbender** "Skeletal Crystallography in Cladistic and Stratocladistic Investigations of Blastoid Phylogeny"

**John Patrick Encarnacion** "Geochronological, Geochemical and Geological Constraints on Models of Ophiolite Generation and Arc Growth: Evidence From the Northern Philippines"

**Joseph Robert Graney** "Applications of Mass Spectrometry in Economic Geology and Environmental Geochemistry: Gas Composition of Inclusion Fluid From Ore Deposits and Sources of Lead Pollution in Lake Sediments"

## In Memoriam

**Donald W. Levandowski** (MS '52, PhD '56) died April 8, 1994. He was 67.

**Mrs. Lois C. (Calkins) Ramsdell**, the widow of **Prof. Lewis S. Ramsdell** who taught mineralogy in the Department, passed away on July 13, 1994, in Palo Alto, CA. Lois is survived by daughters Betty Mills of Missoula and Helen Reeve of Mesa, AZ.

*Editor:* A. N. Halliday

*Chairman:* R. Van der Voo

*Faculty:* R. Burnham, E. J. Essene, W. R. Farrand, D. C. Fisher, P. D. Gingerich, A. N. Halliday, S. E. Kesler, R. A. Lange, K. C. Lohmann, M. W. McElhinny, P. A. Meyers, T. C. Moore, S. B. Mukasa, J. R. O'Neil, S. I. Outcalt, R. M. Owen, D. R. Peacor, H. N. Pollack, D. K. Rea, L. J. Ruff, K. Satake, W. B. Simmons, G. R. Smith, B. A. van der Pluijm, J. C. G. Walker, L. M. Walter, B. H. Wilkinson, Y. Zhang

*Visiting Faculty, Research Scientists and Post-doctoral Scholars:* J. C. Alt, C. Badgley, C. J. Ballentine, E. Barrera, J. M. Budai, J. Christensen, L. Collins, R. Cox, C. Hall, S. Huang, C. Jones, K. D. Klitgord, D. C. Lee, J. Magloughlin, D. McShea, J. M. Parés, P. D. Polly, R. C. Rouse, J. Stamatakos, C. Stearns, D. Teagle, T. Torsvik, P. J. Van Keken, T. Vennemann, D. V. Wiltschko

*Support Staff:* D. Austin, S. Baird, N. Ballis, P. Fugate, N. Crowley, C. Henderson, J. Hinchcliff, T. Huston, M. Johnson, P. Kunde, T. Merline, W. Wilcox, L. Wingate, C. Wooden, S. Zeff

*Geo-Alumni Advisory Board:* H. Foster, R. D. Haag, A. M. Isaacs, J. F. Joity (Chair), A. A. Levinson, J. A. Masterson, D. Medwedeff, F. Metzger, D. G. Nussman, J. Ruiz

*The Regents of the University:* D. Baker, P. W. Brown, L. B. Deitch, S. H. McFee, R. McGowan, P. H. Power, N. M. Varner, J. L. Waters and J. J. Duderstadt (ex officio)

DEPARTMENT OF GEOLOGICAL SCIENCES  
The University of Michigan  
1006 C. C. Little Building  
Ann Arbor, MI 48109-1063

DEPARTMENT OF GEOLOGICAL SCIENCES  
The University of Michigan  
1006 C. C. Little Building  
Ann Arbor, MI 48109-1063

Place  
Stamp  
Here

## Kenji Satake and Michigan Geophysicists Called in to Evaluate Tsunami Disasters



In the last two years, about 2000 people have lost their lives because of tsunamis, which is a Japanese word meaning "harbor waves." In the American media, they are incorrectly called tidal waves, although they have nothing to do with tides. Tsunamis are generated by submarine geological phenomena such as earthquakes, volcanic eruptions, or landslides.

The recent destructive tsunamis were triggered by

earthquakes and devastated the coastal regions of Nicaragua (September 2, 1992), Flores Island, Indonesia (December 12, 1992), Hokkaido, Japan (July 12, 1993), and Java Island (June 2, 1994). The maximum run-up height of all of these tsunamis was more than 10m. After such devastating tsunamis, field surveys were usually made by geologists, geophysicists, and coastal engineers from many countries. A recent trend is to form an international and interdisciplinary team. Electronic mail and bulletin boards play an important role here, because such a survey must be made very quickly, within a few weeks of the tsunami disaster. From Michigan, Prof. **Kenji Satake** went to Nicaragua, and grad student **Yuichiro Tanioka** visited Okushiri Island, Japan, with other scientists. The purpose of these surveys is to document tsunami behaviors by measuring tsunami heights and estimating the direction and velocity of the waves.

Most tsunamis are caused by shallow submarine earthquakes. Indeed, all four tsunamis mentioned above were caused by magnitude 7-8 earthquakes. Earthquake fault motion causes ocean bottom deformation, which generates tsunamis. Tsunamis can propagate a very long distance; the 1960 Chilean earthquake tsunami propagated across the Pacific Ocean and killed 60 people in Hawaii and 100 in Japan! We now understand the generation and propagation processes reasonably well and can simulate them on computers. Hence we can use tsunami waveforms to study tsunami source processes as seismologists use seismograms to study earthquakes.

Satake has developed a method to estimate the slip distribution on an earthquake fault from the tsunami waveforms recorded on tide-gauges. He and his students have applied this method to study many recent and old earthquakes in the Pacific. Tsunami waveforms are particularly useful in the study of old earthquakes for which little or no seismic data exist. Good-quality seismic data have been available only since the 1960s, whereas tsunami waveforms have been recorded since the mid-19th century. Satake and Tanioka have been studying the Japanese earthquake which occurred in 1854 from the tsunami recorded on the west coast of the U.S. Grad student **Jean Johnson** has been systematically studying earthquakes in the Alaska-Aleutian arc using tsunami and other data. One of her new findings downgraded the 1957 Aleutian earthquake, which was believed to be the third largest of the century, to seventh in the rankings. She also studied the 1964 Alaskan earthquake using geodetic and tsunami data and found that the slip was not uniform on the fault plane but concentrated on two spots where the slip was as large as 20m.

The 1992 Nicaraguan earthquake caused much larger tsunamis than are to be expected from seismological analysis. Several similar earthquakes have occurred in the past in the world and have been called "tsunami earthquakes" to be distinguished from a "tsunamiogenic earthquake," which describes any earthquake that generates a tsunami. The reason why these tsunamis are unusually large has not been known. Seismic wave analysis of the Nicaragua event shows that the fault motion continued for an unusually long time. Furthermore, comparison of the tsunami data collected in the field with numerical computations from various fault models shows that the Nicaragua fault motion occurred in the top 10km of oceanic crust. This earthquake was much shallower than typical subduction-zone earthquakes. Satake now believes that the unusually large tsunamis are due to slow fault motion within subducted sediments.

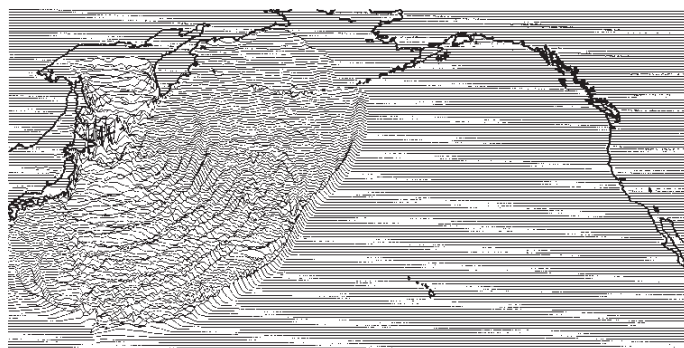
Tsunamis are also caused by volcanic eruptions or landslides. The generation mechanism of these non-seismic tsunamis are not well known and researchers are just beginning to study them. Grad student **Nazli Nomanbhoy** and Satake modeled the tsunamis from the 1883 eruption of Krakatau, Indonesia. A 270 m deep caldera was formed as a result of the eruption. They tested various hypotheses and concluded that a submarine explosion is the most likely mechanism of the tsunami, which claimed 34,000 lives. The largest tsunami height from the recent Flores Island earthquake (1992) cannot be explained by fault motion alone; Satake and colleagues introduced a local submarine landslide into their modeling and succeeded in reproducing the observation.

The tsunami run-up process on land greatly depends on local topography. For example, the field survey of the Hokkaido tsunami revealed that the maximum run-up height was 30m in a small valley on Okushiri Island, but 20m or less a short distance away. In order to reproduce such local variation, one has to carry out computation on a very detailed data base (topography and ocean depth). One of the recent computations made by the Michigan group models the coasts using a 200m mesh. Any topographical feature larger than this, e.g., a breakwater, can be included. To this end, the geophysicist has close interaction with coastal engineers; this year alone, Satake gave two invited lectures at engineering schools.

Tsunamis are also recorded in sediments. Recently, a USGS geologist found a tsunami deposit which provided evidence for an earthquake occurring in the Seattle area about 1000 years ago. The paleoseismological data including tsunami deposits have shown that a large subduction earthquake occurred about 300 years ago in the Pacific northwest, along the Cascadia Subduction Zone. Abnormal sediments in Texas and Mexico have been interpreted to be tsunami deposits, apparently from a gigantic meteorite impact near Yucatán at the Cretaceous/Tertiary boundary, when a mass extinction took place. The Michigan geophysicists are planning to use these geological data to quantify the geological phenomena that caused tsunamis. Such integrated studies of geology, geophysics and coastal engineering would also contribute to reducing future tsunami hazards.

Another tsunami recently occurred on October 4, 1994, generated from an M8 earthquake in the Kurile Islands. The tsunami from this event was observed in Japan and Kurile Islands. A tsunami warning was issued for Hawaii where schools were closed and tourists were evacuated from beaches. The amplitude of the tsunami when it

arrived at Hawaii was only a foot or so. The figure shows a snapshot of tsunami propagation 5 hours after the earthquake, as calculated by Satake. This earthquake was first considered to be a typical subduction event in the Kurile trench, but seismological analysis revealed some unusual features. Tsunami data seem to be the key to understanding the source process of this earthquake.



