GEOSCIENCE NEWS

for the Alumni and Friends of the
Department of Geological Sciences
University of Michigan, Ann Arbor, Michigan

July 1997

A Quarter Century of Research In Paleomagnetism and Tectonics

Rob Van der Voo, our latest recipient of the Geoalumni Award, spins a magnetic tale of accomplishment. *See page 3.*

In this Issue:

Greetings from the Chair

Dear Friends of the Department:

This morning I have returned to the office after a two-week trip to China, highlighted by an 8-day field trip to the Tibetan Plateau and three of the Neogene basins that adjoin it on the northeast. My traveling companions were Rob Van der Voo, Catherine Badgley and Xiaozhong Luo, all more experienced Asian hands than I am. The trip was hosted by scientists from Lanzhou University and, we hope, will lead to a cooperative project focused on the uplift history of the northeastern Tibetan Plateau and its consequences for the regional environment and fauna. The uplift history of the Tibetan Plateau and its effect on worldwide environmental changes is a particularly hot topic in earth science these days.

This trip and its hoped-for ensuing research project has served to emphasize to me the true international nature of the science conducted by our department. The department is full of hallway and coffee-pot stories of field work conducted in places like Antarctica (Sam Mukasa), Egypt (Phil Gingerich), Panama (Lynn Walter), Greenland (Rob Van der Voo), or the South Atlantic (Phil Meyers).

One of the best measures of the strength and vitality of a geology department is the range of research topics it addresses. We usually consider this range in terms of scientific subspecialty, like isotope geochemistry or earthquake seismology. For global impact of research results, however, range in terms of geography is of similar importance. Our departmental T-shirt design of a couple of years ago is a map of the world with a red dot for everyone's research sites; the compilation looks well-measled with spots on all continents and in all oceans.

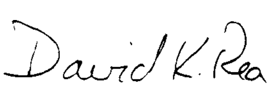
To substantiate this perception of lots of international activity, I have taken a quick look at the titles of the major research grants now funded in the department. There is a proportion of these grants that are not area specific, such as investigations of geological or geochemical process and the equipment grants. The great majority involve samples from a particular place and investigations of international locations outnumber those sited in the U.S. by about 3.5 to 1. Part of this international aspect is the result of having five marine geologists here, but even so, roughly two thirds of the faculty have active research projects based on rocks, sediments or geophysical data from other countries, international waters, or the earth's deeper interior.

Earth science knows no arbitrary boundaries, whether horizontal or vertical, although some places are much harder to get to and work in than others. I am proud that our department works on problems that present themselves at so many places around the world, and I hope you are too.

On another note, I am pleased to report that two of our faculty have been honored this spring by the University. Phil Gingerich has been awarded the Distinguished Faculty Achievement Award in recognition of his remarkable career in vertebrate paleontology. Becky Lange has been awarded the Class of 1923 Memorial Teaching Award for outstanding teaching of undergraduates. These awards are among the most prestigious made by the University to its professors and we are delighted by this recognition given to deserving geology faculty.

The Geological Society of America annual meeting will be in Salt Lake City this fall. Our departmental reception will be held Monday night, October 20th. Please join us then for an evening of reacquaintance and refreshment.

Sincerely yours,



David K. Rea
Professor and Chair

A Special Note:

On page 22 of this issue, you will find a readership survey. It would be a great help to us in charting the future of the *Geoscience News* if you would take a few moments to provide us with your comments. Thank you.

A Quarter Century of Research In Paleomagnetism and Tectonics: Taking the Pulse of the Earth

***Rob Van der Voo** has been on the full time faculty at Michigan for twenty-five years, eleven of those as Chair of Geological Sciences. His contributions have been recognized with several awards, including the University of Michigan Distinguished Faculty Achievement Award and the G.P. Woollard Award of the GSA. Since 1994 he has been the Arthur F. Thurnau Professor in our Department. Last year he was awarded the Geoalumni Award for Excellence in Research and Teaching. This year he gave the Cox Lecture, the distinguished lecture of the GP Section of the AGU, named after Allan V. Cox. Next year he will be the College of LS&A's Distinguished Lecturer. After a sabbatical leave he will be appointed Director of the Honors Program for LS&A. Here we give an overview of the scope and impact of his remarkable research program at Michigan.*

The paleomagnetic laboratory at the University of Michigan celebrates its silver anniversary this year, which prompts us to look into the past and ongoing research activities in this corner of the Department. Some 45 graduate students have worked in the lab and finished their MSc or PhD degrees in the last 25 years. This total probably accounts for about 7% of our living alumni with advanced degrees; moreover countless undergraduates have had more than just a passing acquaintance with the facility. The research described here is largely a product of the collective efforts and energies of these former students, as well as postdoctoral fellows and visiting scientists. **Rob Van der Voo** has asked that this article be dedicated to all these fantastic colleagues, past and present, with the inscription to each (borrowing from Mike Royko, the late columnist of the *Chicago Tribune*): "Thanks for everything. You were my best. Don't tell the others."

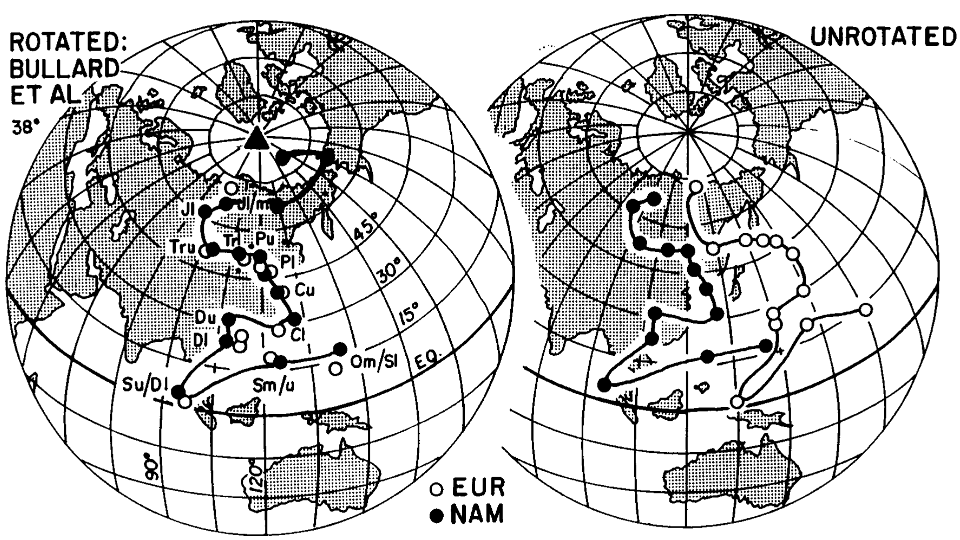
Started in 1972 when **Rob** was a beginning assistant professor (he arrived in 1970 as a postdoctoral fellow), the lab steadily grew in instrumentation from an initial inventory of a Schonstedt Spinner Magnetometer (yes, it's still functioning) and an alternating field demagnetizer. Acquisition of the first cryogenic magnetometer (1975), a Schonstedt thermal demagnetizer (1976), a Curie balance (1980), and a shielded room (1985) followed, and in the 1990's, a new cryogenic magnetometer, alternating field demagnetizer, thermal demagnetizer and anisotropy of susceptibility apparatus replaced older equipment items.

Let us begin by having a brief refresher as to how paleomagnetism contributes to our knowledge.

What can Paleomagnetism do for You?

In a nutshell, if a piece of the Earth's crust twists (rotates) a bit, if it tilts, or if it moves more than 500 km laterally over the surface of the Earth, paleomagnetism could probably reveal this movement. Well, that *is* a simplification, but the fact remains that faithful records of the ancient magnetic field, when measured as directions with a declination and an inclination in (oriented) rock samples, are a function of the ancient latitude of the rocks at the time the magnetization was acquired; moreover, the orientation of the rocks with respect to ancient north is revealed by the declination which acts as a frozen compass needle. As the latitude of a place changes, so then does the magnetic inclination. Michigan's famous Petoskey stones, the "state fossils," were deposited by coral reefs in the Devonian in warm, equatorial shallow waters and, sure enough, magnetic inclinations of Devonian rocks in our part of the world have near-zero, equatorial inclinations. In contrast, today's inclination of more than 65^{o} downwards corresponds to the present-day latitude of about $45^{o,}$ and we can blame the deterioration of our local climate on North America's steady northward drift since the Devonian period.

Where the "art" inserts itself into the science is where the bulk of the laboratory work comes in. Magnetizations in rocks are carried by tiny iron-bearing mineral grains, mostly iron-oxides such as



Apparent polar wander paths for Europe (open symbols) and North America (closed symbols) for the Ordovician through Middle Jurassic. On the right they are plotted for the present-day positions of the continents and on the left for their positions with the Atlantic Ocean closed.

magnetite, but occasionally iron-sulfides, such as pyrrhotite. When these grains alter by oxidation to, for example, hematite, or by oxidation and hydration to minerals such as goethite, the original magnetization is replaced by a later or "secondary" magnetization in a process called remagnetization. Often, such alteration or weathering leaves some original magnetite untouched and surrounded by younger oxides or oxyhydroxides. The resulting magnetization, needless to say, is now a composite of ancient ("primary") and secondary components. The tedious laboratory measurements, and the complex *Zijderveld* plots that are so generated, arise from the need to separate, in a process called stepwise demagnetization, these different components from each other. Such demagnetization is done in a zero magnetic field, provided by a shielded room, lest the samples acquire a new magnetization during treatment.

Interestingly, a secondary magnetization need not be thought of as totally useless. In certain situations, a secondary magnetization's direction can be compared with known directions for the geological past and allows us thereby to date the event that caused the rocks to acquire a new component of magnetization. The research group at Michigan has found that many remagnetizations are introduced in North American rocks at the times when the Appalachian or Laramide orogenies occurred. Speculatively, this has been linked to interactions between the rocks and extensive fluid migrations driven cratonward by the mountain building processes.

The Bits and Pieces of Plate Tectonics, or, of Megaplates and Microplates: What Went Where?

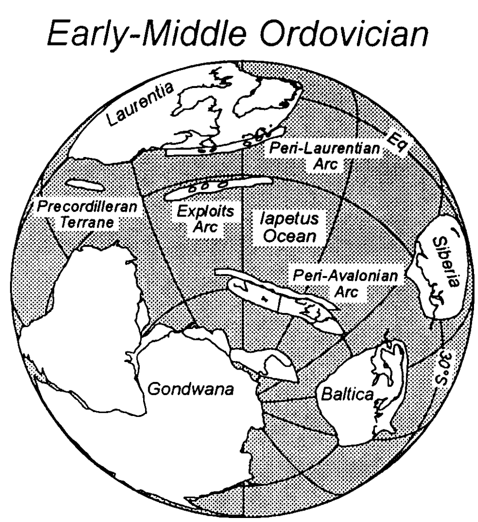
It is editorial commentaries with titles such as the above (e.g., by Dick Kerr in *Science*, 1980), that encapsulate the essence of paleomagnetic studies by **Van der Voo** (or others). By collecting oriented samples from a given continental block, paleomagnetists determine where the pole position is located for the time the magnetization was acquired, while holding the continental block fixed. In reality, it is mostly the pole that is fixed,

A bearded Van der Voo, sampling Precambrian rocks in North Greenland.

while the continent moves, and so the newly determined pole position is called an *apparent* pole and a path connecting several such poles, while again holding the continent fixed, is called an Apparent Polar Wander Path (APWP). When two APWPs from different continents are compared, for the same time window and in their present-day positions, one typically finds that these APWPs do not coincide for earlier geological times. This is, of course, because these continents have drifted with respect to each other, as well as relative to the rotation axis of the Earth. Only when the correct relative configuration of the continents is achieved, and the APWPs are adjusted for the movements that occurred since that configuration, does one find that these APWPs are coincident. Paleomagnetists work this story in reverse: they seek to make APWPs coincide and in so doing "discover" the relative ancient continental positions.

In our laboratory, this type of work has taken students, postdocs and faculty to all corners of the Earth for collecting, the main goal being a determination of the positions of the continents for geological times, especially before the Mesozoic. The collective publication record of the lab includes many studies, of course, on North American rocks (PhD studies by **Rowland French** '76, **Doyle Watts** '79, **John Geissman** '80, **Don Alexander** '81, **Doug Elmore** '81, **Chris Scotese** ('83 via the University of Chicago), **Chad McCabe** '85, **Mike Jackson** '86, **Rex Johnson** '87, **Roberto Molina-Garza** '91, **Dongwoo Suk** '91, **Bernie Housen** '94, **Steve Potts** '94, and **Weixin Xu** '96, and MSc studies by **Ken Grubbs** '75, **Ike Vitorello** '75, **Steve Henry** '76, **Andy French** '78, **Peter Brown** '82, **Mike Wisniowiecki** '82, **Susan Schwartz** '83, **Kathleen Devaney** '84, **Chris Lynnes** '84, **Ra Eldredge** '85, **Martha Ballard** '85, **Julie Gales** '88, **S.T. McWhinnie** '88, **Reid Wellensiek** '88, **Art Lombard** '89, **Margo Liss** '92, **Sean Todaro** '94, **Liz Meyers** '96, **Don Cederquist**, in progress, **Allen McNamara**, in progress). However, it also includes a Devonian pole for Australia (**Neil Hurley**, PhD '86), Precambrian, Ordovician, Devonian and Tertiary poles from Africa (**Valerian Bachtadse**, research associate '85-'87, **Joe Meert**, PhD '93, **Hamzah Lotfy**, PhD '92 via El-Minya University in Egypt), a Cambrian pole from Antarctica (**Doyle Watts**, Ph.D '79), Precambrian, Devonian and Cretaceous poles from Greenland (**Niels Abrahamsen**, visiting scientist '87; **Carola Stearns**, PhD '88), Cretaceous and Tertiary poles from the southern Caribbean (Carola Stearns PhD '88, **Fred Mauk**, Faculty), poles of a variety of Precambrian and Paleozoic ages from Hercynian Europe (**Meridee Jones**, M.Sc '78; **John Hagstrum**, MSc '79; **Russ Perigo,** MSc '82; **Hervé Perroud**, research associate '80-84; **Jean-Pierre Lefort**, visiting scientist '80; **Trond Torsvik**, visiting scientist '95; **John Stamatakos**, research scientist '92-'95; **Josep Parés**, visiting scientist '95; **Arlo Weil**, PhD in progress) and from Asia (**Wu Fang**, Ph.D '89; **Kwang-Ho Kim**, visiting scientist '89; **Zhongmin Wang**, PhD '93; **Shangyou Nie** (PhD'90, via the University of Chicago).

