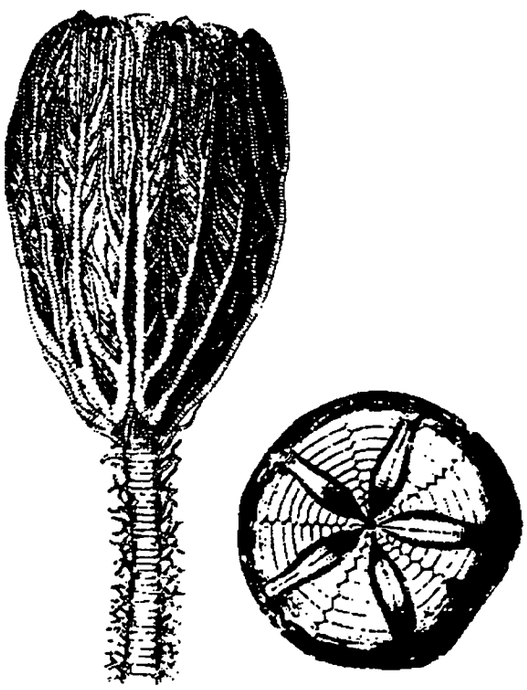
Indiana University
Department of Geological Sciences

Research Profile 1993



Department of Geological Sciences
Indiana University
Bloomington, IN 47405

To prospective graduate students in Geological Sciences

Some beginning graduate students have not only a particular field in mind, but even a specific professor with whom they would like to study. Many don't. They have uncertainties ranging from minor to gigantic. For all, research will be an integral part of graduate study. For those joining us at Indiana, the discussions of research on the following pages will — sooner or later — be of interest. In the meantime, here's some advice.

Follow your interests, whether firm or flimsy, long-term or recent. Don't worry if your initial choice of field within the earth sciences represents a working hypothesis rather than a secure decision. Don't worry if your interest in geoscience feels diffuse rather than passionate. Interests — strong ones — are indeed what inspire people to complete graduate degrees and to develop careers in science. They do not, however, blossom automatically when you begin correspondence with graduate schools. Interests come and go, sometimes rapidly; but at the beginning, nearly all develop slowly. We know that — we've been there.

Don't feel that you must choose a particular field because your undergraduate experience prepares you for it or avoid another because your preparation has not been optimal. If there is ever a time to make a change, to choose what you would *like* to do, this is the time. Don't let sketchy information about today's job markets, or forecasts about tomorrow's, rule your choice of field. Start from your interests, and remember that they can and will be refined by your own development and by practical considerations during your entire lifetime, including your years in graduate school.

You may or may not feel hungry for the information on the following pages. Some prospective students, particularly those who have already completed master's degrees and are looking for a doctoral program, may dissect and analyze this brochure. Many others may only glance at it. We provide it as the start of a dialogue and urge you to contact directly faculty members whose research area is of interest to you.

Write to any faculty member (or for general information, to the Graduate Adviser) at Department of Geological Sciences, Indiana University, Bloomington, Indiana 47405. Or call (812) 855-7214 and we'll call back. If convenient in this day and age, fax (812) 855-7899, being sure to indicate to whom your message should be delivered.

Table of Contents

with telephone numbers and e-mail addresses *

* all phone numbers are (812) 855-////
and e-mail addresses are "username.indiana.edu"

Graduate Programs in the Geological Sciences

The Department of Geological Sciences has a wide range of specializations, from geobiology to geophysics, from paleontology to petrology, and from economic to environmental geology. We have 30 teaching and research faculty, many with strongly multidisciplinary interests. Our field projects take us to Europe, Asia and Australia, as well as North, Central and South America, and we have excellent analytical facilities, both in terms of equipment and support staff. This brochure is designed to give prospective students and interested colleagues some insight into the strengths of our research programs, and breadth of staff and facilities.

Degree Programs

Several graduate degree programs are available at Indiana University. Within the Department of Geological Sciences all degrees from the B.A. and B.S. to the Ph.D. are available in all of the fields of study outlined in this brochure. In addition to these, degrees from related fields in Chemistry and Environmental Science are available because of several faculty with joint appointments. We also offer a specific three-year, double Masters degree in Geological Sciences and Environmental Sciences in cooperation with the School of Public and Environmental Affairs.

Department of Geological Sciences all programs outlined in this brochure	M.S., M.A.T., Ph. D.
Department of Chemistry especially analytical and physical geochemistry	M.S., Ph.D.
School of Public and Environmental Affairs especially environmental sciences	M.S., Ph.D.

Funding

Funding for our research programs comes from a wide range of sources. Many of our faculty are funded by the National Science Foundation, but our research has also been funded by the Department of Energy, the National Aeronautics and Space Administration, the Petroleum Research Fund of the American Chemical Society, the U.S. Geological Survey, the U.S. Bureau of Land Management, the U.S. Bureau of Mines, the National Oceanographic and Atmospheric Administration, the Office of Surface Mining, the Environmental Protection Agency, the Gas Research Institute, and over a dozen industrial sources. Graduate student assistantships and fellowships are available from these sources and through the College of Arts and Sciences as teaching assistantships (Associate Instructorships); about 20 are awarded annually.

How to Get in Touch

The best first contact is the scientist who most closely fits your particular research interest. However, the graduate student record office, administered by Mary Iverson (812-855-7214), is the best place to get more detailed information on application materials and deadlines. All faculty may be contacted by telephone or E-mail at the numbers given in the table of contents, or, of course by mail: at Department of Geological Sciences, Indiana University, Bloomington, IN 47405.

Facilities available through the Department of Geological Sciences

Indiana Geological Survey

Indiana Geological Survey, Norman Hester, Director.
The Indiana Geological Survey occupies the east wing of the Geology Building with a staff of 26 full-time, permanent geoscientists and a support staff of 23, as well as temporary part-time and full-time personnel employed on specific projects. Working relationships between the Department and the Survey are good, especially as relates to Indiana and mid-western geology. The Director, Norman Hester, is a full time professor of the Department of Geological Sciences, which ensures good communication and cooperation with Departmental research activities. His research interests are focused on Pennsylvanian stratigraphy with an emphasis on the reconstruction of sedimentary environments, the formation and preservation of peats, and the prediction of coal quality and the feasibility of underground mining operations. A particular project underway is the use of seismic stratigraphy to reconstruct the evolution and tectonic history of rifts and grabens, the Rough Creek Graben of the southern Illinois Basin in particular. In connection with this, broad-scale studies of tectonic controls on sedimentation in the Illinois and Appalachian Basins are on-going.

In addition to its main office, the Survey has a separate core storage and examination facility, and a sample preparation and physical testing lab. The Survey is equipped with a wide variety of field, physical testing, and chemical analytical equipment. In addition it has a well-equipped photography lab and a completely automated state-of-the-art drafting section with a CAD system capable of generating digitized base maps for GIS applications.

The Survey conducts multidisciplinary research in the broad fields of energy and mineral resources, environmental geology and geologic hazards, and geochemistry. Projects include: evolution and tectonic history of the Illinois Basin, investigations on geologic controls on deposition of low-sulfur coals, geologic characterization of petroleum reservoirs, characterization of limestones used in clean coal technology, coal mine reclamation, geologic framework of groundwater resources and their susceptibility to contamination, and hazards associated with mined-land subsidence, earthquakes, and lake-shore erosion. The Survey is actively engaged in public-service activities, education programs, and cooperative studies with other federal and state agencies and universities.

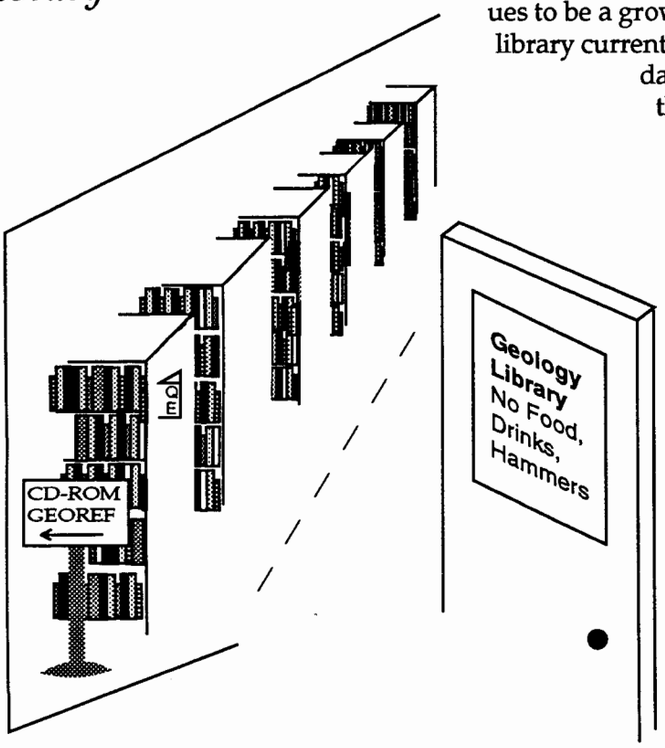
There are abundant opportunities for students to do research on Indiana geology, and the Survey supports their research in a number of ways. Subsurface records from over 70,000 wells are readily available, and access to equipment is possible. Survey staff are available for advice and

consultation and many have supervised student theses or been members of thesis committees. Students may also be employed on one or more of the many internally- and externally-funded projects being carried out by the Survey staff. Some of these may evolve into thesis projects while others will provide valuable field and laboratory experience to students in conducting professional-level research in areas outside of their thesis topic.

Geological Sciences Library

Geological Sciences Library: Lois Heiser, Librarian.

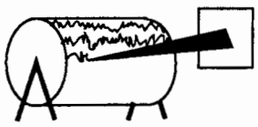
The Geology Library, occupying the entire sixth floor of the Geology Building, continues to grow in size and reputation and now has passed 93,000 volumes, 290,000 maps and 23,000 microfilms. CD-ROM continues to be a growing format in the earth sciences. The library currently has three CD-ROM stations, and 27 data files on 44 disks. GEOREF receives the greatest use. The ability to set up a separate workstation allows students and faculty to search GEOREF for as long as they need. Improvements continue to be made in the automated IU library catalog. It is possible to display current issues of journals received as well as the call number and holdings of the bound volumes. In addition, the user can immediately see the status of any title (reserves, charged out, lost) or journal runs which have been shelved in the storage area. Regular funds, private donations, and exchange of the Indiana Geological Survey's publications help to make this one of the most complete geology libraries in the country.



Graphics, Cartography and Photography

The Department of Geological Sciences and the Indiana Geological Survey share six full time and two part time employees. The combined facilities include three computer graphic work stations with large font digitizers and one larger format plotter for the preparation of graphics from line work drawings to full color map separates. Photographic facilities include a fully equipped black and white darkroom, 200-18% enlarger copy camera, film processor and macro- and micro-photographic capabilities. These facilities support all faculty and faculty-student joint research projects.

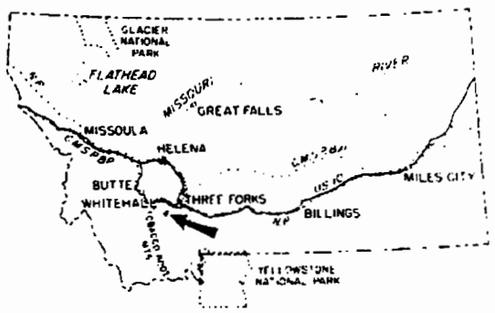
Seismic Station



The Departmental seismic station has been in continuous operation since 1964. It is one of the most sensitive in the region because it is firmly anchored in bedrock, and has six channels — three long-period components for monitoring world-wide earthquakes, and three short-period components for local, low intensity monitoring. The station also maintains three portable seismic recording instruments for the study of micro-earthquake and aftershock studies. It also maintains a 48 channel seismic system for reflection and refraction seismology, and a 12 channel system for refraction studies.

Geological Field Station

Geological Field Station, Cardwell, Montana, Lee J. Suttner, Director. The Department of Geology maintains a Geologic Field Station, a permanent teaching and research facility in the Tobacco Root Mountains of southwestern Montana. In addition to comfortable living quarters and dining facilities, the Station possesses a modest library, a rock-preparation laboratory, and a fleet of vehicles that can be rented at a modest rate for field research. Courses taught at the Field Station include introductory physical and historical geology, advanced undergraduate geologic mapping and field study and advanced graduate-research seminars. The Field Station serves as a base for graduate students and visiting scientists who are actively doing research in the northern Rocky Mountains.



Electron Beam Facility

Electron Beam Facility: Dr. Michael J. Dorais, Director.
The Department is continually upgrading our analytical facilities. In 1992 we replaced our 20-year-old E-TEC autoprobe with a new Cameca SX50 superprobe, and we replaced one Phillips XRG-2500 diffractometer with an automated 3100 series model. Permanent equipment is listed below.

Cameca SX50 Superprobe, with four spectrometers, energy dispersive X-ray analysis, SEM, BSE and cathodolminescence capabilities
PAD V Scintag automated X-ray diffractometer
Phillips XRG-3100 automated X-ray diffractometer
Phillips XRG-2500 X-ray diffractometers (2)
Huber Precession Camera
Ion Tech ion thinner
Denton DV-502 carbon coater
Nuclide Luminoscope (2)

Analytical Chemistry Facility

Analytical Chemistry Facility: Mark Gilstrap, Manager.
The departmental analytical facilities are unique among even large universities. Even before the present facility was completed in 1964, great pride has been taken in our ability to perform elemental determinations routinely possible only at Federal facilities.

These laboratories, which provide student access to both modern analytical instrumentation and classical wet chemical methods, are currently being rebuilt. The entire existing facility will be relocated to the same floor as the Geochemistry Section of the Indiana Geological Survey in order to provide a more facile interaction with these related facilities. Completion is expected by mid-summer 1993.

In addition to the latest safety considerations, and scrupulous attention to airborne contaminants, care is being taken to preserve some of the more unique features of the facility such as the ability to do perchloric acid digestions.

The Instrumentation Laboratory will be immediately adjacent to the wet chemical preparation laboratory. Two of our major instruments, the JY-38VHR ICP and the Perkin-Elmer 5100 Zeeman AA, were upgraded to the latest hardware and software revisions just this year. Both in-house and world-wide network connections are routinely used to communicate results.

Jobin-Yvon JY-38VHR Sequential Slew-Scan Inductively Coupled Argon Plasma Spectrometer
Jarrell-Ash Atomcomp 26 channel ICP Spectrometer model 975 w/ ThermoSpec software and hardware upgrades
Perkin-Elmer 5100/Zeeman Flame/Furnace Atomic Absorption Spectrometer
Coulometrics 5010/20/30 Carbonate/Total Carbon Analyzer
Leco SC132 Sulfur Determinator
Dionex 4500i Ion Chromatograph
Wescan 266 Ion Chromatograph
Shimmadzu RF5000 U Spectofluorometer

Mass Spectrometry Laboratory

Mass Spectrometry Laboratory: Steve Studley, Manager.
The mass spectrometry laboratory is undergoing an expansion, as part of the building remodeling and renovation, that will allow the research instruments to be housed in one facility. A new Finnigan MAT Incos 50 GC/MS system has been purchased to replace an older demonstration model that has been in the lab for the past year. The Incos 50 will be installed in the expanded lab along with the Finnigan MAT TSQ-700 triple-quad system that has been temporarily housed in a separate laboratory in the Geology building.

The addition of these two instruments expands the services of the lab to

provide the capability of determining structural information from samples as well as isotope ratio information. The new facility should be completed in late February 1993. Permanent equipment includes:

Nuclide 6-60-rms isotope ratio mass spectrometer w/ dual Faraday cup collector system
Finnigan MAT Delta-E isotope ratio mass spectrometer
Finnigan MAT Delta-S gas chromatograph-combustion-isotope ratio mass spectrometer system prototype
Finnigan MAT 252 isotope ratio mass spectrometer with GC/Combustion interface, microvolume, and multiport inlets
Finnigan MAT Incos 50 GC/MS quadrupole mass spectrometer system
Finnigan MAT TSQ 700 automated GCMS/MS triple-quadrupole mass spectrometer system
Adjacent laboratory housing C,H,O, and S extraction lines

Electron Microscope Facility

Electron Microscope Facility: Bradley Johnson, Manager, Biology.
Complementing the optical and electron microscope capabilities of our superprobe are several other electron microscopes on campus. Most of these are housed in the Biology Department, but others are in the Physics or Optometry Departments.

Cambridge S250 MKII SEM
GW Electronics BSE dector
GW Electronics cathodoluminescence dector
Tracor Northern TN 5500 EDX dector
Phillips EM 300 TEM
Phillips EM 301 TEM
Denton carbon coater (2)
Polaron E 5100 sputter coater
Siemens 101 TEM
Varian 981-2145 electron beam gun (3)
Varian 981-2148 LEED electronics (2)
Varian 981-0127 Auger/LEED optics (2)

Computer Facilities

Computer Facilities: Brian Snow, Manager.
Computer facilities available for research exist in the Department and in a campus-wide facility. Within the Department, we have 5 Sun, 3 DEC (MicroVAX), over 30 Apple and over 50 PC workstations. Most stations are connected through a Departmental network, supporting NFS, Novell, Ethertalk and Internet. Also available on campus (through University Computing Services) are 9 VAX computers and an AMDAHL mainframe. The Department and University support a wide variety of hardware and software in many diverse fields.

Electronics Shop

Electronics Shop: Terry Stigall, Manager.
The Department maintains an electronics shop, with testing equipment and a stock room. Ms. Stigall maintains and troubleshoots all electronic equipment in the Department. This includes computers and related equipment, the Superprobe and X-ray diffractometers, the seismograph station, and geophysical field equipment. She also designed, implemented and maintains the Departmental computer network, and designs and builds specialized electronic equipment as needed.

Machine Shop

Machine Shop: Charles Miller, Machinist.
The department's machine shop houses all typical equipment, including several lathes, vertical milling machines, surface plates, and a Taft Pierce surface grinder. In addition to maintaining much of the Departmental equipment, Mr. Miller has designed, built and installed portable seismographs, a large capacity flume for hydrodynamic study of modern invertebrates, and high temperature furnaces for experimental petrology.

Rock Preparation Laboratory

Rock Preparation Laboratory: Lou Bucklin, Manager.
The Department supports a rock preparation facility, with the part-time supervision of Lou Bucklin. The lab is set up to prepare thin sections, with both water and oil lubricated rock saws, a thin section cut off saw, and grinding and polishing plates. We are also set up for rock crushing and mineral separation, with a jaw crusher, disk grinder and steel, tungsten carbide and alumina shatter boxes. For mineral separation the Department has four automated sieve shakers)RO-TAP), a Franz magnetic separator, and a dedicated fume hood for use of heavy liquids.

Biogeochemistry and Organic Geochemistry

Research Faculty

Simon C. Brassell *Biological, Organic, and Petroleum Geochemistry; Basin Analysis*
Professor, Geological Sciences and Environmental Sciences; B.Sc., Ph.D. Bristol (England), 1980.

John M. Hayes *Biological, Organic, and Petroleum Geochemistry*
Distinguished Professor, Geological Sciences, Chemistry, and Environmental Sciences; B.S. Iowa State; Ph.D. M. I. T, 1966.

John P. Jasper *Chemical Oceanography, Organic Geochemistry, Biogeochemistry*
Assistant Scientist, Geological Sciences and Chemistry; A.B. Chicago; Ph.D. M.I.T. (Woods Hole), 1988.

Peter J. Ortoleva *Geochemistry, Kinetics and Transport Mechanisms, Basin Analysis*
Professor, Chemistry and Geological Sciences; B.S. Rensselaer Polytechnic Institute; Ph.D. Cornell, 1970.

Lisa M. Pratt *Sedimentary and Organic Geochemistry, Stratigraphy*
Associate Professor, Geological Sciences; B.A., M.S. North Carolina; M.S. Illinois; Ph.D. Princeton, 1981.

Jeffrey R. White *Aquatic Chemistry, Biogeochemistry, Limnology*
Associate Professor, Geological Sciences; B.A. Gettysburg College, M.S. Rutgers, Ph.D. Syracuse, 1984.

Facilities

All major analytical equipment needed for biogeochemical and organic geochemical research is available in the Department of Geological Sciences. Our instrumentation for stable isotopic measurements includes two coupled gas chromatograph-mass spectrometer units with the capability of determining carbon isotopic ratios of individual organic compounds. In fact, one of these instruments is the prototype of the Finnigan isotope ratio monitoring instrument. Structural identification of organic molecules is done using a Finnigan MAT 700 triple-sector mass spectrometer or an Incos 50 ion trap. Routine gas chromatography of hydrocarbons is performed on one of three Hewlett Packard 5890A instruments. Organic-sulfur compounds are monitored with a gas chromatograph equipped with a flame photometric detector in addition to a flame ionization detector. The Biogeochemical laboratories are also equipped with a LECO carbon/sulfur analyzer and a Geofina Hydrocarbon Meter for doing programmed pyrolysis/gas chromatography. In addition to major equipment, our laboratory facilities include numerous wet-chemical benches with fume hoods, sample preparation area for organic geochemical materials, freeze-drying apparatus, refrigerators, nitrogen evaporator, and cryogenic vacuum lines for isotopic preparation of carbon, nitrogen and sulfur samples.

Research

A growing community of students, faculty, postdoctoral fellows, and research staff (a total of 29 people during 1992) is working on the analysis and interpretation of molecular and isotopic records of ancient environments and biogeochemical processes. Both details of specific environments and global phenomena are being explored. In order to develop an improved understanding of biogeochemical processes, considerable attention is being devoted to the study of modern environments. The work of biogeochemists is relevant to the search for fossil-fuel resources and to the monitoring of environmental changes. Projects within the laboratories are focused both on petroleum geochemistry and on the study of ancient greenhouse phenomena.

Representative Publications

Carroll, A.R., S.A. Graham, and S.C. Brassell (in press). Upper Permian lacustrine oil shales of the Junggar Basin, northwest China. *Amer. Assoc. Petrol. Geol. Bull.*

Des Marais, D.J., H. Strauss, R.E. Summons and J.M. Hayes (1992). Carbon isotope evidence for the stepwise oxidation of the Proterozoic environment. *Nature*, **359**, p. 605-609.

Freeman, K.H. and J.M. Hayes (1992). Fractionation of carbon isotopes by phytoplankton and estimates of ancient CO_2 levels. *Global Biogeochemical Cycles*, **6 (2)**, p. 185-198.

Gubala, C.P., D.R. Engstrom, and J.R. White (1990). Effects of iron cycling on 210Pb dating of sediments in an Adirondack lake, U.S.A. *Can. J. Fish. Aquat. Sci.*, **47**, p. 1821-1829.

Jasper, J.P. and J.M. Hayes (1990). A carbon-isotopic record of CO_2 levels during the Late Quaternary. *Nature*, **347**, p. 462-464.

Jasper, J.P., F.G. Prahl, A.C. Mix, and J.M. Hayes (1992). Photosynthetic ^{13}C fractionation and estimated CO_2 levels in the Central Equatorial Pacific over the last 255,000 years. *Paleoceanography* (invited manuscript in progress).

Meshri, I. and P. Ortoleva, eds. (1990). Prediction of Reservoir quality through chemical modeling. *AAPG Memoir 49*, 175p.

Pratt, L.M., R.E. Summons, and G.B. Hieshima (1991). Sterane and triterpane biomarkers in the Precambrian nonesuch formation, north American midcontinent rift. *Geochimica et Cosmochimica Acta*, **55**, p. 911-916.

Shannon, R.D. and J.R. White (1991). The selectivity of a sequential extraction procedure for iron oxyhydroxide and sulfides in freshwater sediments. *Biogeochemistry*, **14**, p. 193-208.