## Two New Faces at Michigan

**Peter van Keken** (PhD 1993, University of Utrecht, Earth Sciences) started this fall as a visiting assistant professor to teach geodynamics. His main research interests are in large scale deformation of the Earth's lithosphere and mantle, with applications to mantle convection with non-Newtonian rheology, salt diapirism and studies of the evolution of the Earth's interior. To study this, Peter develops computer models of the slow deformation in the Earth, making use of the results of high pressure rock deformation experiments. The resulting computer predictions are then related to observations at the Earth's surface and in the Earth's interior. In addition to this, his interest lies in using high speed, parallel supercomputers to solve geological and mathematical problems.

**Chris Ballentine** has recently arrived with his wife **Ros Owen** from Switzerland. Chris is a physical chemist with a background in mass spectrometry and rare gases as applied to crustal fluids. He has a Ph.D. from Cambridge University where he worked under the supervision of Professor Keith O'Nions and made some of the earliest measurements of combined He, Ne and Ar isotopic compositions in natural crustal fluids in Europe. His work on the Pannonian, Vienna and Po Basins, the Magnus Field (North Sea) and fluid inclusions in Alpine carbonate veins overlaps significantly with many of the new initiatives being developed within the U-M Radiogenic Isotope Geochemistry Laboratory at this time. As well as assisting with the establishment of rare gas geochemistry, he will be intimately involved in the development and application of the new inductively coupled magnetic sector multiple collector mass spectrometer (Plasma 54). However, most important of all, he and Ros are expecting their first baby in January. Think you are too busy? Talk to Chris and Ros about it!

## James Rogers Receives AAPG Distinguished Service Award

James P. Rogers (BS '52, MS '53) has received the Distinguished Service Award of the American Association of Petroleum Geologists (AAPG) "for his service to the AAPG, including his efforts in promoting ethical conduct and high professional standards as president of the DPA."

Jim was born in New Jersey in 1930 and following graduation from the U-M in 1953, he was employed by the Gulf Oil Corporation (Tulsa), Shell Oil (Denver, Oklahoma City, Houston, Coral Gables, Wichita, and Tulsa) and Cleary Petroleum (now W.R. Grace and Co.). In 1970 he became an independent consulting geologist and he formed his own company, National Geological Services, Inc., in 1979. Jim served the Division of Professional Affairs of AAPG as a member of the advisory board (1983-1986), vice president (1986-1987), president-elect (1989-1990), and president (1990-1991). Since then he has continued his service to the AAPG with several other significant committee appointments and we are proud and delighted to see him receive this major and very appropriate award.

## Steven G. Henry Receives AAPG's Matson Award

Steve Henry (BS '73, MS '78, PhD '81) is the 1994 winner of the George C. Matson Award from the American Association of Petroleum Geologists. The award recognizes the best paper presented at the AAPG annual convention, judged on quality of content and excellence of presentation. The title of his paper was "A new pre-salt source rock for central west African deep water?" and was co-authored by Bill Brumbaugh and Nick Cameron. It addressed the question of the likely source rock for the hydrocarbon accumulations in the off-shore west African rifts of Angola, Congo and Gabon, which developed in the early stages of the opening of the South Atlantic Ocean. He will receive the award at the 1995 AAPG annual meeting in Houston.

Steve is a geophysical consultant in Houston. Through his company GEOLEARN he coordinates the training services provided by Earth View Associates, Inc.

## Gabrielle Tenzer Wins Marine Policy Fellowship in Washington, D.C.

Gabrielle Tenzer (MS '94) has won a Marine Policy Fellowship under the National Sea Grant Federal Fellows Program. The fellowship, one of only twenty awarded nationwide, places highly qualified graduate students with hosts in the Legislative Branch or Executive Branch of the Federal Government, or other appropriate policy-oriented institutions in the Washington, D.C., area. The fellows work on substantive national policy issues related to aquatic resources for a period of one year. Gab's interest in applying her scientific background to policy issues at the federal level is not a recent development. Previously, she has worked in Washington as a Summer Environmental Assistant in the Department of Energy and as a researcher/extern studying the historical context of environmental law. She will take up her new Marine Policy Fellowship in January 1995.

# Geolumni Information Form

Please fill out and return this form to the address on the back as soon as possible. (Please Type or Print)

Name \_\_\_\_\_ Residence Telephone \_\_\_\_\_  
Surname First Middle Area Number

Residence Address \_\_\_\_\_  
Street Address City State Zip

Business Address \_\_\_\_\_ Business Telephone \_\_\_\_\_  
Position Company Area Number

Street Address City State Zip

Degree \_\_\_\_\_ College or University \_\_\_\_\_ Year \_\_\_\_\_

Degree \_\_\_\_\_ College or University \_\_\_\_\_ Year \_\_\_\_\_

Degree \_\_\_\_\_ College or University \_\_\_\_\_ Year \_\_\_\_\_

Spouse \_\_\_\_\_  
Name Year of Wedding

Children \_\_\_\_\_  
Name Birth Date Name Birth Date

Children \_\_\_\_\_  
Name Birth Date Name Birth Date

Children \_\_\_\_\_  
Name Birth Date Name Birth Date

Reference Address (name and address of parents, nearest relative, or someone who will be able to reach you):

Name \_\_\_\_\_ Telephone \_\_\_\_\_  
Relationship Area Number

Street Address City State Zip

Please send us any news of your "doings" to be included in the next newsletters; simply write it on the reverse side of this sheet.

research activities. Postdoctoral fellow **John Stamatakos**, with Rob and visiting scientist **Josep Maria Parés** (from Barcelona) did fieldwork in July in northern Spain to sample the strongly curved Cantabrian orocline. What is interesting about this curved mountain belt is that apparently the belt was originally much straighter, but tightened during Permian or younger deformation. Visiting scientist **Trond Torsvik** from the Geological Survey of Norway is continuing his work on late Precambrian paleopole positions for northern Norway. **Weixin Xu** is completing this year his PhD thesis studies to explore the effects of chemical change due to hydrothermal alteration on magnetic oxides in ocean-floor basalts and the Precambrian Stillwater Complex, and a new graduate student, **Chun-Ying Lee** is initiating studies of new aspects of this project (funded by NSF). Electron microscopy techniques and rock magnetism are used to examine the carriers of magnetization. This past summer, **Steve Potts** and **Sean Todaro** finished their theses on Ordovician and Silurian rocks from Newfoundland and Maine, whereas **Liz Meyers** is now working on the paleomagnetic laboratory measurements of her Silurian rocks from Maine and New Brunswick. Two other new graduate students joined the group this fall: **Nathan Winslow** and **Don Cederquist**, who will begin their paleomagnetic laboratory work on rocks from Newfoundland, Spain and East Africa.

**Jim Walker** has taken on additional teaching responsibilities for the Environmental Studies Program and for the Department of Atmospheric, Oceanic and Space Sciences and has been focussing most of his attention on developing new courses. Current research involves numerical simulation of hydrodynamics and chemistry of midlatitude marl lakes and the microphysics of marine stratiform clouds, a major influence on global climate.

**Lynn Walter** and her group have been active in field and laboratory research efforts. Lynn and **Anna Martini** traveled to south Louisiana to sample waters from offshore oil wells. As sole females on the rig, they got to occupy the VIP suite, the only room with a private bath. Formation waters from Pleistocene-age sands/shales were produced from up to 15,000' in connection with a DOE/Pennzoil-funded experimental borehole transecting an active fault zone in the Eugene Island Block. **Vicky Hover** and **Joshua Bartone** also made it down to the Mississippi delta where they scuba dived to collect sediment boxcores for pore water/solid phase characterization in very muddy water. They discovered that marked changes occur in porewater chemistry suggesting early and significant uptake of both potassium and boron in these clay-rich sediments.

**Ruth Blake** is continuing her experimental work on feldspar dissolution kinetics and mechanisms in solutions of various salinities and

organic acid contents. Ruth has found that NaCl content plays a major role in controlling Si and Al mobility which has significant application to diagenesis in subsurface environments.

Anna, **Joyce Budai Jim Richards** and Lynn have been busy characterizing the hydrogeology and water/gas chemistry of the Devonian age Antrim Shale in the Michigan Basin. The Antrim group has a new graduate student member, **Tim Ku** from Rochester. Tim is interested in stable isotope systematics of water recharge along the basin margin. The Gas Research Institute provided funding for their integrative project and exploration/production activities for Antrim gas have continued to increase. In addition to Shell, both Chevron and Amoco have stepped in to provide logistical and financial support for the research effort. The mission is to understand fluid flow in this complexly fractured reservoir, as well as to predict areas of best gas production.

On the administrative front, Lynn has taken on several panel assignments, one for the International Science Foundation (Soros Fund for research in the Former Soviet Union) and another for the National Science Foundation (EAR division). She is also taking over as editor (along with alumnus **John Geissman** from University of New Mexico) for the Geological Society of America Bulletin as of January 1, 1994. Despite her hectic schedule, Lynn took time to celebrate Maggie's second birthday by getting her a little sister, Thistle, to herd around the house.

**Youxue Zhang** cannot believe that summer passed by so quickly. In May, he went to the Baltimore AGU meeting. In June, he checked out the beautiful Indian country of the Four Corners area with **Eric Essene**, **Liping Wang** and a field assistant to collect some kimberlites, mantle xenoliths, and minerals in ant hills. In July, he survived the heat and humidity in Hong Kong and the Western Pacific AGU Meeting there. And in August he enjoyed the beach, mansions and the Gordon Conference in Newport, RI. Between the travels he did some research and busied himself in trying to raise matching money for his recent NYI award from NSF (see article elsewhere in this issue). Although he had planned to concentrate on assembling the multi-anvil press, he had to disassemble the parts already assembled due to the reconstruction of the building. Besides the field work in June, graduate student Liping Wang is working toward the completion of his MS thesis. **Robert Cooper** did as many partitioning experiments as allowed by the power and cooling water supply which were often turned off for construction. New graduate student **Donggao Zhao** arrived in the summer and is beginning his research.

## Henry Pollack Receives Distinguished Alumnus Award from the University of Nebraska

The University of Nebraska has awarded a Distinguished Alumnus Award to Henry Pollack, who received his Masters Degree from the Department of Geology in Lincoln in 1960. The award was presented at a banquet in Lincoln on October 7. Following an undergraduate degree at Cornell, Henry, a native of Nebraska, went back to his home-state university and wrote a Masters thesis on the stratigraphy of the Dakota Group as exposed along the Front Range in Colorado.