From these studies, many paleogeographic maps have resulted, some of which are shown in the figures accompanying this article. In some cases, the group at U-M has modified existing



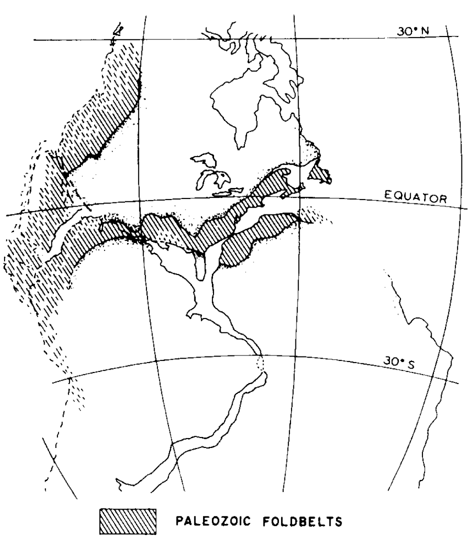
Map of the Ordovician world showing positions of terranes within the Iapetus Ocean.

proposals for continental configurations, such as those for the supercontinents of Pangea (in the late Paleozoic/early Mesozoic) and Rodinia (in the Neoproterozoic), whereas in other cases it has come up with positions for continental blocks that were not previously known.

It is not only the larger continental blocks (cratons) that are of interest. Starting with **Van der Voo**'s PhD research on the rotations of small blocks in the present-day Mediterranean area, microplates and displaced terranes have been studied in many other parts of the world as well, including Mexico (with **Jaime Urrutia-Fucugauchi**, visiting scientist '82), the Caribbean, central and southeastern Asia, southern Alaska and in the New England and Canadian Maritime Appalachians. An accompanying figure illustrates a study (with **Prof. Ben van der Pluijm,** and **Conall MacNiocaill,** research associate '95) of terranes in the northern Appalachians and how they were caught up and telescoped in the Siluro-Devonian orogeny that closed the early Paleozoic ocean between North America and Gondwana in which these terranes formed as island arcs.

Improvements in Paleomagnetic Analysis and Reliability

Throughout this period of active involvement in procuring new paleomagnetic poles and paleogeographic maps, the team at Michigan has been at the forefront in



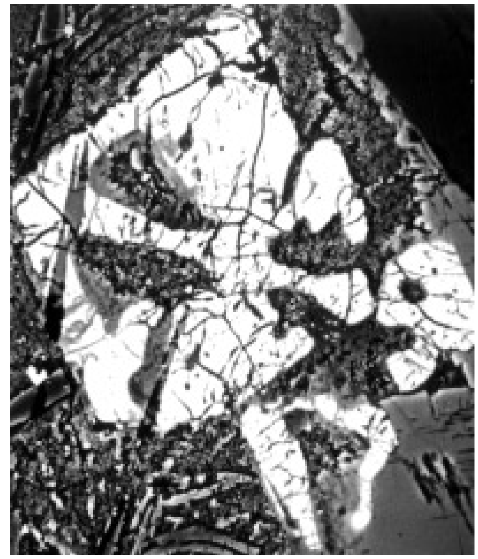
Van der Voo's reconstruction of Pangea with the Gulf of Mexico tightly closed.

terms of documenting the reliability of their results with increasingly sophisticated methods. As in any scientific discipline, the paleomagnetic database contains good data and bad data, and the problem is not so much in recognizing which are which in hindsight, but to sniff out the unreliable result or the wrong interpretation as the samples are still being analyzed before publication.

Earlier, the circumstances leading to remagnetization were briefly mentioned. What if remagnetization had occurred, but no-one recognized it as such? In that not-so-hypothetical case, the age of the magnetization could be significantly younger than the age of the rocks leading to erroneous interpretations.

Fortunately, a number of tests exist that can constrain the age of magnetization. If a baked contact next to an intrusion has a magnetization that is the same as that of the intrusion (because this baked margin was thermally re-magnetized at the same time as the intrusion was emplaced), and if the host rock far away from the intrusion carries a different magnetization, then this "positive" contact test provides evidence that the magnetization of the country rock is older than the magnetization in the intrusion. Similar (fold-, conglomerate-) tests exist in other geometrical situations and collectively, such tests have provided several key poles with a high reliability factor. This factor, incidentally, is an invention of **Van der Voo**, who in the late 1980's felt the need to come up with a parameter that quantified the relative reliability of a given result. It has since become a widely used quality factor. It is not surprising that this need was felt, because just some seven years earlier an erroneous interpretation of displaced terrane movements in the Appalachian-Caledonian Mountain belt had been published by **Van der Voo** and Scotese, precisely because Permian remagnetizations of Devonian rocks had not been recognized as such.

Another assessment method has been advanced at Michigan in a collaboration between **Van der Voo** and **Prof. Donald R. Peacor**, involving the use of electron microscopy. Knowledge about the minerals that are potential carriers of the magnetization is tremendously important

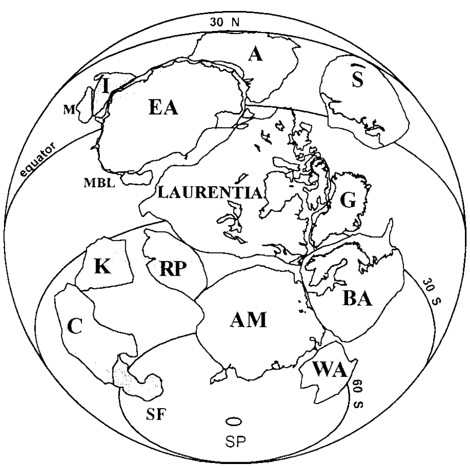


Scanning electron microscope image of a magnetite that has been altered (formation of cracks due to inherent shrinkage because of loss of titanium, which has diffused out to form secondary sphene elsewhere). The grain's magnetization presumably changed as a result.

as paleomagnetists try to decide how and when the magnetization was acquired. For magnetite, for instance, its primary nature may be revealed by its titanium content, whereas its magnetic stability can be deduced from the grain size. Grains that are larger than several micrometers (µm) are usually not able to preserve an ancient remanent magnetization; instead, it is the tiny grains of about 0.05 µm that are important. Such grains cannot be seen with an ordinary microscope, which is why **Rob** and Don and their students (**Dongwoo Suk**, PhD '91; **Weixin Xu**, PhD '96; and **Weiming Zhou**, PhD in progress) have examined a large variety of rock types, in which the magnetization history is fairly clear, with scanning and transmission electron microscopy, in order to build up a catalogue of case histories. Combined with modern rock magnetic research, these studies have been truly pioneering and promise to become a standard component in future studies.

Magnetostratigraphy

A fairly recent, yet rapidly growing, component of the research of **Rob**'s group has involved the study of geomagnetic reversals in the last 30 million years. While reversals have often been documented in Paleozoic and Precambrian rocks, sections are typically insufficiently complete to carry out detailed stratigraphic investigations and, hence, the studies of the team at Michigan have only rarely involved magnetostratigraphy (one study by Neil Hurley excepted). But in 1996, **Prof. Xiao-Min Fang** of Lanzhou University (China) arrived in the laboratory with thousands of samples from Miocene, Pliocene and Quaternary lacustrine, fluviatile and eolian deposits, collected near the northeastern margin of Tibet in Gansu Province, China. Xiao-Min and his Chinese colleagues are interested in the ages of these sediments, which can be determined by comparing the observed reversals with a standard global magnetic polarity time scale, because these ages



The Rodinia supercontinent in the Precambrian. Van der Voo and his coworkers have refined the positions of the Congo craton (C), the Kalahari craton (K), northern Europe (BA), the Amazonia Block (AM) and the Rio de la Plata block (RP), located below North America (=Laurentia).

can constrain the timing of incision by large river systems in central China, such as that of the Yellow River and, hence, theories about the uplift of Tibet. **Xiao-Min** and **Rob** are now testing the idea that the bulk of this uplift occurred rather late, i.e., in the Pliocene, in northeastern Tibet. If true, this would be evidence for different uplift ages, progressively younging northward from the Himalayas through Tibet, and could constrain theories about why Tibet is such a high-elevation plateau in the first place. Documenting the uplift of Tibet is exciting for another reason: the suggestion has been made that it has influenced or caused Asian monsoons, possibly global climate, and perhaps even the Plio-Pleistocene glaciations.

Theoretical Studies Using Paleomagnetism

When the right student comes along, someone with great mathematical skills and interests in things theoretical, the geomagnetic field of the Earth may constitute an attractive study object. The basic premise of paleomagnetism, namely that the geomagnetic field in the past was, on average, that of a geocentric dipole, has been validated to first order by many analyses of world-wide data spanning the last five million years, but there is good reason to believe that a small non-dipole field may have persisted over long times, as shown by studies of **Michael W. McElhinny** (Adjunct Professor). An analysis carried out at Michigan by **Dave Coupland** (MSc'79), extended the search for these non-dipole fields to earlier geological times, and showed that the non-dipole field, while never very large (<5% of the total field), was never really absent either.

A whole new methodology, however, was needed for an analysis of a somewhat different aspect of geomagnetism and plate tectonics. The idea that the continents and oceans move with respect to each other and with respect to the rotation axis is no longer being debated, but what about the rotation axis itself? Theoretically, a shift of the rotation axis with respect to the whole Earth has been shown to be entirely possible, even likely, given that this axis seeks to align itself with the Earth's largest principal moment of inertia. Such a re-alignment is called true polar wander. And if the various lighter and denser portions of the Earth are in constant movement, the moments of inertia must change and true polar wander would occur. To test this idea, **Donna Jurdy** (PhD'74) carried out a mathematical analysis in which the effects of relative continental movements and a movement of the rotation axis could be separated, finding that true polar wander has not been statistically significant since the Early Cretaceous. In a similar vein, **Laura Ullrich** (MSc'79) analyzed the drift rates of the major continental cratons with respect to the rotation axis since the Archean, in order to see whether plate velocities revealed a trend as a function of geological times (they do not). With the arrival of new faculty member **Prof. Carolina Lithgow-Bertelloni**, this combined aspect of paleogeography and geodynamics may well move up to the departmental front burner in the near future. In preparation for this, **Rob** is taking a sabbatical leave in the coming academic year, hoping to spend some time with colleagues in geodynamics and seismology at the University of Utrecht, with the idea to match results from mantle tomography with paleogeographically deduced subduction zone locations for Early Tertiary and Mesozoic times.

Alternating Periods of Continental Assembly and Dispersal: The Pulse of the Earth

As mentioned earlier, **Rob** and his students have studied the configurations of the supercontinents of Pangea and Rodinia, but also the timing of when, and the fashion in which, these supercontinents assembled or broke apart. The logical question that occurs next, he comments, is whether "earlier supercontinents, as yet undocumented, have existed in Proterozoic and late Archean times?"

This question is easier posed than answered. The data for earlier Precambrian times, naturally, become very scarce for most continents other than North America. But a few well-chosen targets for paleomagnetic study, perhaps in Africa or Australia, may provide key poles that will help in an analysis of earlier Precambrian supercontinent configurations. "If we look at the times of major orogenies," **Rob** predicts, "it is logical to anticipate that the next oldest supercontinent existed at about 1.8-1.6 billion years ago. Considering the time spans in which Rodinia and Pangea existed, this age, in turn, leads to a cyclicity of some 700 million years." Thus, each cycle consists of periods of supercontinent assembly, as well as break up and dispersal, inevitably leading to assembly again to complete what has been called the *Wilson Cycle* after J. Tuzo Wilson. **Rob** confesses that he is already scheming to test this new prediction in the coming decade.

Alumni Board News
by Al Levinson

The Geological Sciences Alumni Advisory Board ("The Board") was created in 1982 and meets formally once a year in Ann Arbor, usually in October. Since its inception it has had 29 members who generally serve five-year terms and whose professional experiences have included almost every aspect of the geological sciences. Some of you know The Board through the "year-end letter" traditionally sent over the signature of the Board's Chairperson. However, this letter provides only a snapshot of the Board's activities, and several alumni recently have asked various Board members questions such as "What does The Board do?" and "Who is on The Board?"

I believe this lack of awareness of The Board and its activities may stem from the fact that The Board intentionally has kept a low profile. However, this has just changed! Starting with this issue of *Geoscience News* The Board will have its own column with which to communicate with you. The objective will be to de-mystify The Board by discussing its mandate, membership, priorities and activities. With this approach we hope to use our unique position to build an even stronger relationship between the Alumni and the Department.