White, J.R., C.P. Gubala, B. Fry, J. Owen and M.J. Mitchell (1989). Sediment biogeochemistry of iron and sulfur in an acidic lake. *Geochimica et Cosmochimia Acta*, **53**, p. 2547-2559.

Economic Geology, Clays and Industrial Minerals

Research Faculty

Simon C. Brassell *Biological, Organic, and Petroleum Geochemistry; Basin Analysis*
Professor, Geological Sciences and Environmental Sciences; B.Sc., Ph.D. Bristol (England), 1980.

Donald D. Carr *Industrial Minerals, Coal Geology*
Senior Scientist, Indiana Geological Survey and Professor, part-time, Geological Sciences; B.S., M.S., Kansas State; Ph.D Indiana, 1969.

Colin Harvey *Economic Geology, Clays and Industrial Minerals*
Research Scientist, Geological Sciences; B.Sc., M.Sc. (Honors) University of Auckland, New Zealand, Ph.D. Indiana, 1980.

Brian D. Keith *Petroleum Geology, Basin Analysis, Sedimentology and Stratigraphy*
Associate Scientist, Indiana Geological Survey and Associate Professor, part-time, Geological Sciences; B.A. Amherst; M.S. Syracuse; Ph.D. Rensselaer Polytechnic Institute, 1974.

Haydn H. Murray *Economic Geology, Clays and Industrial Minerals*
Professor, Geological Sciences; B.S., M.S., Ph.D. Illinois, 1951.

Lisa M. Pratt *Sedimentary and Organic Geochemistry, Stratigraphy*
Associate Professor, Geological Sciences; B.A., M.S. North Carolina; M.S. Illinois; Ph.D. Princeton, 1981.

Edward M. Ripley *Petrology of Metallic Ore Deposits, Isotopic Geochemistry*
Professor, Geological Sciences; B.S. Illinois State, M.S. Minnesota; Ph.D. Penn State, 1976.

Facilities

Most analytical facilities needed for the described research are located within our building. Examples include: three stable isotope ratio mass spectrometers with associated sample preparation systems, C-O-H-S elemental analyzers, two coupled gas chromatograph-mass spectrometer units with the ability to analyze individual organic molecules, fluid inclusion microthermometry units, laser ablation fluorination system for isotopic microanalysis, Cameca SX-50 automated microprobe with SEM capabilities, differential thermal analyzers, X-ray diffractometers, high intensity magnetic separator for clay size materials and inductively coupled plasma and atomic absorption spectrometers for major and trace element analyses. We also have a rock preparation lab, machine shop, electronics shop, PC lab and central computing facilities.

Research

Research in economic geology at IU covers aspects of fossil fuels, industrial minerals and metallic ore deposits. Within fossil fuels, Simon Brassell's research is in molecular organic geochemistry as it relates to the identification of petroleum source rocks and to the development and application of molecular tools in the evaluation of depositional environments and processes of petroleum formation-accumulation. Lisa Pratt studies the geology and organic geochemistry of fine-grained sedimentary rocks, especially in the evaluation of potential petroleum source rocks, and the genesis of metalliferous black shales. Brian Keith's research centers on the determination of geologic controls over reservoir character and the potential for future exploration for industrial minerals. Don Carr evaluates a variety of industrial minerals, including carbonate building stones, aggregate, gypsum and sand and gravel. His research deals with the chemical and physical properties of materials and how they relate to stone use, preservation and durability. Haydn Murray and Colin Harvey do research on the origin, depositional environments, geochemistry and uses of clay and industrial minerals. They study residual, hydrothermal and sedimentary deposits using a wide range of analytical techniques. Edward Ripley's research interests include the genesis of metallic ore deposits and application of stable isotopes to petrogenetic problems. Processes of ore formation in sedimentary, hydrothermal and magmatic environments are under investigation using a combination of analytical, theoretical computational and experimental methods.

Representative Publications

Carr, D.D. (1989). Limestone and dolomite, *in* Surface Mining, Littleton, Colo., Society of Mining Engineers, p. 425-449.

Carr, D.D. (1990). Economic geology of Salem limestone in the Indiana building-stone district, *in* Architectural elements and paleoecology of carbonate shoal and intershoal deposits in the Salem limestone (Mississippian) in south-central Indiana. *Ind. Geol. Survey Guidebook 14*, p. 53-56.

Graham S.A., S.C. Brassell, A.R. Carrol, X. Xiao, G.J. Demaison, C.L. McKnight, Y. Liang, J. Chu and M.S. Hendrix (1990). Characteristics of selected petroleum source rocks, Xinjiang Uygur autonomous region, northwest China. *Amer. Assoc. Petrol. Geol. Bull.*, **74**, p. 493-512.

Harvey, C.C., L. Farris (1991). The Lang Bay kaolin resource, British Columbia. *Proc. 27th Forum on the Geology of Industrial Minerals.*

Harvey, C.C., H.H. Murray (in press). The geology, mineralogy and exploitation of halloysite clays of Northland, New Zealand, *Keller Monograph, Clays and Clay Minerals.*

Keith, B.D. and L.H. Wickstrom (1992). The Lima-Indiana trend, *in* Stratigraphic Traps III, AAPG Atlas of Oil and Gas Fields, Treatise on Petroleum Geology Series, p. 347-367.

Lira, R. and E.M. Ripley (1990). Fluid inclusion studies of the Rodeo de los Molles REE and Th deposit, Las Chacras Batholith, Central Argentina. *Geochimica et Cosmochimica Acta*, **54**, p. 663-673.

Murray, H.H. (1976). Benefication of selected industrial minerals and coal by high intensity magnetic separation. *IEEE Transactions on Magnetics*, **MAG-12, No. 5**, September.

Murray, H.H. (1989). Clay minerals for advanced ceramics. *Mining Eng.*, p. 1123-1125.

Murray, H.H. (1991). Overview — clay minerals applications. *Appl. Clay Sci.*, **5**, p. 379-395.

Ripley, E.M., and T. Al-Jassar (1987). Sulfur and oxygen isotopic studies of melt-country rock interaction, Babbitt Cu-Ni deposit, Duluth complex, Minnesota. *Econ. Geol.*, **82**, p. 87-107.

Trindade L.A.F., S.C. Brassell and E.V. Santos Neto (in press). Petroleum migration history in the Potiguar basin, Brazil, as reflected by mixed oils. *Amer. Assoc. Petrol. Geol. Bull.*

Zaback, D.A. and L.M. Pratt (1992). Isotopic composition and speciation of sulfur in the Miocene Monterey formation: Reevaluation of sulfur reactions during early diagenesis in marine environments. *Geochimica et Cosmochimica Acta*, **56**, p. 763-774.

Geobiology and Paleontology

Research Faculty

Simon C. Brassell *Biological, Organic, and Petroleum Geochemistry; Basin Analysis*
Professor, Geological Sciences and Environmental Sciences; B.Sc., Ph.D. Bristol (England), 1980.

J. Robert Dodd *Paleoecology, Carbonate Sedimentology and Petrology*
Professor, Geological Sciences; B.A. Indiana; M.A., Ph.D. Caltech, 1961.

Donald E. Hattin *Stratigraphy, Sedimentology, Paleoecology and Paleontology*
Professor, Geology; B.S. Massachusetts; M.S., Ph.D. Kansas, 1954.

John M. Hayes *Biological, Organic, and Petroleum Geochemistry*
Distinguished Professor, Geological Sciences, Chemistry, and Environmental Sciences; B.S. Iowa State; Ph.D. M.I.T., 1966.

Alan S. Horowitz *Geobiology and Paleontology*
Senior Scientist and Professor, part-time, Geological Sciences; B.A. Washington and Lee; M.S. Ohio State; Ph.D. Indiana, 1957.

N. Gary Lane *Geobiology and Paleontology*
Professor, Geological Sciences; B.A. Oberlin; M.S., Ph.D. Kansas, 1958.

Lisa M. Pratt *Sedimentary and Organic Geochemistry, Stratigraphy*
Associate Professor, Geological Sciences; B.A., M.S. North Carolina; M.S. Illinois; Ph.D. Princeton, 1981.

Carl B. Rexroad *Geobiology and Paleontology*
Senior Scientist, Indiana Geological Survey and Professor, part-time, Geological Sciences; B.A., M.S. Missouri, Ph.D. Iowa, 1955.

Michael Savarese *Geobiology and Paleontology*
Assistant Professor, Geological Sciences; B.S., M.S. Rochester; Ph.D. California/Davis, 1989.

Robert H. Shaver *Paleobiology and Stratigraphy*
Professor (ret.), Geological Sciences, B.S., M.S., Ph.D., Illinois, 1951.

Facilities

Facilties used in geobiological and plaeontological studies range from simple to highly sophisticated. The paleontology lab suite includes a sample preparation lab and associated equipment; an acid bath lab; a flume for experimental biomechanics; Macintosh II and Hewlett-Packard computer work stations dedicated to image analysis, morphometrics and other paleontologic applications; and salt-water aquaria. A variety of microscopes including SEM and cathodoluminescence are available as is a thin section preparation lab and extensive fossil collections from Indiana and beyond. A well-equipped organic geochemistry laboratory and sample preparation facilities and mass spectrometers for stable isotope analysis are also valuable facilities for research in this area.

Research

Research in geobiology and paleontology at Indiana University ranges from study of chemical fossils in Precambrian rocks to flume experiments with models of fossils of many types. Our faculty and students have or are conducting research on calcareous algae, sponges, archeocyathids, corals, bryozoans, brachiopods, crinoids, blastoids, mollusts, ostracods, conodonts and vertebrate footprints. Emphasis in research on body fossils is on the study of evolutionary paleontology, phylogenetic inference, functional morphology, paleoecology, depositional reconstruction, taphonomy and biostratigraphy. Study of chemical fossils emphasizes their use in interpreting depositional environments, geochemical cycles and interpreting the history of the earth, especially its biosphere, hydrosphere and atmosphere.

Representative Publications

Dodd, J.R. and R.J. Stanton (1990). Paleoecology, concepts and applications (second edition). Wiley-Intersciences, New York, 400p.

Hasenmueller, W.A., and D.E. Hattin (1990). New species of the bivalve *Anomia* from lower and middle Turonian parts of the Greenhorn limestone, central Kansas. *J. Paleontol.*, **64**, p. 104-110.

Hattin, D.E. (1990). *Puebloites greenhornensis* Cobban & Scott from Turonian part of Greenhorn limestone, north-central Kansas and northeastern Wyoming. *Cretaceous Research*, **11**, p. 351-358.

Hattin, D.E., and D.S. Hirt (1991). Paleoecology of scalpellomorph cirripeds in the Fairport Member, Carlile Shale (Middle Turonian), of central Kansas. *PALAIOS* , **6**, p. 553-563.

Horowitz, A.S., D.B. Macurda, Jr., and J.A. Waters (1986). Polyphyly in the Pentremitidae (Blastoidea, Echinodermata). *Geolog. Soc. of Am. Bull.*, **97**, p. 156-161.

Kennedy J.A. and S.C. Brassell (1992). Molecular records of 20th century El Niño events in laminated sediments from the Santa Barbara basin, California. *Nature*, **357**, p. 62-64.

Lane, N.G. (1991). New late Devonian (Famennian) echinoderms from Xinjiang Province, Peoples Republic of China (abst.) (with J.A. Waters, C.G. Maples, and Hou Hong-fei): *Geol. Soc. Amer. Ann. Meeting, San Diego, California*, p. A279.

Lane, N.G. (1991). *Life of the Past*. 3rd Edition. Macmillan Publishing, 334p.

Pachut, J.F., and A.S. Horowitz (1987). Multivariate discrimination and classification of some North American Mississippian species of Fistulipora M'Coy, *in* J.R.P. Ross, ed. Bryozoa: Present and past. Papers presented at the 7th international conference of Bryozoa. Western Washington University, Bellingham, Washington, August 4-9, 1986, p. 205-212.

Rexroad, C.B., and A.S. Horowitz (1990). Conodont paleoecology and multielement associations of the Beaver Bend Limestone (Chesterian) in Indiana. *Courier Forschungs Institute Senckenberg*, **118**, p. 493-537.

Rexroad, C.B., and W.J. Varker (1991). The new Mississippian conodont genus Synclydognathus. *J. of Paleon.*, **66**, p. 945-957.

Savarese, M., L.M. Gray and C.E. Brett (1986). Faunal and lithological cyclicity in the Centerfield member (Middle Devonian) of western New York: A reinterpretation of depositional history. *New York State Museum Sci. Service Bull.*, **457**, p. 32-56.

Savarese M. and P.W. Signor (1989). New occurrences of archaeocyathans in the upper Harkless formation of Esmeralda county, Nevada, and their paleoecological significance. *J. of Paleon.*, **63**, p. 539-549.

Savarese, M. (1992). Functional analysis of archaeocyathan skeletal morphology and its paleobiologic implications. *Paleobiology*, **18 (4)**, p. 464-480.

Shaver, R.H. (1991). A history of study of silurian reefs in the Michigan basin environs, *in* Catacosinos, P.A., and Daniels, P.A., Jr., (eds.) *Early sedimentary evolution of the Michigan basin*. Geolog. Soc. of Am. Special Paper, **256**, p. 101-138.

Summons, R.E. and J.M. Hayes (1992). Principles of molecular and isotopic biogeochemistry, *in* J.W. Schopf and C. Klein (eds.) *The Proterozoic Biosphere, a Multidisciplinary Study*. Cambridge Univ. Press.

Geophysics and Tectonophysics

Research Faculty

Haydar Al-Shukri *Geophysics, Seismology, Geotomography*
Research Associate, Geological Sciences; B.S., M.S. Baghdad University, Ph.D. St. Louis University, 1990.

Ned K. Bleuer *Quaternary Geology, Geomorphology, Neotectonics*
Associate Scientist, Indiana Geological Survey and Assistant Professor, part-time, Geological Sciences; B.S. Wisconsin, M.S. Illinois; Ph.D. Wisconsin, 1971.

Bruce J. Douglas *Structural Geology, Rock Mechanics, Tectonics*
Assistant Scientist, Geological Sciences; A.B. Colgate; M.A., Ph.D. Princeton, 1983.

Jeremy Dunning *Structural Geology, Tectonics*
Associate Professor, Geological Sciences and Environmental Sciences; B.A. Colgate; M.S. Rutgers; Ph.D. North Carolina, 1978.

Michael W. Hamburger *Geophysics, Seismology , Tectonics*
Associate Professor, Geological Sciences; B.A. Wesleyan; M.Sc., Ph.D. Cornell, 1986.

Gary L. Pavlis *Geophysics, Seismology , Tectonics*
Associate Professor, Geological Sciences; B.S. South Dakota State; Ph.D. Washington, 1982.

Vishnu Ranganathan *Hydrogeology; Subsurface Fluid, Heat and Mass Transport*
Assistant Professor, Geological Sciences; B.S. Bombay, M.S. Cincinnati; Ph.D. Louisiana State, 1988.

Albert J. Rudman *Geophysics*
Professor, Geological Sciences; B.S., M.A., Ph.D. Indiana, 1963.

Facilities

The seismology group makes extensive use of a variety of computer facilities available within the Department and the University. Departmental facilities include a cluster of Sun workstations within the seismology research laboratory, complemented by an extensive collection of software. Through the Indiana University Center for Innovative Computer Applications, we also have access to specialized graphics facilities and programming talent. Finally, the central campus computer facilities provide unrestricted access to a number of VAX computers and a large AMDAHL mainframe, linked in a campuswide computer network.

The Rock Mechanics group has extensive facilities for conducting experiments over a wide range of conditions. The primary equipment includes: (1) a triaxial system with independent pore-pressure control, which with planned future upgrades will allow experiments in the 25° to 300°C temperature range; (2) a uniaxial testing machine configured for creep experiments up to 1600°C under controlled fugacity conditions; (3) a uniaxial testing machine configured for precision loading of small samples, and (4) a shock loading frame. All equipment is operated with a HP-7500 series computer data acquisition and control system. The lab also has numerous fixtures and associated measuring devices to produce specific sample configurations. Additional sample preparation equipment is available within the lab including low-speed saws and polishing laps plus an ion mill for preparing SEM/TEM samples.

Research

The greatest strength of the geophysics program at IU lies in seismology. Research activities range from the theoretical work of Al Rudman in synthetic seismograms and Gary Pavlis in tomography, to Pavlis's research in the precise locations of earthquake hypocenter locations, to Michael Hamburger's work, in part with Pavlis and Haydar Al-Shukri on the tectonic significance of the distribution of earthquakes in active seismic zones. Regions of tectonic interest include the southwest Pacific, the Himalaya Mountains of central Asia, and the New Madrid seismic zone in the mid-continent, USA, where Ned Bleuer is also involved in prehistoric liquefaction studies. To these research efforts are added Rudman's and Al-Shukri's interests in potential field theory and applications, and Rudman's and Vishnu Ranganathan's interest in conductive and convective heat transfer in the crust. In ductile and brittle rheological studies, Bruce Douglas has been worked on models of upper mantle rheology, and he and Jeremy Dunning are heavily involved in experimentally investigating the effect of surfactants on stable crack propagation.

Representative Publications

Al-Shukri, H.J. and B.J. Mitchell (1988). Reduced seismic velocities in the source zone of New Madrid earthquakes. *Bull. of Seism. Soc. Am.*, **78**, p. 1491-1509.

Al-Shukri, H.J. and B.J. Mitchell (1990). Three-dimensional attenuation structure in and around the New Madrid Seismic zone, *Bull. Seismo. Soc. Am.*, **80**, p. 615-632.

Al-Shukri, H.J., B.J. Mitchell and H.A.A. Ghalib (1988). Attenuation of seismic waves in the New Madrid seismic zone, *Seismo. Res. Let.*, **59**, p. 133-139.

Bear, G.W., H.J. Al-Shukri, and A.J. Rudman (1992). Three-dimensional linear gravity inversion using an iterative stochastic least squares method, EOS. *Trans. Am. Geophys. Union*, **73**, p. 82.

Douglas, B.J., J.D. Dunning and D.L. Goldsby (submitted). Subcritical crack propagation: The effects of temperature and aging-under-load. *J. Geophys. Res.*

Dunning, J.D., R. Kornbrekke, and M. Miller (1990). Surfactant-induced weakening of geologic materials. *Surfactants in Solution*, **10**, p. 297-320.

Eneva, M.G. and M.W. Hamburger (1989). Spatial and temporal patterns of earthquake distribution in Soviet Central Asia: Application of pair analysis statistics. *Bull. Seis. Soc. Am.*, **79**, p. 1439-1456.

Hamburger, M.W., W.A. Swanson, and G.A. Popandopulo (in press). Velocity structure and seismicity in the Garm region, Central Asia. *J. Geophys. Res.*

Meyerholtz, K.A., G.L. Pavlis, and S.A. Szpakowski (1989). Convolutional quelling in seismic tomography. *Geophysics*, **54**, p. 570-580.

Obermeier, S.F., N.K. Bleuer and others (1991). Evidence of strong earthquake shaking in the lower Wabash Valley from prehistoric liquefaction features. *Science*, **251**, p. 1061-1063.

Pavlis, G.L. (1986). Apprasing earthquake hypocenter location errors: A complete, practical approach for single event locations. *Bull. Seis. Soc. Amer.*, **76**, p. 1699-1717.

Pavlis, G.L. and M.W. Hamburger (1991). Aftershock sequences of intermediate-depth earthquakes in the Pamir-Hindu Kush Seismic Zone, *J. Geophys. Res.*, **96**, p. 107-117.

Ranganathan, V., and J.S. Hanor (1988). Density-driven groundwater flow near salt domes. *Chem. Geol.*, **74**, p. 173-188.

Rudman, A.J., and D. Epp (1983). Conduction models of the temperature distribution in the east rift zone of Kilauea Volcano. *Jour. of Volcanology and Geothermal Res.*, **16**, p. 189-203.

Rudman, A.J. and others (in press). Workstation computation of synthetic seismograms for vertical and horizontal profiles: A full wavefield response for a two-dimensional layered half-space. *Computer & Geosciences.*

Hydrogeology and Environmental Geochemistry

Research Faculty

Hendrik M. Haitjema *Hydrogeology and Groundwater Modelling*
Associate Professor, Environmental Sciences and Geological Sciences; Ir. Delft University of Technology (Netherlands); Ph.D. Minnesota, 1982.

Noel C. Krothe *Hydrogeology and Aqueous Geochemistry*
Associate Professor, Geological Sciences; B.S. Bloomsburg State; M.A.T. Indiana; M.S., Ph.D. Penn State, 1976.

Greg A. Olyphant *Hydrogeology, Quaternary Geology and Geomorphology*
Associate Professor, Geological Sciences and Geography; B.A. Cal State; M.A., Ph.D. Iowa, 1979.

Vishnu Ranganathan *Hydrogeology and Aqueous Geochemistry, Basin Analysis*
Assistant Professor, Geological Sciences; B.S. Bombay, M.S. Cincinnati; Ph.D. Louisiana State, 1988.

Jeffrey R. White *Aquatic Chemistry, Biogeochemistry, Limnology*
Associate Professor, Environmental Sciences and Geological Sciences; B.A. Gettysburg College, M.S. Rutgers, Ph.D. Syracuse, 1984.

Facilities

Professors Jeffrey White and Noel Krothe have laboratories for water analyses which contain a wide suite of instruments for aqueous analytical chemistry including an ion chromatograph and spectrophotometers. They also make routine use of the stable isotope and ICP laboratories maintained by the Department. Quantitative hydrogeologic research at IU benefits from two well-networked arrays of powerful workstations with sophisticated 3-D computer graphics for scientific visualization of data and for mathematical modeling, operated by Vishnu Ranganathan and Hendrick Haitjema.

Research

Research in hydrogeology and aqueous geochemistry at Indiana University deals with a large variety of issues. Large-scale groundwater flow, the estimation of fluid and solute fluxes and transport properties of rocks are investigated by Ranganathan and Haitjema. The groundwater models are used by Haitjema in designing pumping schemes to withdraw contaminants from the subsurface. White studies the aqueous chemistry and biogeochemistry of lakes and lake sediments, while Krothe is interested in the geochemistry of groundwaters, using dyes as tracers for subsurface flow in karst terrains, and the movement of agricultural contaminants in groundwaters. Greg Olyphant is currently involved in a project concerning acid mine drainage, erosion and sediment transport near abandoned coal mines and the movement of water in the unsaturated zone.

Representative Publications

Cassidy, D.P. and V. Ranganathan (1992). Groundwater upwelling near Bay St. Elaine salt dome in south Louisiana, as inferred from fluid property variations. *Am. Assc. of Petr. Geol. Bull.*, **76**, p. 1550-1568.

Charles, D., J. White and 11 others (1990). Paleoecological investigation of recent lake acidification in the Adirondack Mountains, N.Y. *J. of Paleolimnology*, **3**, p. 195-241.

Haitmeja, H.M. (1991). An analytic element model for transient axi-symmetric interface flow, *J. of Hydrology*, **129**, p. 215-245.

Haitjema, H.M., A.M. Ebrahem, and S. Mitchell-Bruker (1989). Very large scale regional aquifer modeling including local detail. *Presented* at the international conference on solving groundwater problems with models, Indianapolis, Indiana.

Kraemer, S.R. and H.M. Haitjema (1989). A modeling approach to regional fracture flow systems. *Presented* at the international conference on solving groundwater problems with models, Indianapolis, Indiana.