The University of Michigan has had many associations with the University of Nebraska over the years. **Russell Smith** (U-M MA '53, PhD '61) and **Al Fagerstrom** (U-M PhD '60) both spent their full academic careers in Nebraska's Geology Department, and **Dick Kettler** (U-M PhD '89) is currently on the Nebraska faculty. **Jim Zumberge** (U-M faculty 1950-62) served as Chancellor of the University of Nebraska from 1972-1975.

## Youxue Zhang Receives Major Awards for his Research in Geochemistry



Assistant Professor Youxue Zhang has recently been given two major awards. The first, the Clarke Medal is awarded by the Geochemical Society to the individual considered by the award committee to be the most distinguished junior geochemist (less than six years post-PhD). As such, this is a very great honor that underscores the international acclaim of Youxue's research. More recently Youxue received a prestigious National Science Foundation National Young Investigator award. This provides partial support for his research program for five years.

Additional funds are provided if they are matched by donations from private and industrial sources.

Youxue is a powerful, original intellect, who has already made several significant contributions to geochemistry and petrology, and these statements of recognition are highly appropriate. His personal history places his contributions in context, and provides an even greater appreciation of Youxue's achievements. Much of what is detailed here is adapted with permission from the introductory speech of Ed Stolper of the California Institute of Technology upon Youxue receiving the Clarke Medal.

Youxue was born in a rural area in Hunan Province in the People's Republic of China. When a teenager, his father encouraged him to continue school even though his family was poor and sometimes he had to go to school without breakfast. Although his record in high school was outstanding, this was the time of the Cultural Revolution, so after graduation, Youxue had to go to the countryside, where he farmed for four years. At this point, entrance to college was opened up on a competitive

basis based on set examinations. Youxue applied to several universities for entrance to their programs in either mathematics, physics, or chemistry; in their infinite wisdom and to the benefit of our field, the entrance committee admitted him to the geology program at Peking University. At first, Youxue's reaction was to decline the offer, wait for the next year, and try again, but his father convinced him that an opportunity like this might not come again, and off he went to Beijing. To quote Youxue, "I was fortunate to have attended Peking University, where I not only obtained a solid science background, but also benefited tremendously from the academic environment and the free spirit created by the professors and students. I hope that this free spirit will continue."

At Peking University, this country boy astounded the city folk with his remarkable performance, particularly in the basic sciences. The story is told by one of his classmates of a mathematics instructor setting a problem in class that he thought would take about twenty minutes for the class to complete, whereupon Youxue went to the blackboard and in an original, unexpected solution, solved the problem in three lines. He had a tenacious way of asking penetrating questions that led some professors to adore him, and others to be exasperated by him.

After college, Youxue competed for the privilege of being allowed to go to graduate school in the United States, and he was selected. Youxue went first to Penn State and then on to Columbia University, where like the proverbial kid in the candy shop, he wanted to taste everything. As Youxue says, "It is indeed a privilege and honor just to do sciences, not only because you are paid for doing what interests you, but also because you are not restricted in the choices of research projects. I have certainly enjoyed this freedom and have worked on a diverse variety of problems." Youxue worked on modeling the evolution of noble gases, carbon, and nitrogen in planetary atmospheres with Alan Zindler, on the petrogenesis of island arc lavas with Charlie Langmuir, and with Dave Walker on theoretical treatment of the slope of the solidus in multicomponent-polymineralic assemblages and on experimental studies of diffusion and mineral dissolution in silicate melts, the topic of his thesis. In this work at Lamont, he demonstrated what is his great strength as a geoscientist: the ability to develop simple, elegant models of complex phenomena that capture the essence of what is going on sufficiently to teach and explain and even predict, without becoming mired in unnecessary detail. This is a gift, but a key one in our field, where natural processes are often so complex to defy complete, rigorous treatment.

After graduation from Columbia, Youxue accepted a post-doctoral fellowship at Caltech to work with Gerry Wasserburg and Ed Stolper on the diffusion of water in silicate melts and glasses. Although it had been known for decades that the chemical diffusion coefficient of "water" in silicate glasses and melts increases dramatically with water content, there was no satisfactory understanding of why this is so. To be sure, there was much theorizing and speculation: some thought it reflected changes in melt structure accompanying dissolution of water, others thought it could reflect alkali-hydronium interdiffusion, and most recently, people were speculating that it was related to the presence in melts and glasses of two forms of dissolved water, i.e., hydroxyl groups and water molecules. Most petrological studies did without a fundamental understanding of why the bulk diffusivity of water is so strongly dependent on composition and simply parameterized it as an exponential dependence.

What Youxue did was to design a simple set of experiments in which he generated concentration profiles in water content in initially hydrous glasses by heating them in a dry atmosphere. He then measured the resulting concentration profiles in total water, hydroxyl groups, and water molecules using micro-Fourier Transform infrared spectroscopy. This was the unique part of his study: by knowing the concentration profiles of the individual species, he was able to distinguish their individual diffusivities and to show that the diffusivity of molecular water is orders of magnitude higher than that of hydroxyl groups under the

conditions of his experiments and that the strong compositional dependence of bulk water diffusivity can be quantitatively understood with this result. This all sounds elegant (which it is) and simple (which it is not). The analysis is complicated by the interconversions among the species as the diffusion experiment proceeds, by the strong dependence of their proportions even at equilibrium on the water content, and by the difficulty of making measurements at the precision and spatial resolution needed.

For all practical purposes, the classical problem of diffusion of water in melts and glasses (with its enormous consequences for glass technology and stability, for understanding transport of water in magmas, and for understanding growth of bubbles and their role in explosive eruptions) has been solved by Youxue. He has shown that his treatment can explain previous data on water diffusion in silicate melts. He also showed that a difference can be expected between the results of hydration and dehydration experiments and that the diffusivity of molecular water agrees well with previous results on diffusion of neutral rare gases. Moreover, he extended his results to the controversial area of understanding oxygen “self-diffusion” in minerals and showed that diffusion of water molecules is the likely mechanism for oxygen exchange in hydrothermal experiments.

This important work—with its careful experiments, the elegant analysis, the clean conclusions and simple model allowing ready application to other systems, and the extension to seemingly unrelated areas such as oxygen exchange in minerals—illustrates Youxue’s style. When coupled with his very wide range of interests, this bodes well for his potential for future contributions to the earth sciences. Already at Michigan he has begun working on an extraordinarily broad front: experimental simulation of volcanic eruptions, a general treatment of the kinetics of reactions in single mineral and melt phases, and ultrahigh pressure studies of water in minerals. The Clarke Medal and NSF National Young Investigator Award are well deserved and signal the arrival of an outstanding young scientist.

## Alumni News

### 1940’s

**Dorothy Matz Skillings** (BS ’47) writes that Dee and Ari Grammatikas were in Michigan in June for her 50th High School reunion. They stopped by and had a delightful Sunday afternoon together going over old times. Dorothy would like to hear from old friends she worked with in the Subsurface Lab with George Cohee, attended class with, and spent the summer with at Camp Davis. Since her appeal three years ago, she has heard from three former classmates. Her address is 1020 E. Thomas L. Parkway, Lansing MI 48917.

**Hollis Newcomb Walker** (MS ’49) worked for the Virginia Highway Research Council from 1966 to 1991 as a petrographer—mostly concrete, and wrote a manual for examining concrete by petrographic methods. It is spiral bound, 286 pages, 120 figures. This might be of interest to petrographers and others interested in engineering/materials science. From 1968-1991 Hollis was an active member of ASTM Committee C-9 on concrete and concrete aggregates. Some of her early work was published by ASTM. Her five daughters have grown up, married, and presented her with six grandchildren. She retired in 1991 and has a small but comfortable house on a hill which overlooks two parks and adjoins the Rivanna River. Watching the change of seasons and rise and fall of the river is very enjoyable. Charlottesville is a great place to live. She keeps busy with hobbies and occasional consulting work. Hollis has great memories of Jackson Hole and Camp Davis and would like to hear from anyone who knew her then.

**John B. Hazelworth** (BS ’47, MS ’49) writes that when he graduated, he pretty much left his home state of Michigan, but he did return several times to visit Camp Michigania on Waloon Lake. So when he retired, he found himself returning more and more to northern Michigan. He just bought a cabin in Petoskey and is hoping to be able to sneak over to Camp Michigania, which is only about 15 minutes away, for the evening lectures. He is enjoying cruising his sailboat, and also getting in on the club races.

### 1950’s

**David W. Plumer** (BA ’54) and his wife, Conway, celebrated their 38th wedding anniversary in July. He will be able to retire from the church in two more years. They live among the Bay of Islands Ordovician formations in Newfoundland with some glacial tills around, and vacation in Hillsboro, NH.

**Harold R. Livingston** (’58) has continued geotechnical foundation investigations for airports and highways throughout Alaska. He extends his scuba diving experiences by collecting photos of marine life in western Alaska waters, including Dutch Harbor, Saint Michael Maars, Little Diomedea, and Platinum.

**Martin Weiss** (MS ’51, PhD ’54) worked for USGS after graduation until 1963 as a geologist in the Military Geology Branch. From 1963 to 1975 he was with NOAA as a geological oceanographer doing micropaleontology with some sea duty. He returned to the USGS in 1975 as an environmental geologist, retiring in 1986. He still works for them part time in Reston, Virginia, as a rehired annuitant.

### 1960’s

**Darwin R. Spearing** (MA ’64, PhD ’69) has completed “Roadside

sea floor than is removed by subduction.

Dave’s student **Hilde Snoeckx** is in the final stretch of her thesis on the Quaternary paleoceanography of the eastern Equatorial Pacific and intends to finish next spring. **Dave Dobson** has just received the hundreds of samples taken on his ODP cruise to the western Equatorial Atlantic and has started the long job of laboratory work. In conjunction with his ODP sample-taking duties, Dave was able to attend the Atlantic Paleooceanography Conference held in Bremen, Germany, last July. **Libby Prueher** has become acclimatized to Michigan and is serving as a TA for the Introductory Oceanography class this fall.