For this, our first direct communication with you through the *Geoscience News*, let me list The Board's purposes:

To provide a vehicle for communication among the Departmental alumni, faculty and students;

To provide input to the Department on economic and employment trends in government and industry which may affect the Department, its students and its graduates;

To consult and advise the Department on its research and instructional programs;

To assist the Department in the identification and solicitation of financial and other resources;

To serve as an external advocate of the Department to the College of LS&A and the central University administration.

Clearly, The Board has wide latitude in the scope of its activities—and a lot of responsibility as well! In the past, The Board has engaged itself in every one of the areas mentioned above, and quite successfully I might add.

As we begin this new concept of "Alumni Board News," I believe that it is appropriate to start with the first item, the matter of communication with alumni. The Board solicits any thoughts, views or ideas that you may have that you believe will be of value to the future prosperity of the Department. In the next issue of *Geoscience News*, you will "meet" the members of the 1997 Board (complete with a group photograph and addresses), but in the meantime please send your communications to me. You are guaranteed a reply!

On behalf of The Board, I wish you all a wonderful summer.

Alfred (Al) A. Levinson, Chairman, Geological Sciences Alumni Advisory Board
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Janet Kappmeyer (MS '82)
Alfred A. Levinson (BS '49, PhD '52)
Donald A. Medwedeff (BS '81)
Fred W. Metzger (BS '73, MS '76)
Joaquin Ruiz (MS '80, PhD '83)
Clarence N. Tinker (BS '54, MS '55)

Awards

Becky Lange receives the Class of 1923 Memorial Teaching Award

Becky Lange is the recipient of the 1997 Class of 1923 Memorial Teaching Award for outstanding teaching of undergraduates at The University of Michigan. Becky's interactions with students taking her classes, from her Freshman Seminar to her instruction at fieldcamp, have received praise and enthusiastic responses. Many have been discovering the excitement and intrigue of earth and environmental sciences for the first time with her clear presentations. Well done Becky!

Scott Tinker designated AAPG Distinguished Lecturer

Scott W. Tinker (MS '85) has been named an AAPG Distinguished Lecturer for the 1997-98 lecture tours. Scott is a Research Scientist with the Marathon Oil Company in Littleton, Colorado. The distinguished lecturers are geoscientists selected by the AAPG Distinguished Lecture Committee for pre-eminence in their specialties. For the coming year six lecturers have been designated; each will spend about four weeks on tour, presenting scientific and educational lectures to universities and geological societies worldwide. Scott's lecture topic is "From Rocks to Models: 3-D Visualization as a Tool to Integrate Sedimentology and Sequence Stratigraphy into Reservoir Modeling."

Richard Williams receives Department of the Interior's Distinguished Service Award

Richard Williams (BS '61, MS '62) has been awarded the Department of the Interior's Distinguished Service Award for his accomplishments in remote sensing with the USGS.

What the Media Say

Science *Magazine writer Richard A. Kerr has been paying a lot of attention lately to the paleoclimatology and paleoceanography research of Michigan students, faculty and alums. Here are snippets from three articles that appeared this year alone. Excerpted with permission from* Science*, v.275, p.161, and p.1267, v.276, pp.680-681. Copyright 1997 American Association for the Advancement of Science.*

Volcanic Ash and Glaciation

In the first article entitled "Out of Fire, Ice?—Part 2" (*Science* v. 275, p.161) Kerr describes the work done by Michigan oceanographers **Dave Rea**, **Libby Prueher** (current PhD student) and **Ted Moore** to identify the catalyst that triggered the deep chill of the past 2.6 million years of northern hemisphere glaciation. Kerr writes "**David Rea** knows as well as anyone that coincidence does not prove causation. But the tighter the coincidence between two events, the stronger the argument for a causal link. And the **University of Michigan** paleoceanographer says a new analysis of a sediment core from the North Pacific has strengthened the case for a link he first proposed four years ago: a connection between a series of volcanic eruptions that rocked the northern rim of the Pacific and the world's precipitous descent into the ice ages 2.6 million years ago."

"Earth had already been cooling for tens of millions of years, perhaps because the rise of the Himalayas affected the atmosphere and weakened the natural greenhouse effect. But 2.6 million years ago, the planet suddenly slipped over the edge into a deep chill from which it has never fully recovered. In the 1970s, a few researchers suggested that a global volcanic outburst recorded in marine sediments at roughly the same time might have triggered the climate shift by lofting debris that shaded the sun, but the records were patchy and imprecise. Now, Rea and his Michigan colleague **Libby M. Prueher** have shown that the eruptions around the North Pacific and the sudden cooling took place within 1000 years of each other. "It looks like the climate system just needed a kick in the pants," says Michigan paleoceanographer **Theodore Moore**, "and this may have been it."

"Rea first drew a connection between North Pacific volcanism and glaciation in 1993, when he saw cores of sediment retrieved from the far northern North Pacific. A roughly 10-fold jump in the frequency of volcanic ash layers from volcanoes up to 1000 kilometers away coincided, as best the eye could discern, with a dramatic increase 2.6 million years ago in the amount of mineral grains scoured from nearby continents by glaciation and carried to sea by rivers and icebergs. Based on a first reading of that sediment record, Rea put the two events within 50,000 to 300,000 years of each other (*Science*, 18 June 1993, p. 1725). That's keeping pretty close company in the geologic record, but the gap left plenty of room for doubts."

"With more precise dating and more analysis, Prueher and Rea have greatly reduced the room for doubt. They find that the best of their cores shows the northern North Pacific switching from preglacial to glacial conditions in just under 1000 years. That's too quick to be driven by other suggested climate forcing mechanisms, says Rea, such as rising mountain ranges or the changing orientation of Earth. And the abrupt climate shift continues to match up with the volcanism."

"Rea is still cautious about claiming a link. "The geologist's most serious disease is assigning cause and effect to things that occur at the same time when they may not have anything to do with each other," he notes. To avoid contracting this dreaded syndrome, he and Prueher are undertaking an even finer dissection of the cores to see if the coincidence can be tightened still more."

Sea-floor Methane Release Warms the Globe?

In the second article entitled "Did a Blast of Sea-Floor Gas Usher in a New Age?" (*Science*, v. 275, p. 1267) Kerr discusses the work of **Gerry Dickens** (PhD '96). "About 55 million years ago, the environment went topsy-turvy and evolution took a leap. A host of modern mammals—from primates to rodents—abruptly appeared in the fossil record of North America. At the same geologic moment, near the end of the Paleocene epoch some tiny shelled creatures called foraminifera suddenly went extinct at the bottom of the sea. And various temperature indicators record a sudden burst of warming on both sea and land, while isotopic signals in forams and mammal teeth suggest a sharp shift in the global carbon cycle.

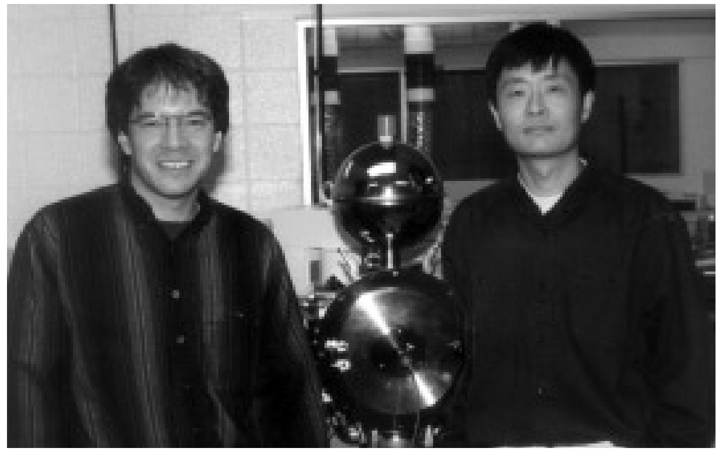
"Now, a new mathematical model points to a single explanation for all these events: a giant release of methane gas from the ocean. In the March *Geology*, paleoceanographer **Gerald Dickens**, water chemist **Maria Castillo**, and geochemist **James Walker** of the University of Michigan use a model of the global carbon cycle to show how a gradually warming ocean might have altered its circulation and triggered a 10,000-year-long burst of methane from the sea floor. Because methane and its oxidation product, carbon dioxide, are greenhouse gases, such a release would have turned the ocean warming into a pulse of greenhouse heating that helped alter the course of evolution on land."

"Although the Michigan gas-blast calculations don't prove this scenario, they "confirm what a lot of us had been suspecting," says paleoceanographer **James Zachos** of the University of California, Santa Cruz. "That's the first time someone has actually done a numerical analysis [of the methane hypothesis]. The results match what we see in the sedimentary record. The new plausibility of the methane mechanism will bolster efforts to pin down what happened in the sea 55 million years ago and spur pursuit of other possible gas bursts", says Zachos."

Orbital Pacing of Ice Ages?

The most recent comment focusses on the work of Michigan alum **Larry Edwards** (MS '86) and his colleagues. In an article entitled "Second Clock Supports Orbital Pacing of the Ice Ages" (*Science*, v. 276, pp. 680-681) Kerr discusses the exciting new age constraints on the timing of past glaciations being achieved by combining protactinium dating with thorium ages of carbonates as elegantly laid out in the paper by Edwards et al., (*Science*, 276, page 282). Kerr explains the importance of this work very nicely.

"For a while, it looked as if a water-filled crack in the Nevada desert might doom the accepted explanation of the ice ages. Twenty years ago, the so-called astronomical theory had carried the day. Oceanographers had found evidence implying



Larry Edwards (MS '86) and Dr. Hai Cheng (Research Associate) with one of the mass spectrometers used to determine the first high-precision proactinium-231 ages, at the University of Minnesota.

that the march of ice ages over the last million years was paced by the cyclical stretching and squeezing of Earth's orbit around the sun, which would have altered the way sunlight fell on the planet's surface. But in 1988, researchers scuba diving in Nevada's Devils Hole came up with a climate record—captured in carbonate deposits in the crack—that seemed to contradict this chronology (*Science*, 6 April 1990, p. 31).

"The Devils Hole record traced climate swings of about the same length as the marine record, but they were out of step with the variations of Earth's orbit. Most glaringly, these carbonates indicated a profound warming trend, which appeared to signal the end of the penultimate ice age, thousands of years before orbital variations could have begun to melt the ice. If the Devils Hole chronology was a true record of the world's ice ages, researchers would have to dump the astronomical mechanism and look for something new.

"But now, after almost a decade of wrangling over whether inaccuracies in the dating of one record or the other might account for the conflict, an arbiter has come forward. On page 782 of the issue of *Science*, geochronologists Lawrence Edwards and Hai Cheng, of the University of Minnesota, and Michael Murrell and Steven Goldstein, of Los Alamos National Laboratory in New Mexico, present the preliminary verdict. They used a new clock, based on the radioactive decay of uranium-235 to protactinium-231, to check the dates of both the Devils Hole record and records of sea-level change in Barbados coral. The result: The marine record is right, and the astronomical theory is on solid ground.

"But the new findings haven't settled the issue cleanly: Puzzlingly, the Devils Hole record seems to be correct as well. To most oceanographers, this bolsters their contention that the Devils Hole and marine records "are two fundamentally different beasts," says Steven Clemens of Brown University. He and others suggest that while the marine records trace the ebb and flow of the ice ages, Devils Hole may chronicle only the climate of a region as small as southwestern North America. "They have convinced us that both kinds of dates are pretty firm," adds geochronologist Teh-Lung Ku of the University of California. "That gives us another layer of confidence that dating isn't the problem.""

Alumni News

1940's

Russell A. Brant (BS '48, MS '49) writes that his activities since graduation in 1949 have held his interest and often presented challenges. He worked in coal resources or related problems for many years with an initial three years with the USGS, followed by 17 with the Ohio Survey, seven years as Assistant State Geologist. He spent seven years with the Ohio River Valley Water Sanitation Commission where he was concerned with acid mine drainage and its impacts on water quality and deep well disposal of wastes. He served 10 years with the Kentucky Geological Survey and was retired in 1986. Since then he has been involved in some consulting, but mostly he has been a volunteer lab technician in the Department of Preventive Medicine at the University of Kentucky. Home activities include working on a gas chromatography project with a friend and associate.

Rae, his spouse of 52 years, shares memories of that post-war excitement and experience. They have four children and three grandchildren; their daughter, the oldest, was born in Ann Arbor and is one semester shy of a degree in Geology. Perhaps his greatest regret is having lost contact with his thesis partners, **Bill Gillespie** (BS '48, MS '49), **Nick Elmer** (BS '48, MS '49) and **Bob Peterson** (BS '49, MS '50).

In September of 1996 he was awarded the W.W. Mather Medal for contributions to the Geology of Ohio. He was honored by the representation of family and friends from many areas. Russell and his wife live in Lexington, Kentucky.

Helen L. Foster (BS '41, MS '43, PhD '46) has fond memories of Orlo Childs. She and Orlo were the only PhD candidates in geology while she was a grad student. Their offices were on the 4th floor of the Natural Science Building, and they used to invite various faculty members and interesting visitors to Orlo's office (he had the best office) for lunch once a week. Helen especially remembers E.C. Case (a short person) entering the office with his hat held on the end of his umbrella, walking up to Orlo and, holding the hat at Orlo's eye level, saying "Good morning, Mr. Childs." They had some memorable times and Helen is sorry that she can no longer share those memories with her old friend.

1960's

Richard J. Pike (PhD '68) was reinstated at USGS in Menlo Park after a one-year layoff, but it took a formal appeal to the U.S. Civil Service to do it. His digital map of the U.S. has gone into its 3rd printing (an unprecedented 30,000 copies). It's the USGS's best-selling map product ever. Richard lives in Atherton CA.