Krothe, N.C. (1988). Hydrologic connection between spring water and the evaporite of the lower St. Louis limestone, Karst Mitchell plain of southern Indiana. *Karst Hydrogeology and Karst Environment Protection*, proceedings of the Intl. Assc. of Hydrogeologists, Guilin, China, October 1988, Volume XXI, Part 1.

Olyphant, G.A., C.P. Carlson and D. Harper (1991). Seasonal and storm-related aspects of sediment yield from a rapidly eroding coal refuse deposit in southwestern Indiana. *Water Resources Res.*, **27 (11)**, p. 2825-2833.

Olyphant, G.A., E.R. Bayless and D. Harper (1991). Seasonal and weather-related controls on solute concentrations and acid drainage from a pyritic coal-refuse deposit in southwestern Indiana, U.S.A. *J. of Contaminant Hydrology*, **7**, p. 219-236.

Ranganathan, V., and J.S. Hanor (1989). Perched brine plumes above salt domes and dewatering of geopressured sediments. *J. of Hydrology*, **110**, p. 63-86.

Ranganathan, V. (1991). Salt diffusion in interstitial waters and halite removal from sediments — examples from the Red Sea and Illinois Basins. *Geochimica et Cosmochimica Acta*, **55**, p. 1615-1625.

Wells, E.R. and N.C. Krothe (1989). Seasonal fluctuation in $\partial^{15}N$ of groundwater nitrate in a mantled Karst aquifer due to transport of fertilizer-derived nitrate, *J. Hydrogeol.*, **112**, p. 191-201.

White, J.R., and C.T. Driscoll (1987). Zinc cycling in an acidic Adirondack lake. *Env. Sci. Technol.*, **21**, p. 211-216.

White, J.R., and C.T. Driscoll (1987). Manganese cycling in an acidic Adirondack lake. *Biogeochemistry*, **3**, p. 87-103.

Igneous, Metamorphic Petrology and Geochemistry

Research Faculty

Abhijit Basu *Sedimentary Petrology, Petrology, Lunar Geology*
Professor, Geological Sciences; B.Sc. Presidency College (India); M.Sc. Calcutta; Ph.D. Indiana, 1975.

James G. Brophy *Igneous Petrology and High-Temperature Geochemistry, Tectonophysics of Magma*
Associate Professor, Geological Sciences; B.A. Amherst; M.Sc. Colorado School of Mines; Ph.D. Johns Hopkins, 1985.

Michael J. Dorais *Igneous Petrology and High-Temperature Geochemistry*
Assistant Scientist, Geological Sciences; B.S. Brigham Young; M.S. Oregon; Ph.D. Georgia, 1987.

Peter J. Ortoleva *Geochemistry, Kinetics and Transport Mechanisms, Basin Analysis*
Professor, Chemistry and Geological Sciences; B.S. Rensselaer Polytechnic Institute; Ph.D. Cornell, 1970.

Edward M. Ripley *Petrology of Metallic Ore Deposits, Isotopic Geochemistry*
Professor, Geological Sciences; B.S. Illinois State, M.S. Minnesota; Ph.D. Penn State, 1976.

David G. Towell *Trace-Element and Isotope Geochemistry*
Associate Professor, Geological Sciences; B.S. Penn State, Ph.D. M.I.T., 1963.

Charles J. Vitaliano *Petrology and Petrography*
Professor (ret.), Geological Sciences; B.S., College of the City of New York, M.A., Ph.D. Columbia University, 1944.

Robert P. Wintsch *Metamorphic, Sedimentary Petrology, Structure, Tectonics, Geochronology*
Associate Professor, Geological Sciences; B.A. Beloit; Ph.D. Brown, 1975.

Facilities

Most analytical facilities necessary to conduct our research are available in-house, and we have access to other equipment through collaboration. Michael Dorais maintains our microprobe and x-ray facility, which includes a state-of-the-art, fully automated (Cameca SX50) electron microprobe, as well as automated and manual x-ray diffractometers. Mark Gilstrap runs our analytical facility with inductively coupled plasma (ICP) and atomic absorption (AA) spectrometers for major and trace element analysis. Jim Brophy has several controlled-atmosphere, high temperature furnaces for experimental studies. Steve Studley supervises use of the stable isotope laboratory for analysis of H, C, N, O, and S isotopes, while Ed Ripley maintains all the necessary mineral and silicate extraction lines. We also have a rock prep lab, machine shop, and electronics shop. We collaborate with scientists at Woods Hole, and the USGS (Reston, Denver) for research using ion microprobes and radiogenic isotopes for geochronology.

Research

Research in hard rock petrology and geochemistry covers a wide range of problems and issues at IU. Brophy, Dorais, Ripley, and Vitaliano all study aspects of igneous petrology. Brophy's and Vitaliano's research focus on extrusive rocks to understand the operation of magma chambers, while Basu looks at lunar soils to extract both subsurface igneous and surficial soil-forming processes. Dorais and Ripley study intrusive rocks, felsic and mafic respectively, to decipher issues of magma mixing and ore genesis. Basu, Brophy, Dorais, and Dave Towell all use trace and rare earth elemental geochemistry in their research, with Brophy actively involved in high temperature, low pressure experiments looking at the partition of trace elements among minerals and silicate liquid. Ripley, Wintsch and Ortoleva are interested in metamorphic rocks. Ripley's interests focus on silicate-sulfide interactions in diagenesis and metamorphism. Wintsch uses methods of metamorphic petrology, whole rock geochemistry, structural geology, and geochronology to unravel suspect terranes in the Appalachians, and to understand petrologic processes in slaty cleavage development and in brittle and ductile fault zones. Ortoleva explores theoretical aspects of pressure solution and fabric development in metamorphic rocks.

Representative Publications

Brophy, J.G. and A. Basu (1990). Europium anomalies in mare basalts as a consequence of mafic cumulate fractionation from an initial lunar magma. *Proc. Lunar Planet. Sci. Conf. 20th, Lunar and Planetary Institute,* Houston, p. 25-30.

Basu, A., B.B. Holmberg and E. Molinaroli (1992). Origin of yellow glasses associated with Apollo 15 KREEP basalt fragments. *Proc. Lunar Planet. Sci. Conf. 22nd, Lunar and Planetary Institute,* Houston, p. 365-372.

Brophy J.G. (1991). Composition gaps, critical crystallinity, and fractional crystallization in orogenic (calc-alkaline) magmatic systems. *Contrib. Mineral. Petrol.*, **109**, p. 173-182.

Dewers, T. and P. Ortoleva (1990). Geochemical self-organization III: A mean field, pressure solution model of spaced cleavage and metamorphic segregational layering. *Am. J. Sci.*, **290**, p. 473-521.

Dipple, G.M., R.P. Wintsch, and M.S. Andrews (1990). Identification of the scales of differential element mobility in a ductile fault zone through multi-sample mass balance. *J. Meta. Geology*, **8**, p. 645-661.

Dorais, M.J., J.A. Whitney and J.C. Stormer, Jr. (1991). Mineralogical constraints on the petrogenesis of trachytic inclusions, Carpenter Ridge Tuff, central San Juan volcanic field, Colorado. *Contr. Mineral. Petrol.*, **107**, p. 219-230.

Dorais, M.J., and C. Floss (in press). An ion and electron microprobe study of the mineralogy of enclaves and host syenites of the Red Hill complex, New Hampshire, U.S.A. *J. of Petrology.*

Ortoleva, P. (1992). Nonlinear chemical waves. *Chichester, John Wiley and Sons,* 302p.

Ortoleva, P. (in press). Geochemical self-organization. *Oxford University Press.*

Ripley, E.M. (1990). Platinum-group element geochemistry of Cu-Ni mineralization in the basal zone of the Babbitt deposit, Duluth Complex, Minnesota. *Econ. Geol.*, **85**, p. 830-842.

Vitaliano, C.J., S. Kish and D.G. Towell (1980). Potassium-argon dates and strontium isotopic values for rocks of the Tobacco Root batholith, southwestern Montana. *Isochron West*, **28**, p. 13-15.

Vitaliano, C.J. and D.B. Vitaliano (1978). Tephrochronological evidence for the time of the Bronze Age eruption of Thera. *Acta of the 2nd International Scientific Conference*: Thera and the Aegean World I.

Wintsch, R.P., J.F. Sutter, M.J. Kunk, J.N. Aleinikoff, M.J. Dorais (1992). Contrasting P-T-t paths: Thermochronologic evidence for a Late Paleozoic final accretion of the Avalon terrane in the New England Appalachains. *Tectonics*, **11**, p. 672-689.

Webster, J. and M.S. Gilstrap (1990). Matrix-independent separation of rare-earth elements and yttrium from geological materials using constant calcium content-oxalate precipitation and cation exchange for determination by high-resolution inductively coupled plasma atomic emission spectrometry (ICP-AES). *Chemical Geology*, **85**, p. 287-294.

Quaternary Geology and Geomorphology

Research Faculty

Ned K. Bleuer *Quaternary Geology and Geomorphology*
Associate Scientist, Indiana Geological Survey and Assistant Professor, part time, Geological Sciences; B.S. Wisconsin, M.S. Illinois; Ph.D. Wisconsin, 1971.

Gordon S. Fraser *Quaternary Geology and Geomorphology; Sedimentology and Stratigraphy*
Senior Scientist, Indiana Geological Survey and Associate Professor, part-time, Geological Sciences; B.S., M.S., Ph.D. Illinois, 1974.

Greg A. Olyphant *Hydrogeology, Quaternary Geology and Geomorphology*
Associate Professor, Geological Sciences and Geography; B.A. Cal State; M.A., Ph.D. Iowa, 1979.

Lawrence J. Onesti *Quaternary Geology and Geomorphology*
Associate Professor, Geological Sciences; B.S. Northwestern; M.A. Michigan State; Ph.D. Wisconsin, 1973.

Facilities

Laboratories for detailed analyses of soils and unconsolidated sediments are available in the Department and Survey. Available field equipment includes a Giddings soil corer, a truck-mounted auges for drilling unconsolidated materials, and portable gamma-ray and neutron logging devices. Instrumentation is available for field studies of wind, streamflow, and sediment transport. The Department also has a machine shop for construction of custom equipment and installations used for monitoring surficial processes.

Research

Research in Quaternary geology and geomorphology by I.U. faculty and research associates in the Indiana Geological Survey includes studies of contemporary erosional and depositional processes as well as local and regional studies of depositional environments and glacial land-systems. A special emphasis is placed on environmental geology with current projects directed toward effects of tectonism on fluvial systems, development of hydrogeologic facies models for glaciated areas, erosion and sedimentation in areas affected by surface mining, and susceptibility of unconsolidated deposits to earthquake hazard. Research projects are supported by grants from the U.S. Geological Survey, National Oceanographic Association, NASA, National Science Foundation, the Environmental Protection Agency, as well as state and local agencies.

Representative Publications

Bleuer, N.K., (1991). The Lafayette bedrock valley system of Indiana; Concept, form and fill stratigraphy. *Geology and Hydrogeology of the Teays-Mahomet Bedrock Valley System: Geolog. Soc. of Am. Special Paper 258*, Melhorn, W.N. and J.P. Kempton, eds., p. 51-77.

Bleuer, N.K. (in press). Nature of glacial and other unconsolidated sedimentary sequence through downhole gamma-ray logging. Indiana Geolog. Surv. Special Paper 49.

Fraser, G.S., et al. (1991). Sediments and sedimentary structures of a non-tidal, barred coast, southern shore of Lake Michigan. *J. Coastal Research*, **7**, p. 1113-1124.

Fraser, G.S. and N.K. Bleuer (1988). Sedimentological consequences of two floods of extreme magnitude in the late Wisconsinian Wabash Valley. *Sedimentological consequences of extreme events: Geolog. Soci. of Am. Special Paper 229*, Clifton, H.E., ed., p. 111-125.

Fraser, G.S., C.E. Larsen and N.C. Hester (1990). Climatically controlled high lake levels in the Lake Michigan and Lake Huron basins. *Quaternary Geology of the Lake Michigan Basin: Geolog. Soc. of Am. Special Paper 251*, Schneider, A.E. and G.S. Fraser, eds., p. 75-89.

Morris, S.E. and G.A. Olyphant (1990). Alpine lithofacies variation: Working toward a physically based model. *Geomorph.*, **3**, p. 73-90.

Obermeier, S.F., N.K. Bleuer and others (1991). Evidence of strong earthquake shaking in the lower Wabash Valley from prehistoric liquefaction features. *Science*, **251**, p. 1061-1063.

Olyphant, G.A., C.P. Carlson and D. Harper (1991). Seasonal and storm-related aspects of sediment yield from a rapidly eroding coal refuse deposit in southwestern Indiana. *Water Resources Res.*, **27(11)**, p. 2825-2833.

Onesti, L.J. (1983). Hydrologic characteristics of six small arctic-alpine watersheds, Central Brooks Range, Alaska. *Proceed. IVth Intl. Conf. on Permafrost, Fairbanks, Alaska*, p. 957-961.

Onesti, L.J. (1989). Suspended sediment load variation of arctic-alpine watersheds in Alaska. *Symp. on Headwater Hydrology, Am. Water Resources Assc., Missoula, Mont.*

Onesti, L.J. and T.K. Miller (1987). Interregional comparison of alluvial stream channel morphology: Great plains vs. central lowlands. *Water Resources Bull., American Water Resources Assc.*, **24 (6)**, p. 1207-1217.

Sedimentary Petrology and Geochemistry

Research Faculty

Abhijit Basu *Sedimentary Petrology, Lunar Petrology and Lunar Geology*
Professor, Geological Sciences; B.Sc. Presidency College (India); M.Sc. Calcutta; Ph.D. Indiana, 1975.

J. Robert Dodd *Paleoecology, Carbonate Sedimentology and Petrology*
Professor, Geological Sciences; B.A. Indiana; M.A., Ph.D. Caltech, 1961.

Donald E. Hattin *Stratigraphy, Sedimentology, Paleoecology and Paleontology, Carbonate Petrology*
Professor, Geology; B.S. Massachusetts; M.S., Ph.D. Kansas, 1954.

Colin Harvey *Economic Geology, Clays and Industrial Minerals, Sedimentary Petrology, Geothermal*
Research Fellow, Geological Sciences; B.Sc., M.Sc. (Honors) University of Auckland, New Zealand, Ph.D. Indiana, 1980.

Alan S. Horowitz *Geobiology, Paleontology, Carbonate Petrology*
Senior Scientist and Professor, part-time, Geological Sciences; B.A. Washington and Lee; M.S. Ohio State; Ph.D. Indiana, 1957.

Enrique Merino *Geochemistry and Petrology*
Associate Professor, Geological Sciences; Ingeniero, School of Mining Engineering, Madrid, Spain; Ph.D. University of California at Berkeley, 1973.

Haydn H. Murray *Economic Geology, Clays and Industrial Minerals*
Professor, Geological Sciences; B.S., M.S., Ph.D. Illinois, 1951.

Peter J. Ortoleva *Geochemistry, Kinetics and Transport Mechanisms, Basin Analysis*
Professor, Chemistry and Geological Sciences; B.S. Rensselaer Polytechnic Institute; Ph.D. Cornell, 1970.

Lisa M. Pratt *Sedimentary and Organic Geochemistry, Stratigraphy*
Associate Professor, Geological Sciences; B.A., M.S. North Carolina; M.S. Illinois; Ph.D. Princeton, 1981.

Edward M. Ripley *Petrology of Metallic Ore Deposits, Isotopic Geochemistry*
Professor, Geological Sciences; B.S. Illinois State, M.S. Minnesota; Ph.D. Penn State, 1976.

Lee J. Suttner *Sedimentary Petrology, Basin Analysis, Sedimentology*
Professor and Chairman, Geological Sciences; B.S. Notre Dame; M.S., Ph.D. Wisconsin, 1966.

Robert P. Wintsch *Metamorphic, Sedimentary Petrology, Structure, Tectonics, Geochronology*
Associate Professor, Geological Sciences; B.A. Beloit; Ph.D. Brown, 1975.

Facilities

The department has a variety of microscopes and chemical analytical facilities that are utilized in sedimentary petrology. In addition to standard polarizing petrographic microscopes and a cathodoluminescence capabilities on three separate instruments, the faculty and students doing research in sedimentary petrology have ready access to the most advanced equipment for x-ray diffraction analysis, electron microprobe, mass spectrometers for stable isotope analysis, and ICP and AA spectrometers for analysis of waters and rocks.

Research

Petrology of sedimentary rocks is fundamental to the understanding of the processes that range from tectonism of the earth to the interaction of the atmosphere, hydrosphere, and the biosphere with the solid earth. Low-temperature geochemical processes contribute to the modification of original sediments as well as to their preservation. More than half of the faculty of the department relate to sedimentary petrology directly or in an interdisciplinary way. Lee Suttner and Abhijit Basu work on the provenance of sand and sandstone. Colin Harvey, Enrique Merino, Haydn Murray and Ed Ripley study sedimentary mineralogy and diagenesis. Organic and inorganic sedimentary geochemistry is included in studies by Merino, Peter Ortoleva, Lisa Pratt, Ripley and Bob Wintsch, while Bob Dodd, Don Hattin and Al Horowitz focus on carbonate rocks. Basu also studies the petrology of lunar soils.

Representative Publications

Basu, A. and E. Molinaroli (1991). Reliability and application of detrital opaque Fe-Ti oxide minerals in provenance determination. *Spec. Pub., Geol. Soc. Lond.*, **57**, p. 55-65.

Branam, T.D., and E.M. Ripley (1990). Genesis of sediment-hosted copper mineralization in south-central Kansas: I. S/C and sulfur isotopic relationships. *Econ. Geol.*, **85**, p. 601-622.

Brown, M.A., and J.R. Dodd (1990). Waulsortian-like carbonate mud bodies in Middle Mississippian strata of southern Indiana and northern Kentucky. *Palaios*, **5**, p. 236-243.

Harvey, C.C., P.R.L. Browne (1991). Mixed-layer clay geothermometers in the Wairakei geothermal field, New Zealand. *Clays and Clay Minerals*, **39**, p. 614-621.

Hattin, D.E. (1990). *Puebloites greenhornensis* Cobban & Scott from Turonian part of Greenhorn Limestone, north-central Kansas and northeastern Wyoming. *Cretaceous Research*, **11**, p. 351-358.

Hieshima, G.B. and L.M. Pratt (1992). Sulfur/carbon ratios and extractable organic matter of the middle Proterozoic Nonesuch formation, North American midcontinent rift. *Precamb. Res.*, **54**, p. 65-79.

Kairo, S., L.J. Suttner and P.K. Dutla (in press). Variability on sandstone composition as a function of depositional environment in coarse-grained delta systems. *Geological Society of America Special Paper.*

Merino, E., C.C. Harvey, H.H. Murray (1989). Aqueous-chemical control on the tetrahedral-aluminum content of quartz, halloysite, illite and other low temperature silicates. *Clays and Clay Minerals*, **37**, p. 135-142.

Merino, E., D. Nahon and Y. Wang (in press). Kinetics and mass transfer of pseudomorphic replacement: Application to replacement of parent minerals by Al, Fe, and Mn oxides during weathering. *American Journal of Science.*

Meshri, I. and P. Ortoleva, eds. (1990). Prediction of reservoir quality through chemical modeling. *AAPG Memoir 49*, 175p.

Ortoleva, P., B. Hallet, A. McBirney, I. Meshri, R. Reeder, and P. Williams, eds. (1990). Self-organization in geological systems: Proceedings of a workshop held 26-30 June 1988, University of California, Santa Barbara. *Earth Science Reviews 29*, Amsterdam, Elsevier, 417p.

Ripley, E.M., N.R. Shaffer and M.S. Gilstrap, (1990). Distribution and geochemical characteristics of metal enrichment in the New Albany Shale (Devonian-Mississippian), Indiana. *Econ. Geol.*, **85**, p. 1790-1808.

Roden, M. and R.P. Wintsch (1992). Zircon and apatite fission-track evidence for an early permian thermal peak and relatively rapid late permian cooling in the Appalachian basin (Abs.). *Geol. Soc. America*, **24**, p. A187.

Wang, Y. and E. Merino (1990). Self-organizational origin of agates: Banding, fiber twisting, composition, and dynamic crystallization model. *Geochimica et Cosmochimia Acta*, **54**, p. 1627-1638.

Wintsch, R.P., and C.M. Kvale (in revision). Differential element mobility during diagenesis of siliciclastic rocks. *J. Sed. Pet.*

Zaback, D.A., L.M. Pratt, and J.M. Hayes (in press). Transport and reduction of sulfate and immobilization of sulfide in marine black shales. *Geology.*

Sedimentology, Stratigraphy and Basin Analysis

Research Faculty

Abhijit Basu *Sedimentary Petrology, Lunar Petrology and Geology*
Professor, Geological Sciences; B.Sc. Presidency College (India); M.Sc. Calcutta; Ph.D. Indiana, 1975.

Simon C. Brassell *Biological, Organic, and Petroleum Geochemistry; Basin Analysis*
Professor, Geological Sciences and Environmental Sciences; B.Sc., Ph.D. Bristol (England), 1980.

J. Robert Dodd *Paleoecology, Carbonate Sedimentology and Petrology*
Professor, Geological Sciences; B.A. Indiana; M.A., Ph.D. Caltech, 1961.

John Droste *Stratigraphy, Subsurface Geology*
Professor (ret.), Geological Sciences; B.S., M.S., Ph.D., Illinois, 1956.

Gordon S. Fraser *Quaternary Geology and Geomorphology; Sedimentology and Stratigraphy*
Senior Scientist, Indiana Geological Survey and Associate Professor, part-time, Geological Sciences; B.S., M.S., Ph.D. Illinois, 1974.

Lloyd C. Furer *Basin Analysis, Tectonics*
Associate Scientist, Indiana Geological Survey; B.S. Ohio Univ.; M.A. Wyoming; Ph.D. Wisconsin, 1966.

Donald E. Hattin *Stratigraphy, Sedimentology, Paleoecology and Paleontology*
Professor, Geology; B.S. Massachusetts; M.S., Ph.D. Kansas, 1954.

Norman Hester *Depositional Environments, Stratigraphy, Coal and Petroleum Geology*
Director, Indiana Geological Survey and Professor, Geological Sciences; B.S., M.S., Ph.D. Cincinnati, 1968.

Brian D. Keith *Petroleum Geology, Basin Analysis, Sedimentology and Stratigraphy*
Associate Scientist, Indiana Geological Survey and Associate Professor, part-time, Geological Sciences; B.A. Amherst; M.S. Syracuse; Ph.D. Rensselaer Polytechnic Institute, 1974.

Peter J. Ortoleva *Geochemistry, Kinetics and Transport Mechanisms, Basin Analysis*
Professor, Chemistry and Geological Sciences; B.S. Rensselaer Polytechnic Institute; Ph.D. Cornell, 1970.

Lisa M. Pratt *Sedimentary and Organic Geochemistry, Stratigraphic Interpretation*
Associate Professor, Geological Sciences; B.A., M.S. North Carolina; M.S. Illinois; Ph.D. Princeton, 1981.

Vishnu Ranganathan *Hydrogeology and Aqueous Geochemistry, Basin Analysis*
Assistant Professor, Geological Sciences; B.S. Bombay; M.S. Cincinnati, Ph.D. Louisiana State, 1988.

Robert H. Shaver *Paleobiology and Stratigraphy*
Professor (ret.), Geological Sciences, B.S., M.S., Ph.D., Illinois, 1951.

Lee J. Suttner *Sedimentary Petrology, Basin Analysis, Sedimentology*
Professor and Chairman, Geological Sciences; B.S. Notre Dame; M.S., Ph.D. Wisconsin, 1966.