An earthquake in Michigan? Yes indeed, **Larry Ruff** writes that 1994 will be remembered as the year of the great Michigan earthquake! On Friday afternoon, September 2, people in and around the Lansing area



*Scott Baird working to install the Ann Arbor USNSN borehole station. The satellite dish provides rapid data transmission.*



felt a magnitude 3.4 earthquake. The felt area ranged from Dexter on the eastern edge, to Grand Rapids at the western edge. The epicenter was just to the southwest of Lansing, with a maximum intensity of 5. This earthquake provided **Kenji Satake**, researcher **Leonid Zimakov**, and graduate

student **Yuichiro Tanioka** with the opportunity to “star” in numerous television appearances; we are still waiting for Hollywood to call! Although the Lansing event proves that earthquakes can occur in Michigan, of course most of our research activity is focused on other parts of the world. **Jean Johnson** continues to study the great tsunamis of the world with Kenji Satake (see article elsewhere in this issue), and **Nazli Nomanbhoy** is studying all the large doublets (earthquake pairs) in the world for the entire century. Another local event this summer was the

installation of the borehole USNSN station in Ann Arbor. We thank many Seismo Lab people (e.g. **Bob Thorson**), **Scott Baird**, and the USGS staff for their hard work in getting this state-of-the-art instrument put in the ground. In addition to this USNSN station, **Larry Ruff** continues to work with other schools throughout Michigan on the MichSeis program to install a network of digital seismographs. On the personal side, we wish the best for Leonid Zimakov and his family as they move on to Dallas, Texas; Leonid has joined the RefTek company there. We shall miss their warmth and insights into Russian affairs. On the other hand, we are happy to welcome our new Geodynamicist, **Peter van Keken**, into the Seismo/Geodynamics Computer Lab (see article elsewhere in this issue). Peter has already “enhanced” our working environment with his scientific discussions and considerable knowledge of obscure European beverages.

**Gerry Smith** and **Bill Patterson** are continuing their analysis of oxygen and carbon isotopes in the growth rings of fossil fish otoliths. They are trying to describe the seasonal variation as a crucial parameter in paleoclimates.

Since the last Newsletter, **Ben van der Pluijm** has indeed moved to a new location in the Department. His office is in the newly renovated Paleomagnetism, Structure and Tectonics Laboratories (PaSTeL), also called Pastel Palace or Lavender Lab by others. An important aspect of the move was the consolidation and enlargement of laboratory space, but it doesn’t hurt that he is now farther away from the interruptions that accompany the ongoing department-wide remodeling. Last spring also saw the completion of two PhD dissertations. **Bernie Housen** successfully defended his work on magnetic anisotropy and deformation fabrics and has since moved to the University of Minnesota for a two-year post-doctoral fellowship. **Steve Potts** put the finishing touches on his Appalachian paleogeography studies in Maine and Newfoundland and now works for an environmental company in Farmington Hills. **Sean Todaro** is close to completing his paleogeographic study of Ordovician arc basalts in Newfoundland while he is working for a consulting firm in Denver. **Liz Meyers** and new students **Nate Winslow** will continue the Michigan tradition of Appalachian studies (with **Rob Van der Voo** and post-doctoral fellow **John Stamatakos**). Studies of the deeper crust (with **Eric Essene**, **Klaus Mezger** (now at Mainz) and **Alex Halliday**) continue with the work of **Jay Busch** (PhD) and post-doctoral fellow **Jerry Magloughlin**, and **Jim Cureton** (MSc) is all but a signature away from leaving for Tomei to join the Peace Corps. New student **John Harris** plans to study deformation patterns in the US Midcontinent region in preparation of an upcoming major research effort between several Midwest schools. The fine details of deformation are not ignored either. **Nei-Che Ho** (PhD) is continuing his work on phyllosilicate fabrics, but has now turned his attention to a sequence of rocks from Wales after completing his study on Martinsburg slates (with **Don Peacor**). Collaboration along similar lines is also planned with former faculty member **David Wiltchko** who has taken a sabbatical leave at Michigan to see the Wolverines win. The joy of moving proved contagious, because Ben and Lies also decided to move to a new home in Ann Arbor during the summer; a few thousand boxes later, Ben is settling again. Research-wise, Ben published on a novel use of thermochronology in shear zone studies and now works on a new method for magnetic anisotropy of deformed rocks (with former post-doc **Carl Richter**, now at the Ocean Drilling program).

The paleomagnetic research laboratory of **Rob Van der Voo** has been adjoined by renovated offices of **Ben van der Pluijm**, **Henry Pollack** and Rob himself as well as a new Structural Geology Laboratory, to form one large, internally-connected complex at the northern apex of C.C. Little. Comfortable furniture invites lounging between teaching and

## GSA Research Awards

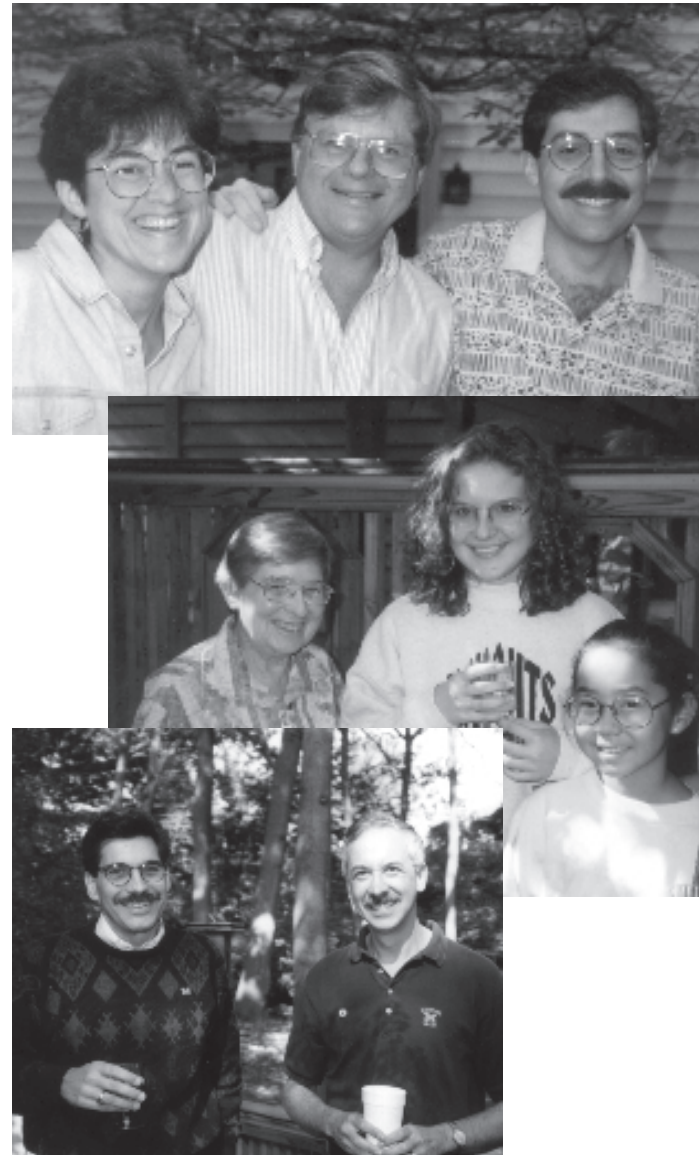
The following Michigan graduate students received Geological Society of America research awards in the latest round of funding: **Margaret Bickmore**, **William Clyde**, **Robert Cooper**, **James Cureton**, **Victoria Hover**, **Robert Klein**, **Anna Martini**, **Elizabeth Meyers**, **Andrew Mughannam**, **Peter Tropper**, **Liping Wang**.

changes in primary productivity and sedimentation rate. Peter will complete this project by developing cross-sectional geochemical and mineralogical profiles through individual nodules to assess the temporal variability of nodule compositions and their relationship to known paleoceanographic events.

**Don Peacor** was delighted to have our British friends visit again. This time Dick Merriman and Brin Roberts brought Steve Hiron along, and they kept the TEM hot for three weeks, working on problems in Welsh pelites, and putting finishing touches on illite and chlorite crystallinity problems. They've got excellent correlations between crystal size and grade, and are beginning to unravel enigmas in tectonic relations—all on the basis of observations at the TEM scale. **Vicky Hover** and **Nei-Che Ho** went to Louisiana and collected some Mississippi mud, to test for early K-exchange with clays and determine early orientation relations in shallow samples, while **Hailiang Dong** continued to get exciting 40Ar-39Ar results on bentonites and shales right here in A2. His results on coherency and polytypism in clays are exciting! The big news for **Geijing Li** and **Weixin Xu** was the addition of a son to their growing family, and along those same lines we heard that **Yen-Hong Shau**, who is an established faculty member by now, is about to tie the knot in Taiwan; we hope to see him next summer to join **Rob Vander Voo** and a new student, **Chunyang Li**, in unraveling rock magnetic enigmas. **Gengmei Zhao** has also just joined us and will be working on clay mineral problems. **Harue Masuda** was able to return to Ann Arbor for a short visit; she is focusing on TEM images of clays in shales from the Nankai Trench. **Wei-Teh Jiang** has taken a professorial position at Cheng Kung University, his alma mater. And in the line of "fun" science with social implications, and for those who remember texasite, we report that we are working on two new minerals which are rare-earth (but praseodymium-poor) sulfates. We expect our data to be inspected with especial zeal. Last, but certainly not least, the trout on the Holy Water rise to dry flies as always.

**Henry Pollack** continues to be actively involved in the reconstruction of climate changes over the past several centuries by analyzing borehole temperature profiles. The research team includes **Shaopeng Huang** who is a post-doctoral research fellow in the Department, and **Paul Shen** of the University of Western Ontario. Paleoclimate reconstruction from geothermal data is receiving global attention, in part through the efforts of a Working Group of the International Heat Flow Commission which Henry chairs. Because climate change has global dimensions, data must be acquired from all the continents. Henry spent two weeks during the bitter 1994 northern hemisphere winter in sunny Australia and New Zealand interrogating the data archives of that region, and Shaopeng returned to China during August to collect data residing at his home geothermal laboratory at the Institute of Geology in Beijing. In a joint project with the Geophysical Institute in Prague, Henry, Paul Shen, **David Chapman** (PhD '76) and Vladimir Cermak offered a week-long workshop for 20 Russian and east European geophysicists on the principles and methodology of reconstructing climate from geothermal records, and in so doing were able to acquire data from a number of Asian sites.