Phil Bjork (BS '62, 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

Roger L. Gilbertson (PhD '72) is now in Santa Cruz, Bolivia, with BHP. He's going to try finding some Devonian crinoids for George McIntosh (PhD '83) up on the altiplano, about a three-day drive from Santa Cruz.

Larry C. Hulstrom (BS '76) is presently a senior engineer with IT Hanford Inc. in Richland WA, a subsidiary of IT Corporation. He is involved with environmental characterization and restoration activities at the Department of Energy's Hanford Site in southeastern Washington. Larry resides in Kennewick WA.

Kathryn Sena Makeig (BS '73) started her own environmental engineering firm in 1993 in Rockville MD. The firm, Waste Science Inc., provides services to the private and public sectors. One of the more interesting projects that involved an application of hydrogeology concerned the movement of ground water in deep soils beneath a factory during the 1993 mid-western floods along the Missouri River. Otherwise, unfortunately, much of the environmental field involves more regulatory interpretation than geology.

Fred Mauk (MS '72, PhD '77) is celebrating "The Big 50" in late June, with an extended bacchanalia at the mountaintop retreat of **Steve Henry** (BS '73, MS '78, PhD '81) and **Krys Swirydczuk** (MS '77, PhD '80) in Cloudcroft, New Mexico. Also planning to attend this event of the half-century are **Dave Brewster** (BS '73, MS '78), **Carola Stearns** (MS '81, PhD '88) and many of Fred's friends from around the country. When not atop Cloudcroft Mountain breathing deeply of the clear mountain air, Fred can be found in Dallas doing custom woodworking.

1980's

Teresa S. Czarnik (BS '84) writes that in March of 1996, she and her husband Tim spent a weekend in a spacious, rustic cabin at Blackwater Falls State Park in West Virginia. In May of 1996 they collected sharks teeth at Englewood Beach (just south of Venice Beach) in Florida. At the end of July, they went camping in northern California, where the wildflowers were in bloom. In California, they saw two old gold mines at Plumas-Eureka State Park. They also explored Lassen Volcanic National Park, where they saw sulphur works. They hiked the length of Bumpass Hell Trail, and saw the panoramic views from the summit of both Lassen Peak and Cinder Cone. Kings Creek Falls was worth the side trip. North of Lassen Volcanic National Park, they walked through a lava tube called Subway Cave. They also camped at McArthur-Burney Falls State Park. Water seeped out of the rock walls to the right and left of the falls, making the falls look extremely wide because the ground water had hit an impermeable rock layer at that nearly horizontal seepage boundary. They finished their camping trip in northern California by spending a few days at Lake Tahoe, including stops at Emerald Bay and Eagle Falls. In August they spent a week at a cabin at Oconee State Park in northwestern South Carolina. Teresa and Tim live in Plainsboro NJ.

Ra (Sarah) Eldridge (MS ’85) writes that after 10 years with BP in Alaska, she transferred to Aberdeen, Scotland, and is enjoying it tremendously. She and John have been there since October and are enjoying a relatively tropical winter with their three year old, Luke. While she dabbles in geophysics in the North Sea, she’s learning all about the geology of a new basin. Ra says they are likely to be there for three years, and they would love to have visitors.

Liza Finkel (MS ’86) is now teaching science at Noble High School in Berwick, Maine. She was recently featured in the *Portland Press Herald* for her innovative approach to teaching science. Instead of teaching earth science one year, then biology the next, then chemistry, etc., Liza takes a more comprehensive approach that gives students an integration of several scientific disciplines at once. The concept, which is becoming popular nationally, is called Every Science Every Year. Prior to moving to Maine, Liza was on the faculty of U-M’s School of Education for three years.

Dave Moecher (PhD ’88) was just officially informed that he has been promoted to Associate Professor with tenure at the University of Kentucky.

Donald L. Sprague (MS ’80) writes from Kuala Lumpur that he and his family (wife Donna, daughters Leah and Caroline) have traveled some this year. They went to Perth and toured southwest Australia by car last spring. Perth is probably the 2nd nicest city on Earth (after Ann Arbor). The climate is a dry Mediterranean type and the city is very spacious with lots of parks and wide roads. Most of the population of western Australia lives in Perth so when you leave the city you are out in the wide open spaces with lots of rolling hills and forests of Karri trees (a giant variety of eucalyptus). They also went to the Indonesian island of Bali. It is not exactly an uninhabited tropical paradise, as there are people everywhere and every square meter of land that can be farmed is being used. The beaches are very nice—that’s the attraction. Don and Donna also plan to go to Saigon. They are looking forward to seeing it because of the prominent place it holds in recent American history. They have been in Malaysia almost three years so far, and there is a pretty good chance they will be returning to the US this year.

Don, Donna, Caroline, and Leah Sprague in Bali, December, 1996

Bryan E. Stepanek (MS ’84) is transferring to Abu Dhabi (UAE) effective April l, l997, after 12 winters in Alaska with BP Exploration. He will be the only American working in the Abu Dhabi Marine Operating Company (ADMA-OPCO), an offshore oil company which employs people from 48 other countries. Bryan, Rebecca, Rachel (3) and Emily (1) are looking forward to the interesting cultural experience and the significant change in climate. Bryan can be reached by e-mail at stepanbe@BP.com.

1990’s

Teri Boundy (PhD ’96) has accepted a job as Assistant Professor at Ball State University, Muncie, Indiana, starting this fall.

Henry Fricke (PhD ’97) has accepted a postdoc at the Geophysical Lab.

In June, **Bernie Housen** (PhD ’94) moved from Minneapolis to Western Washington University in Bellingham, to join the geology department as an Assistant Professor, replacing Myrl Beck, who is retiring (in job status, not personality). Bernie, Beth, their daughter Rachel and son Wil are looking forward to exchanging flat landscapes and cold winters for lots of nice mountains and rain in the winter.

Klaus Mezger (postdoc ’90) is moving to the University of Muenster (Germany) as professor.

Andy Nyblade (PhD ’92), after five years as a research geophysicist at Penn State, has moved on to a tenure-track appointment there. Andy has developed a course in environmental geophysics with a significant field component that is attracting a strong enrollment. Andy and spouse Sue Brantley are proud parents of a daughter Madeline.

The Michigan Bookshelf

Every now and then we highlight books by members and former members of our Department that have been published recently. Here are three new ones:

Earth Structure: An Introduction to Structural Geology and Tectonics by **Ben van der Pluijm** and Stephen Marshak (WCB/ McGraw-Hill).

Roadside Geology of Louisiana by **Darwin Spearing** (MA ’64, PhD ’69) (Mountain Press Publishing Company).

Fundamentals of Geological and Environmental Remote Sensing by **Robert K. Vincent** (PhD ’73) (Prentice Hall).

Mixing the mantle: The role of a high viscosity lower mantle

by Peter Van Keken

***Peter van Keken** joined the ranks of the tenure track faculty in September 1996, after a two-year visiting Assistant Professorship here. In between teaching a variety of classes in geodynamics and planetary geology, he has been able to secure NSF funding for two projects and modernize the computational geodynamics facilities on the fourth floor of the C. C. Little Building. His main research interests are in the dynamics of the Earth's lithosphere and mantle, investigating topics such as the role of rheology in mantle convection, thermal evolution of the Earth, and modeling techniques for plume formation and thermochemical convection. One of the research projects is a collaborative work with noble gas geochemist **Chris Ballentine** to study the role of volatile degassing in mantle convection.*

Terrestrial noble gas isotope geochemistry provides one of the most powerful geochemical tools presently available for understanding the volatile evolution of the Earth. Evidence from noble gases has placed constraints on the timing and magnitude of mantle outgassing and its role in the formation of the atmosphere. The data require the existence of reservoirs with very different volatile concentrations within discrete portions of the mantle, and play a critical role in defining the extent of volatile transport within the mantle. These observations place constraints on models for the chemical evolution and present day state of the Earth's interior. In particular, differences observed in noble gas isotopes between mid-ocean ridge basalts (MORB) and ocean island basalts (OIB) address whether or not the mantle can be described by whole mantle convection or layered convection models.

Numerical studies of mantle convection better constrain the thermal and chemical evolution of the Earth. In view of the large uncertainties in the parameters that govern the dynamics of the lithosphere and mantle, forward modeling creates a unique opportunity to provide parameter ranges for which mantle dynamics has a sufficient Earthlike signature. The interplay between forward modeling and geophysical and geochemical observations of mantle dynamics provides a powerful way to improve our knowledge and understanding. It is important that hypotheses which are put forward to describe the Earth's present state and evolution satisfy both basic physical principles and surface observations (such as the geochemical record, heatflow, plate velocities, seismic wave propagation, geoid and topography).

The rheology of lithosphere and mantle places an important control on the dynamics of the Earth's interior, and consequently on its mixing behavior. Information on deformation of mantle silicates is obtained through laboratory experiments and inversion from surface observables.

Although the rheology of olivine and related mineral assemblages under upper mantle conditions are fairly well known, there is only very limited data available on creep mechanisms in the lower mantle. At present it is not possible to perform creep experiments on relevant mantle silicates under lower mantle temperature and pressure conditions.

However, independent information on the effective viscosity in the lower mantle can be obtained from inversion of geodetic measurements, such as geoid, topography and variations in the Earth rotation. In recent years, a consensus has emerged that indicates a lower mantle viscosity profile that increases with depth, with a maximum viscosity as high as two to three orders of magnitude larger than the upper mantle viscosity. This radial distribution of viscosity is an expression of creep of mantle silicates under the ambient lower mantle conditions. It indicates that, at least in parts, convection in the lower mantle is much more sluggish than in the upper mantle.

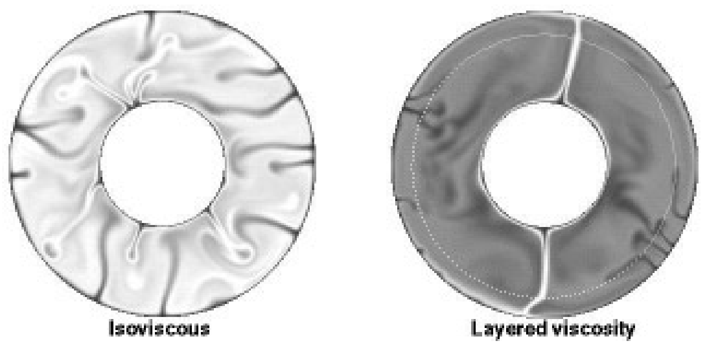


Figure 1: Snapshots of temperature of a time-dependent convection calculation with isoviscous (left) and depth-dependent rheology (right). The model on the right has a higher viscosity in the lower mantle, leading to more sluggish convection and stable plumes.

The higher viscosity in the lower mantle may provide a natural explanation for the differences in noble gas systematics of MORBs and OIBs. One may imagine the situation of a rapidly convecting (and mixing) upper mantle on top of a sluggish lower mantle that only every now and then supplies hot plumes that bring up lower mantle material.

The main purpose of this study has been to investigate whether or not this simplified view can be supported by the nature of mantle convection. We have tested this by comparing a suite of simplified models of mantle convection. We have simplified the model by using a cylindrical geometry and assuming that the viscosity is only depth-dependent. Present-day computational resources do not yet allow a parameter study of mantle convection in its natural, 3-D spherical geometry. Using a 2-D box is an often used simplification, but this may lead to artifacts due to the boundary conditions and the lack of curvature. Assuming convection in a cylinder (Figure 1)

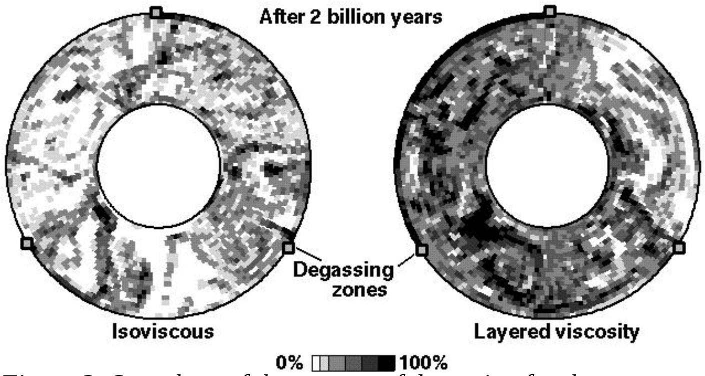


Figure 2: Snapshots of the amount of degassing for the two models in Figure 1. The darker cells are more degassed. Due to the more rapid convection in the upper mantle in the right hand model, the degassing occurs more rapidly.

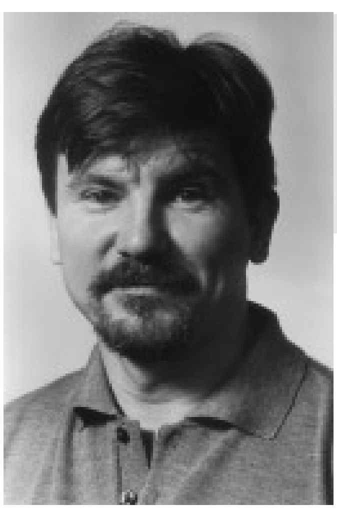
provides a reasonable trade-off between computational cost and geometrical approximation.

In all models we have matched the driving forces expressed by parameters like the Rayleigh number and internal heating coefficient such that the average heat flow from the mantle is similar to the present-day value. The only difference in the models is the value of the viscosity in the lower mantle, which ranges from being equal to the upper mantle viscosity, to an increase of a factor of 100 with respect to that of the upper mantle. Figure 1 compares two snapshots of temperature for a typical convection calculation with constant viscosity (Figure 1a), and with a 30x increase in the lower mantle (Figure 1b). The more sluggish nature of convection in the lower mantle is evident by the presence of a few nearly stationary plumes. In order to maintain an overall convective vigor that is similar to that of the isoviscous models, the upper mantle needs to convect more rigorously, and this is expressed by the large number of small-scale downwellings in the upper mantle.