Facilities

All the standard and many specialized equipment items for study of sedimentary rocks are available in the department and survey. The extensive collection of cores and well samples and geophysical logs in the Geological Survey are a particularly valuable resource in research on the Illinois Basin and the Department has an extensive library of geophysical logs from the western interior of the U.S. Researchers working in this area have facilities such as the latest x-ray diffraction equipment, mass spectrometers for stable isotope analysis, scanning electron microscope, and electron microprobe for studying mineralogy and mineral chemistries of sedimentary rocks. The Geologic Field Station in Montana is a convenient base of operation for field work in the northern Rockies.

Research

A large number of faculty members and geologists in the Indiana Geological Survey are involved in many aspects of research in sedimentology, stratigraphy and basin analysis. Our location on the east flank of the Illinois Basin makes study of the formation, history, and depositional settings in this basin particularly convenient. Researchers in the department are studying rocks deposited in the basin as old as Proterozoic and as young as Pennsylvanian. Indeed, some of our faculty and students have studied the sedimentology of the Pleistocene sediments that blanket the northern part of the state and fill the valleys to the south. Others work on topics such as sequence stratigraphy in Cretaceous rocks of the western interior of the U.S., the relationship between tectonics and sedimentation in the Rocky Mountain foreland. Cretaceous basins in the Rocky Mountains. But geography is no limit. Our faculty and students are conducting work on sedimentology, stratigraphy and tectonics of basins of rocks around the world and even beyond. Basu and his students have studied the sedimentology of lunar sediments.

Representative Publications

Basu, A. (1990). Recycled grains in lunar soils as an additional, necessary, regolith evolution parameter. *Proc. Lunar Sci. Conf. 20th, Lunar and Planetary Institute,* Houston, p. 231-238.

Basu, A. and E. Molinaroli (1991). Reliability and application of detrital opaque Fe-Ti oxide minerals in provenance determination. *Spec. Pub., Geol. Soc. Lond.*, **57**, p. 55-65.

Brown, M.A., and J.R. Dodd (1990). Waulsortian-like carbonate mud bodies in middle Mississippian strata of southern Indiana and northern Kentucky. *Palaios*, **5**, p. 236-243.

Cassidy, D.P. and V. Ranganathan (1992). Groundwater upwelling near Bay St. Elaine salt dome in south Louisiana, as inferred from fluid property variations. *Am. Assc. of Petrol. Geol. Bull.*, **76**, p. 1550-1568.

Dodd, J.R. and R.J. Stanton, Jr. (1991). Cyclic sedimentation in three Neogene basins in California. *Spl. Pub. Int. Assoc. Sedimentol.*, **12**, p. 201-215.

Droste, J.B., and G.L. Carpenter (1990). Subsurface stratigraphy of the Blue River group (Mississippian) in Indiana. *Indiana Geological Survey Bulletin 62*, 45p.

Droste, J.B., and R.H. Shaver (1987). Paleoceanography of Silurian seaways in the midwestern basins and arches region. *Paleoceanography*, **2**, p. 213-227.

Farrimond P., G. Eglinton, S.C. Brassell, and H.C. Jenkyns (1990). The Cenomanian/Turonian anoxic event in Europe: An organic geochemical study. *Mar. Petrol. Geol.*, **7**, p. 75-89.

Fraser, G.S. (1989). *Clastic Depositional Sequences: Processes of Evolution and Principles of Interpretation.* Prentice Hall Publishing Co., Englewood Cliffs, New Jersey, 449p.

Furer, L.C., M. May, E. Kvale, and L.J. Suttner (1991). Stratigraphic positioning of the lower Cretaceous conglomerates, Wind River basin, Wyoming and implications for possible hydrocarbon traps. *Amer. Assoc. Pet. Geol. Bull.*, **75**, p. 577.

Hamburger, M.W. and J.A. Rupp (1988). The June 1987 southeastern Illinois earthquake: Possible tectonism associated with the LaSalle anticlinal belt. *Seismol. Res. Lett.*, **59**, p. 151-157.

Hattin, D.E. and V.L. Warren (1989). Stratigraphic analysis of a fossil *Neogoniolithon*-capped patch reef and associated facies, San Salvador, Bahamas. *Coral Reefs*, **8**, p. 19-30.

Hieshima, G.B. and L.M. Pratt (1992). Sulfur/carbon ratios and extractable organic matter of the middle Proterozoic Nonesuch formation, North American midcontinent rift. *Precamb. Res.*, **54**, p. 65-79.

Ortoleva, P., B. Hallet, A. McBirney, I. Meshri, R. Reeder, and P. Williams, eds. (1990). Self-organization in geological systems: Proceedings of a workshop held 26-30 June 1988, University of California, Santa Barbara. *Earth Science Reviews 29*, Amsterdam, Elsevier, 417p.

Ranganathan, V. (1992). Basin dewatering and formation of brine plumes near salt domes. *J. of Geophys. Res.*, **97**, p. 4667-4683.

Shaver, R.H., and J.A. Sundeman (1989). Silurian seascapes: Water depth, clinothems, reef geometry, and other motifs — a critical review of the Silurian reef model. *Geolog. Soc. of Am. Bull.*, **101**, p. 939-951.

Tectonics and Structural Geology

Research Faculty

Haydar Al-Shukri *Geophysics, Seismology, Geotomography*
Research Associate, Geological Sciences; B.S., M.S. Baghdad University, Ph.D. St. Louis University, 1990.

Bruce J. Douglas *Tectonics and Structural Geology*
Assistant Scientist, Geological Sciences; A.B. Colgate; M.A., Ph.D. Princeton, 1983.

Lloyd C. Furer *Basin Analysis, Tectonics*
Associate Scientist, Indiana Geological Survey; B.S. Ohio University; M.A. Wyoming; Ph.D. Wisconsin, 1966.

Michael W. Hamburger *Geophysics, Seismology, Tectonics*
Associate Professor, Geological Sciences; B.A. Wesleyan; M.Sc., Ph.D. Cornell, 1986.

Peter J. Ortoleva *Geochemistry, Kinetics and Transport Mechanisms, Basin Analysis*
Professor, Chemistry and Geological Sciences; B.S. Rensselaer Polytechnic Institute; Ph.D. Cornell, 1970.

Gary L. Pavlis *Geophysics, Seismology, Tectonics*
Associate Professor, Geological Sciences; B.S. South Dakota State; Ph.D. Washington, 1982.

Lee J. Suttner *Sedimentary Petrology, Basin Analysis, Sedimentology*
Professor and Chairman, Geological Sciences; B.S. Notre Dame; M.S., Ph.D. Wisconsin, 1966.

Robert P. Wintsch *Metamorphic, Sedimentary Petrology, Structure, Tectonics, Geochronology*
Associate Professor, Geological Sciences; B.A. Beloit; Ph.D. Brown, 1975.

Facilities

The facilities needed for this research are more than adequate, including extensive computing facilities and state-of-the-art electron microscopic and microanalytical tools. Most analytical facilities necessary to conduct our research are available in-house, and we have access to other equipment through collaboration. Included is a fully automated Cameca SX50 electron microprobe, as well as automated and manual x-ray diffractometers, a chemical analytical facility with inductively coupled plasma (ICP) and atomic absorption (AA) spectrometers for major and trace element analysis, a stable isotope laboratory for analysis of H, C, N, O, and S isotopes, mineral and silicate extraction lines and a rock prep lab, machine shop and electronics shop. Also available for use are a cluster of Sun workstations with an extensive collection of software. There are specialized graphics facilities and unrestricted access to a number of VAX computers and a large AMDAHL mainframe, linked in a campuswide computer net.

Research

Bruce Douglas and Robert Wintsch are involved in hardrock structural problems in the northern Rockies and Appalachians from the origin of slaty cleavage, to structural analysis within and across terrane boundaries. Peter Ortoleva is interested in the origin and development of preferred mineral orientations and layering in metamorphic rocks from a theoretical point of view. Many of our faculty are involved with research related to mechanical aspects of geological deformation, and their research is cross listed here. Michael Hamburger, Gary Pavlis and Haydar Al-Shukri are conducing seismologic research in areas of active tectonics including the Himalayan mountain system, the subduction environment of the southen Pacific, and the New Madrid fault zone of the central United States. Lloyd Furer is working on intracratonic tectonic problems in the northern Cordillera and the midcontinent from a stratigraphic approach. Lee Suttner is working on tectonic problems in the Cordillera using sedimentology, stratigraphy and provenance as primary tools.

Representative Publications

Al-Shukri, H.J., and B.J. Mitchell (1987). Three-dimensional velocity variations and their relation to the structure and tectonic evolution of the New Madrid seismic zone. *Jour. Geophys. Res.*, **92**, p. 6377-6390.

Douglas, B. (1986). Deformational history of an outlier of metasedimentary rocks within the Coast Plutonic Complex, British Columbia, Canada. *Can. J. Earth Science*, **23**, p. 813-826.

Estey, L. and B. Douglas (1986). Upper-mantle anisotropy: A preliminary model. *J. Geophys. Res.*, **91**, p. 11393-11406.

Furer, L.C. (1989). Tectonic factors controlling initiation and distribution of silurian reefs in Illinois basin, southwestern Indiana: *Am. Assoc. Pet. Geol. Bull.*, **73**, p. 1031.

Furer, L.C. (in review). Basement tectonics in the southeastern Illinois Basin and their effect on Paleozoic sedimentation. *Am. Assoc. Pet. Geol. Bull.*, 21 p.

Hamburger, M.W., I.B. Everingham, B.L. Isacks, and M. Barazangi (1990). Seismicity and crustal structure of the Fiji Platform, Southwest Pacific. *J. Geophys. Res.*, **95**, p. 2553-2573.

Hamburger, M.W., D.E. Sarewitz, T.L. Pavlis, and G.A. Popandopulo (1992). Structural and seismic evidence for intracontinental subduction in the Peter the First Range, Soviet Central Asia. *Geol. Soc. Amer. Bull*, **104**, p. 397-408.

Malone, A. and L.J. Suttner (1992). Evidence against recurrent movement along the Willow Creek fault zone during deposition of the Morrison Formation (Jurassic), Northern Tobacco Root Mountains, Montana. *Rocky Mountain Geologist*, **28**, p. 47-64.

May, M.T., L.C. Furer, J.H. Meyers, L.J. Suttner, E.P. Kvale, and P.G. DeCelles (1992). Complexities in fluvial stratigraphic sequences in medial to distal portions of a developing foreland basin: An example from the Lower Cretaceous of Wyoming and Montana. *Absts. with Program; Am. Assc. of Petrol. Geol. Annual Meeting (Calgary)*, p. 84.

Meyers, J.H., L.J. Suttner, L.C. Furer, and M.T. May, (in press). Intra-basin tectonic control of fluvial sandstone bodies in the Cloverly formation (Early Cretaceous), West-central Wyoming, U.S.A. *Basin Research.*

Pavlis, G.L., M.W. Hamburger, and I.L. Nersesov (1989). Anomalies in the magnitude-frequency relation of earthquakes in the Garm region, Soviet Central Asia. *Bull. Seism. Soc. Amer.*, **79**, p. 1913-1926.

Wintsch, R.P., and M.S. Andrews (1988). Deformation induced growth of sillimanite: "Stress" mineral revisited. *J. of Geology*, **96**, p. 143-161.

Wintsch, R.P., M. S. Andrews and C. Ambers (1990). The case for thrust napping and against fold napping in the Avalon terrane of southeastern Connecticut, *in* Socci, A.D., S. J. Skehan, and G.W. Smith, (eds.). Geology of the composite Avalon terrane of southern New England, *Geol. Soc. America*, Spec. Paper **245**, p. 209-233.

Wintsch, R.P., C.M. Kvale, and H.J. Kisch (1991). Open system, constant volume development of slaty cleavage, and strain induced replacement reactions in the Martinsburg Formation, Lehigh Gap, PA, *Geological Soc. Am. Bull.*, **103**, p. 916-927.

Faculty and Research Staff
Current Projects

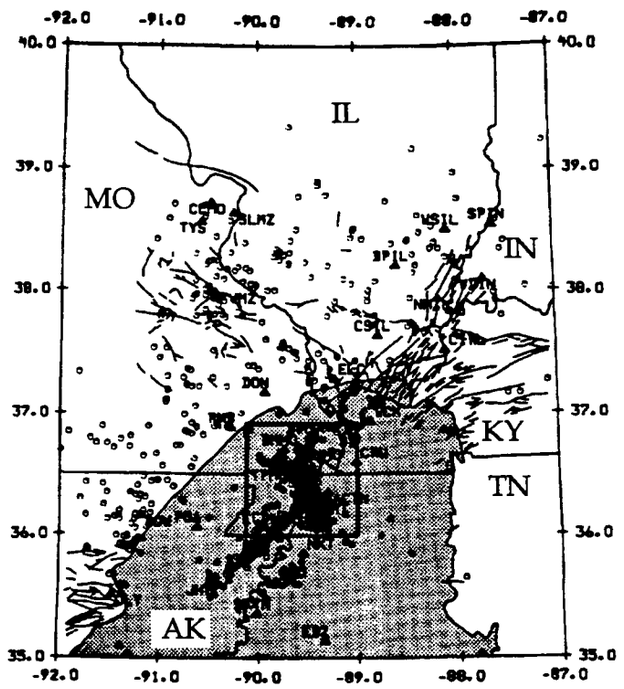
Haydar Al-Shukri

Geophysics, Seismology

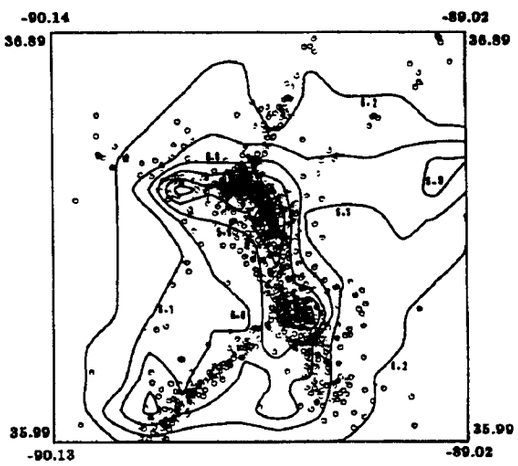
Research Associate, Geological Sciences; B.S., M.S. Baghdad University, Ph.D. St. Louis University, 1990.

Al-Shukri's major research field is earthquake seismology with special interests in geotomography using seismic and potential field data to view the earth heterogeneities in three dimensions. He has developed and applied a number of tomographic procedures to examine crustal and upper mantle velocity and attenuation structures beneath the New Madrid seismic zone and surrounding regions. One of the main objectives was to study the association between seismic wave velocity, attenuation and pore-fluids. This research was conducted to examine the existence of fluids in the fault zone and their effects in reducing the deviatoric stress necessary to generate earthquakes.

More recently, through his association with IRIS (Incorporated Research

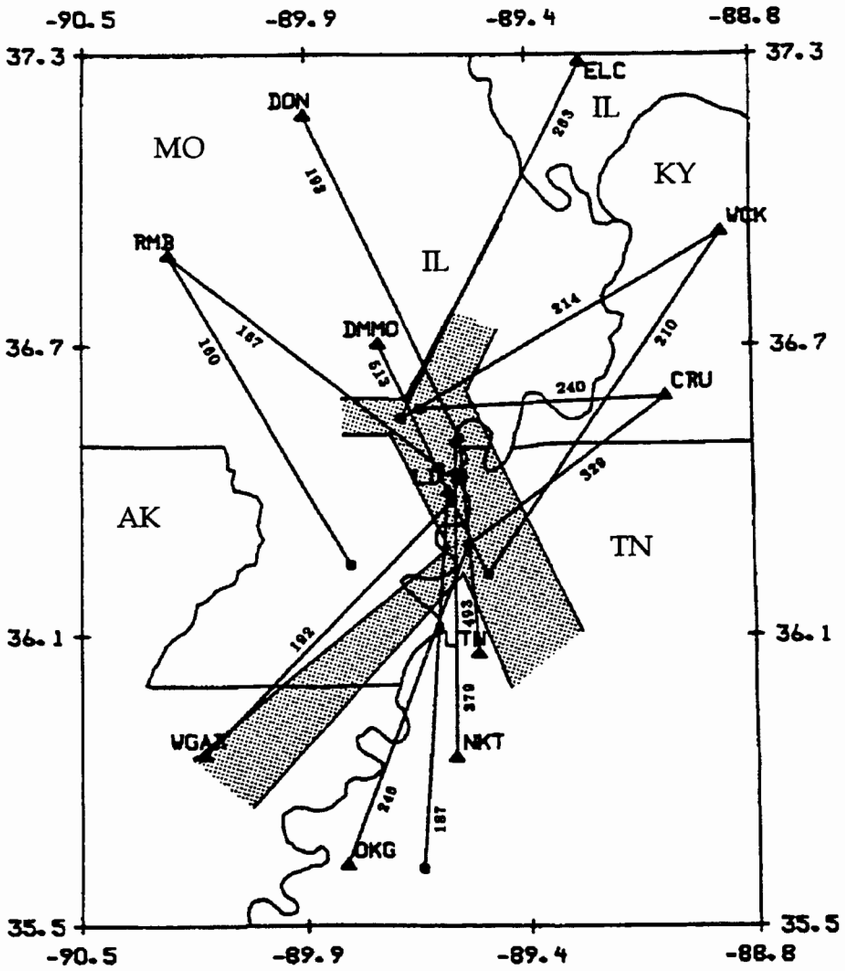


Map of the northern Mississippi Embayment (shaded) and surrounding tectonic features (modified from Heyl and McKeown, 1978). Circles denote some of the earthquake epicenters located by the U.S. Geological Survey/Nuclear Regulatory Commission. The solid rectangle delineates the area beneath which the three-dimensional velocity structure has been studied.



Velocity variations contoured at 0.1 km/sec intervals for the upper crust (0-14 km) beneath the most active portion of the New Madrid seismic zone (see figure at right). The circles denote epicenters of well-located earthquakes determined between 1980 and 1986.

Institutions for Seismology) he has broadened and diversified his research area to include analysis of 3-component broad band data from small and large aperture seismic arrays to study near-surface station site effects on the high frequency waves, source characteristics, path effects, shear wave splitting, and anisotropy. Another area of research is the development of a new approach of inverting potential field data to determine three-dimensional distribution of density and susceptibility in the earth.



Q_p^{-1} values (x 10^5) determined for several selected paths beneath the high seismicity region of the New Madrid area. This figure indicates that the most seismically active areas (shaded) attenuate seismic waves much faster than the surrounding regions. The results shown in this figure and the reduction of seismic wave velocities are consistent with the idea that fluid-filled cracks are prevalent in the active portion of the New Madrid seismic zone.

Representative Publications

Al-Shukri, H.J., and B.J. Mitchell (1987). Three-dimensional velocity variations and their relation to the structure and tectonic evolution of the New Madrid seismic zone. *Jour. Geophys. Res.*, **92**, p. 6377-6390.

Al-Shukri, H.J. and B.J. Mitchell (1988). Reduced seismic velocities in the source zone of New Madrid earthquakes. *Bull. of Seism. Soc. Am.*, **78**, p. 1491-1509.

Al-Shukri, H.J., B.J. Mitchell and H.A.A. Ghalib (1988). Attenuation of seismic waves in the New Madrid seismic zone, *Seismo. Res. Let.*, **59**, p. 133-139.

Al-Shukri, H.J. and B.J. Mitchell (1990). Three-dimensional attenuation structure in and around the New Madrid Seismic zone, *Bull. Seismo. Soc. Am.*, **80**, p. 615-632.

Abhijit Basu

Sedimentary Petrology, Lunar Petrology and Geology

Professor, Geological Sciences; B.Sc. Presidency College (India); M.Sc. Calcutta; Ph.D. Indiana, 1975.

Basu attempts to better understand the petrological evolution of the crust, especially the surficial material, of the earth and the moon. Properties of such material are functions of provenance, weathering, transport, deposition, and diagenesis. Therefore, understanding the processes that affect any of these variables is a prerequisite. A student may expect to conduct quantitative provenance studies of sands and sandstones of the earth and the regolith of the moon if s/he works with Basu. The ultimate goal is to reconstruct the geology of the part of a planetary crust that has been eroded to give rise to a body of sediment. Principally these studies have centered around the determination of petrologic, structural, and chemical properties of detrital minerals and rock-fragments; and, relating these properties through mass-balance to infer the proportions of source rock contribution to bodies of sands, sandstones, and the lunar regolith through time. A second major area of research is focused on the evolution of the lunar regolith. Processes that are responsible for the production, evolution, and growth of agglutinates are investigated by studying the properties and distribution of agglutinates in lunar soils of various compositions, maturities, and geologic contexts.

Basu is also interested in lunar basalt petrogenesis. His primary goals are understanding the source regions and magmatic processes responsible for producing KREEP basalts. Current studies include the origin of yellow interstitial glass in KREEP basalts from several sites of the moon (Basu et al., 1992) and the fractionation, if any, of lunar impact melts at different scales. Apart from using mineral-chemistry to interpret provenance, Basu is also investigating the effects of early diagenesis in destroying provenance information in sandstones. One current research project is a quantitative comparison of the petrologic, mineralogic, chemical and isotopic properties of early cemented concretions in Eocene volcaniclastic sandstones of Scow Bay, Washington with those of their host sandstones.

Basu is currently collaborating with E. Molinaroli (University of Venice, Italy), R. Cullers (Kansas State University), L. Melim (University of Florida), D. S. McKay (NASA), R. Valloni (University of Porma, Italy), G.G. Zuffa (University of Bologna, Italy), J. Arribas (University of Madrid, Spain), and C. Bangs Rooney (TEXACO, U.S.A., former graduate student). Basu's research is supported by NASA and NSF.

Representative Publications

Brophy, J.G. and A. Basu, (1990). Europium anomalies in mare basalts as a consequence of mafic cumulate fractionation from an initial lunar magma. *Proc. Lunar Planet. Sci. Conf. 20th*, p. 25-30.

Basu, A., (1990). Recycled grains in lunar soils as an additional, necessary, regolith evolution parameter. *Proc. Lunar Sci. Conf. 20th, Lunar and Planetary Institute*, Houston, p. 231-238.

Basu, A. and E. Molinaroli, (1991). Reliability and application of detrital opaque Fe-Ti oxide minerals in provenance determination. *Spec. Pub., Geol. Soc. Lond.*, **57**, p. 55-65.

Basu, A., E. Molinaroli, M. Blom, S.J. Wentworth, and D.S. McKay, (1991). Petrology and provenance of Apollo 15 Station 6 core 15009 and its bearing on site geology. *Proc. Lunar Planet. Sci. Conf. 21st, Lunar and Planetary Institute*, Houston, p. 221- 228.