On the teaching front, **Lynn Walter** and Henry's course in Hydrogeology is in its second season. This course, involving both physical and chemical aspects of water in the subsurface, was initially offered in Fall '93, and is an important foundation course for students thinking about careers in environmental geology. The class has enjoyed guest lectures by **Jan Kappmeyer** (MS '82), President of Cypress Environmental in California and **Bob Haag** (BS '76, MS '79), President of Haag Environmental in Ohio. The class has also visited the municipal well field in nearby Milford to observe aquifer tests being conducted by G.R. Kunkle and Associates, headed by **George Kunkle** (MS '55, PhD '61).



*Snapshots from this year's Alumni Board meeting. Shown are: top, l-r, Jan Kappmeyer, Eric Essene, Drew Isaacs; middle, l-r, Helen Foster, Valerie Haag, Rachel Haag; bottom, l-r, John Joity, Fred Metzger.*

**Dave Rea** spent most of the summer dividing his time between two projects. The first was compiling the results of the Ocean Drilling Program work in the North Pacific done on Leg 145 in the summer of 1992, helping to edit the papers that will come out in the Scientific Results volume for that cruise, and writing the book's synthesis chapter on the paleoceanographic history of the North Pacific. The second effort, detailed elsewhere in this newsletter, involved working on manuscripts resulting from the Great Lakes paleolimnology project conducted jointly with **Ted Moore**. Another project, carried out in cooperation with **Larry Ruff**, involved quantification of the amount of sediment carried by the oceanic plates into the subduction zones of the world. Dave has spent a lot of time determining how much sediment comes into the ocean and so was curious about how much is leaving by the subduction route. He and Larry found that an order of magnitude more sediment is deposited on the

Geology of Louisiana" since moving to Grand Lake, Colorado, last year and has started on Arkansas. This summer he was a seasonal interpretive ranger of Rocky Mountain National Park, bringing a good bit of geology to the staff and the interpretive program. He says this "retirement" stuff is great!

**Bruce C. Corliss** (BS '52, MS '60) writes that after 33 years of teaching geology at Delta College, a community college in central Michigan, he has "graduated" to the rank of Professor Emeritus. He retired in May 1993. In retirement, Bruce is doing some consulting work and planning to continue his annual treks to the Grand Canyon. Since 1972, he has guided some 400 people on white water rafting trips on the Colorado River through the Grand Canyon. He never seems to get enough of such a fantastic place. Bruce is also making good progress on his list of places to see before he dies. In the past year he has been to Mexico, Costa Rica, Panama Canal, Spain, France, Italy, Germany and Poland. Next up is Southeast Asia, India and Egypt.

### 1970's

**William W. Collier** (BS '68, MS '71) writes that after a brief stint as Technology Manager for Exxon Exploration Co. in Houston, he has accepted a position in Beijing, China, as president of Esso China Limited. He and his wife will move to Beijing in the fall. Both their children are off to college; Amy is a senior at Kenyon in Gambier, Ohio, while Mark is a freshman at Texas Lutheran College in Seguin, Texas.

**Brian R. Shaw** (MS '75) says it was good to receive the *Geoscience News* after it took a circuitous route to reach him, and that he is not lost. When he last heard from the Department he was in the oil business working with Roger Gilbertson for BHP Petroleum (Americas). His activities included field studies in northeast Canada along the Taconic thrust front in Quebec and Newfoundland examining the structural history of several Ordovician basins. He left the oil business in 1992 and now works for Battelle Memorial Institute at the Pacific Northwest Laboratory in Richland, Washington. The laboratory is one of the Department of Energy's nine multiprogram national facilities. Headquarters for Battelle are in Columbus, Ohio, right on the campus of Ohio State University. He enjoys football season much more than in the past. His responsibilities for Battelle include development and management of environmental, natural resource and energy industry collaborative programs, interaction with industrial clients, and research in resource assessment. Probably the biggest adjustment leaving the oil industry in Houston was that Washington is not green and wet. Eastern Washington is a desert with less than 7 inches of rain a year!

**Gordon D. Wood** (MS '73) has been doing fieldwork in the Tarim Basin (Xinjiang Province), Fuyang Basin (Anhui Province), China, and the Carpathian Mountains, Poland.

**Evelyn Jessup Bingham** (BS '75) writes from Miami, AZ, that she uses her geology degree somewhat indirectly, keeping a large open pit copper mine in compliance with a myriad of environmental regulations. She and her husband, Brent, stay busy raising two daughters. Arizona has been good to them, but they miss the high country of Colorado where they lived 15 years. Evelyn would like to hear from any old friends.

### 1980's

**John Geissman** (BS '73, MS '76, PhD '80) simply cannot wait (har-har) to assume the duty of Co-Editor of the Bulletin of the Geological Society of America (with Lynn Walter), in January, 1995, for six years. He warns that both he and Lynn are actively looking for new Associate Editors, so lay low if you hear either John or Lynn around! All goes [reasonably] well

in the "Land of Enchantment," especially when the green chile is roasting, eh Professor Lohmann? John remains eternally grateful for his continued opportunity to participate in GS 440, U-M's summer field course at Camp Davis.

**Jacqueline C. Shulters** (BS '83) is happily living and working in the San Francisco Bay area. Her current role at Radian Corp. is as project director of an investigation (geology, hydrology, distribution of contaminants) at a Department of Defense Superfund Site in northern California. Outside of work she spends time enjoying everything California has to offer, from white water rafting and hiking to museums and restaurants. She was in Ann Arbor for a day this summer and was amazed by how much construction is going on around campus. C.C. Little has changed greatly since her days as an undergraduate, and she thinks it's wonderful that the Department has continued to grow.

**Christina B. Behr-Andres** (BS '84) has just accepted a new position as assistant professor in the Civil Engineering Department at the University of Alaska-Fairbanks. Her husband, Bob, will be employed by the Institute of Northern Engineering at UAF this fall also.

**Steve Henry** (BS '73, MS '78, PhD '81) and **Krys Swirydczuk** (MS '77, PhD '80) are still in Houston with Krys working in Conoco's Russia Business Unit, and Steve's company GEOLEARN coordinates the training services provided by Earth View Associates, Inc. Steve took this summer off and drove with the children (now 10, 8, and 6) 11,000 miles to Alaska to see his sister. Krys met them in Denver for AAPG, Canada and Alaska, and New Mexico where they have a "dacha." The rest of her summer was spent in Russia, with family in England or back in the office in Houston. Steve's AAPG presentation on a new source rock in West Africa received the George C. Matson Memorial award for the best paper. Camp Davis was a favorite stop on the way to Alaska and the hospitality provided by the families of **Dave Chapman** (PhD '76) and **John Geissman** (BSC '73, MS '76, PhD '80) were highlights on the way back.

**David R. Brosnahan** (MS '77) was married to Godela Maria Fick, a physician from Würzburg, Germany, on May 28, 1994. She is undergoing residency training to practice in the US, while David is Chief Mineralogist for Barrick Goldstrike Mines Inc., Elko, NV.

## Kelly Retirement Dinner

Michigan economic geology alumni gathered recently for a reception and dinner to honor Bill and Anna Kelly on the eve of Bill's retirement. The dinner was held at the Sheraton Hotel in Seattle in conjunction with the October, 1994, annual meeting of the Geological Society of America. Attendees included Greg Arehart, Bob and Mary Ann Blair, Shelby Boardman, Phil Brown, Ray and Anne Coveny, George Davis, Eric Essene, John Geissman, Jose and Emelina Gomez, Steve Kesler, Jim O'Neil, Bruce Nesbitt, Erich Petersen, Jamie Robertson, Joaquin Ruiz, Bob Seal, Zach Sharp and Joe Wagner. John Thoms and Ed Van Hees bought tickets but could not be there because of other commitments, and Alex Brown and Steve Zajac sent regards from France and Ukraine, respectively. Lots of other alums and friends wanted to attend, but could not because of conflicts or the simple fact that Seattle is a long way from anywhere except Tacoma and Vancouver.

Most of the people at the dinner were students and staff who had worked directly with Bill over the years. With a bit of encouragement from Jamie Robertson, who served as informal MC of the evening, many of Bill's students were finally able to discuss those long-ago days. Highlights included George Davis' account of his qualifying exam and Joe Wagner's review of Bill's sartorial recommendations. By the end of the evening, it was clear that Bill had been a major influence on lots of successful scientists and that they appreciated it. Everyone joined in wishing Bill and Anna a happy retirement and in hoping that we can get

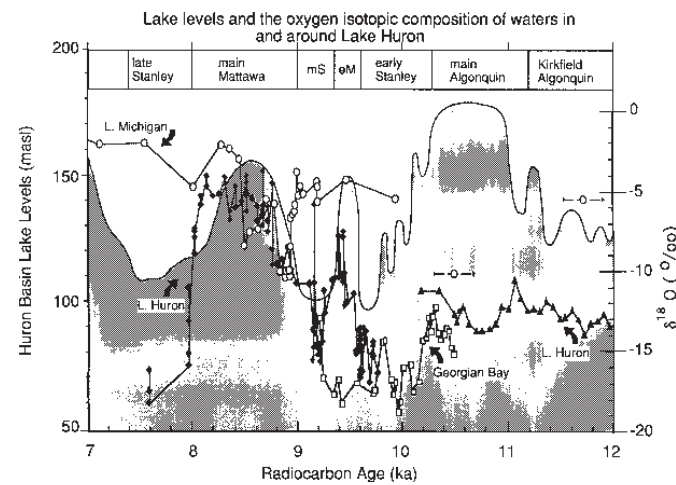
together for another dinner like this, perhaps to celebrate the tenth anniversary of their retirement or just some big fish that Bill catches in a few years.



Top: Guest of Honor Bill Kelly, Emelina and Jose Gomez. Middle: Bob Blair of Cyprus-Amex Mining, Bob Seal, USGS, and Greg Arehart, Argonne National Lab. Bottom: Jamie Robertson, Wisconsin Geological and Natural History Survey, and Joe Wagner of Doe Roe Mining Company.