This more rapid convection in the upper mantle compared to the isoviscous case has interesting consequences for the rate of degassing of volatiles at mid-oceanic ridges. This is simulated in Figure 2, which shows the amount of degassed material for the two models in Figure 1. We have modeled three degassing zones at the indicated spots and the models have evolved for 2 billion years. Each indicated particle has moved through a degassing zone at least once. The ingrowth of ^{4}He (due to radiogenic decay of U and Th) into previously degassed particles is indicated by the intensity of the particles. Black indicates recently degassed particles. The increase of ^{4}He makes the particles shift towards white. After 2 billion years, approximately 20% of the mantle has been degassed in the isoviscous case, compared to 40% in the layered viscosity case.

Our first conclusion is that, although the overall convective vigor of the two models is similar, the degassing rate of the layered viscosity models is much larger due to the more rapid circulation in the upper mantle. Our second conclusion is that the sluggish nature of the lower mantle convection alone is not sufficient to explain the observed difference between MORB and OIB sources. From models such as those shown in Figure 2, we cannot identify a distinctly different nature between upper mantle and lower mantle in terms of helium content.

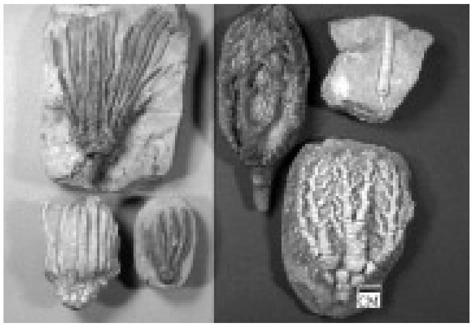
With this type of modeling we have provided a negative test to our hypothesis that the higher viscosity in the lower mantle is responsible for geochemical heterogeneity. It leads us back to a long-standing controversy between the geochemical layered mantle convection model, and the geodynamical consensus for some form of whole mantle convection that is based on a large number of geophysical observations. Our search for a unifying model currently focuses on the interplay between more realistic temperature- and pressure-dependent rheology and thermodynamical phase boundaries in the Earth's transition zone.



Current Life:
Interpreting the Functional Morphology and Evolutionary Histories of Crinoids
by Tomasz Baumiller

***Tomasz Baumiller** arrived in Ann Arbor last July to take up a position as Assistant Curator in the Museum of Paleontology and Assistant Professor in Department of Geological Sciences. Tom received his PhD at University of Chicago in 1990. He spent a year as a Post-doctoral Fellow at Ohio State, and then five years on the faculty of Harvard's Department of Earth and Planetary Sciences. Tom studies the functional morphology of modern and fossil organisms by employing experimental, theoretical, and field-based approaches, as he explains in the article which follows.*

The problem of deciphering how organisms function has a long tradition in biology and paleontology: even pre-Darwin, it was recognized that morphological structures fulfill functions and thus have a "purpose" and to many natural historians the study of functional morphology was a way of identifying the principles laid down by the "designer." Although the theory of natural selection did away with the concept of a designer, functional morphology retained its status as an important discipline in evolutionary biology as its focus shifted to the study of "adaptations." A more recent development, especially among paleontologists, is to extend studies of functional morphology beyond mere



Examples of fossil crinoids representing taxa with many, finely-branched arms (right) and those with few, unbranched arms (left).

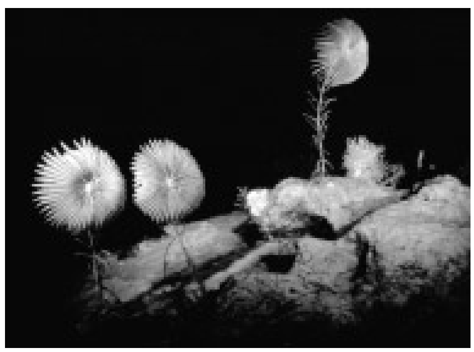
descriptions of adaptations and to use them in explaining evolutionary trends and evolutionary transitions; this is the approach I have used.

In my research, understanding how organisms function serves only as the first step for addressing a broader issue, namely, what is the effect of functional morphology on evolutionary properties (speciation/extinction). An example is the study of the functional morphology and evolutionary history of crinoids. This group of echinoderms has a very rich fossil record (ca. 1000 genera) and their remains constitute a large proportion of many mid-continent Paleozoic limestones.

As passive suspension feeders, crinoids utilize a planar array of arms and arm branches lined with sticky tube feet to intercept particles carried by the currents; the arms and arm branches are well represented in the fossil record. The filters of Paleozoic crinoids span a very broad morphological spectrum, ranging from taxa with few, unbranched arms, to those with tens of finely-branched arms. I set out to understand (1) what were the functional consequences of these morphological differences, (2) whether these differences could affect the patterns of environmental distribution among crinoids, and (3) could they account for differences in the evolutionary patterns among taxa with different morphologies.

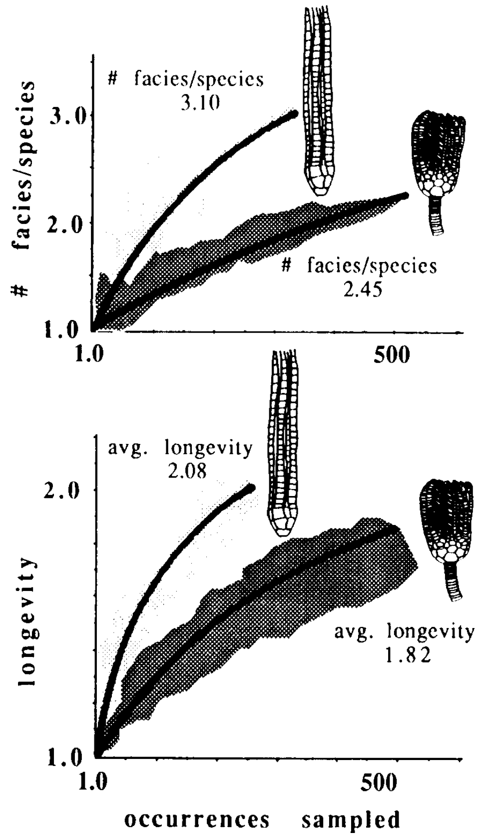
Functional morphology of filter feeding

Although a large body of engineering literature is devoted to understanding the fluid dynamics of filtration, it is generally concerned with man-made filters, which differ in important respects from biological filters: in the former, fluid is constrained by a duct and thus forced to pass through the filter, whereas in the latter, fluid is free to move around the feeding structures due to the filter's resistance. In fact, it is this very resistance of a filter to flow that is of primary importance to understanding the functional morphology of crinoid feeding. The basic principle is intuitively obvious: filters with many, closely spaced fibers have a high resistance, while those with a few, widely spaced fibers have a low resistance. As a consequence, for resistant filters at low current velocities most of the approaching fluid diverges around them rather than passing through them. For an organism which relies on the fluid to supply it with particles, such a situation may prove intolerable: it may starve. The goal was to determine the threshold current velocity at which a crinoid of a given morphology could no longer receive sufficient particles to satisfy its metabolic rate.



Stalked crinoids in ca. 300 meter deep water off the west coast of Grand Bahama Island. Crown diameter is approximately 50 centimeters.

To determine this, a variety of parameters involved in particle capture and crinoid metabolic rates had to be quantified. This was accomplished by collecting live crinoids by submersibles and SCUBA and conducting observations and experiments in flow tanks. Once the required parameters were obtained, an analytical solution describing particle capture rates for crinoid-like filters was employed to calculate the threshold velocity for a range of fossil crinoid morphologies. The results indicated that crinoids with finely-branched arms required current velocities in excess of 10 cm/s to satisfy their energy requirements; crinoids with few, unbranched arms required much lower velocities.



Rarefaction analysis for facies distribution and longevities among Mississippian crinoids. This techniques normalizes for differences in the number of species and number of occurrences. The shaded regions represent 95% confidence intervals based on 500 bootstrap simulations of the data. Top: Pattern of facies distribution among crinoids with different filter morphologies. Bottom: Pattern of longevity for those same groups of species. Species with many, finely-branched arms have shorter stratigraphic ranges than species with few, unbranched arms.

Ecological and evolutionary consequences

Given these results, I next examined the distribution of Paleozoic crinoids among different facies. I found that crinoids with finely branched arms occurred in fewer facies and that they generally occurred in facies interpreted to represent higher current velocities, while crinoids with unbranched arms occurred in more and a broader array of facies, results consistent with the functional differences.

The differences in patterns of environmental distribution between the different filter morphologies could have evolutionary consequences. For example, organisms occupying a broader array of environments (generalists) are less likely to form isolated populations and thus a lower propensity to speciate than those taxa with finely-branched arms constrained to living in more restricted habitats (specialists). Moreover, environmental disturbance is also less likely to lead to the extinction of broadly distributed taxa (generalists). Evolutionarily, this implies that taxa with many, finely-branched arms should be evolutionarily shorter lived and be more speciose. To test this prediction, I examined the fossil record of Paleozoic crinoid genera categorized by their filter morphology, and found statistically robust patterns consistent with the predictions: crinoids with many, finely-branched arms were more diverse and had shorter stratigraphic ranges than taxa with few, unbranched arms.

The above example demonstrates that although the ever-popular contingency may play an important role in evolution, many trends and large scale patterns may have simple, deterministic explanations. Furthermore, it emphasizes that paleontological studies can go well beyond being descriptive and that they are just as amenable to the hypothetico-deductive method as are the non-historical sciences.

Staff Profile: Bill Wilcox

With this issue, Geoscience News begins a series of staff profiles in recognition of the employees of the department whose hard work behind the scenes makes it all possible.

William Dean Wilcox

Title: Coordinator of Building Services

Family: Married 19 years

Wife Diana, Children: Isaac (14), and Jesse (10)

Education: BA, Anthropology, SUNY Albany 1972. School of Social Work, U-M 1975, Digital Equipment Technology, Washtenaw Community College, 1983.

Bill Wilcox began with U-M in 1978 as a temporary stockeeper for the U-M Hospitals ICU. In August 1978 he was appointed as a Media Assistant for Post Graduate Medicine at U-M Medical School/Hospitals complex, with several promotions over five years to Media Engineer II. Bill joined Geological Sciences in 1984 as Supervisor of Equipment and Supplies, replacing Stu McDonald. He was reclassified in 1991 to his present position.

There are some who argue that Bill Wilcox is one of the most critical individuals among the Department's support staff. Broadly stated, his responsibilities involve facilitating the work of the faculty, staff, and students as necessary, with an emphasis on physical plant, facilities, and field camp. That physical plant includes the 63,685 square feet of C. C. Little, much of which has been renovated in a continuous series of major projects begun in 1986. All of this space must be serviced and maintained. Bill also monitors department inventory, space assignments, door keying, furnishings, field trip equipment and vehicle preparation, and department storage. Every year, Bill hires kitchen, secretarial and maintenance support staff for field camp, orders supplies and equipment, and generally coordinates non-academic on-campus services for Camp Davis.

For the past three years, Bill's time has been monopolized acting as the intermediary between the department and the various contracting groups and departments involved in the infrastructure renovation of C. C. Little. Bill knows the building and its systems perhaps better than anyone, and because of this he has been able to smooth out many of the difficult phases of this ongoing project. Intense frustration and frequent conflict have marked this period of his work life. There are rewards, however. The variety of tasks means that challenge takes on a new form almost every day. This also means a considerable day-to-day independence. Bill gets satisfaction seeing his efforts and the procedures he has initiated result in improvement of Department conditions. In the nine years prior to the present renovation cycle, Bill and his family were able to spend part of each summer at Camp Davis-definitely a reward in light of Ann Arbor's often muggy summers. Someday he hopes to take advantage of the many fine field trips offered each year by the faculty. Bill appreciates the opportunity to examine the departments rock and mineral specimens. He also takes an interest in preserving the department's historical artifacts, pictures, and equipment.

Recreation outside of work comes in many forms. Bill is an avid landscaper and gardener with a special interest in the Chinese Hibiscus. His preferences in literature lean strongly toward science fiction, natural history, and reading the Bible. Generally he detests TV, but does watch Babylon 5 fanatically. He also enjoys field trips to collect geological specimens; fossil fish from the Green River Formation, fossils from the Florida Gulf Coast, Idaho Opal, Montana sapphire, and Petoskey Stones. It is hard to imagine the Department without Bill Wilcox, and the order and good will that he brings to bear in our daily lives.

Faculty, Research Staff, and Student News

Robyn Burnham and her student **Beth Kowalski** spent the month of February collecting Miocene fossil plants from intermontane basins in the Ecuadorian Andes. They visited over 40 localities and collected more than 400 plant fossils during the trip, sampling a variety of delicious Ecuadorian food along the way.

This fall, **Eric Essene** and **Joyce Budai** were able to attend the fall GSA meeting together for the first time in quite a while. The most notable item is that daughter Michelle (29) is graduating as medical student at the University of Minnesota this spring. She will be doing a pediatric and family practice residency at a hospital in Minneapolis associated with the University.