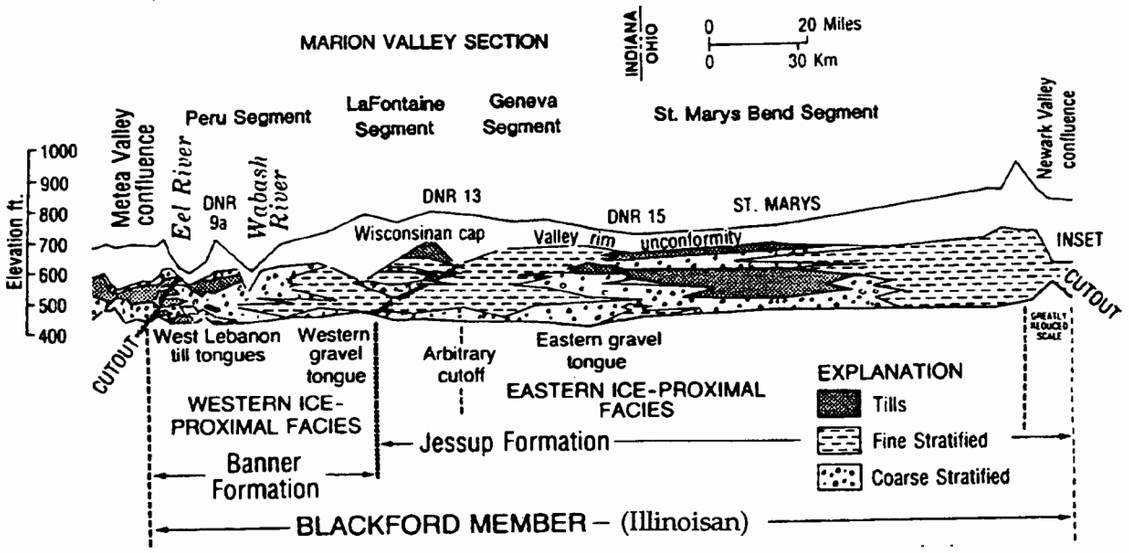
Molinaroli, E., M. Blom, and A. Basu, (1991). Methods of provenance determination tested with discriminant function analysis. *J. Sedim. Petrology* , **61**, p. 900-908.

Basu, A., B.B. Holmberg and E. Molinaroli, (1992). Origin of yellow glasses associated with Apollo 15 KREEP basalt fragments. *Proc. Lunar Planet. Sci. Conf. 22nd, Lunar and Planetary Institute, Houston*, p. 365-372.

Ned K. Bleuer — Quaternary Geology and Geomorphology

Associate Scientist, Indiana Geological Survey and Assistant Professor, part-time, Geological Sciences; B.S. Wisconsin, M.S. Illinois; Ph.D. Wisconsin, 1971.

Bleuer studies glacial geology, stratigraphy and has a special interest in geomorphology and stratigraphy of glacial and Quaternary deposits in Indiana. To better define and characterize geomorphology, Bleuer uses airphoto and satellite imagery. Field-based stratigraphic studies are aided by Indiana Geological Survey supported drilling and logging in more complicated areas. He then applies this stratigraphic information to hydrologic and environmental problems. The disruption of soil and fluvial sedimentary structures representing liquification features are also applied to seismicity, especially in southern Indiana.



Generalized longitudinal cross section of the Marion valley plug, the Blackford Member, showing relations and nomenclature of the independent, dam-separated, lake deposits of Indiana and Ohio. Till deposits representing ice dams related to each lake deposit mark the positions of disconformable cutout and inset relations are present within the Blackford Member, and especially along the Valley rim unconformity between these Illinoisan and overlying Wisconsinian deposits.

Representative Publications

Bleuer, N.K. (1991). The Lafayette Bedrock Valley System of Indiana; Concept, Form and Fill Stratigraphy. *Geology and Hydrogeology of the Teays-Mahomet Bedrock Valley System: Geological Society of America Special Paper 258*, Melhorn, W. N. and J. P. Kempton, eds. p. 51-77.

Bleuer, N.K., W.N. Melhorn, W.J. Steen and T.M. Bruns (1991). Aquifer systems of the buried Marin-Mahomet trunk valley (Lafayette Bedrock Valley System) of Indiana. *Geology and Hydrogeology of the Teays-Mahomet Bedrock Valley System: Geological Society of America Special Paper 258*, Melhorn, W.N. and J.P. Kempton, eds. p. 79-89.

Obermeier, S.F., N.K. Bleuer and others (1991). Evidence of strong earthquake shaking in the lower Wabash Valley from prehistoric liquefaction features. *Science*, **251**, p. 1061-1063.

Bleuer, N.K. (in press). Nature of Glacial and Other Unconsolidated Sedimentary Sequence Through Downhole Gamma-Ray Logging. *Indiana Geological Survey Special Paper 49.*

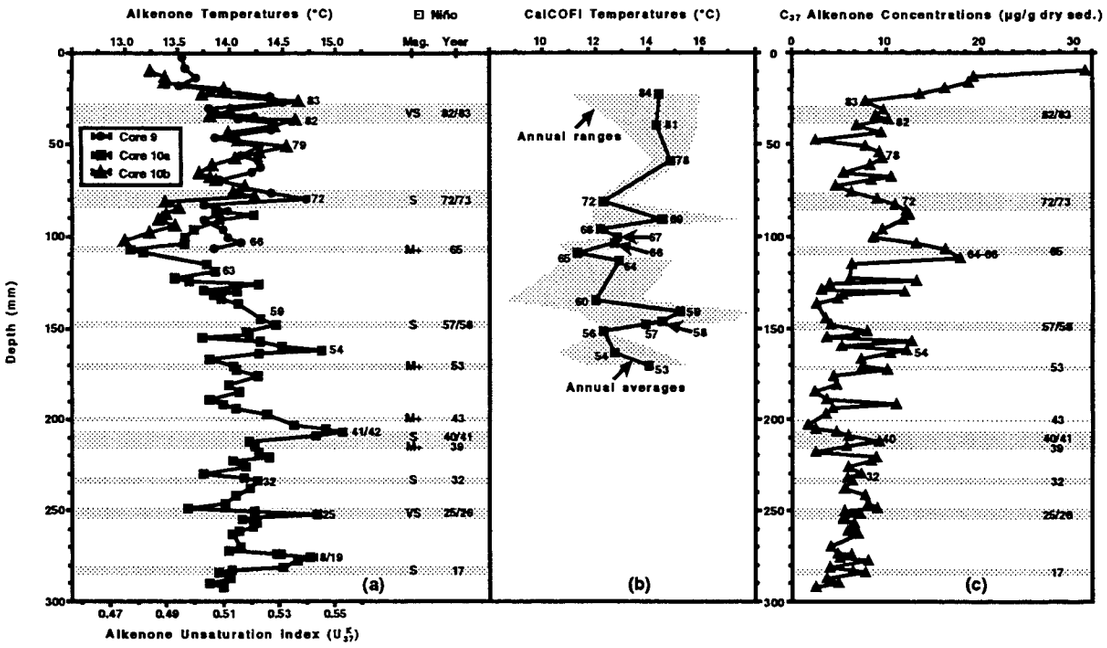
Munson, P.J., Munson, C.A., Bleuer, N.K., and Labitzke, M.D. (in press). Distribution and dating of prehistoric earthquake liquefaction in the Wabash Valley of the central U.S. *Seismological Research Letters.*

Simon Brassell — Biological, Organic and Petroleum Geochemistry; Basin Analysis

Professor, Geological Sciences and Professor, part-time, Environmental Sciences; B.Sc., Ph.D. Bristol, 1980.

Brassell's research interests encompass the biological origins and geological fate of organic matter, including studies of molecules as signals of climatic and environmental change in the sedimentary record and aspects of petroleum geochemistry. Three themes illustrate the approach and scope of these research areas. They all depend on the application of several analytical methods, especially gas chromatography-mass spectrometry which provides the selectivity and sensitivity to identify and quantify individual components within the complex mixtures that typify environmental samples.

Molecular Signals of Global Climate Change. The distributions of organic components in sediments include marker compounds that are diagnostic of their biological source and of their fate since deposition. Thus, sediments preserve a record of biogeochemical processes which can be unraveled and applied in the interpretation of present-day environments and climatic fluctuations. Remarkably, molecular signals not only reflect the response of organisms to changing environments, but can also record oceanic surface water temperatures. Recent results show that molecules in sediments from offshore California document variations in water temperatures associated with El Niño events, the oceanic component of a dynamically coupled ocean/atmosphere climatic change which varies in frequency, time-scale and strength, and is chiefly manifest as a warming of Pacific Basin surface waters (Kennedy and Brassell, 1992).



A) Profile of twentieth-century variability in alkenone temperatures for three cores of laminated sediments from the Santa Barbara basin. Magnitudes and dates of equatorial El Niño events are shown with their intensities assessed as 'very strong' (VS), 'strong' (S) and 'moderate to strong' (M+) and with their rough duration represented by the shaded intervals. B) Annual averages of all CalCOFI temperatures measured at 20m water depth plotted against age equivalent sediment depths. C) Downhole profile of C_{37} alkenone concentrations showing major fluctuations in their abundance which do not correspond with El Niño events (shaded as in A).

Geological Records of Ancient Climates. Research addressing contemporary environmental changes prompts questions related to the causes and antiquity of such phenomena; in particular: (i) are the fluctuations observed today a function of the normal systematic variability/ cyclicity in the Earth's climate, or to what extent can they be attributed to man's activities? (ii) do present-day climate changes represent an acceleration compared to events in the geological past? Resolution of these matters requires a continuing examination and evaluation of both recent and ancient climatic perturbations. Within this area Brassell's research activities include studies of molecular signals in sediments which are attributable to climatic variations associated with ice ages and their relationship to periodicities in the Earth's orbit. Earlier episodes of Earth history are also important, e.g. as the Cretaceous period when global climate was equable and when massive amounts of organic carbon were sequestered in sediments during so-called "Oceanic Anoxic Events." Investigation of ancient environments adds a geological perspective to the operation, variability and fragility of the present Earth system and provides a vital baseline against which man's influence on modern climatic fluctuations can be assessed.

Petroleum Geochemistry. A third theme in Brassell's research focuses on the processes of oil formation and the chemical characterization of petroleums. These entail studies of source rocks and petroleums and include the applications of molecular characteristics to evaluate both the origins and thermal migration history of petroleums. Investigations of the compositions of petroleums helps assess their origins and their biodegradation by microbes in reservoirs. The pervasiveness of hydrocarbons and their combustion products in modern environments stems from the burgeoning growth in their industrial usage over the past century and represents a significant anthropogenic perturbation of the global carbon cycle. Such topics also bear directly on the environmental impact of petroleum usage and on its amelioration, such as bioremediation of petroleum spillages.

Representative Publications

Brassell, S.C., I.T. Marlowe, G. Eglinton, U. Plaumann and M. Sarnthein (1986). Molecular stratigraphy: a new tool for climatic assessment. *Nature*, **320**, p. 129.

Brassell, S.C. and G. Eglinton (1986). Molecular geochemical indicators in sediments, *in* Organic Marine Geochemistry, American Chemical Society Symposium Ser. **305**, p. 10.

Farrimond, P., G. Eglinton, S.C. Brassell and H.C. Jenkyns (1988). The Toarcian black shale event in northern Italy. *Org. Geochem.*, **13**, p. 823.

Farrimond, P., G. Eglinton, S.C. Brassell and H.C. Jenkyns (1990). The Cenomanian/ Turonian anoxic event in Europe: An organic geochemical study. *Mar. Petrol. Geol.*, **7**, p. 75.

Marlowe, I.T., S.C. Brassell, G. Eglinton and J.C. Green (1990). Long-chain alkenones and alkyl alkenoates and the fossil coccolith record of marine sediments. *Chem. Geol.*, **88**, p. 349.

Graham S.A., S.C. Brassell, A.R. Carroll, X. Xiao, G.J. Demaison, C.L. McKnight, Y. Liang, J. Chu and M.S. Hendrix (1990). Characteristics of selected petroleum source rocks, Xinjiang Uygur Autonomous Region, northwest China. *Amer. Assoc. Petrol. Geol. Bull.* **74**, p. 493-512.

Trindade L.A.F., S.C. Brassell and E.V. Santos Neto (1992). Petroleum migration history in the Potiguar Basin, Brazil, as reflected by mixed oils. *Amer. Assoc. Petrol. Geol. Bull.*

Carroll, A.R., S.A. Graham, and S.C. Brassell (1992). Upper Permian lacustrine oil shales of the Junggar Basin, northwest China. *Amer. Assoc. Petrol. Geol. Bull.*

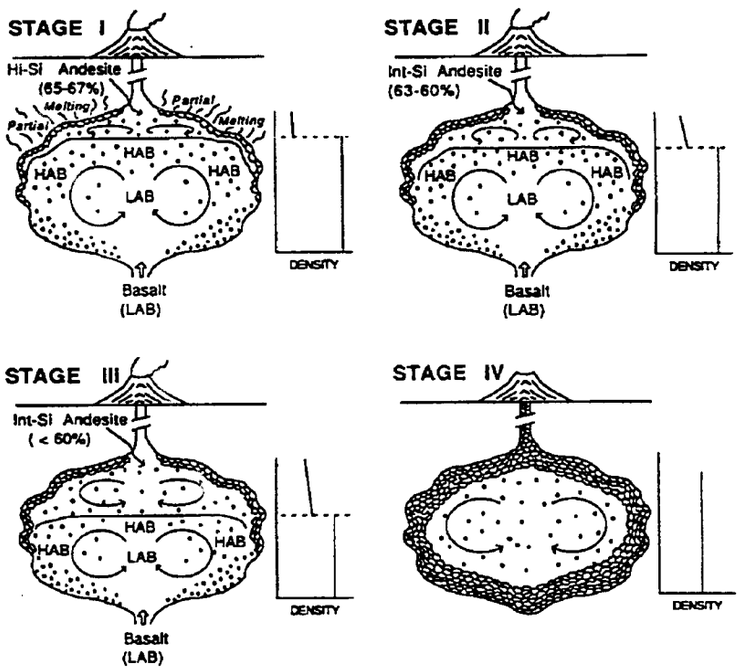
Kennedy J.A. and S.C. Brassell (1992). Molecular records of twentieth century El Niño events in laminated sediments from the Santa Barbara Basin. *Nature*, **357**, p. 62-64.

James G. Brophy

Igneous Petrology, High-Temperature Geochemistry, Tectonophysics

Associate Professor, Geological Sciences; B.A. Amherst, M.Sc. Colorado School of Mines; Ph.D. Johns Hopkins, 1985.

Brophy's primary research interests center around the chemical and physical processes involved in magmatic differentiation. His research program makes use of a wide range of techniques including geologic field mapping, petrologic and geochemical laboratory analysis (major and minor element geochemistry, electron micro-probe analysis) and fluid dynamic modeling. Over the years, Brophy and students have conducted research in several areas including the Aleutian Islands, the Cascade Mountains of western Oregon, the Basin and Range province of the western U.S. and, most recently, the East Pacific Rise. These studies, largely funded by the National Science Foundation, have considered such diverse topics as the role of subducted oceanic crust in the high-pressure formation of island arc basalt, the relative roles of lower crustal melting, magma mixing, and fractional crystallization in the formation of andesitic magma, the growth and temporal evolution of low-pressure andesitic magma chambers (figures above) and, most recently, the physical mechanisms of low-pressure fractional crystallization.



Suggested evolutionary stages in the development of Aleutian calc-alkaline magma chambers. (Brophy 1990)

Representative Publications

Brophy, J.G. (1987). The Cold Bay Volcanic Center, Aleutian Volcanic Arc. II: Implications for fractionation and mixing mechanisms in calc-alkaline andesite genesis. *Contrib. Mineral. Petrol.*, **97**, p. 378-388.

Brophy, J.G. (1989). Basalt convection and plagioclase retention: A model for the generation of Hi-Alumina arc basalts. *J. Geol.*, **97**, p. 319-329.

Brophy, J.G. (1990). Andesites from northeastern Kanaga Island, Aleutians: Implications for calc-alkaline fractionation mechanisms and magma chamber development. *Contrib. Mineral. Petrol.*, **104**, p. 568-581.

Brophy, J.G. and A. Basu (1990). Europium anomalies in mare basalts as a consequence of mafic cumulate fractionation from an initial lunar magma. *Proc. Lunar Planet. Sci. Conf. 20th*, p. 25-30.

Brophy, J.G. (1991). Composition gaps, critical crystallinity, and fractional crystallization in orogenic (calc-alkaline) magmatic systems. *Contrib. Mineral. Petrol.*, **109**, p. 173-182.

Singer, B.S., J.R. O'Neil, and J.G. Brophy (1992). Oxygen isotope constraints on the petrogenesis of Aleutian arc magmas. *Geology* **20**, p. 367-370.

Donald D. Carr

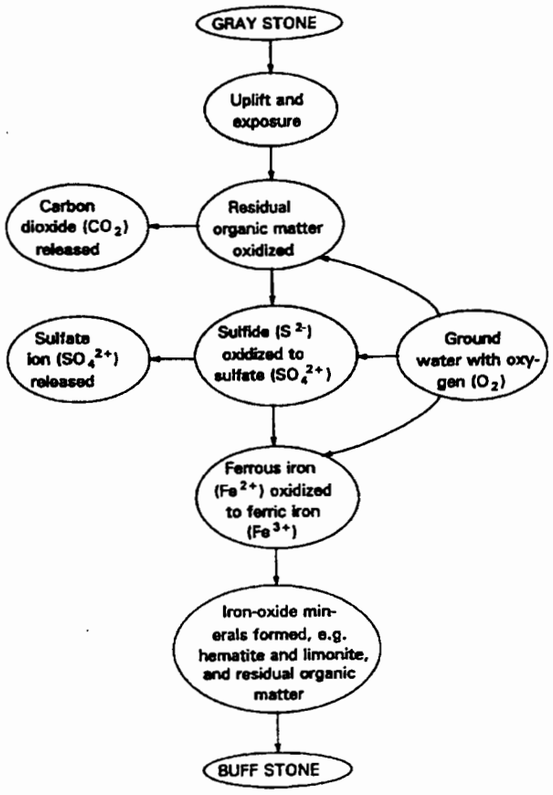
Industrial Minerals, Coal Geology

Senior Scientist, Indiana Geological Survey and Professor, part-time, Geological Sciences; B.S., M.S. Kansas State; Ph.D. Indiana, 1969.

Donald Carr is interested in the relationships of the physical and chemical properties of limestones and dolomites to their use and durability as building stones. Indiana Limestone, the commercial product produced from the Salem Limestone in south-central Indiana, has been the nation's leading dimension limestone for more than a century, and so the building constructed with this stone afford a veritable laboratory for observing the changes in stone through time in both urban and non-urban environments.

Fluctuations in production of Indiana Limestone are reflected in the changes in economic conditions and architectural styles. The solid bearing-wall construction of earlier years required little knowledge of physical properties, but the "International Style" of architecture of later years, featuring thinner walls and more intricate connections, places new emphasis on physical properties.

Donald Carr retains a strong interest in the industrial minerals native to Indiana, such as sand and gravel, gypsum, and the materials used for crushed stone products, but he also maintains an interest in the entire field of industrial minerals. He is completing a project as senior editor for the sixth edition of *Industrial Minerals and Rocks*, to be published by the Society for Mining, Metallurgy, and Exploration in 1993.



Principal chemical reactions involved in the natural conversion of Indiana Limestone from gray to buff color. Figure from the Proceedings of the 28th Forum of the Geology of Industrial Minerals, in press, published by the West Virginia Geological Survey.

Representative Publications

Carr, D.D., and N. Herz (1989). An introduction to mineral resources *in* Concise Encyclopedia of Mineral Resources, Oxford, Pergamon Press, p. xvii-xxiii.

Carr, D.D. (1989). Limestone and Dolomite in *Surface Mining*, Littleton, Col., Society of Mining Engineers, p. 425-449.

Carr, D.D. (1989). Geometry and Depositional Environments of Oolite Bodies in the Ste. Genevieve Limestone (Mississippian) in Southern Indiana: *Indiana Geological Survey Guidebook for the 1989 AAPG Eastern Section Meeting, September 10-13, 1989*, p. 1-14.

Carr, D.D. (1990). Economic Geology of Salem Limestone in the Indiana Building-Stone District *in* Architectural Elements and Paleoecology of Carbonate Shoal and Intershoal Deposits in the Salem Limestone (Mississippian) in South-Central Indiana: *Ind. Geol. Survey Guidebook 14*, p. 53-56.

J. Robert Dodd — Paleoecology, Carbonate Sedimentology and Petrology

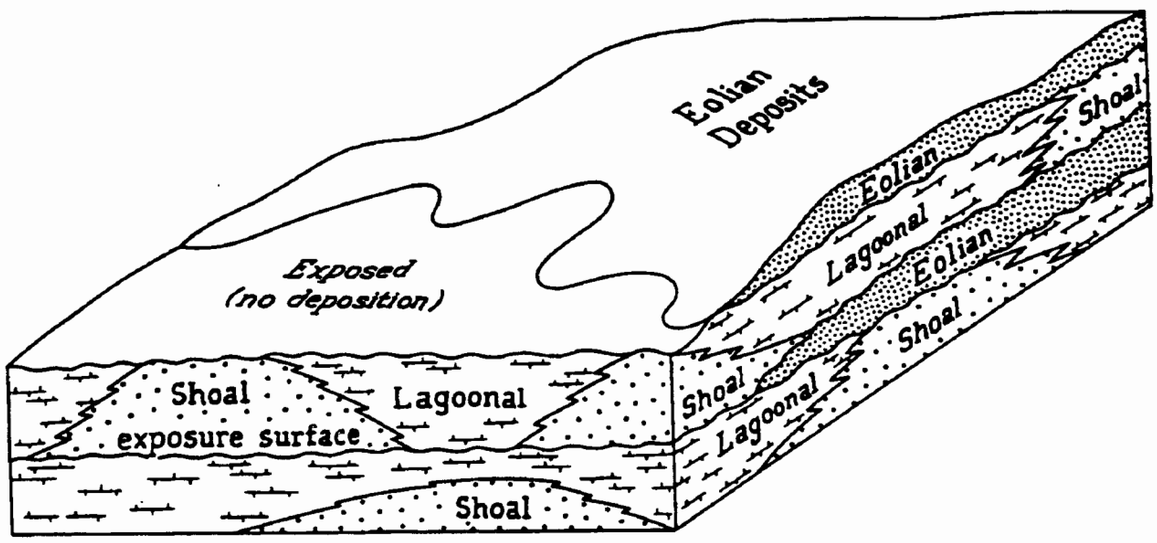
Professor, Geological Sciences; B.A. Indiana; M.A., Ph.D. Caltech, 1961.

For a number of years Dodd has worked with Bob Stanton of Texas A&M University on using fossils and sedimentary rocks to interpret the paleoecology and sedimentologic features of Neogene strata in the Eel River and San Joaquin Basins of California. He is also co-author of a textbook on concepts and applications of paleoecology.

Depositional processes, environments, and diagenesis of the St. Genevieve Limestone. The St. Genevieve contains several intervals of eolian carbonates and several exposure surfaces. Dodd has been investigating the origin of these eolian units, their geographic and stratigraphic distribution, and their relationship to subaereal exposure surfaces. The presence of unconformities within the section allow application of the methods of sequence stratigraphy to study of this unit. He is working on this project with Patty Merkley, a former I.U. student, and Ralph Hunter of the U.S.G.S. Graduate students Charles Zuppann, Clay Harris, and Karl Leonard (now with Exxon) worked on an early part of this project.

Depositional processes producing the Salem Limestone and relation of petrographic features of the Salem to sedimentary structures in the unit. The Salem is well exposed in numerous quarries in the Bloomington area. The recent development of extensive use of a chain saw-like quarrying method has resulted in beautiful exposure of sedimentary structures. These allow a more detailed view of depositional processes than has previously been possible. Dodd is working on this project with Todd Thompson of the Indiana Geological Survey. The work is being supported by the Marathon Oil Company.