## Quaternary Paleoclimatology of the Great Lakes Region

Ted Moore and Dave Rea have been following in a long tradition of Michigan Geofaculty that began at the turn of the century—conducting investigations of the Quaternary paleo-climate record preserved in and around the Great Lakes. Rea and Moore have applied modern methods of high-resolution seismic reflection profiling, satellite navigation, accelerator mass spectroscopic  $^{14}\text{C}$  dating, and the microanalytical techniques of the department's Light Stable Isotope Laboratory (K.C. Lohmann and Jim O'Neil proprietors) to questions considered by faculty predecessors: Frank Leverett (1908-1928), George Stanley (1930-1945), Jim Zumberge (1950-1962), Don Eschman (1953-1987), Jack Hough (1966-1974) and Bill Farrand (1965-).



In conjunction with colleagues from the Geological Survey of Canada and the University of New Brunswick, Moore and Rea have studied seismic profiles and sediment cores from Lake Huron and Georgian Bay under the auspices of a grant from the Ocean Sciences division of the National Science Foundation. From these data and several radiometric dates, they determined the history of the water level in the Huron and adjacent basins, finding several periods of low water and intervening times represented by highstands. The shaded background of the adjacent Figure shows the lake level history between 7 and 12ka as deduced from earlier studies and from seismic and coring studies carried out for this project.

Michigan graduate students David Dobson and David Dettman assisted with this project. As part of his doctoral thesis supervised by K.C. Lohmann, Dave Dettman (PhD, 1994) determined the modern isotope systematics of Lake Huron and Georgian Bay and analyzed ostracodes from the sediment cores to provide a historical record of the  $\delta^{18}\text{O}$  values of lake water. Dave Dobson (MS, 1994) digitized the seismic profiles and

micron gold mine and then went to the Klondike for a first-hand look at both the placer and lode gold deposits. Steve also attended the SEPM Conference on Basin-wide Diagenesis and Mineralization at Lake of the Ozarks in Missouri, where he talked about the Appalachian MVT project. The rest of the summer was spent working with Joe Graney who successfully defended his Ph.D. degree in October. Now that school has started, Steve and Larry Ruff are busy developing a new course on Environmental Geology (which is actually a revival of a course that Bill Kelly, Jack Dorr, and others taught years ago).

Becky Lange had a great time teaching the last two weeks of GS 440 at Camp Davis this summer with Jeff Alt and teaching assistants Jay Busch and Tracy Frank. Now that the experimental igneous petrology laboratory is up and running, and graduate students Sharon Feldstein and Jean Tangeman are about to submit their first papers for publication, Becky Lange is becoming increasingly involved with undergraduate activities. Undergraduate Laura Forman is doing an honors thesis on ferric-ferrous equilibria in alkali silicate liquids that involves both experiments and thermodynamic modeling. In addition, Becky is the faculty liaison for the Undergraduate Geology Club. In order to ensure continuity of this important organization from year to year, it helps to have a faculty member involved. The activities planned this year include an informal lecture series hosted by the undergraduates in which various faculty, post-docs, graduate students, and undergraduates present a slide show or talk on numerous topics, including job and internship opportunities, what it is like to do research on a ship in the middle of the ocean for two months, adventures doing field work in eastern Africa, and what an Antarctic summer is like. The Undergraduate Geology Club will be helping the Graduate Geology Club organize such traditional activities as our annual Fall Picnic and Spring Banquet. There is much enthusiasm and energy that the undergraduates bring to our department, and they are a group that we hope to see grow over the next several years.

In a departure from his traditional research update, Phil Meyers has decided to report how the Organic Geochemistry Group has been involved in several programs that are designed to attract young students to careers in science, or at least to educate young students about scientific research, whatever their careers may ultimately be. These are examples of similar activities in which others in the Department and elsewhere in the University also participate.

The Young Scholars' Program exposes students from inner-city high schools, principally in Detroit but also from other cities in Michigan, with science projects at The University of Michigan. The program is currently funded by a grant from NSF and is administered by B.J. Evans, now of the Chemistry Department and formerly of Geological Sciences. Promising students are nominated to the program by their high school science teachers. The students live on campus for eight weeks during the summer, and they participate in a variety of educational and cultural activities in addition to working side-by-side with graduate students and professors in laboratories. This past summer, Jaygarick Stewart from Detroit Western International High School joined the Organic Geochemistry Group. He worked on two projects, both dealing with records of paleoenvironmental change in sediments. Determination of the carbon contents of a 12m piston core of Lake Ontario sediment was his major effort. He found that the change from native forests to post-colonization farming in the early 1800's increased both sedimentation rates and productivity rates in the lake. His results form part of the presentation by Jim Silliman, his graduate student mentor, at the fall 1994 AGU meeting in San Francisco. His other project was to examine evidence of the Eocene onset of Antarctic glaciation in a deepsea core from the southern Indian Ocean. This project will be continued next summer.

The Organic Geochemistry Group has participated in the LSA College Undergraduate Research Opportunity Program for about five years. This program brings freshmen and sophomores into research programs early in their education to provide the students with actual scientific experience which helps them in their career decisions. Two to three students have worked in the laboratory each year, each being assigned a specific research project. In each of the last three years, one of these students has discovered the pleasure and relevance of geological science and has become a concentrator in the department. All of the students have made significant contributions to the various research projects with which they have been involved.

Jim O'Neil happily spent the period from January to August, 1994, on sabbatical leave at the University of Lausanne and lived in the same apartment house where Eric Essene and Joyce Budai lived during their sabbatical leave. Jim thoroughly enjoyed the camaraderie and scientific exchange with University of Michigan alums Mike Cosca (PhD '88) and Zach Sharp (PhD '88) who have positions at the University of Lausanne. Jim and Zach are writing a textbook on the principles of light stable isotope geochemistry. Their tentative title is "Isotopes Lite." Henry Fricke is using 18O measurements of tooth enamel from archeological specimens (both Vikings and Inuits) to determine the rate of climate change in Greenland during the Little Ice Age. Ella Reinhard made similar measurements of tooth enamel of Pleistocene cave bears from Spain and was able to correlate climate change registered in the oxygen isotope record of the bear teeth with global climate change. Ruth Blake is using enzyme-mediated reactions to investigate rates, mechanisms and equilibrium oxygen isotope fractionations in laboratory studies of isotope exchange reactions between biogenic phosphate and environmental fluids. Andy Mughannam's stable isotope and chemical study of rocks from the Tuolumne Intrusive Series (Yosemite National Park) has placed important constraints on processes by which zoned plutonic sequences develop. Sang-Te Kim is using stable isotope measurements to understand the mechanism of certain replacement reactions that may be useful in addressing the important environmental problem of water contamination by heavy metals.

Bob Owen reports that one of his research projects nearing completion involves an effort by Peter Knoop, Bob and Dr. Charles Morgan (at the University of Hawaii) to apply various geostatistical and numerical analysis techniques to the problem of interpreting large geochemical data sets. Peter's recent thesis research has focused on using a combination of factor analysis, linear modeling, and kriging methods to identify and evaluate patterns of compositional variability in ferromanganese nodules. Oceanographers have long recognized that nodule compositions represent a potentially important source of information about the environmental conditions under which the nodules have grown. However, previous attempts to extract such information have been hampered by the lack of regional scale data sets and by analytical inconsistencies between smaller scale studies of nodules in adjacent areas. Peter's work has focused on assessing regional-scale, spatial variability in the geochemistry of nodules from the northeast tropical Pacific Ocean. The data set, which was obtained from the Ocean Minerals Company (OMCO), is the most comprehensive of its type available: It includes geochemical analyses, determined using highly uniform and closely controlled analytical protocols, for more than 4,500 grab samples collected from an area spanning 3.5 million km<sup>2</sup> of seafloor. Geostatistical examination of these data suggest that bulk nodule compositions can be explained by variable contributions from only a few different accretionary processes, and that these are primarily linked to



should be accomplished in the near future. Meanwhile, **David Fox**, measuring growth lines in elephant tusks, narrowly avoided being inventoried as a regular fixture of the Morphometrics Lab, and **Talia Sher**, a Biology graduate student, started work on a project on sexual dimorphism in mastodons and mammoths. Getting the autumn off to a good start, **Brian Bodenbender** successfully defended his dissertation on evolutionary relationships among blastoid echinoderms, inferred from morphologic, crystallographic, and stratigraphic data.

**Philip Gingerich** spent the summer writing about new fossil sea cows (Sirenia) collected in Egypt last autumn, with brief visits to Wyoming to work with Will Clyde and Jonathan Bloch on Eocene projects there. **Xiaoyuan Zhou** is preparing to defend his dissertation on the mesonychid ancestors of whales this month. **Mark Uhen** spent the summer studying whale skeletons at the Smithsonian Institution supported by a Smithsonian Predoctoral Fellowship. Phil and Mark are working together this year with support from a Rackham faculty-student Research Partnership award. Phil expects to spend November and December with Will Clyde in Pakistan looking for primitive whales and sea cows in a beautifully exposed early middle Eocene shallow marine shelf sequence.

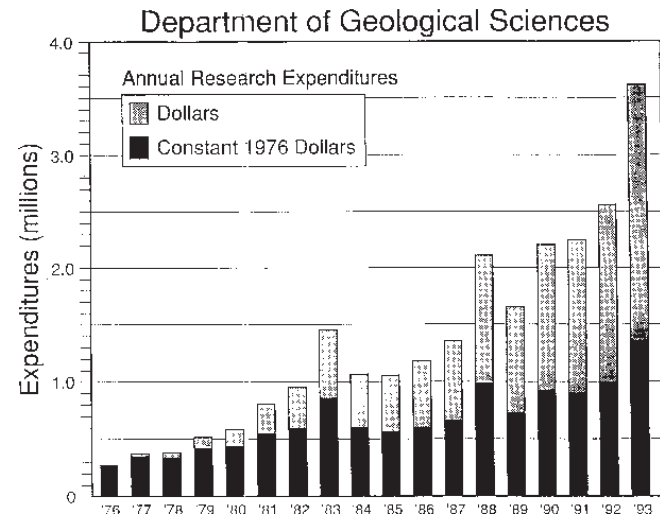
**Chris Hall** reports that the first half of 1994 has seen the completion of a comprehensive automation project with the argon dating facility of RIGL. With motorized valves and new streamlined control software, it is now much easier for prospective users to become acquainted with the system. A measure of this is that the lab has processes in excess of 2800 mass spectrometer runs already in 1994.