Eric's newest PhD student **Steve Keane** is developing trace element thermobaromatry, first on the substitution of Zr and Ti in garnets. This work involves trace element analysis of garnets collected by **Charlie DeWolf** (PhD '93) and Steve in the Wind Rivers Mountains in Wyoming. A first paper is in submission to *Geology* on this work. Steve has been using the Oak Ridge SIMS with Lee Riciputi and is planning to undertake high pressure experiments with Craig Manning at UCLA. Some of this work also involves **Steve Bohlen** (PhD '79). **Peter Tropper** (PhD '98) is also working with Craig at UCLA on glaucophane stability at present. Eric continues research on high grade metamorphic rocks in the Grenville Province with **Meg Streepey** and **Ben van der Pluijm**. **Grigore Simon** has one paper recently published with Eric on selenide mineral stabilities and one paper in submission deposits to *Economic Geology* with **Steve Kesler** and Eric on the implications for selenide ore. Eric is also researching mantle rocks and minerals from diamondiferous kimberlite pipes with **Donggao Zhao** and **Youxue Zhang**, and on mantle garnets and their inclusions from the Four Corners ultramafic diatremes with **Liping Wang** and Youxue. Donggao, Youxue and Eric have a manuscript ready for submission on the calibration and use of rutile-ilmenite oxybarometry. Liping, **Don Peacor**, **Roland Rouse** (PhD '72), Youxue and Eric are also studying a chrome titanate mineral that has just been approved as a new mineral. It will be named carmichaelite to honor Ian Carmichael, Professor at U-C Berkeley, **Becky Lange**'s advisor, and Eric's good friend. Eric is also working with Roland and Don on three rare earth sulfate/oxalate hydrates (shades of W.W. Crook III!), each of which has just been approved as a new mineral. The occurrence of these minerals is even more bizarre than their formulae; they grow as microcrystals in residual soils in the Smoky Mountains Tennessee.

As mentioned briefly in the last newsletter, **Bill Farrand** is beginning a phased retirement in July '97. He will continue for another three years as Director of the Exhibit Museum of Natural History on a half-time basis (as at present), but will no longer be active in the Department. Carola Stearns will take over the geomorphology course, Earth Surface Processes and Soils, which is a requirement for the environmental geology concentration, during this time. The glacial geology course will no longer be offered in the foreseeable future, seemingly ending a Michigan tradition.

The Exhibit Museum will keep Bill more than busy enough, as he tries desperately to finish off several long-standing research projects. In addition, he will be in the field again this summer, examining prehistoric cave sites in northern Spain and southwest France. The Museum is gearing up for a new major exhibit on ancient whales based on the recent collections of Phil Gingerich in Egypt and Pakistan. The exhibit will open in early October 1997 and will feature a 19-ft long skeleton of *Dorudon atrox*, complete with a small but functional pelvis and hand limbs, that will hang from the ceiling of the Hall of Evolution.

Dan Fisher continues to wrestle tusks in and out of his lab, and the picture of changes in proboscidean life history during the late Pleistocene is slowly coming into focus. Initial results, supporting the importance of human hunting as the cause of late Pleistocene mastodon extinction, were presented at the annual meeting of the Society of Vertebrate Paleontology, and covered subsequently in the national press. Meanwhile, his development of procedures for incorporating stratigraphic data in the reconstruction of evolutionary relationships has begun to draw fire from the opposing camp, and a major symposium on use of stratigraphic data in phylogenetic analysis is scheduled for next fall's SVP meeting. Collaborative projects with current graduate students **David Fox**, **Lindsey Leighton**, **Will Clyde**, and **Jonathon Bloch**, and with former graduate student **Brian Bodenbender** (MS '90, PhD '94), are exploring various ramifications and applications of "stratocladistics," so it looks like exciting times lie ahead for all. As if the summer didn't look complicated enough already, a new mastodon site showed up in mid-May, so Dan and students are currently splitting their time between the Museum of Paleontology and a late Pleistocene pond bottom.

Phil Gingerich has just come back from a Penrose Conference on the Paleocene-Eocene boundary where my work with **Paul Koch** (MS '85, PhD '89), **Jim Zachos**, and lately **Will Clyde** was featured in what we hope will be the first ever consensus on the boundary by marine and continental biostratigraphers. This is due to the happy coincidence of the first appearance of a cosmopolitan early Eocene mammalian fauna and a benthic foraminiferal extinction event tied together by the terminal Paleocene carbon isotope excursion, possibly due to thermal dissolution of hydrated methane. In addition, Phil has been busy working on a new early Eocene Tethyan land mammal from a slice of obducted oceanic crust now in Baluchistan but then off the northwestern coast of Indo-Pakistan. He is going to Baluchistan again to try to find more of the fauna.

Research scientist **Chris Hall** has been developing a new detector system for use with some of RIGL's mass spectrometers, including the new Plasma-54. A prototype amplifier board which can switch between traditional current detection and charge detection mode under digital control is being tested. The goal is to improve on signal to noise ratios for extremely small samples. He is also collaborating with **Chris Ballentine** on upgrading the software for the noble gas mass spectrometers.

In an NSF funded project to use new $^{40}Ar/^{39}Ar$ techniques to date ore deposits, Chris, in collaboration with **Steve Kesler** and **Grigore Simon**, has dated adularia and sericite associated with gold mineralization at the Twin Creeks mine in Nevada. In one portion of the mine, it appears that mineralization took place about 43 million years ago, but preliminary runs on material across a fault zone gave much older ages. This was very unexpected, and further analyses will be performed to verify the initial results.

Also a suite of glass shard samples from Ocean Drilling Program tephra layers are being irradiated for laser $^{40}Ar/^{39}Ar$ dating. The stratigraphy of these tephra is extremely well constrained, so this has the potential of allowing for precise time scale calibration. Unfortunately, glass, which is not normally used for dating, is the only material available in sufficient quantities. Early tests with glass shards suggest that some of their traditional problems may be associated with anomalous isotope fractionation effects, which can be avoided by keeping the samples cool prior to analysis. There should be results for the next newsletter.

Alex Halliday has been doing a lot of traveling recently with invited lectures at Cornell, Yale, University of Florida, Washington University, University of Pittsburgh, University of Toronto, McMaster, Brock and Guelph. There is considerable interest in the new technique of multiple collector inductively coupled plasma mass spectrometry and the exciting discoveries that are being made in areas as different as the early evolution of the solar system and climate dynamics. The postdocs in Alex's group have been furiously busy. **Der-Chuen Lee** is producing tungsten isotopic data which are providing new constraints on the formation of the Moon and Mars. **John Christensen** has been discovering that there are lead isotopic records of changes in climate and ocean circulation preserved in ferromanganese crusts and retrievable using a laser. **Mark Rehkämper** has discovered some striking variations in platinum group element abundance patterns in ultramafic xenoliths which appear to relate to the mechanisms of growth of the continental lithosphere. **Thomas Pettke** has just started in the lab and is already producing an interesting record of changes in dust provenance with time in the Pacific Ocean. **Hailiang Dong** has completed his PhD on dating clay diagenesis and taken a position as a postdoc at Princeton. PhD student **Dan Barfod** is producing very nice helium and now neon isotopic data for the Cameroon line and is getting ready to head out with **Chris Ballentine** to collect some more samples. **Wen Yi** has now produced an excellent dataset for weird and wonderful elements that nobody has much clue about in the Earth's mantle, including indium, tin, cadmium and tellurium. **Xiaozhong Luo** has gotten the U-Th method working well and is about to head off to China to collect a bunch of mud, dust and soil with **Rob Van der Voo**, **Dave Rea** and **Catherine Badgeley**. According to Dave, half the world's dust comes from Asia so what better place to look at erosion. We have some new faces showing up soon. **Claudine Stirling** is a new postdoc who has just completed her PhD at A.N.U. working on U-Th disequilibrium series dating. **Kevin Burton**, who has been doing Os isotope geochemistry in Paris, should arrive this summer. Finally, we had a very stimulating and enjoyable time with Ken Farley and Tom Ahrens, two Turner speakers who came through from CalTech this semester. Partying with Tom can be a lot of fun as you can tell from the masked gathering at Alex's house.

Jean Tangeman, Damon Teagle, Joe Graney, Tom Ahrens, Der-Chuen Lee, Jim O'Neil, Becky Lange, Lynne Barfod (l-r)

Steve Kesler was back in Australia in January and February, first as guest lecturer for the Economic Geology Study Group of the Geological Society of Australia and then giving a short course on porphyry copper deposits at the University of Western Australia. He then took the short course to Indonesia and the Philippines, where he visited the King King gold-rich porphyry system in Mindanao, which is the subject of a research project by MSc candidate, **John Fortuna**. Other trips included Denver for the AIME/SME/SEG convention, along with MSc candidate, **David Borrok**, who was in search of a job (see below), and Spokane, along with MSc candidate, **Jim St. Marie**, for a research conference organized by Cominco, Ltd. In between these, he managed a visit to the Prospectors and Developers Conference in Toronto, which was also attended by PhD candidate, **Grigore Simon**, and MSc candidate, **Sue Duly**. Steve ended the term giving a porphyry copper course in Santo Domingo and visiting a number of deposits and prospects on the island. The Ore Deposits Lab will be unusually lonely this summer. In addition to David Borrok, who is leaving to take up a full-time job with Asarco, all of the students will be out on summer exploration jobs, with Grigore in Cuba and Romania, Sue in Ontario, Jim in Washington state, and John in Nevada and the Philippines. Hopefully, this will give Steve a chance to catch up on things, as he begins his term as President-elect of the Society of Economic Geologists.

Becky Lange is very excited about the prospect of a sabbatical next year. She is planning to spend part of that time doing field work in both Mexico and Central America, looking at subduction zone magmatism. Becky is particularly interested in determining rates of eruption and magmatic differentiation along continental margins. The other part of her sabbatical will be spent setting up an acoustic interferometer for measuring the compressibility of silicate melts at high temperatures. The long term goal is to develop this technique for use at high pressure such that the compressibility of hydrous magmatic melts can be directly determined. Good news from the NSF this last round means that this work on the transport properties of volatile-bearing melts can continue for the next three years. In the meantime, **Jean**

Tangeman and **Sharon Feldstein** are both planning to defend their PhD theses next Fall. Jean Tangeman just got back from a trip to Europe where she presented an invited lecture on her research in both Germany and France. **Fred Ochs** will spend part of this summer setting up our newly acquired rapid-quench cold-seal pressure apparatus (shared with **Youxue Zhang**) and the other part doing field work in the Aurora volcanic field of eastern California.

FLASH! LAKE NICARAGUA EXPEDITION GEARING UP! **Ted Moore** and **Dave Rea** have joined with postdoctoral student **Jerry Urquhart** from the University of Michigan's Department of Biology, in planning an exploratory expedition to see if the sediments of Lake Nicaragua might contain a detailed record of tropical paleoclimate. The idea for this expedition was originally proposed by Dr. **Paul Colinvaux**, of the Smithsonian's Tropical Research Center in Panama and the Center for Great Lakes and Aquatic Sciences (CGLAS) at the University of Michigan. Paul is an expert in tropical pollen studies and has focused his attention on the impact of ice age climates on the tropics. He is also Jerry's advisor for his postdoctoral work on tropical climate change based on pollen studies. Dave has had so many offers to travel to exotic places that he could not accept them all and had to bow out of the trip to Nicaragua in order to participate in the **Van der Voo** et al. expedition to China. However, our friends from Minnesota, **Tom Johnson** and **Nigel Wattrus** will be joining Ted, Jerry, and Paul, to undertake one of the first seismic reflection and coring cruises on Lake Nicaragua. Jerry has arranged for us to cooperate with Nicaraguan scientists from the Center for the Development of Aquatic Resources of Nicaragua and has chartered us a palatial cruise ship (see photo) on which to sail with our Nicaraguan colleagues. The lake is the largest body of fresh water between Lake Titicaca to the south and the Great Salt Lake to the North. It is a bit smaller than Lake Erie and has bottom sediments that are at least 2-3% TOC (total organic carbon). We expect to find in the sediments a rich fossil assemblage of not only pollen, but also ostracodes and diatoms. We hope that the sediments in the deeper parts of the lake may contain a detailed record of climate fluctuations that capture the nature of climate change from glacial to Holocene times,and if we are very lucky we may even find records of sufficient detail to trace the character of El Niño fluctuations that impact this region. In addition to helping us locate the best places to core, the seismic reflection data obtained by Tom and Nigel should give us some insights into the structural development of the lake basin itself. Geologic maps of the region indicate the presence of Neogene marine sediments exposed on land to the west of the lake and separating the lake from the Pacific ocean by only a few tens of kilometers. Two active volcanoes sit in the eastern part of the lake and form part of a chain of volcanoes associated with the Middle America Trench. Some of our older associates may recall that the San Juan River - Lake Nicaragua route was at one time considered to be the best choice for the development of a canal linking the Atlantic and Pacific Oceans. The best bathymetric maps of the lake that we have today date back to the 1850s - 1890s when the U. S. commissioned surveys to determine the feasibility of such a canal route. The story has it that the U. S. Congress was ready to vote the money for this canal project until the U.S. Post Office jumped the gun by


Scenes from the annual Spring Banquet. Among those attending: (clockwise from top left) Spencer and Lisa Kraemer and Kelly and Stephen Fuks; Becky Lange, Jim O'Neil; Lisa Kraemer, Kelly Fuks; Arlo and Sarah Weil, Meg Streepey; Nate Diedrich and Tim Ku; Holly Godsey and Henry Fricke; Kia Baptist and Matthew Nwosu.

issuing a stamp showing the two Lake Nicaragua volcanoes, one of them smoking ominously. As soon as Congress saw "smoking volcanoes" their risk management people advised them to call the whole deal off.

The waters of Lake Nicaragua themselves may yet hold a few dangers. They are reported to be inhabited by sharks that have found their way into the lake via the San Juan River that drains into the Caribbean. CGLAS scientists are a bit wary of this new opportunity to add one more alien species to the Great Lakes ecosystem. The trip to the Lake is planned to take place in early June and is being sponsored by contributions from the National Science Foundation, the University of Michigan, and the University of Minnesota.