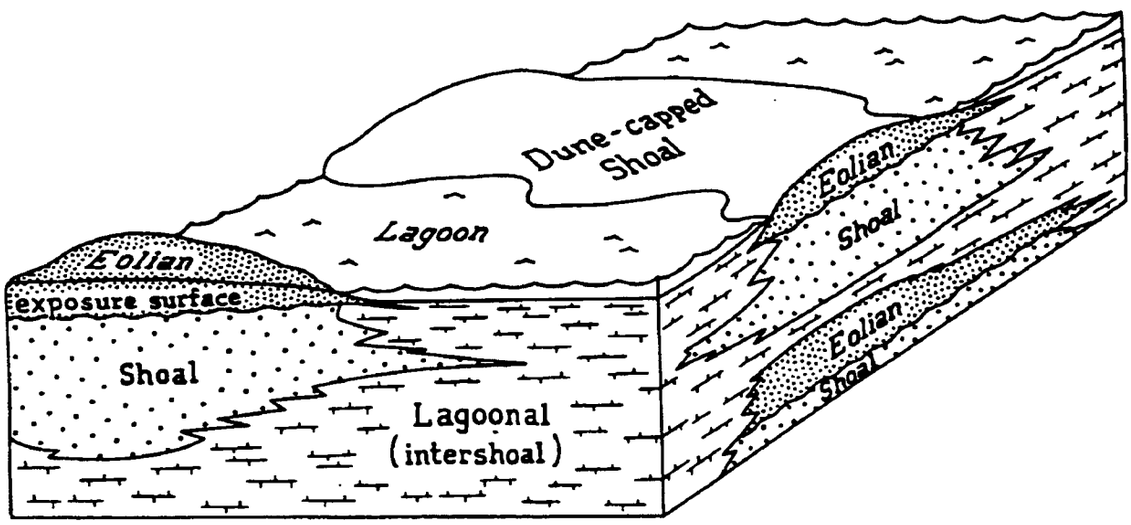
Depositional process producing the ooid shoals of the Ste. Genevieve Limestone. These shoals are important petroleum reservoirs in the subsurface of the Illinois Basin. Many details of their



A model to explain Ste. Genevieve eolianites with sea-level variation.

origin such as the nature of surface on which the form, rate of deposition, nature of the depositing currents, changes during their history, cause of cessation of growth, remain to be learned. A large shoal is well exposed in two quarries near Orleans, Ind. A research seminar under Dodd's direction recently completed a preliminary study of this problem. Graduate students Clay Harris, Karl Leonard, and Charles Zuppann have also worked with him on this project. More work needs to be done to follow up the tentative findings of this project.

Dodd investigates the petrology and the diagenesis of carbonate rocks to understand processes and environmental conditions leading to their deposition. Specifically, he studies optical, luminescence, and SEM petrographic, and, oxygen and carbon isotopic properties of these rocks to attain these goals. A major part of his petrologic research is carried out on the Mississippian rocks of southern Indiana and neighboring states and is supported from industrial grants.



A model to explain Ste. Genevieve eolianites without sea-level variation.

Representative Publications

Dodd, J.R. (1987). Valmeyeran (Middle Mississippian) carbonate rocks of southern Indiana: *Great Lakes Section, SEPM, Guidebook Series*, 127p.

Carbonate Petrology Seminar, Indiana University, 1987, Ramp Creek and Harrodsburg Limestones: A shoaling upward sequence with storm-produced features in southern Indiana, U.S.A.: *Sed. Geol.*, **52**, p. 207-226.

Dodd, J.R. and R.J. Stanton, (1990). Paleoecology, Concepts and Applications (Second Edition): Wiley-Intersciences, New York, 400p.

Brown, M.A., and J.R. Dodd, (1990). Waulsortian-like carbonate mud bodies in Middle Mississippian strata of southern Indiana and northern Kentucky: *Palaios*, **5**, p. 236-243.

Dodd, J.R. and R.J. Stanton, Jr. (1991). Cyclic sedimentation in three Neogene basins in California: *Spl. Pub. Int. Assoc. Sedimentol.* **12**, p. 201-215.

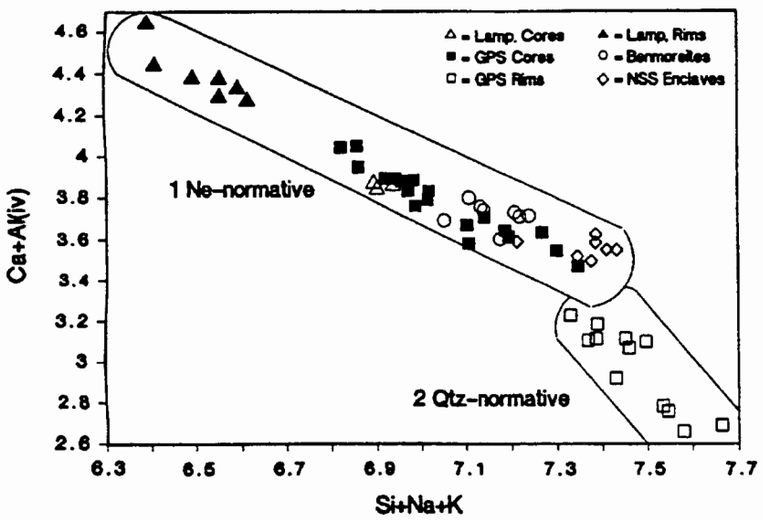
Hattin, D.E. and J.R. Dodd (1992). Mississippian paleosols, Paleokarst and eolian carbonates in Indiana. *Misc. Report No. 3, Ohio Div. Geological Survey*, 35p.

Horowitz, A.S. and J.R. Dodd, eds. (1992). Chesterian sections (Late Mississippian) along Interstate 64 in southern Indiana. *Great Lakes Section SEPM Guidebook, Indiana Univ. Dept. Geol. Sci.*, 204p.

Michael Dorais — Igneous Petrology and High-Temperature Geochemistry

Assistant Scientist, Geological Sciences; B.S. Brigham Young, M.S. Oregon, Ph.D. Georgia, 1987.

Dorais' research focuses on chemical and physical processes of magmatic differentiation through combined field and laboratory investigations of both intrusive and extrusive igneous rocks. A major strategy is to utilize the textural, chemical, and mineralogic characteristics of mafic igneous inclusions as a window into otherwise inaccessible subsurface magmatic processes. In particular, such inclusions provide important insights into the compositional nature of liquid lines of descent in plutonic igneous rocks, and represent a key to understanding the complexity of natural differentiation processes.



The variation in the composition of amphiboles in the Red Hill complex, New Hampshire, showing the strong correlation between amphibole and host magma composition, particularly SiO_2 activity. (Dorais and Floss, 1992.)

An additional area of interest is the application of ion-probe analytical techniques to the determination of trace element abundances in major and accessory igneous minerals. Field-based investigations have included studies in the San Juan Mountains of Colorado, the Sierra Nevada Batholith and the White Mountain Magma Series of New Hampshire. Dorais' research is funded by the National Science Foundation.

Representative Publications

Whitney, J.A., M.J. Dorais, J. Stormer, Jr., S.W. Kline and D.J. Matty (1988). Magmatic conditions and development of chemical zonation in the Carpenter Ridge Tuff, central San Juan volcanic field, Colorado. *Am. J. Sci.* **288-A**, p. 16-44.

Dorais, M.J., J.A. Whitney and M.F. Roden (1990). Origin of mafic enclaves in the Dinkey Creek pluton, central Sierra Nevada batholith, California. *Journal of Petrology*, **31**, p. 853-881.

Dorais, M.J. (1990). Compositional variations in pyroxenes and amphiboles of the Belknap Mountain complex, New Hampshire: Evidence for the origin of silica-saturated alkaline rocks. *American Mineralogist*, **75**, p. 1092-1105.

Dorais, M.J., J.A. Whitney and J.C. Stormer, Jr. (1991). Mineralogical constraints on the petrogenesis of trachytic inclusions, Carpenter Ridge Tuff, central San Juan volcanic field, Colorado. *Contr. Mineral. Petrol.*, **107**, p. 219-230.

Dorais, M.J., and C. Floss (1992). An ion and electron microprobe study of the mineralogy of enclaves and host syenites of the Red Hill complex, New Hampshire, U.S.A. *Journal of Petrology*.

Dorais, M.J. (in press). Pyroxene in enclaves and syenites of the Red Hill complex, New Hampshire: An ion and electron microprobe study. *Contr. Mineral. Petrol.*

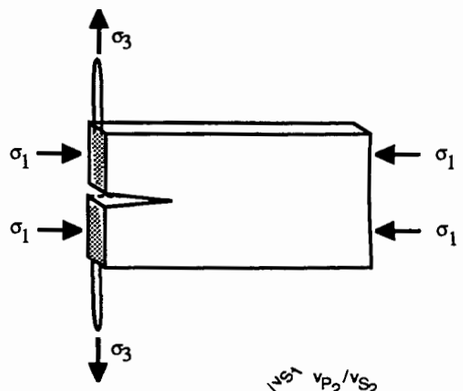
Bruce Douglas

Tectonics and Structural Geology

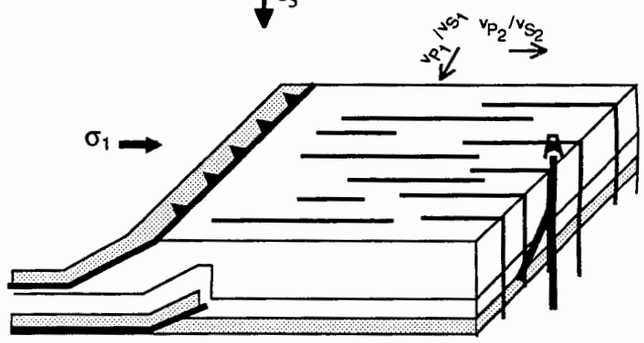
Assistant Scientist, Geological Sciences; A.B. Colgate; M.A., Ph.D. Princeton, 1983.

At the present time Douglas is engaged in several laboratory and field based projects. All of these projects emphasize combining either theoretical or experimental data with field/natural, site-specific data. The underlying theme that permeates most of the research is understanding the deformation mechanisms that control geologic phenomena.

Several laboratory studies (design to right) are in progress documenting the role of subcritical crack propagation during the brittle failure of geologic materials. One study involves the propagation of cracks in various chemical environments. A second study involves the fracture propagation in shales under conditions of hydrocarbon maturation. A third study is directed at computationally modelling fault/fracture propagation with applications for compound earthquakes, regional joint sets, and thrust fault propagations in active fold and thrust belts.



A number of field studies are centered in southwestern Montana. One involves studies of the deformational mechanisms of the metamorphic basement rocks in the Tobacco Root Mountains. A second study involves mapping and balanced cross section work to determine the partioning of displacement transfer between thrust systems for a transect of the Cordilleran Thrust Belt (see figure to right). A regional, tectonic project is also in progress investigating the rheological properties of the South American lithosphere above a 1,000 km portion of the Chile Trench.



Representative Publications

Douglas, B.J. (1986). Deformational history of an outlier of metasedimentary rocks within the Coast Plutonic Complex, British Columbia, Canada. *Can. J. Earth Science*, **23**, p. 813-826.

Hanson, D.R., B.J. Douglas, and H.A. Spetzler (1988). Limits of seismic Q and shear strength in polycrystalline reaction bonds. *EOS Transactions Am. Geophys. Union*, **69**, p. 1451.

Douglas, B.J. (1991). Balanced cross section construction. **In** Suttner, L.J. (ed.) *Manual for geologic field study of northern Rocky Mountains*, Indiana University, p. 474-502.

Hultberg, J.W. and B.J. Douglas (1992). The rheology of the mantle lithosphere beneath southern South America and the influence of a subducting spreading center. *EOS Transactions Am. Geophys. Union*, **73**, p. 591.

McDonald, S.K., B.J. Douglas and J.D. Dunning (1992). Modeling of subcritical crack growth in various pH environments. *EOS Transactions Am. Geophys. Union*, **73**, p. 515.

Swanson, P.L., B.J. Douglas and J.D. Dunning (1992). Resistance to mode-I fracture in brittle polycrystalline materials: A contribution from crack plane friction. *EOS Transactions Am. Geophys. Union*, **65**, p. 1081.

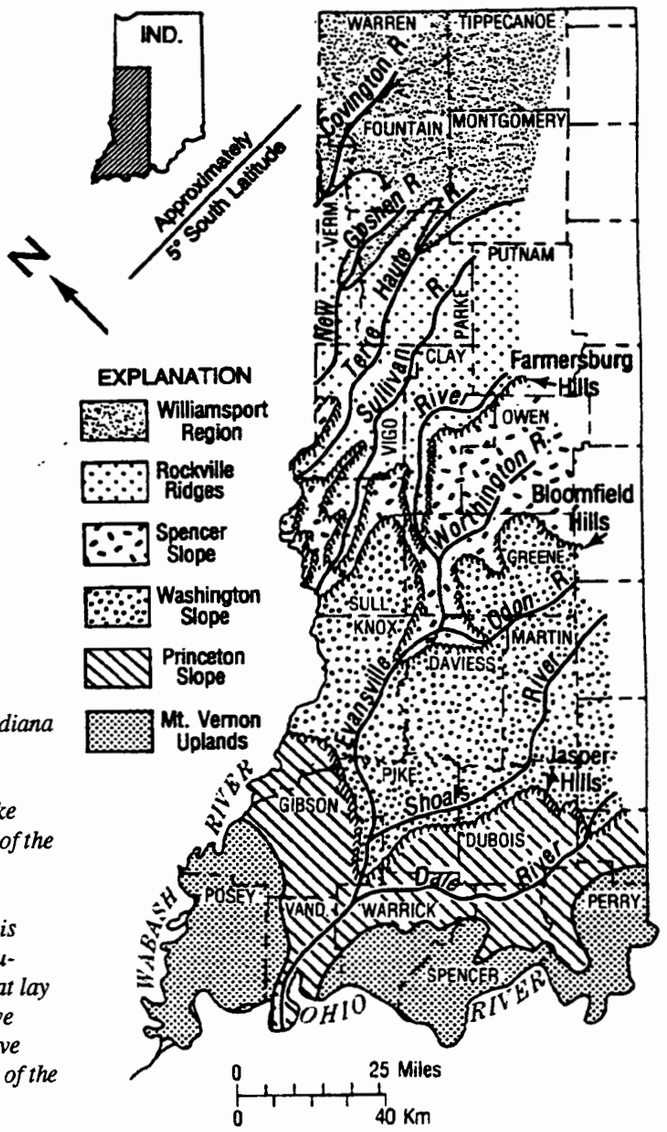
Douglas, B.J., J.D. Dunning and D.L. Goldsby, (submitted). Subcritical crack propagation: The effects of temperature and aging-under-load, *J. Geophys. Res.*

John B. Droste

Stratigraphy, Subsurface Geology

Professor (ret.), Geological Sciences; B.S., M.S., Ph.D. Illinois, 1956.

For several decades Droste's research has treated the subsurface geology of the Paleozoic rocks of Indiana and adjacent states. These studies are focused on lithostratigraphy, on interpretation of environments of deposition, and on local and regional tectonic events as they relate to petroleum geology.



Map showing the physiographic regions in Indiana about 325 million years ago. The long and moderately straight ridges and valleys of the Rockville Ridges, named for Rockville in Parke County, were the area of carbonate outcrops of the Sanders Group and Blue River Group. Long, straight valleys lay between prominent long, straight ridges. The well control in this area is good, and details of topography are well documented. In numerous places the ridgetops that lay 2-3 miles apart were capped by Ste. Genevieve Limestone and stood as much as 200 feet above valley bottom land floored by the middle part of the Salem Limestone.

Representative Publications

Droste, J.B., and S.J. Keller (1989). Development of the Mississippian-Pennsylvanian Unconformity in Indiana: *Indiana Geological Survey Occasional Paper*, **55**, 11p.

Droste, J.B., and A.S. Horowitz (1990). Influences on the position of Chesterian sand belts in Indiana. Proceedings *of the Indiana Academy of Science*, **99**, p. 39-45.

Droste, J.B., and G.L. Carpenter (1990). Subsurface Stratigraphy of the Blue River Group (Mississippian) in Indiana: *Indiana Geological Survey Bulletin*, **62**, 45p.

Droste, J.B. and Kelles, S.J. (1992). Subsurface stratigraphy and distribution of oil fields of the Buffalo Wallow Group (Mississippian) in Indiana. *Indiana Geological Survey Bulletin*, **63**.

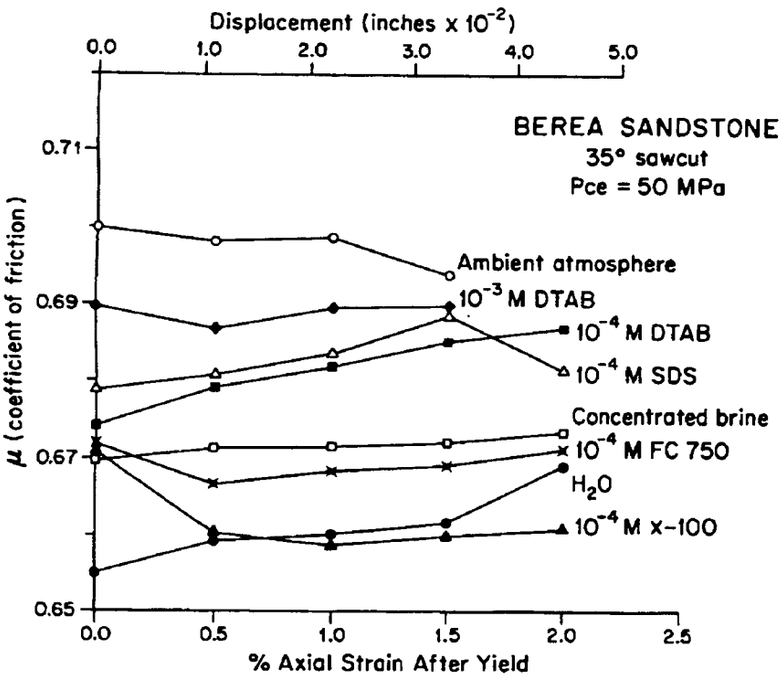
Droste, J.B. (in preparation). Subsurface stratigraphy and distribution of oil fields of the Stephensport Group (Mississippian) in Indiana. *Indiana Geological Survey Bulletin.*

Jeremy Dunning

Structural Geology, Tectonics

Associate Professor, Geological Sciences and Associate Professor, part-time, Environmental Sciences; B.A. Colgate; M.S. Rutgers; Ph.D. North Carolina, 1978.

Dunning's research examines the role of aqueous environments in stress corrosion (chemical weakening) of geologic materials. Typical research projects include stable crack propagation, fault mechanics stick-slip experiments, and hydraulic fracturing. Research applications include the role of chemistry in the stability of highly stressed rocks and fault asperities. The lab facilities available include a rock mechanics laboratory containing two mechanical loading frames of 1000 and 20,000 lb. capacity, a 225-ton hydraulic loading frame equipped with a pressure vessel with 60,000 psi confining and pore pressure capabilities, and complete sample preparation capability.



Variation of the coefficient of friction of Berea sandstone as function of pore-fluid chemistry, for single-cycle tests.

Representative Publications

Dunning, J., R. Kornbrekke, and M. Miller (1990). Surfactant-induced weakening of geologic materials. *Surfactants in Solution*, **10**, p. 297-320.

Douglas, B.J., J. Dunning and D.L. Goldsby (1990). The role of H^+ and OH^- - like species in substantial crack propagation (abstract), *EOS Transactions Am. Geophys. Union*, **71**, p. 640.

Douglas, B.J., J. Dunning and D.L. Goldsby (submitted). Subcritical crack propagation: The effects of temperature and aging-under-load, *J. Geophys. Res.*

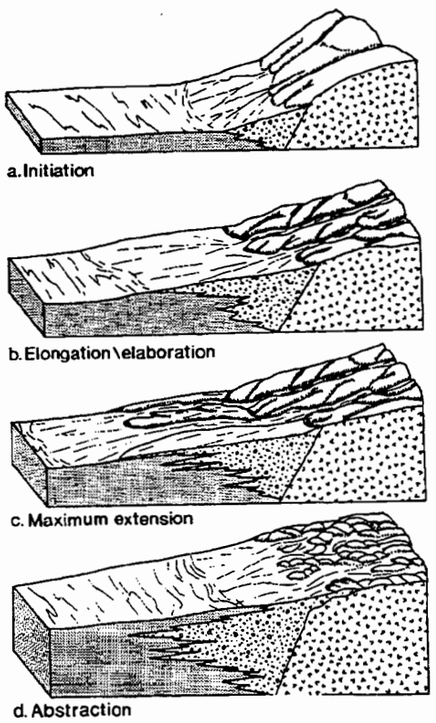
Dunning, J., B. Douglas and S. Macdonald (submitted). The role of pH in subcritical cracking of geologic materials. *J. Geophys. Res.*

Gordon S. Fraser — Quaternary Geology and Geomorphology, Sedimentology and Stratigraphy

Senior Scientist, Indiana Geological Survey and Associate Professor, part-time, Geological Sciences; B.S., M.S., Ph.D. Illinois, 1974.

Fraser's work is in geomorphology and environmental geology with emphasis on application of facies of Quaternary depositional sequences to environmental problems. Recent research focuses various aspects of proglacial sedimentation, glacial depositional processes in stagnating ice sheets, sedimentological effects of catastrophic flow in river valleys, and Holocene paleoclimatology in the Great Lakes region. Future research includes study of the impact of neotectonism on fluvial systems.

Fraser also studies sedimentology with special emphasis on the analysis of the physical processes involved in the formation of depositional sequences. Recent research focuses on fluvial and coastal sedimentary processes, effect of geomorphological processes on deposition of stratigraphic sequences, and effects of topography on sedimentation during transgressions. Future research will include the analysis of tidal sequences to determine the history of lunar orbital mechanics, and analysis of the effects of drainage basin dynamics in uplifted areas on stratigraphy and sedimentation in adjacent depositional basins.



Block diagrams showing the changes that can occur in an alluvial fan and its source area drainage basin at various stages in their evolution following uplift of the source area at the margins of a foreland basin (from Fraser and DeCelles, in press).

Representative Publications

Fraser, G.S. and N.K. Bleuer (1988). Sedimentological consequences of two floods of extreme magnitude in the late Wisconsinian Wabash Valley. Sedimentological consequences of extreme events. *Geological Society of America Special Paper 229*, Clifton, H.E., ed. p. 111-125.

Fraser, G.S., (1989). Clastic Depositional Sequences: Processes of Evolution and Principles of Interpretation. Prentice Hall Publishing Co., Englewood Cliffs, New Jersey, 449p.

Fraser, G.S., C.E. Larsen and N.C. Hester (1990). Climatically Controlled High Lake Levels in the Lake Michigan and Lake Huron Basins. Quaternary Geology of the Lake Michigan Basin: *Geological Society of America Special Paper 251*, Schneider, A. E. and G. S. Fraser, eds. p. 75-89.

Fraser, G.S., et al. (1991). Sediments and sedimentary structures of a non-tidal, barred coast, southern short of Lake Michigan. *Journal of Coastal Research*, 7, p. 1113-1124.