The argon lab has been involved with projects ranging from Philippine ophiolites (**John Encarnacion**) to rocks from Antarctica (**Sam Mukasa**) and Tanzania (**Cassi Paslick**). **Joe Meert** studied the timing of polar wander, and **Jay Busch** has continued work on determining the history of tectonics in a portion of the Grenville belt. **Eleanor Dixon** and **Peter Tropper** have both used the high spatial resolving power of the laser probe to data individual amphibole crystals and **John Christensen** has dated single sanidine crystals from Utah volcanic rocks.

Chris' own research has concentrated on four projects: a study of high-Ti lunar basalts from the Apollo 11 site; refining the geomagnetic polarity time scale with high precision  $^{40}\text{Ar}/^{39}\text{Ar}$  ages of biotites found in ocean sediments; a direct and independent test of some predictions made by the UCLA group regarding age "domains" in K-feldspars; and a major effort in collaboration with **Alex Halliday**, **Don Peacor** and **Hailiang Dong**, to find out exactly how argon is retained in clay minerals. The latter project has yielded a wealth of new information and has suggested a new way of thinking with respect to argon dating of clays. It now appears that both radiogenic  $^{40}\text{Ar}$  and neutron-induced  $^{39}\text{Ar}$  have very similar chances

of being retained in illite crystals, and this could lead to the widespread application of  $^{40}\text{Ar}/^{39}\text{Ar}$  dating to the problems of diagenesis, basin formation, and regional hydrothermal events. Chris is also involved in a pilot study with **Steve Kesler** to see if what they have learned with clays can be applied to the dating of ore mineralization.

**Alex Halliday** has spent much of the year since returning from sabbatical leave at Cambridge, planning and developing a new set of research programs. While on sabbatical, Alex received funding for the first inductively coupled magnetic sector multiple collector mass spectrometer (Plasma 54). Alex has been awarded over \$1 million from



*Research funding continues to increase at U-M. This graph shows annual Departmental expenditures on externally funded research in millions of dollars for the period 1976 to 1993. This parameter is but one of several indications of the healthy levels of research and teaching activity being documented by our Internal Review Committee. An External Review Committee is expected to visit the Department over the coming year (see letter from the Chair at the front of this issue).*

NSF, DOE and the University of Michigan to develop this new field of mass spectrometry and apply it to problems in geochemistry. Since then, the big event of the year has been the arrival of the prototype version of this instrument (Plasma 54), and the development of the new measurement capabilities associated with it. With several graduate students (**John Chesley**, **Matthias Ohr**, **Charlie DeWolf** and **Der-Chuen Lee**) recently completing their Ph.D.s, and several others (**Dan Barfod**, **Eleanor Dixon**, **Hailiang Dong**, **Xiaozhong Luo**, **Cassi Paslick**, **Wen Yi**), getting started on new projects, the sabbatical served as a great springboard for research initiatives, and Alex is now involved in research in areas as different as short-lived radionuclides in the early solar system, new methods for determining the ages of sulfides, laser probe Sr isotopic microsampling of phenocryst growth zones, dating accessory mineral overgrowths in sandstone aquifers, determining the rates of growth of metamorphic garnets and redetermining the atomic weights of Te, W, Mo and Sn. Also, while on sabbatical, he received funding to purchase two used rare gas mass spectrometers from Cambridge

University enabling the development of natural rare gas isotope geochemistry. The plan is to focus initially on the rare gas geochemistry of hydrocarbon reservoirs and fluid inclusions. Expansion of the rare gas facility and development of Plasma 54 techniques will involve a considerable range of research scientists and postdocs including **Chris Ballentine** (see article elsewhere in this issue), **Chris Hall**, **Der-Chuen Lee** who is staying on as a postdoc, **Charlie Jones**, **John Christensen** and **Damon Teagle**. At the time of writing the renovations needed for all this redirection and expansion are in progress and there will be much more to report by the next issue of the newsletter.

**Steve Kesler** spent the summer catching up on research and cleaning up the ore deposits lab. With some help from **Bill Kelly**, he identified, stored (and sometimes disposed of) material from several hundred(?) years of thesis and research work, as well as installing a new polishing system and fluid inclusion set-up. After that, he left for a week in Nevada visiting **David Stenger** at his M.Sc. project at the Twin Creeks

used the resulting data set to construct isopachous maps of the several sedimentary intervals identified on the profiles. The thickness data are interpreted as indicating sediment transport pathways within and between the lake basins. The ostracode assemblages in the sediments were quantified by Prof. Alison Smith of Kent State University, and interpreted as indicating changes in the lacustrine environments. Prof. Larry Krissek at Ohio State University is studying the mineralogy of the lake sediments.

Some of the oxygen isotopic results of this project are shown here and compared to recent results from southern Lake Michigan by Steve Colman of the U.S. Geological Survey. Rea and Moore were able to show that it is the times of unusually low water levels in Lake Huron and Georgian Bay that are dominated by the isotopically very light waters indicative of ice cap meltwaters. The lake highstands, on the other hand, tend to hold isotopically heavier waters, presumably of more local origin. This result is exactly opposite to the "conventional wisdom" of those studying the Quaternary geology of the Great Lakes region but so far has withstood the test of peer review. As of the fall of 1994 eight manuscripts resulting from this work are in press or in review, on topics such as the seismic stratigraphy, the litho-stratigraphy, the isotopic systematics of the lakes and the downcore record, the ostracode assemblages, and the potential errors in radiocarbon dating of these materials.

Moore and Rea have received NSF funding for three more years of paleolimnology research in the Laurentian Great Lakes and looking forward to their next cruise in the summer 1995 field season.

## Faculty, Research Staff, and Student News

The past six months have been exceedingly busy with both research and a double move for the Subsurface Laboratory. **Joyce Budai** has been working closely with **Lynn Walter**, and graduate students **Anna Martini**, **Jim Richards** and **Tim Ku**, on a broadly based evaluation of the Devonian Antrim Shale in the Michigan Basin. Lynn Walter and Joyce Budai, together with **Linda Abriola** (Department of Civil and Environmental Engineering) are being funded by the Gas Research Institute to evaluate the interrelationships between water and gas chemistry and fluid dynamics controlling gas production patterns in this naturally fractured, unconventional gas reservoir. The study has been great fun for all concerned and has allowed Joyce to spend more time in the stable isotope lab. In a related study Joyce, Lynn Walter, and Anna Martini are working on water/rock interactions between bedded Silurian evaporites and associated brines in the Niagaran and Salina sections of the Michigan Basin.

As some alumni may know, the well core collection of the Subsurface Laboratory is stored in the lowest level of the Church Street parking structure. This summer the ceiling and floor of that space was completely rebuilt as part of a larger renovation of the structure. The good news was that this work has greatly improved the storage area and given us a little more room for cores and a layout area. The bad news was that we had to move all the cores and well cuttings out of the space for four months, and then return them in September. We are pleased to announce that the move back in is complete, and by February 1995 we will also have newly renovated offices adjacent to the core storage area for visiting researchers working on core material.

**Eric Essene** says that this report is like going back to school in Kentucky, so what *did* he do last summer in 500 words? He had a busy summer mostly in Ann Arbor. He and **Joyce Budai** have been involved with daily

therapy for their child Zachary (age 4) after a major operation to extend Zach's leg capabilities. This will be a continuing effort for the next year and more. Zach shows slow improvement—he now can sit and hold his head up (most of the time). Fortunately, his vocabulary exceeds considerably his physical skills. Adam (age 6) is in first grade, proudly announcing he is now a "grader." He is joining a recreational soccer team this fall. Michelle (now 26!) has finished her first year in medical school at the University of Minnesota this August and visited A2 this summer. Karen (24) also spent a week this summer with the A2 family; she threatens to begin grad school in architecture next year. We shall see!

This summer Eric went in the field with **Liping Wang** (MS/PhD student) and **Youxue Zhang** to the Four Corners area of SW USA and saw lots of mantle rocks and minerals in kimberlites. He also accompanied **Klaus Mezger** (Postdoc, '89-'91) and **Ben van der Pluijm** in yet another trip to the Grenville in Ontario this July. They found many datable materials in the Central Metasedimentary Belt. They stayed at the mosquito-ridden Sharbot Lake Campground, fabled in the minds of UM hardrockers ca. 17 years ago for the somewhat loony (so to speak) behavior of an unnamed grad student, tall and blond and from Dartmouth! **Jerry Magloughlin** (current postdoc) and Eric spent some good days in the NW Adirondacks in early September, collecting hornblends for argon isotope work and camping at the Gouverneur Rod and Gun Club like always. They also spent one night at Cranberry Lake, a beautiful site that still echoes from the depredations and stews of a fall field trip in 1975, from **Bohlen**, **Metzger**, **Nesbitt**, **Pattridge**, **Perkins**, **Valley**, and **Van Den Berg** (memorialized as Van der Whacker after a lonely Adirondack peak on this trip).

These last six months for **Bill Farrand** have been spent largely dealing with the administration of the Exhibit Museum, which means mostly trying to find more money to supplant the cutback of general fund support by the College. The Museum is putting on a new face—new track lighting in display areas, the interactive Weather Wall exhibit, colorful panels in the fourth floor corridor, a bright red banner above the front entrance, and soon a new display in the rotunda. New exhibits coming along in mid-winter are a mosasaur model which will be "swimming" above the heads of visitors and a new dinosaur skeleton. The dino, *Deinonychus*, a 9-ft long "velociraptor," is the focus of the Museum's "Buy a Bone" campaign which appeals to the public to make contributions by sponsoring a particular bone. (The skull goes for \$1,000.) All alumni who return to Ann Arbor are invited to see the "new" Museum and drop into Bill's office for a chat (phone: 313-763-4191).

Otherwise Bill presided over the 13th biennial conference of the American Quaternary Association (AMQUA) which met at the University of Minnesota in June to discuss the concordance or conflict of "Data and Models in Quaternary Research." Wearing another hat, as vice-chairman of the US National Committee for INQUA (the International Quaternary Association), Bill continues to promote US participation in INQUA's 1995 congress in Berlin.