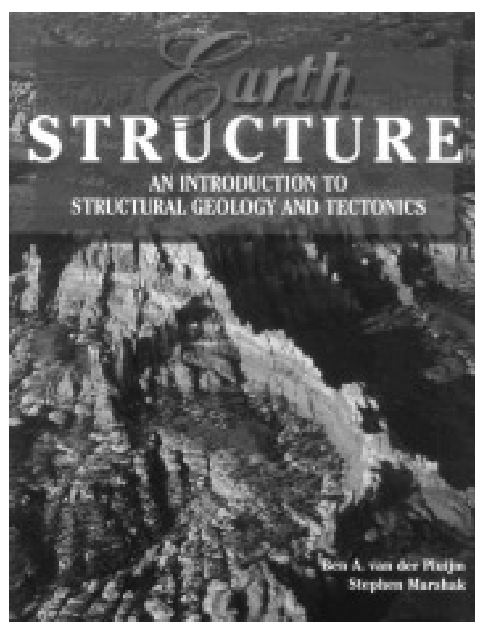
Don Peacor says this has been both a particularly happy year in that so many people have finished their research and moved on to other things, but also sad in that we miss their company. The list is extensive: **Vicky Hover** (BS '77, PhD '96) is now busy writing grant proposals from her new position at Rutgers after finishing up her thesis on water-clay interactions. Both **Gejing Li** (MS '91, PhD '96) and **Weixin Xu** (PhD '96) are now postdocs at Arizona State University, hopefully keeping the TEMs smoking as members of **Peter Buseck**'s research group, and for our part **Weiming Zhou** certainly keeps our TEM hot carrying on in Weixin's footsteps with research on magnetic oxides. **Hailiang Dong** (PhD '97) has just defended his thesis and moved on to a postdoc position with **Tullis Onstott** at Princeton, having done lots of good things in developing Ar-Ar analysis of clays, as well as having shaken up some sacred cows in the area of clay mineralogy. And **Chunyun Wang** is just about to finish his MS work on clay particle size distributions. **Gengmei Zhao** has moved from being a student, having completed her MS thesis work on retrograde diagenesis of clays, to being a new mother (!), and **Li-Shun Kao** is taking over the research on clay-organic-metal interactions. We've sorely missed **Nei-Che Ho**, who we expect soon to be president of the business school he is attending, but in the meantime we are looking forward to his return for the Fall semester to complete his PhD on studies of preferred clay mineral orientations. **John Harris** is having fun, in part applying the equipment which Nei-Che developed.

We've done some updating on equipment, a never-ending process. We've just put the finishing touches on the new Scintag theta-theta powder diffractometer system, which also includes an entirely modernized Philips unit, so the department is set up pretty well there; and we just installed a new variable-pressure SEM in the EMAL, and all users are raving.

In the Winter Term **Henry Pollack** substituted for **Bruce Wilkinson** (on sabbatical) in the introductory course "Geology of the National Parks." What a challenge! While the course is considered to be just another pathway into a geology concentration, it demands a rather different organization than does a more traditional course. This is because no national park illustrates just one concept, and so one must "revisit" a given park several times at different points in the course. Graduate student instructor **Karen Boven** handled the lab superbly, and together they pulled it off. Henry hosted three visitors this term, Roberta Rudnick from Harvard, Richard Alley from Penn State, and **George Davis** (PhD '71) from the University of Arizona. Roberta and Richard both presented Turner lectures, and George appeared in the Geophysics, Structure and Tectonics Seminar. Henry was invited by undergrad **John LeGolvan** to speak to a special group of U-M students, the members of Les Voyageurs. This group, whose special focus is outdoor adventure travel, meets weekly in their clubhouse near the Argo canoe livery on the Huron River. One of the club's early members was **Larry Gould** (BS '21, MA '23, SCD '25, LLD '54), and Henry played a video (transcribed from old movie film) of Gould's 1928 Antarctic expedition out of Little America; Gould was second in command of the expedition, in which the leader, Admiral Byrd, became the first person to fly over the South Pole, in a Ford Tri-Motor. Henry also lectured at the University of Utah, on his way to a GSA field trip through Arches and Canyonlands National Parks. **Shaopeng Huang**, Assistant Research Scientist in the Geothermal Lab, went to the Geophysical Institute in Prague for three weeks in February to work with Czech colleagues in the analysis of a large dataset of borehole temperature profiles from central and eastern Europe and Russia, reconstructing the climate of these regions over the past five centuries. Shaopeng and Henry are compiling a global database of such data as part of their research into recent climate change and its causes.

Jerry Smith is using Pliocene fish bones from the Pasco Basin of Washington to suggest changes in the history of the Columbia River. Fish bone identifications can be used in the same way rock sources have been used to identify upstream tributary sources. In combination with rock provenance data and stable isotope measurements (with **Bill Patterson**, MS '91, PhD '95), the fish data indicate that the Pasco Basin (the low point on the Columbia basalts, in south central Washington) first connected the Snake River and the upper Columbia river to the outlet to the Pacific in the late Pliocene. This timing for the assembly of the modern Columbia is about 6 million years later than recently published estimates.

This winter, **Ben van der Pluijm**'s structure/tectonics textbook with **Stephen Marshak** (University of Illinois) was published. The months before this birth were quite hectic with proofs, figure corrections and additions, and even a last minute reorganization. *Earth Structure: An Introduction to Structural Geology and Tectonics* (WCB/McGraw-Hill) is concerned with the



deformation of the Earth's lithosphere. Using a conversational style, the book integrates topics pertaining to all scales of observation, from the atomic scale to tectonic plates, and emphasizes linkages between structural geology and tectonics. We'll see how it survives the scrutiny of colleagues and students. Meanwhile, research in structure and tectonics kept going with the help of a great group of students. The Grenville project with **Eric Essene** is now focusing on the timing of late normal faulting in this Neoproterozoic mountain belt. Geochronologic data from the Adirondacks obtained by graduate student **Meg Streepey** indicate that extension lasted until about 900 Ma, which is well beyond the 'accepted' time for Grenville activity, but at least not as young as Iapetan rifting (perhaps). Speaking of the Appalachians, graduate student **Allen McNamara** has been working on the detailed Gondwanan location of Avalon (southern Newfoundland) with **Rob Van der Voo** and former postdocs **Conall MacNiocaill** (now at Oxford University). Conall, Ben and Rob added their perspective to the heated discussion on the origin and history of the Precordillera in South America in a recent *Geology* article. Lately, Ben has become more involved with **Arlo Weil**'s work in Cantabria as this project, headed by Rob Van der Voo, turns increasingly toward the kinematics of thrusting in oroclines (curved mountain belts). On a different scale, a new microstructural project on the properties of fault gouge was started with **Don Peacor**. Graduate student **John Harris**, who completed his MS (1996) on calcite strain in the Hudson Valley, uses the texture goniometer and other equipment to understand the role of clay transformations during fault gouge formation (in part with former postdoc **Peter Vrolijk**, now at Exxon Research). It is already clear that mineral transformations have been greatly undervalued relative to mechanical processes (cataclasis). Finally, **Leah Joseph** is putting the finishing touches on a combined grain size and magnetic fabric study to understand ocean circulation patterns during glacials and interglacials, in a project with **David Rea**. On the home front, Ben's kids continue to educate him in sports; in fact, they led him to a crushing victory in the Department's NCAA basketball pool.

The geophysics department will see major changes this summer, ranging from a reconstruction of the research facilities on the fourth floor to the arrival of new faculty and students. The seismo/geodynamics/heatflow lab areas are finally up for renovation, which will, hopefully, include air conditioning, and new walls and ceilings. The renovation is just in time to have our new faculty watch the change from old to new. **Carolina Lithgow-Bertelloni** and **Lars Stixrude** will strengthen the geophysical side of the department together with graduate students **Gerd Steinle-Neumann** and **Boris Kiefer**. **Henry Pollack** and **Peter van Keken** are saying good-bye to **Deb Tjoa**, who will leave to work with Texaco in Midland Texas. She is providing final touch-ups to her MS thesis in which she studied the role of radiogenic heating in mantle convection.

In the mean time, Peter van Keken, **Larry Ruff** and **Ben van der Pluijm** are involved in a variety of educational projects. Peter and Larry will install a MichSeis seismograph out at Camp Davis. In its first three days of operation in the geodynamics lab, the seismograph registered two major earthquakes. In addition to major global earthquakes, we hope to be able to study regional earthquake activity, particularly associated with the Yellowstone hot spot region and the Wasatch fault system.

Peter, Ben and **Nazli Nomanbhoy** are starting up a project to incorporate computer aided learning into a selected number of first year seminars and concentrator classes. The major goal of the project is to allow students interactive access to geophysics and geological data sets, which allows the students to get a much better understanding of the dynamical Earth than text book snapshots can provide. Ultimately, the goal is to establish a modern computing facility for the undergraduate and graduate program.

Geoscience News is compiled twice a year for alumni and friends by the Department of Geological Sciences at the University of Michigan, Ann Arbor MI 48109-1063.

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Editor: A. N. Halliday

In Memoriam

Edwin N. Goddard, a faculty member in the Department for twenty-one years, died on February l, l997, at the age of 92. Although born in Wisconsin, The University of Michigan was the venue for all of his higher education; he earned his undergraduate degree in 1927 and his Master's degree a year later. His PhD research focused on the Jamestown district, a major fluorite-producing camp in the Front Range mineral belt of Colorado. He was granted his PhD in 1936.

Eddie joined the U.S. Geological Survey in 1930. As a geologist with the USGS, he visited and studied virtually every mineral district in the Front Range. These studies, along with those by T.S. Lovering (U-M faculty 1934-57), formed the basis for USGS Professional Paper 223, *Geology and Ore Deposits of the Front Range, Colorado*, published in 1950. Although many detailed studies of the mining districts of Colorado have been completed by accomplished geologists in the years since, the wealth of information contained in this monograph has served as a valued point of departure, not only for many specific studies, but for the generalist as well.

A student group on an outcrop of Lyons Sandstone (a famous building stone) north of Boulder, Colorado. Edwin Goddard is standing, second from right. Jack Dorr is sitting, second from right, and Erwin Stumm is seated, second from left.

During World War II, Eddie examined mineral districts in the Caribbean and was then assigned to study and evaluate the iron deposits of Alaska. With the end of hostilities, Eddie returned to the West to pursue his interest in igneous-related fluorspar deposits. Before he left the USGS, he completed maps of the Zuni Mountains in New Mexico and the Judith Mountains in Montana—both fluorite-bearing districts

His skill in producing high-quality geologic maps was recognized by his peers, and he was chosen to be map editor for the USGS. Perhaps most notable of the many maps he was associated with was the *Geologic Map of North America*, published in 1965 by the USGS. Eddie chaired the group of prominent geologists that assembled this masterpiece.

In 1949, Eddie departed from the USGS and returned to the University of Michigan where he was a member of the faculty until his retirement in 1970. His best-known courses were the undergraduate lectures in Structural Geology, the graduate course on the Tectonics of North America, and the summer field course, then operating out of Boulder, Colorado. Eddie also served as Chairman of the Department from 1951-55. In the late '50s and early '60s Eddie was one of the mainstays of the Department's multi-disciplinary study of the Huerfano Park region of southern Colorado. As the Apollo program for exploration of the Moon got underway in the mid-60s, Eddie became a member of the NASA Geology Experiments Team, training astronauts for geological reconnaissance on the Moon, and helping to design experimental equipment.

Eddie was no couch-potato. He climbed Mount Elbert, the highest peak in Colorado, on a Sunday—his "day off." When stationed in Washington, D.C., he often canoed on the Potomac River. He organized touch football and softball games for exercise and fun, not only in the D.C. area, but also in Montana during days off from field work, and later in Colorado and at the U-M summer field camp. In retirement he swam in the Pacific Ocean almost every day until the age of 87, and upon relocating to Michigan in 1991 he continued to swim daily until he turned 90.

Eddie was married for 43 years to Virginia Hobbs, who preceded him in death. In 1972 he married Betty Stumm, the widow of Erwin Stumm, a professor paleontology in the Department from 1947-1969; Betty survives and lives in Portage, Michigan. Eddie Goddard will long be remembered as a man devoted to his profession, his alma mater and his family, and particularly for his contributions to this Department and its students over two decades.

Stewart Wallace *and* ***Henry Pollack*** *contributed to the Goddard obituary above.*

Degrees Granted

PhD

Hailiang Dong "Development of $^{40}Ar/^{39}Ar$ Technique for Clays: Correlation Between Mineralogical Characterization and Radiogenic Isotope Dating"

Victoria C. Hover "Sediment-Pore Fluid Interactions During Diagenesis of Modern and Ancient Mudrocks"

Robert T. Klein "A Study of Biological and Physical Controls on the Stable Isotope and Trace Metal Content of Biogenic and Inorganic Calcium Carbonate"

Anna Martini "Hydrochemistry of Saline Fluids and Associated Water and Gas"

MS

David Borrok "The Vergenoeg Massive Iron Oxide-Fluorite Deposit, Bushveld Complex, South Africa: Support for a Magmatic-hydrothermal Formation Model"

David Fox "Growth Increments in Gomphothermi Tusks"

John Harris "Relative Timing of Calcite Twinning Strain and Fold Development, Hudson Valley Fold-Thrust Belt, USA"

Leah Joseph "Use of Grain Size and Magnetic Fabric Analyses in the Distinction Between Depositional Environments"

Steve Keane "Preservation of Early Histories in Granulites from Trace Element Zoning in Garnet"

Timothy Ku "Oxygen and Sulfur Isotope Compositions of Pore Water Sulfate in Marine Carbonates: Significance of Sulfide Oxidation and its Role in Carbonate Dissolution"

David Stenger "Geology, Geochemistry and Alteration at the Twin Creeks Mine, NV: Relationships to Gold Mineralization"

Luke Walker "Oceanic/cratonic Partitioning of Marine Carbonates by Phanerozoic Continental Drift"

Nate Winslow "Radiated Wave Energy and Apparent Stress Drops of Deep Earthquakes"

Gengmei Zhao "Retrograde Diagenesis of Clay Minerals of the Freda Sandstone, Wisconsin"

BS

Rochelle Allen
Michael Beres
Jeffrey Edge
Jarrett Elsea
Kristin Green
Justin Ham
Matthew Handyside
Jennifer Jubenville
Elissa Koch
Shannon Owen
Alyson Robbins
Daniel Schauble
Cara Stackpoole
Andrew Winkelman

Geoscience News Readership Survey

Changes in technology and budget constraints require that we periodically examine the mission and effectiveness of the *Geoscience News*. It would be a great help to us if you would take a few minutes to answer some questions and return this survey. Thank you.