Fraser, G.S. (in press). Sedimentology and history of alluviation of the Late Wisconsinan Wabash River. *Indiana Geological Survey Special Report.*

Fraser, G.S. (in press). Sedimentation in an interlobate outwash stream: Impact of multiple lateral sediment sources on patterns of alluviation. *Sedimentary Geology.*

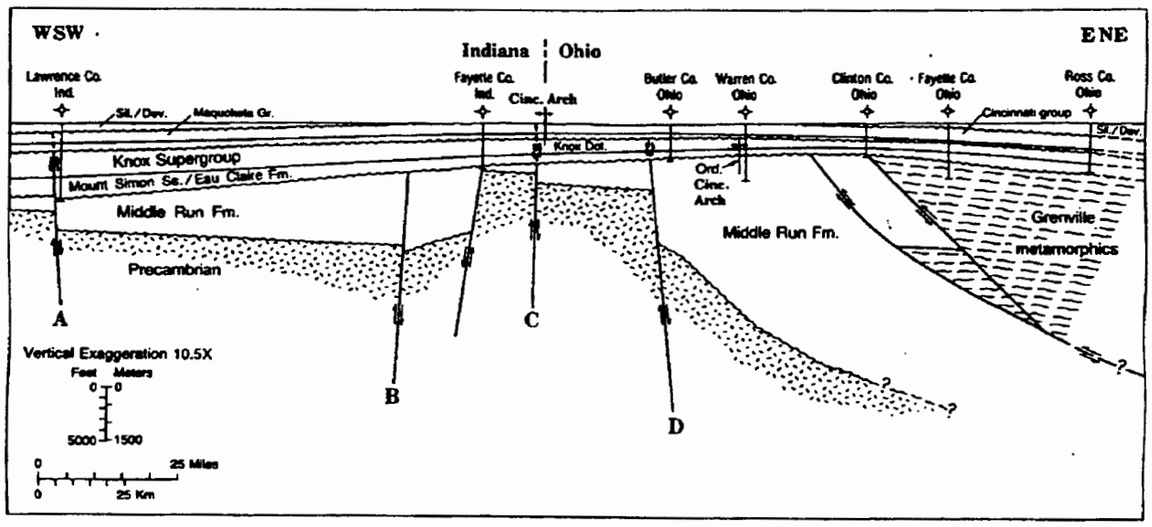
Fraser, G.S., and P.G. de Celles (in press). Geomorphic controls on sediment accumulation at margins of foreland basins. *Basin Research.*

Lloyd Furer

Basin Analysis, Tectonics

Associate Scientist, Indiana Geological Survey; B.S. Ohio University; M.A. Wyoming; Ph.D. Wisconsin, 1966.

Furer is involved jointly with Lee Suttner in study of Cretaceous fluvial systems in the Rocky Mountain foreland basin and is primarily responsible for coordinating all subsurface aspects of the study. He has over 25 years of experience in subsurface stratigraphic studies of a variety of continental-margin basins in California and Alaska and interior basins of the western U.S. and Canada during his employment in the petroleum industry. Since joining the Indiana Geological Survey in 1988, he has also developed and continues to refine models linking recurrent movement of high-angle faults in basement rocks both to the location of Silurian reefs and Pennsylvanian coastal-plain rivers located along the margins of the Illinois Basin. Furer is involved in cooperative regional stratigraphic and structural evaluations of the Illinois Basin with the neighboring State Geological Surveys in order to develop a better understanding of the factors that influence sedimentation in an intracratonic basin. Funding for this work is provided by industry and government sources.



Cross section showing basement structure and the east continental rift basin in southeastern Indiana and southwestern Ohio. (from Furer, in review)

Representative Publications

Furer, L.C. (1989). Tectonic implications of regional correlations and formatting of the Pennsylvanian Mansfield Formation and equivalents in the Illinois Basin. *Illinois Basin Studies*, **1 (28)**, Illinois Basin Consortium.

Furer, L.C. (1989). Tectonic factors controlling initiation and distribution of Silurian Reefs in Illinois Basin, Southwestern Indiana. *Am. Assoc. Pet. Geol. Bull.*, **73**, p. 1031.

Furer, L.C. (1989). Regional correlation and zonation of the lower Pennsylvanian Mansfield Formation of southwestern Indiana. *Am. Assoc. Pet. Geol. Bull.*, **73**, p. 1031.

Furer, L.C., M. May, E. Kvale, and L.J. Suttner (1991). Stratigraphic positioning of the Lower Cretaceous Conglomerates, Wind River Basin, Wyoming and implications for possible hydrocarbon traps. *Amer. Assoc. Pet. Geol. Bull.* **75**, p. 577.

Furer, L.C. (in review). Basement tectonics in the southeastern Illinois Basin and their effect on Paleozoic sedimentation. *Am. Assoc. Pet. Geol. Bull.*

Hendrik Haitjema — Hydrogeology and Groundwater Modelling

Associate Professor, Environmental Sciences and Associate Professor, part-time, Geological Sciences; Ir. Delft University of Technology (Netherlands); Ph.D. Minnesota, 1982.

The research group focuses on the development and application of groundwater flow models, which use a rather new modeling technique: the analytic element method.

Conjunctive Surface/Groundwater Modeling. Regional groundwater movement is composed of infiltrating rainwater which eventually finds its way to surface waters. Traditionally, when modeling groundwater, surface water bodies (streams, lakes, etc.) are merely seen as "boundary conditions" on the groundwater elevation. It is now possible to predict the groundwater inflow rates into the streams, in order to compare it to observed "base flows" in the streams. By integrating this stream flow analysis in the models Haitjema's group is developing a more coupled surface water-groundwater modeling technique.

Three-Dimensional Flow Modeling. Most saturated flow models, particularly when applied on a regional scale, deal with horizontal flow only. When modeling groundwater flow on a local scale, however, a complete three-dimensional solution may be needed. Haitjema is developing three-dimensional solutions with several features. For example, he is including partially penetrating wells in a horizontal flow model. The resulting model is very efficient, modeling three-dimensional flow locally (near the well), while treating the regional flow as horizontal.

Groundwater Response to Global Climate Change. Haitjema is currently studying the range of effects climate change may have on regional groundwater flow. The project, funded by the U.S. Department of Energy's National Institute for Global Environmental Change (NIGEC), is designed to provide information about the sensitivity of the groundwater resource to geographically large-scale changes in recharge. The anticipated changes in recharge and the modeling experiments are on an unprecedented scale, including the entire northern half of the state of Indiana, as well as parts of Illinois, Michigan and Ohio. The objectives include an assessment of groundwater levels, and of groundwater availability both regionally and locally.

Representative Publications

Haitjema, H.M. and S.R. Kraemer (1988). A new analytic function for modeling partially penetrating wells. *Water Resources Research*, **24**, p. 683-690.

Haitjema, H.M., A.M. Ebrahem, and S. Mitchell-Bruker (1989). Very large scale regional aquifer modeling including local detail, presented at the International Conference on Solving Groundwater Problems with Models, Indianapolis, Ind.

Kraemer, S.R. and H.M. Haitjema (1989). A modeling approach to regional fracture flow systems, International Conference on Solving Groundwater Problems with Models, Indianapolis, Ind.

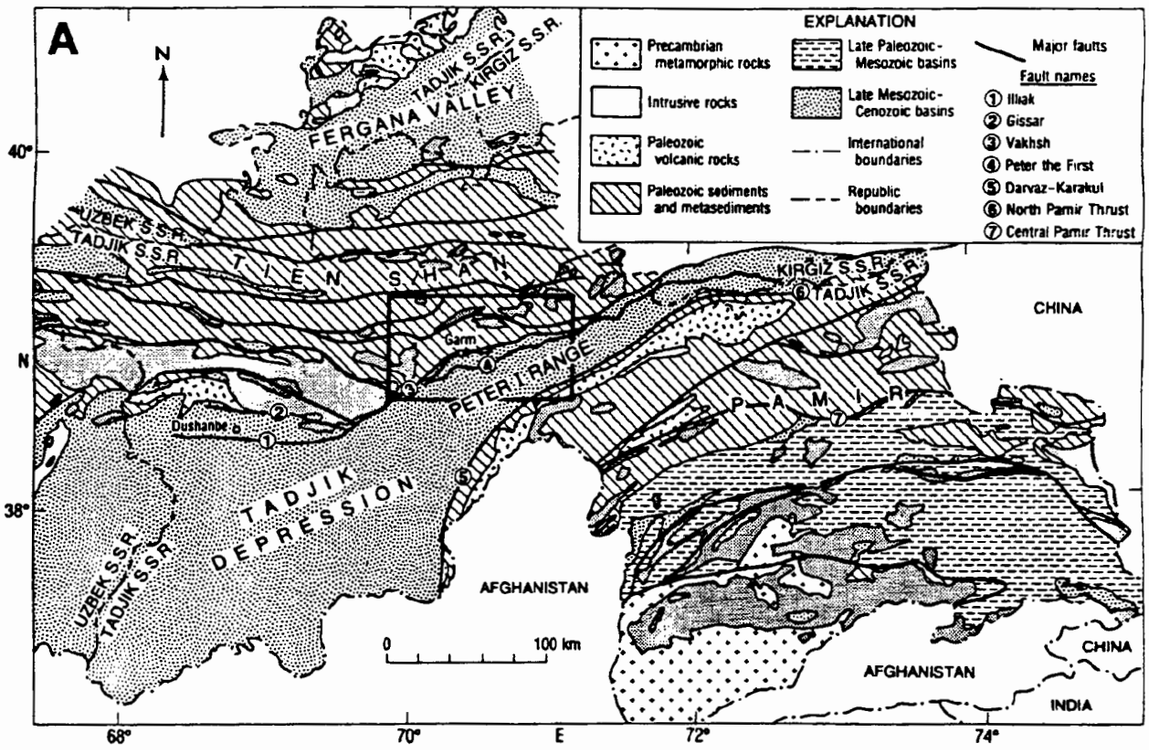
Haitjema, H.M. (1991). An analytic element model for transient axi-symmetric interface flow. *Journal of Hydrology*, **129**, p. 215-245.

Michael W. Hamburger

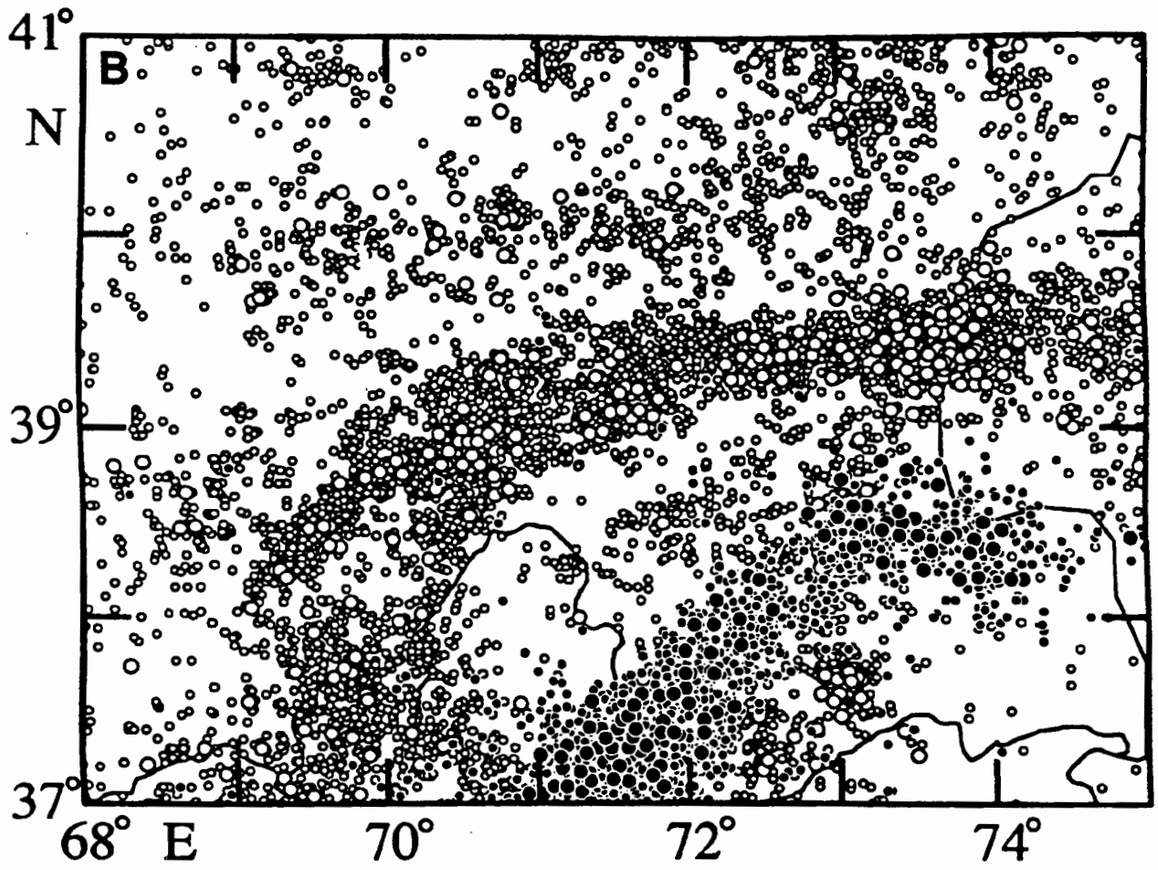
Geophysics, Seismology, Tectonics

Associate Professor, Geological Sciences; B.A. Wesleyan; M.Sc., Ph.D. Cornell, 1986.

Michael Hamburger's major research interests are in seismotectonics, earthquake prediction, and application of satellite geodetic measurements to geodynamic problems. He currently has active research programs in the subduction zone environments of the Southwest Pacific (Fiji-Tonga region) and the Philippines, as well as zones of continental collision in the Pamir-Tien Shan mountain region of Central Asia and the Caucasus mountains of southwestern Asia. Several major field research projects are based in the former USSR. They include: (1) analysis of earthquake distribution, velocity structure, and focal mechanisms in the Pamir-Tien Shan region (Tadjikistan); (2) study of deep earthquakes and mantle velocity structure associated with the Pamir-Hindu Kush deep seismic zone; (3) a project to analyze structural geology, stratigraphy, and active deformation in the Pamir-Tien Shan region (in collaboration with Professor Terry Pavlis of the University of New Orleans); (4) establishment of a new, state-of-the-art digital, broadband seismic network, designed for earthquake prediction and nuclear test monitoring studies in Kyrgyzstan; and (5) two new projects to apply new satellite geodetic techniques (the *Global Positioning System*) for geodynamic measurements in the Caucasus Mountains (Soviet Georgia and Armenia) and in Central Asia (in collaboration with MIT's Robert Reilinger, Brad Hager and Peter Molnar).



Regional geology and seismicity of the Pamir-Tien Shan area, Tadjikistan. This shows geologic structure of the region. The Tadjik Depression sedimentary basin is intensely deformed by convergence between the Pamir and Tien Shan ranges.



This frame (approximately same area as tectonic map, previous page) shows earthquake locations, from the Soviet Central Asia regional seismic network, 1964-1980. Shallow earthquakes (depth ≤70 km) are shown by open circles; deep earthquakes (depth ≥70 km) by filled circles. Small symbols represent events with magnitudes ≤4.0; large symbols, M>4.0.

Representative Publications

Hamburger, M.W. and J.A. Rupp (1988). The June, 1987 southeastern Illinois earthquake: Possible tectonism associated with the LaSalle anticlinal belt. *Seismol. Res. Lett.*, **59**, p. 151-157.

Hamburger, M.W. and B.L. Isacks (1988). Diffuse back-arc deformation in the Southwest Pacific. *Nature*, **332**, p. 599-604.

Pavlis, G.L., M.W. Hamburger, and I.L. Nersesov (1989). Anomalies in the magnitude-frequency relation of earthquakes in the Garm region, Soviet Central Asia. *Bull. Seism. Soc. Amer.*, **79**, p. 1913-1926.

Eneva, M.G. and M.W. Hamburger (1989). Spatial and temporal patterns of earthquake distribution in Soviet Central Asia: Application of pair analysis statistics. *Bull. Seis. Soc. Am.* **79**, p. 1439-1456.

Hamburger, M.W., I.B. Everingham, B.L. Isacks, and M. Barazangi (1990). Seismicity and crustal structure of the Fiji Platform, Southwest Pacific. *J. Geophys. Res.*, **95**, p. 2553-2573.

Pavlis, G.L. and M.W. Hamburger (1991). Aftershock sequences of intermediate-depth earthquakes in the Pamir-Hindu Kush Seismic Zone. *J. Geophys. Res.*, **96**, 18, p. 107-117.

Hamburger, M.W., D.E. Sarewitz, T.L. Pavlis, and G.A. Popandopulo (1992). Structural and seismic evidence for intracontinental subduction in the Peter the First Range, Soviet Central Asia. *Geol. Soc. Amer. Bull*, **104**, p. 397- 408.

Hamburger, M.W., W.A. Swanson, and G.A. Popandopulo (in press 1992). Velocity structure and seismicity in the Garm region, Central Asia. *Geophys. J. Int.*

Colin Harvey — **Economic Geology, Clays and Industrial Minerals**

Research Fellow; Geological Sciences; B.Sc., M.Sc. (Honors) University of Auckland, New Zealand, Ph.D. Indiana, 1980.

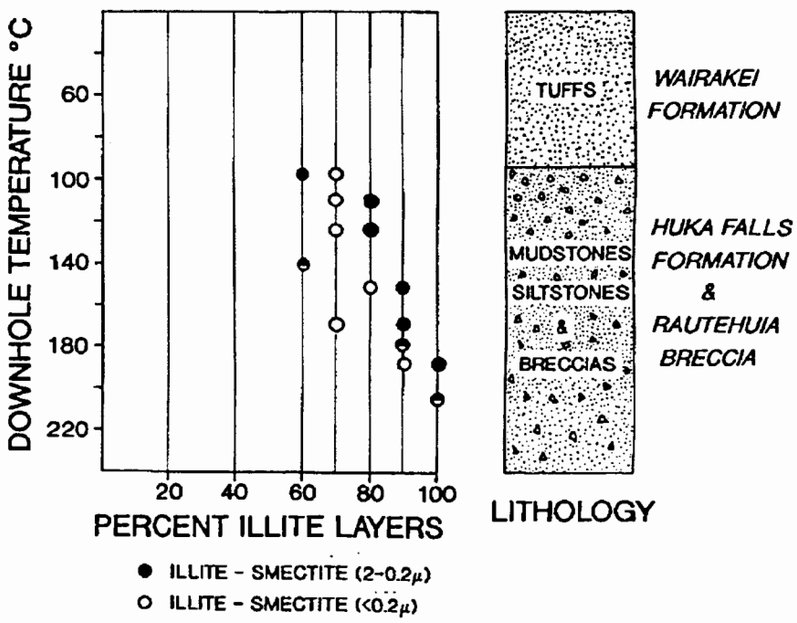
Harvey's research interests extend from the application of clay minerals in industrial processes — to the study of clay minerals as the alteration products in active and fossil hydrothermal systems and — more recently on the use of mixed-layer clays as mineral geothermometers in hydrothermal systems and sedimentary basins.

Current projects include:

(a) Collaborative studies with the Geothermal Institute in New Zealand into the alteration mineral assemblages and alteration processes in the Wairakei hydrothermal system, with specific attention to the use of mixed-layer clays as geothermometers.

(b) Mineralogical studies of weathering and/or low temperature hydrothermal alteration of granodiorites in British Columbia, Canada.

(c) Resource evaluations of weathering and/or low temperature hydrothermal kaolins in the Republic of Indonesia.



The relationship between mixed-layer clay structures and downhole measured temperatures in the Wairakei Hydrothermal system in New Zealand (from Harvey and Browne, 1991).

Representative publications

Merino, E., C.C. Harvey and H.H. Murray (1989). Aqueous-chemical control on the tetrahedral-aluminum content of quartz, halloysite, illite and other low temperature silicates. *Clays and Clay Minerals*, 37, p. 135-142.

Harvey, C.C. and P.R.L. Browne (1991). Mixed-layer clay geothermometers in the Wairakei Geothermal Field, New Zealand. *Clays and Clay Minerals*, 39, p. 614-621.

Harvey, C.C. and L. Farris (1991). The Lang Bay Kaolin Resource, British Columbia. *Proc. 27th Forum on the Geology of Industrial Minerals.*

Harvey, C.C. and H.H. Murray (in press). The geology, mineralogy and exploitation of halloysite clays of Northland, New Zealand. *Keller Monograph, Clays and Clay Minerals.*

Donald Hattin

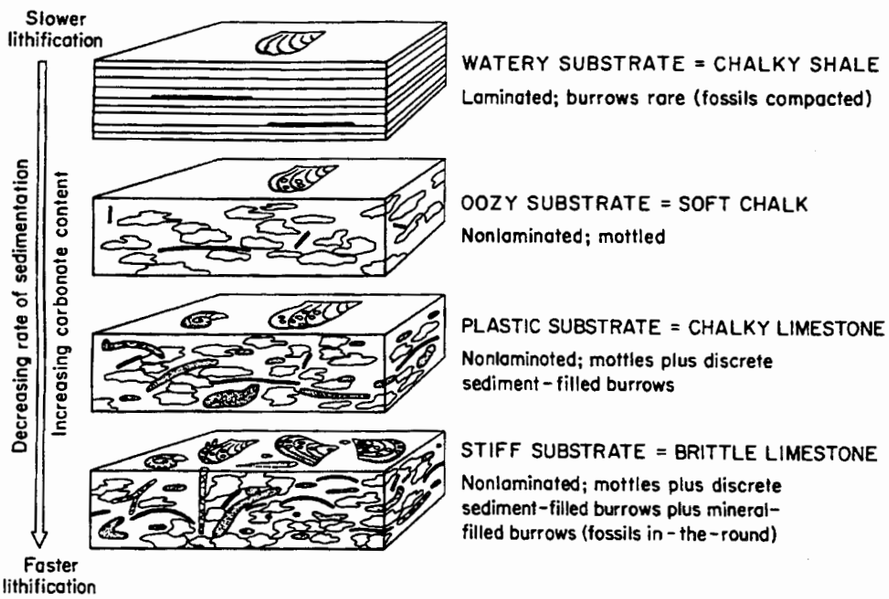
Stratigraphy, Sedimentology, Paleoecology and Paleontology

Professor, Geology; B.S. Massachusetts; M.S., Ph.D. Kansas, 1954.

Hattin's work is in paleoecological studies of Upper Cretaceous benthic organisms, especially including oysters, cirripeds, and rudists. He also does taxonomic studies of Upper Cretaceous benthic organisms, including oysters, anomiids, and cirripeds.

In addition he studies Cretaceous stratigraphy of the Western Interior Basin, with emphasis on depositional environments, cyclicity, basinwide correlation of carbonate-rock intervals, and stratigraphic manifestations of contemporaneous tectonic uplift.

During the past two years Hattin has been researching emergence surfaces in the middle Mississippian St. Louis Limestone of south-central Indiana, and plans extension of this work to cyclostratigraphic analysis on a regional basis.



Block diagrams showing, from top to bottom, the relationship between bioturbation and substrate firmness in upper Cretaceous pelagic-carbonate sediments of the U.S. Western Interior.

Representative Publications

Hattin, D.E. and V.L. Warren (1989). Stratigraphic analysis of a fossil *Neogoniolithon*-capped patch reef and associated facies, San Salvador, Bahamas. *Coral Reefs*, **8**, p. 19-30.

Hasenmueller, W.A., and D.E. Hattin (1990). New species of the bivalve *Anomia* from Lower and Middle Turonian parts of the Greenhorn Limestone, central Kansas. *J. Paleontol.*, **64**, p. 104-110.

Hattin, D.E., (1990). *Puebloites greenhornensis* Cobban & Scott from Turonian part of Greenhorn Limestone, north-central Kansas and northeastern Wyoming. *Cretaceous Research*, **11**, p. 351-358.

Hattin, D.E., and D.S. Hirt, (1991). Paleoecology of scalpellomorph cirripeds in the Fairport Member, Carlile Shale (Middle Turonian), of central Kansas. *PALAIOS* , **6**, p. 553-563.

Hattin, D.E., (1991). Lithodemes, suites, supersuites, and complexes: intrusive, metamorphic, and genetically mixed assemblages of rocks now embraced by North American Code of stratigraphic nomenclature. *Precamb. Res.* **50**, p. 355-357.