After what seemed like never-ending preparations, **Dan Fisher**'s plans to produce casts of the Brennan mastodon trackway finally shifted into high gear toward the end of this past summer. This final phase was greatly facilitated by the contribution of an "industrial strength" power sprayer, for spraying polyester resin onto the mold surface, by the Wagner Spray Tech Corporation. Spraying large volumes of plastic onto one-of-a-kind molds that require a small army to wrestle into position is not a job for the faint-hearted, but all went well. The most delicious moment was when mold and cast finally parted with a resounding POP! that echoed off the Central Campus Recreation Building across Washtenaw Ave. The finished trackway still awaits installation in the Exhibit Museum, but this

*Continued on page 12 . . .*

# Contributors to the Geological Sciences Campaign for Michigan over the past two years

*Editor's Note: The last list provided was for a single year. However, because of the timing of publication this was, in reality, less than a whole year. As a result it was inevitable that certain names were missing. To minimize this problem in future we will publish a list of donations every year for the past two years. If your name has been omitted, please do not hesitate to get in touch with the new Editor, Alex Halliday, at (313) 764-1435.*

## Individual

Donald and Cheryl Alexander  
Mr. and Mrs. William Ames  
John and Camille Amoruso  
Norbert L. Archbold  
Laura S. Badalamenti  
Dorothy W. Bailey  
Juliane K. Bailey  
Scott Baird  
Giulio G. Baldrighi  
Eric and Doris Ball  
Frank M. Barnes  
William S. Bartels  
Robert A. Basse  
Julius and Barbara Beers  
Catherine D. Belknap  
Richard W. Benner  
John and Ruth Boeckerman  
William B. Borrmann  
Erika J. Boss  
William H. Boyer  
John R. Branch  
Mr. and Mrs. Arthur Brandon  
Thomas Brocher and Anne Okubo  
Carolyn Broderick  
David R. Brosnahan  
Chris D. Brotherhood  
Roger E. Brown and Denise J. Carty  
William and Ruth Brown  
Robert and Marjorie Bryer  
Margaret V. Buckwalter  
Mr. and Mrs. Charles E. Buzby IV  
Matthew Douglas Cabell  
James E. Campbell  
Lois J. Campbell  
William S. Carlson  
Keith and Jean Carpenter  
Ronald and Barbara Cassell  
Richard and Nancy Cassin  
Steven A. Catlin  
Donald H. Chapman  
Mr. and Mrs. Orlo E. Childs  
Paul E. Christensen  
Howard S. Christie  
Mr. and Mrs. Bruce R. Clark  
Brian P. Cohee  
William and Karen Collier  
Alice and Allen Corey  
Kit B. Cornell

Lawrence Coskey  
John and Anita Cotton  
David Coupland  
David M. Courtis  
Raymond M. Coveney, Jr.  
Hanley B. Cox  
John P. Craddock  
Robert W. Culver, Jr.  
Ruth B. Curtis  
William Gerald Cutler  
Timothy and Teresa Czarnik  
Lana Ann Czerniakowski  
Massis Davidian  
Dorothy W. Davis  
John M. de Sisto  
Essie M. Dean  
Roy Dean  
Susan and Cornell DeJong  
David B. DeWitt  
John H. DeYoung, Jr.  
Marla Diamond  
Thomas P. Dickerson  
William and Kathleen Dixon  
Ruth P. Dorr  
Robert H. and Nancy R. Dott  
Carolyn Downey  
Ben Eric Drake  
William L. Duggan  
Richard G. Dunlop  
Paul A. Dunn  
John and Alma Durr  
Jeni Durst  
Mercie and Kenneth Easlick  
William W. Easton  
Robert H. Edwards  
Donald A. Ehman  
Mr. and Mrs. Lance Erickson  
Mary and Jay Erikson  
Thomas and Margaret Ervin  
Ralph E. Eshelman  
Eric J. Essene  
John A. Fagerstrom  
Marion K. Fake  
Jefferson Eitig Faye  
Mr. and Mrs. Robert H. Fear  
James L. Folcik  
Helen L. Foster  
David M. Fountain  
Stefany and Gary Freeman  
Eugene H. Freier

John and Molly Geissman  
John and Helen Gilbert  
William H. Glezen  
Edwin N. Goddard  
Mr. and Mrs. Aris G. Grammatikas  
Mr. and Mrs. Henry H. Gray  
Mr. and Mrs. John F. Greene  
Alberta F. Grimshaw  
Robert and Ruth Haag  
William G. Haag  
Merrill and Maria Haas  
Shlomo A. Hagai  
Jonathan T. Hagstrum  
Rena Hansen  
David and Ann Hardy  
Margaret J. Hastedt  
James E. Hesse  
Harvey E. Heinbach  
Steven G. Henry and Krystyna Swirydczuk  
Judith and Bradley Horn  
David A. Howell  
Walter E. Hull  
James D. Hume  
Suzanne J. Hurter  
Karen J. Husby-Coupland  
Jordan N. Hymowitz  
Andrew Isaacs and Jan Kappmeyer  
John and Donna Marie Joity  
Robert J. Jones  
Donna Jurdy and Michael Stefanick  
Thomas Charles Juster  
Charles J. Kaiser  
Haig F. Kasabach  
Janice M. Keller  
John W. Kendrick  
Cecil C. Kersting  
Stephen E. Kesler  
John E. Kilgore  
William A. Kneller  
Edwin and Katherine Knetzger  
Mr. and Mrs. Jack A. Kohn  
John W. Kosztowny  
Alexander A. Krezel  
Paul Krueger  
Konrad R. Kruger  
Madlyn M. Kruger  
Mary and Wallace Lamoreux  
Rebecca A. Lange  
Charles G. Lee  
Arthur W. Leibold III

Alfred A. Levinson  
Mr. and Mrs. Richard T. Liddicoat, Jr.  
Robert M. Linsley  
Mark Lipton  
Kacey Lohmann  
Art D. Lombard  
Persis M. Long  
Peter T. Lucas  
Curtis L. Lundy  
Christopher Lynnes  
W. Bruce MacKenzie  
Richard and Marian Mahard  
William and Helen Malin  
Ann M. Manchester  
Georgia Manchester  
Stephen L. Manchester  
Thomas C. Manchester  
Lawrence E. Mannion  
Mr. and Mrs. Peter M. Mann  
Susan Markert  
Philip Lewis Martin  
James A. Masterson  
Margaret T. McCaul  
Wardley D. McMaster  
John S. Merchant  
Frederick and Laurie Metzger  
Philip A. Meyers  
Anthony S. Mignery, Jr.  
Gregg and Susan Millman  
David Mogk  
Margaret E. Mooney  
David and Anne Morley  
Katherine M. Muir  
George H. Musselman  
Winifred L. Nash  
Joan P. Neuschler  
Lawrence E. O'Brien  
Hannah E. Ohr  
Barbara and Peter Olsen  
John P. Olson  
James R. O'Neil  
Robert M. Owen  
John William F. Parker  
Alan R. Paul  
Frances Manchester Pendleton  
Erich U. and Nancy M. Petersen  
David W. Plumer  
Robert and Dorothy Prasil  
Christopher R. Rampson  
Mr. and Mrs. Leon Reiter

Mr. and Mrs. Bruce Renaud  
Duane and Kathryn Renken  
Albert G. Richards  
Mr. and Mrs. Robert T. Riedel  
Marriane H. Robertshaw  
Mr. and Mrs. Frederick L. Roeser  
Robert and Kathleen Rosowski  
Mark Allen Ryan  
Mr. and Mrs. Edward G. Sable  
Lowell and Ann Satin  
Tracy L. Schauer  
Mr. and Mrs. Stephen S. Scherer  
Bettina Schmeling  
Robert Scholten  
Ronald E. Seavoy  
Yen-Hong Shau  
Robert J. Shedlock  
Edward C. Silverman  
Dorothy M. Skillings  
Audrey E. Smith  
William T. and Barbara B. Smith  
Mrs. William T. Sparrow, Jr.  
Darwin and Sue Spearing  
Linda Sperling  
Donald Lee Sprague  
Lee L. Stroves  
Winifred Stubenvoll  
Waldo D. Sturm  
Mr. and Mrs. John M. Sweet  
Derek B. Tatlock  
Elizabeth A. Terando  
Bart and Naz Tichelaar  
Clarence N. Tinker  
Scott W. Tinker  
Steven J. Tkach  
Peiti Tung  
John H. Tyler  
Ben van der Pluijm  
Mr. and Mrs. Rob Van der Voo  
Richard W. Vian  
W. Gregory Vogt  
Mark and Sally Vukasovich  
Mary and Eugene Walker  
Stewart R. Wallace  
Donald W. Watson  
Paul L. and Alice E. Weis  
Howard and Beth Williams  
Edwin D. Williamson  
Mr. and Mrs. Michael D. Wilson  
Howard R. Witt

Laurel G. Woodruff  
Carolyn R. Woodward  
George L. Worden  
Mr. and Mrs. Richard V. Wyman  
Ruth and Harvey Yablonsky  
Jiajun Zhang  
Jean Peterman Zimmer

## Corporate

AFMS Scholarship Foundation  
Amerada Hess Corporation  
American Association of University Women  
American Chemical Society  
Amoco Foundation, Inc.  
Arco Foundation, Inc.  
Baily Engineering & Testing  
Baltimore Gas & Electric Co.  
California Technology International  
Chevron U.S.A., Inc.  
Conoco, Inc.  
Crimmins-Forman Market Research, Inc.  
Exxon Company, U.S.A.  
Exxon Education Foundation  
Ford Motor Company Fund  
John F. Greene & Company  
Idaho Beverages, Inc.  
Lodestar Magnetics, Inc.  
Louisiana Land & Exploration Co. Foundation  
Marathon Oil Foundation  
Michcon Foundation  
Mobil Foundation, Inc.  
North Atlantic Treaty Organization  
Occidental Oil & Gas Charitable Foundation  
David & Lucille Packard Foundation  
Paramount Communications Foundation  
PPG Industries Foundation  
Rohm & Haas Company  
Shell Development Company  
Shell Oil Company Foundation  
Shell Western E & P Inc.  
Tandy Corporation  
Texaco Philanthropic Foundation  
Union Oil Company of California Foundation  
Union Pacific Corporation  
U. S. Steel Foundation Inc.