Please tell us a little bit about yourself:

Highest UM degree: ☐ Bachelor ☐ Masters ☐ Doctorate

☐ Male ☐ Female

Internet habits:

	Yes	No
Do your have e-mail?	☐	☐
Do you have access to the World-Wide Web?	☐	☐
Have you visited **www.geo.lsa.umich.edu**?	☐	☐

In general, do you:

- ☐ read *Geoscience News* cover to cover?
- ☐ read articles which catch your eye and skim the rest?
- ☐ skim it quickly?
- ☐ not even look at it?

Do you feel the *Geoscience News*:

- ☐ needs more science content?
- ☐ needs more human interest?
- ☐ strikes a satisfactory balance
- ☐ no opinion

Please evaluate our regular features:

Here is a list of articles which appear regularly in *Geoscience News*. Please rate their relative interest by circling a position on the line from Very Interested to Not Interested At All

Feature	Description	Very Interested — Doesn't Matter — Not Interested At All
Greetings from the Chair	Generally a one-page summary of recent happenings in the Department or items of special note	|—|—|—|—|—|—|
Alumni News	Brief descriptions of the whereabouts and activites of UM Geology alumni	|—|—|—|—|—|—|
Awards	Alumni, Faculty and Staff members who have received professional/scientific awards	|—|—|—|—|—|—|
Faculty, Research Staff, and Student News	Short descriptions of the research and teaching activities of Faculty, Research Staff, and Students	|—|—|—|—|—|—|
Degrees Granted	Listing of degrees granted and theses titles	|—|—|—|—|—|—|
In Memoriam	Alumni who have passed away	|—|—|—|—|—|—|
List of the Lost	List of alumni for whom we no longer have valid addresses-asking help to locate	|—|—|—|—|—|—|
Campaign for Michigan Donors	Annual listing of all those who have donated to the Geological Sciences Campaign for Michigan	|—|—|—|—|—|—|

Please evaluate some of our past feature articles:

Here is a list of articles from the last three issues of *Geoscience News*. Please rate their relative interest by cicling a position on the line fromVery Interested to Not Interested At All, and indicate if you remember that specific article.

Article	Check if you remember this article	Very Interested — Doesn't Matter — Not Interested At All
From December, 1996		
Life on Mars? Allen Treiman (PhD '82) discusses the possible evidence of life in Martian meteroites	☐	|—|—|—|—|—|—|
Clarence C. Little Brief biography of the man for whom our building is named.		
A bit of History: Alexander Winchell Brief summary of the career of Geological Science's longest-serving chair	☐	|—|—|—|—|—|—|
Where the Interent Meets the Big Bang Reprint of an Information Technology Digets article highlighting Ben van der Pluijm's use of the Worl-Wide-Web as a teaching tool		
News from Camp Davis Highlights of the 1996 summer session at Camp Davis	☐	|—|—|—|—|—|—|
Focus on Research in the GIGL Activities of the Geochronology and Isotope Geochemistry Laboratory and its application to the breakup of Gondwanaland		
From June, 1996		
Cracking the Killer Lakes of Cameroon Technical discussion of the causes of CO_2 "Limnic Eruptions"	☐	|—|—|—|—|—|—|
Plant Invasions: which are significant? Reprint in modified form of an article first appearing in Geotimes, by Robyn Burnham, UM Museum of Paleontology		
A bit of History: Israel C. Russell Professor Israel C. Russell, recipient of first National Geographic Society research grant in 1890	☐	|—|—|—|—|—|—|
Grand Opening for RIGL Extension Dedication ceremonies and lecture, along with a brief description of the expanded Radiogenic Isotope Geochemistry Laboratory		
U-M Greenland Expedition recalled Brief description of the 70th anniversary celebration of UM's greenland expeditions of 1926-1932	☐	|—|—|—|—|—|—|
"Survival is a good crew" Damon Teagle recounts the ill-fated Ocean Drilling Project Leg 163 voyage		

Comments and suggestions:

If you would be interested in writing a brief article for Geoscience News, please provide your name and contact information so that our editor may get in touch with you.

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DEPARTMENT OF GEOLOGICAL SCIENCES
Attn: Dale Austin
The University of Michigan
2534 C. C. Little Building
Ann Arbor, MI 48109-1063

Geoalumni Information Form

Use this form to update your mailing address or to provide information to be used in the Alumni News section of the *Geoscience News*. (Please type or print)

Name ______________________________ Phone ( ) ______________

Residence Address ______________________________
Street Address City State Zip

Business Address ______________________________ Business Phone ( ) ______________
Position Company

____
Street Address City State Zip

e-mail address ______________ would you like to be added to an alumni e-mail group? yes ☐ no ☐

Degree ________ College or University ______________________________ Year ________

Degree ________ College or University ______________________________ Year ________

Degree ________ College or University ______________________________ Year ________

Spouse ______________________________
Year of Wedding

Child ______________________________ Child ______________________________
Name Birth Date Name Birth Date

Child ______________________________ Child ______________________________
Name Birth Date Name Birth Date

Child ______________________________ Child ______________________________
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 ______________________________ Phone ( ) ______________
Relationship

____
Street Address City State Zip

Please send us any news of you "doings" to be included in the next newsletters; simply write below.

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The List of The Lost

From time to time we publish the names of alumni and friends of the department with whom we have lost contact or no longer have current addresses. We would be grateful to receive information about these folks' whereabouts so we can update our database. ND=no degree

Amanda Joyce Alexander MS-82
Nasser Saad Al-Muneef MS-74
Enrique Manuel Araujo ND-56
Gary Mervyn Archibald MS-60
Robert Holt Ardrey MS-78
Joanne Mary Bahura BS-83
Colin Woods Baker MS-82
Muhammed Abu Bakr MS-62
Alferid Balian ND-71
Irene Diane Banas BS-78
James Barkeley BS-76
Susan Barkeley BS-76
Orhan Baykal ND-46
Debra Kim Bennett BS-74
Michael Henry Berry BS-72
Daniel John Bickel BS-68
Thomas Edward Biggs BS-56
James Boudouris BS-52 MS-55
Evelyn Tollefsen Bourne AB-51
Darwin Spencer Braden BS-58
Eleanor Johnson Buchanan BS-47
Richard L. Buck BS-55
Chris Buczynski BS-81
John Davis Burgener BS-69
George Allen Chase BS-59
Pong Ill Cheong ND-55
Conduff Green Chidress Jr. MA-79
Robert Ciernik BS-92
Mary C. Hoyt Clayton BS-57
Mary Alice Collins ND
Johdan Coplan BS-54
Frank Edward Coupal MS-54
John Joseph Covert BS-80
Michael Z. Creech BS-83
Elizabeth Ellen Culotta MS-88
David Harrison Dahlem PhD-65
Mark Philip Daiber BA-83
John Mehne Danaher BS-81
Edith Bryan Decker ND-44
Margaret M. Norton Delach MA-46
Carol Irene Dell PhD-71
John DeSisto BS-40 MS-41
Timothy Douthit BS-85
Lisa Durbin BS-82
David W. Elias BS-50
Floyd McDonald Ervin BS-47 MA-53
George Lawrence Evans BS-59
Lee Hendrick Farbsten BS-42
Edward Farmer BS-89
Kim Finkbeiner BS-89
John Doster Focht MS-56
Richard Stanley Gabrielson ND-72
Christodoulos A. Galas BS-56 MS-58
Scott Verne Galbraith BS-77
Luis Garza-Rios BS-89
Armando A. Giardini BS-51 MS-53 PhD-56
Robert L. Goss BS-49
Lia Ann Fong Gough MS-84
Ellen Graber PhD-89
David Lawrence Graf BS-57
Richard John Greenwood MS-69
Richard Clay Harbke MS-60 MBA-62
Donald Paul Harndon BS-53
Edgar Douglas Haymond BS-56
Howard O. Henson BA-48 BS-49
Rudi Nicholas Hiebert BS-86
Mary E. Hileman BS-67 MS-69 PhD-73
Patricia N. Hooley BS-69 Cert-70 MA-73
Ralph Dennis Horvat BS-73
Martha House BS-89
Lorne D. Howes BS-57
Walter Leroy Hurt BS-47
John R. Hutton BS-59 MS-60
Eric Hansen Inglis BS-78
Robert Watson Jack BS-52
Mark C. Johnston MS-89
Thomas Hume Johnston BS-59
Francis Gwynn Jones MS-78
John Joseph Kelly BS-50 MS-52
Jeffrey Keith Kimball BS-77 MS-79
Ray W. Kincaid BS-48
Anthony Stanly Kinder BS-53 MS-54
James Olsen Kistler BS-50
Jubal Lee Kolhmeier BS-77
Roger W. Kolvoord BS-62
Richard H. Kosonen BS-61
Janice Holda Krause BS-66
Eric Kreckman BS-89
Ragvir Gopal Kumble MS-62
Douglas Haig Kyle MS-58
Colleen Loretta Lanford BS-80
Jon Robert Lauer AB-78
Malcolm McLean Lawson BS-60
Robert Warren Leeder BSE-49 MA-50
Jon Lehman BS-74
Dallas Marion Lemmon BS-57
Alfredo Leon-Gonzales MS
Marcel Romuald Lizotte BS-59 MS-62
Cornelius James Loeser MS-47
John Long BS-51
Douglas Joseph Lootens BS-57 MS-59
Charles K. Lucas BS-50
Curtis P. Mabie MS-58
Jose Alberto MacCourtney MA-44
Carlton Wesley Malstrom BS-51
Peter Mellen Mann BS-51 JD-57
Jacob Margulies BS-89
Ernest Millard Marshall MS-50 PhD-77
Maureen McArthur MS
Leon Charles McCaughan BS-69 MS-71
John Elliott McEneaney BS-75
Donald William McIntosh BS-59
Joseph Arthur McIntosh BS-43 MS-47
Gordon Warner McMillan BS-49 MS-50
Henry Edmond Millson BS-81
Roger Gregory Mitzel BS-60
Chee Sun Mok MS-48
Lance E. Murakami BS-79
Daniel L. Murphy PhD-61
Robert Price Neault BS-51
Thomas Gwyn Newport BS-50
Daniel John O'Halloran BS-48 MS-49
Milton Harold Patterson BS-52
Douglas Peacock BS-70
Erwin Stuart Perelstein AB-56
Patricia Woodhull Perkins MS-53
Jean Ruth Pesce BS-74
Robert Allen Phelps BA-53
Richard Allan Ploch MS-60 MAL-63
Mark Owen Pomroy BS-72
Lorna Ann Porter BS-72
Ricardo Davis Presnell MS-83
Talal M. Rabiah PhD-89
Mary Elizabeth Rebone BS-82
Richard W. Redding AB-71
George Alexander Reilly PhD-77
Kenneth Frederick Riehle BS-49
Samuel H. Riggs BS-58
James Albert Rodwell BS-62
Burton Clarke Rogers AB-51
Kenneth Joseph Rogers MS-57
Paul J. Roper BS-62
Melvin Rotblatt AB-45
Daniel Nicholas Rubel PhD-64
Chester Rutkowski BS-51
Peter Schappach BS-87
David Ernest Schieck MS-72
Barbara Jean Schlecte BS-84
Arthur Henry Schultz MS-53
Arijeet Sengupta MS-84
Willis H. Shafer BA-52 BS-60
Helen Adair Shaver BS-44
Thomas Skimming BS-58
Alois M. Skutnik BS-50
Amanda Lee Smith BS-82
Edward William Smith BS-42
George Ephriam Sokolsky MS-60
John Paul Sonneborn BS-58
Marvin Andrew Speece MS-84
David John Stawski BS-61
Andrew Charles Steele BS-85
Ralph James Steele BS-48
Margaret Skeels Stevens MS-61
Carlee Irene Stewner BS-71
Ruth Maloney Stinson BA-45
Laurence Richard Stott MS-74
Michael Robert Street BS-60
Franklin T. Sukany BS-59
Rachel Elena Tabachnick PhD-88
Michael Tilchin BS-78
Walter James Truettner MS-54
Barbara L. Ruderman Turner BS-69
Jill Ellen Vandermeer BS-78
Robert Elmer Vantine BS-43
Geraldine Morse Blume Vaughn BS-51
Richard Allen Watson BS-58
Rick Webb MS-85
Julia Ann Broadfoot Wells BS-67
Sean Westergaard BS-91
Anthony Loomis Worth BS-59
Jean Davies Wright MS-55
Stephen Jonathan Zier BS-59

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