Hattin, D.E and J.R. Dodd (1992). Mississippian paleosols, paleokarst and eolian carbonates in Indiana. *Ohio Division of Geological Survey, miscellaneous report No. 3*, 35p. (Field trip No. 13, Annual Meeting of Geological Society of America, Cincinnati, Ohio).

John M. Hayes **Biological, Organic and Petroleum Geochemistry**

Distinguished Professor, Geological Sciences, Chemistry and Adjunct Professor, Environmental Sciences; B.S. Iowa State; Ph.D. M.I.T., 1966.

Hayes and his students and postdoctoral associates study the cycling of carbon in ancient and modern environments; the isotopic biogeochemistry of carbon, hydrogen, and nitrogen; and techniques of isotopic analysis.

Techniques of compound-specific isotopic analysis are being applied to the study of biogeochemical processes in ancient depositional environments. In the first case in which ^{13}C abundances were determined for numerous individual hydrocarbons (Freeman *et al.*, 1990), it was shown that isotopic compositions of individual compounds in lacustrine sediments varied widely and reflected derivation of some substances from CH_4-consuming bacteria. Other aspects of the flow of carbon in the ancient ecosystem were also clarified and the potential of this line of inquiry was demonstrated dramatically. A much more detailed, stratigraphic study of units within the Green River Oil Shale has just been completed. Because the abundance of sulfur varied cyclically in the Green River lakes, it has been possible to study effects of varying mechanisms of anaerobic diagenesis and to show that the isotopic record reflects these changes. Future studies will focus on late Proterozoic and early Cambrian marine sediments.

As work on compound-specific isotopic investigations of ancient systems has proceeded, an information gap has become clearly evident. Although isotopic compositions of numerous individual compounds are becoming known for *paleo*ecosystems, there have been no parallel examinations of modern systems. Because interpretations of compound-specific isotopic compositions cannot refined until such information is available, a major field program has now been undertaken in collaboration with oceanographic experts (S. G. Wakeham and colleagues, Skidaway Institute of Oceanography). Isotopic compositions of lipids from particulate organic carbon recovered from a range of depths in the water column of the Santa Monica Basin, offshore southern California, are being determined in the course of an annual cycle of cruises. Results are developing nicely and reveal that much of the isotopically significant reworking of primary products is taking place within the marine water column rather than in sediments.

Representative Publications

Summons, R.E. and J.M. Hayes (1992). Principles of molecular and isotopic biogeochemistry, in J.W. Schopf and C. Klein (eds.) *The Proterozoic Biosphere, a Multidisciplinary Study.* Cambridge University Press.

Kohnen, Math E.L., S. Schouten, J.S. Sinninghe Damste, J.W. de Leeuw, D.A. Merritt and J.M. Hayes (1992). Improved recognition of paleobiochemicals by a combined molecular sulfur and isotope geochemical approach. *Science*, **256**, p. 358-362.

Freeman, K.H. and J.M. Hayes (1992). Fractionation of carbon isotopes by phytoplankton and estimates of ancient CO_2 levels. *Global Biogeochemical Cycles* **6 (2)**, p. 185-198.

Des Marais, D.J., H. Strauss, R.E. Summons and J.M. Hayes (1992). Carbon isotope evidence for the stepwise oxidation of the Proterozoic environment. *Nature*, **359**, p. 605-609.

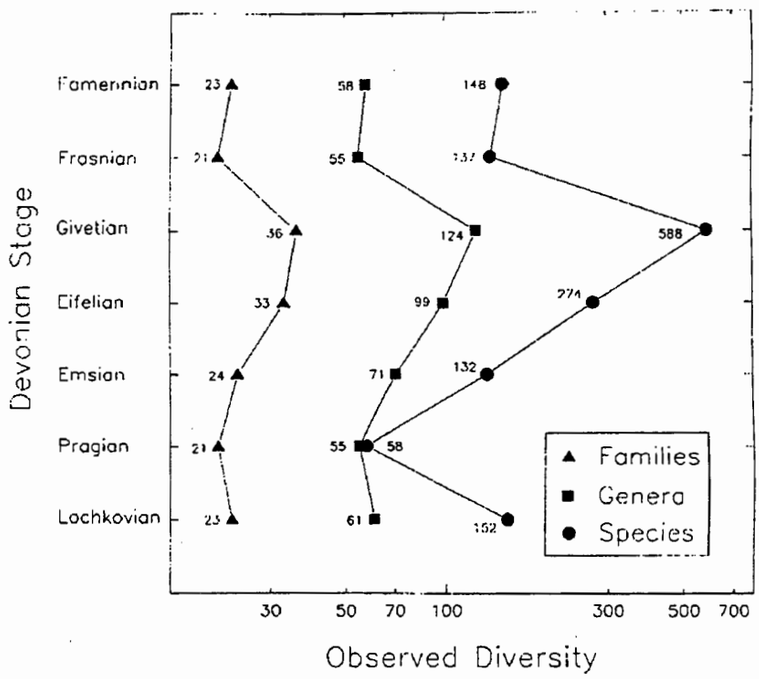
Alan S. Horowitz

Geobiology and Paleontology

Senior Scientist and Professor, part-time, Geological Sciences; B.A. Washington and Lee; M.S. Ohio State; Ph.D. Indiana, 1957.

Horowitz's general interests are in Mississippian paleontology and stratigraphy, but he works on the systematics of Paleozoic bryozoans and blastoids. Both fossil groups have a long history of study at Indiana University extending to the beginning of the century and both groups are well represented in the Paleozoic section exposed in Indiana.

He is currently investigating the diversity of bryozoans in the fossil record compared with Recent faunas, the taxonomy of some Mississippian bryozoans and blastoids, and the biochronology of conodonts in the Devonian and Mississippian. The bryozoan studies have been a collaborative effort with J. F. Pachut of Indiana University-Purdue University at Indianapolis. The results of this work shows that among Devonian bryozoans there is a major drop in diversity between the Givetian and Frasnian stages (see figure at right) rather than between the Frasnian and Famennian, the most commonly cited extinction event. J. A. Waters of West Georgia College is collaborating with him on studies of blastoids and he collaborates with C. B. Rexroad of the Indiana Geological Survey on conodont projects.



Representative Publications

Horowitz, A.S., D.B. Macurda, Jr., and J.A. Waters (1986). Polyphyly in the Pentremitidae (Blastoidea, Echinodermata). *Geological Society of America Bulletin*, **97**, p. 156-161.

Pachut, J.F., and A.S. Horowitz (1987). Multivariate discrimination and classification of some North American Mississippian species of Fistulipora M'Coy. In J.R.P. Ross, ed. *Bryozoa: Present and Past.* Papers presented at the 7th International Conference of Bryozoa. Western Washington University, Bellingham, Washington, August 4-9, 1986, p. 205-212.

Droste, J.B., and A.S. Horowitz (1990). Influences on the position of Chesterian sand belts in Indiana. *Proceedings of the Indiana Academy of Science*, **99**, p. 39-45.

Rexroad, C.B., and A.S. Horowitz (1990). Conodont paleoecology and multielement associations of the Beaver Bend Limestone (Chesterian) in Indiana. *Courier Forschungs Institute Senckenberg*, **118**, p. 493-537.

Horowitz, A.S. (1991). A fossil site near Sulphur, Indiana (Chesterian, Mississippian). In M.E. Kahrs, ed. *Lagerstatten (Extraordinary Preserved Fossil Faunas). MAPS Digest - EXPO XIII Edition*, p. 61-70.

Horowitz, A.S. and J.F. Pachut (in press). Specific generic and familial diversity in Devonian Bryozoa. *Journal of Paleontology.*

John P. Jasper **Chemical Oceanography, Organic Geochemistry, Biogeochemistry**
Assistant Scientist, Geological Sciences and Chemistry; A.B. Chicago; Ph.D. M.I.T. (Woods Hole), 1988.

Jasper and coworkers employ molecular and isotopic geochemistry to reconstruct levels of marine dissolved CO_2 and atmospheric CO_2 partial pressure.

Cooperative research projects with John Hayes in "CO_2 paleobarometry" have developed from earlier work of Popp *et al.* (1989) which summarized evidence that the abundance of ^{13}C in marine organic matter should vary with the dissolved CO_2 concentration in photic-zone water. In a study of organic materials from the Gulf of Mexico, Jasper and Hayes (1990) showed that, for the past 100,000 years, variations in the abundance of ^{13}C in compounds derived from coccolithophorid algae (alkenones) are well correlated with changes in atmospheric pCO_2 known from analyses of the Vostok ice core. More recently, based on relationships between CO_2 levels and isotopic compositions of gross photosynthate, Freeman and Hayes (in press) have developed new estimates of variations in paleoatmospheric CO_2 levels during the past 160 million years.

Current research includes CO_2 reconstructions in the late Quaternary on the timescales of glacial-interglacial climatic variations and of the Industrial Revolution. The goals of these investigations are to reconstruct high resolution ~255,000-year records of dissolved CO_2 and equilibrium pCO_2 levels in oceanic surface waters that were expected to have (1) remained near air-sea equilibrium, and (2) been removed from air-sea equilibrium by the balance of processes affecting dissolved CO_2. A sediment core from the central equatorial Pacific provided an opportunity to investigate a "non-equilibrium" environment. Isotopic analyses of a time-series record of alkenones indicate that the climatically-varying balance of physical and biological processes attenuates the subsurface eutrophic layer's CO_2 levels relative to paleoatmospheric levels (Jasper *et al.*, 1992). In an analogous study on a core from the Feni Drift in the northeast Atlantic, oceanic and atmospheric CO_2 levels will be reconstructed in a high latitude, near-equilibrium environment. Secondary projects include examination of ~200 year records of the effects of dissolved CO_2 on organic biomarker biosynthesis in marginal sea environments (the Black Sea and the Gulf of California) and a preliminary map of glacial-to-interglacial pCO_2 variations in the equatorial Pacific (Jasper *et al.*, 1991). The examination of relatively short records of ^{13}C abundance and CO_2 levels give further insight into the processes recorded in more ancient records. Understanding the environmental and biosynthetic factors bearing upon the carbon isotopic composition of organic compounds will continue to be an area of inquiry.

Representative Publications

Jasper, J.P. and J.M. Hayes (1990). A carbon-isotopic record of CO_2 levels during the Late Quaternary. *Nature*, **347**, p. 462-464.

Jasper, J.P., J.M. Hayes, F.G. Prahl, A.C. Mix, S.G. Wakeham, J. Crusius and R.F. Anderson, (1991). Isotopically-derived estimates of dissolved CO_2 and equilibrium pCO_2 from late Quaternary sedimentary records in the equatorial Pacific and the Black Sea. *Trans. A.G.U. Eos*, **72**, p. 272.

Jasper, J.P., F.G. Prahl, A.C. Mix, and J.M. Hayes (in press). Photosynthetic ^{13}C fractionation and estimated CO_2 levels in the Central Equatorial Pacific over the last 255,000 years. *Paleoceanography.*

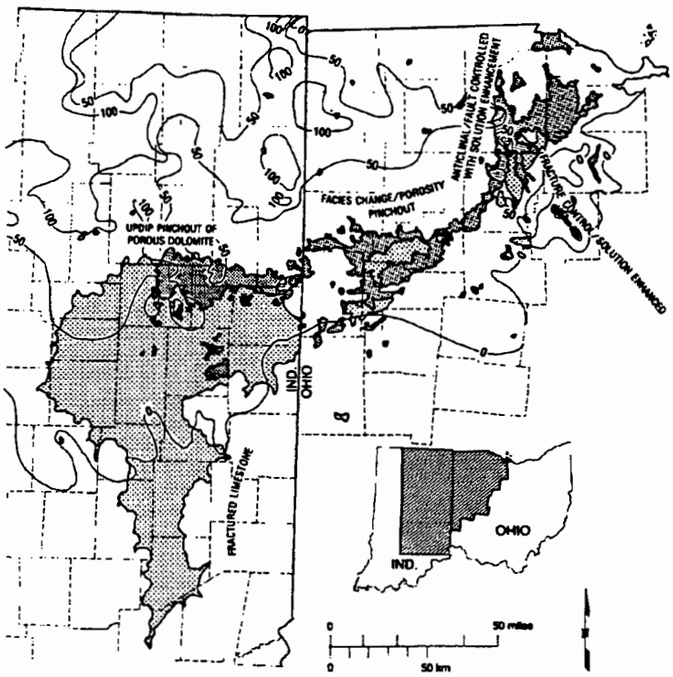
Brian Keith

Petroleum Geology, Basin Analysis, Sedimentology and Stratigraphy

Associate Scientist, Indiana Geological Survey and Associate Professor, part-time, Geological Sciences; B.A. Amherst, M.S. Syracuse, Ph.D. Renesselaer Polytechnic Institute, 1974.

Keith's research involves work on a variety of local to regional-scale outcrop and subsurface studies in the Illinois basin. His primary interests are in defining the long term tectonic controls on Paleozoic carbonate facies and the application of sequence-stratigraphy concepts to interior cratonic basins. This is particularly oriented toward defining the occurrence of potential petroleum reservoirs within the basin.

A major effort is starting in the study of geologic controls over reservoir character and the potential for future exploration in Mississippian carbonates. Some of this effort will involve cooperative studies with research personnel at the Illinois and Kentucky Surveys and with industry geologists. Considerable potential exists for graduate student research in the depositional and diagenetic history of carbonate reservoir rocks and the controls over reservoir quality.



Map showing the following: 1) percentage of the Trenton Limestone interval that is dolomite in the vicinity of the Lima-Indiana trend. The variation in thickness of dolomite in the Trenton is highly variable and complex. The percentage map is used to convey the regional pattern of this thickness distribution. 2) Distribution of oil- and gas-producing areas of the Lima-Indiana trend. 3) Nature of trapping conditions in different areas of the trend. Estimated recoveries for the different areas are fractured limestone, below commercial gas volumes; updip pinch-out, 100-500 bbl of oil/acre; anticlinal/fault controlled with solution enhancement, 4000-12,000 bbl of oil/acre; and fracture control/solution enhanced, no information available.

Representative Publications

Keith, B.D., ed. (1988). The Trenton Group (Upper Ordovician Series) of eastern North America — deposition, diagenesis, and petroleum. *AAPG Studies in Geology*, **29**, 317 p., *Contains:*
Keith, B.D., Regional facies of the Upper Ordovician series of eastern North America, p. 1-16.
Fara, D.R. and B.D. Keith, Depositional facies and diagenetic history of the Trenton Limestone in northern Indiana, p. 277-298.

Keith, B.D. and L.H. Wickstrom, (1992). The Lima-Indiana trend. *in* Stratigraphic Traps III, AAPG Atlas of Oil and Gas Fields, Treatise on Petroleum Geology Series, p. 347-367.

Keith, B.D. and C.W. Zuppann, eds. (in press). Mississippian Oolites and their modern analogs. *AAPG Studies in Geology.*

Noel Krothe — Hydrogeology and Aqueous Geochemistry

Associate Professor, Geological Sciences; B.S. Bloomsburg State; M.A.T. Indiana, M.S., Ph.D. Penn State, 1976.

Noel Krothe specializes in the flow and chemistry of ground and surface water. His research projects utilize major and minor ion chemistry, physical flow studies, and stable isotope geochemistry. The main directions of his research center on four areas in hydrogeology:

Carbonate Hydrogeology: One of the most problematic areas of hydrogeology is flow and water chemistry in fractured and solution controlled aquiffers. Normal groundwater modeling such as finite element and finite difference is difficult to apply to these problems because most significant flow does not obey Darcy's law. Field investigations utilizing organic and inorganic tracers in projects concerning the dissolution rates of carbonate rocks and the development of epikarst are ongoing. This research focuses on physical flow, epikarst storage, and macropore flow in karst terraces. Similar studies are also being conducted in other fractured rocks and in unconsolidated deposits.

Arctic Hydrology: Research concerning the formation of icings, groundwater flow, ground/sulfur water chemistry, and stream discharge has been completed in the Brooks Range of Alaska. Future studies are planned to determine dissolution rates in arctic carbonate areas.

Pollution Problems: The fate and transport of both inorganic and organic pollutants are being investigated in varied geologic settings. Problems dealing with transport of nitrogen, polychlorobiphenyls, and acid mine water are currently under investigation. Research concerning groundwater conditions in coal bearing rocks and at abandoned mine sites has been ongoing since 1978 with research grants from Argonne National Laboratories, USGS and the Office of Surface Mining. Additional support has come from the Division of Reclamation and the Indiana Department of Natural Resources through grants from the Office of Surface Mining. Abandoned coal spoils have been studied to determine the effects of acid waters and the rate of oxidation of pyritic materials in coal refuse. Groundwater in undisturbed bedrock has been characterized chemically to determine if the water is being impacted by shallower surface mining activities.

Mineral Spring Genesis: The genesis of mineral springs occurring in Southern Indiana is part of ongoing research. Stable isotopes, tritium, and water chemistry of these springs are being studied to determine their origin. Recent research indicated two possible mechanisms: evaporite dissolution or mixing of fresh water and brines.

Representative Publications

Krothe, N.C. (1981). Water chemistry in a permafrost environment, Alaska *in* The Northern Community – A Search for Quality Environment. Proc. ASCE Ann. Mtg., Seattle, WA, p. 570-590.

Giles, B.E., J.E. Cocroft and N.C. Krothe (1984). Hydrochemical Study of Mined and Unmined Areas in the Carbondale Group (Pennsylvania), S.W. Indiana. *Proceedings of the Fifth Annual Water Resources Symposium, Bloomington, Ind.*, J.D. Martin, ed.

Gutentag, E.D., J.J. Heines, N.C. Krothe, R.R. Lucky and J.B. Weeks (1984). Geohydrology of the High Plains Aquifer in Parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas and Wyoming. *U.S. Geological Survey Professional Paper 1400-B*, 63p.

Krothe, N.C. (1988). Hydrologic Connection Between Spring Water and the Evaporite of the Lower St. Louis Limestone, Karst Mitchell Plain of Southern Indiana, *Karst Hydrogeology and Karst Environment Protection.* Proceedings of the International Association of Hydrogeologists, Guilin, China, October 1988, Volume XXI, Part 1.

Wells, E.R. and N.C. Krothe (1989). Seasonal Fluctuation in $\partial^{15}N$ of Groundwater Nitrate in a Mantled Karst Aquifer due to Transport of Fertilizer-Derived Nitrate, *J. Hydrogeol.*, **112**, p. 191-201.

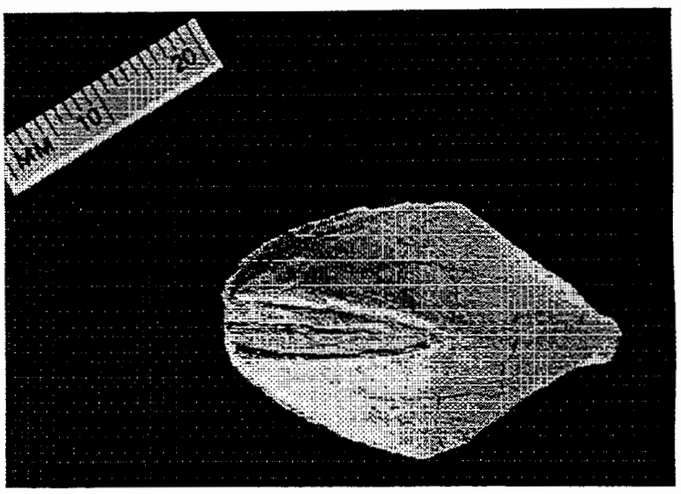
N. Gary Lane

Geobiology and Paleontology

Professor, Geological Sciences; B.A. Oberlin; M.S., Ph.D. Kansas, 1958.

Lane is continuing to work on two research projects. Last year he spent a month in China collecting the latest Devonian crinoids from Xinjiang province and Middle Carboniferous microcrinoids from south China. This coming May-June he will return to China for five weeks of field work in these areas and in new areas that promise to yield new Silurian crinoid faunas. This research is being funded through NSF, and includes two of his former students, IU Ph.D. recipients Johnny Waters of West Georgia College and Chris Maples of the Kansas Geological Survey. At the Xinjiang sites they found the world's largest known fauna of Famennian crinoids and blastoids, including several new genera and species. These show biogeographical relationship with fossils from western Europe, especially Germany and England. They provide evidence for existence of an extensive east-west seaway across Eurasia, the paleo-Tethys, during Devonian time. At the south China sites they collected microcrinoids and blastoids that include some with southern Australasian affinities.

He is also working on a very unusual Silurian crinoid fauna from the Mississinewa Shale of northeastern Indiana with Bill Ausich of Ohio State University, another IU Ph.D. While the fauna is not very diverse it is the only inter-reef crinoid fauna known from Indiana. The preservation is remarkable and the taxa are conspicuously different from reef-dwelling echinoderms that occur nearby. The specimens are very delicate and lightly constructed, with thin plates, long narrow stems, and slender arms.



Pentremites, an extinct blastoid echinoderm from Upper Mississippian rocks of southern Indiana.

Representative Publications

Lane, N. Gary (1991). New Late Devonian (Famennian) echinoderms from Xinjiang Province, Peoples Republic of China (abst.) (with J. A. Waters, C. G. Maples, and Hou Hong-fei). *Geol. Soc. Amer. Ann. Meeting, San Diego, California*, p. A279.

Lane, N. Gary (1991). *Life of the Past*. 3rd Edition. Macmillan Publishing, 334p.

Hou Hong-fei, N. Gary Lane, J.A. Waters, C.G. Maples (1992). Stratigraphy and Paleontology of a new Famennian echinoderm fauna from the Hongguleleng Formation of Xinjiang, with redefinition of the formation. *Stratigraphy and Paleontology of China*, **2**, 35p.

N. Gary Lane et al. (1992). Honors H202: A sophomore honors course at Indiana University that integrates field geology and field botany. *GSA Abstracts with Program*, p. A133.

N. Gary Lane et al. (1992). Honors H202: The Natural History of Southern Indiana. A sophomore level course at Indiana University that utilizes natural areas. *Natural Areas Conference*, (abst.), Bloomington, Ind.

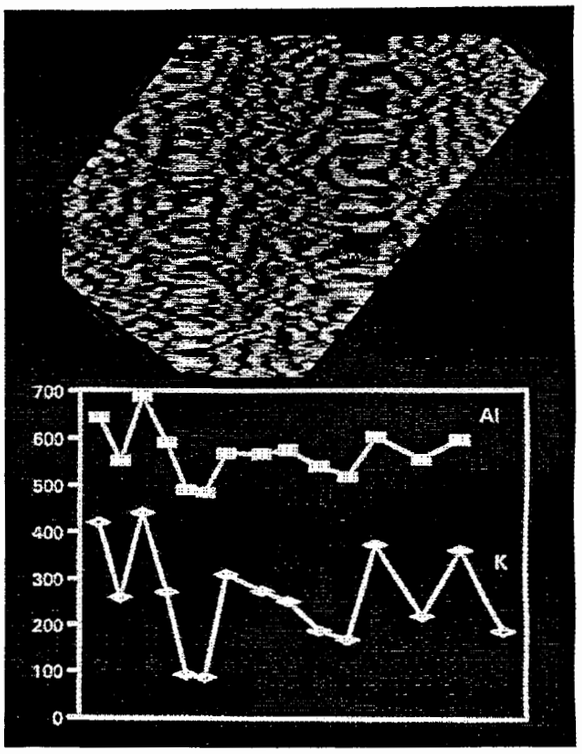
J.A. Waters, C.G. Maples and N. Gary Lane (1992). Comparison of Famennian echinoderm communities, apparent loss of endemism caused by biogeographic pathways, climate or the aftermath of mass extinctions? *GSA Abstracts with Program*, p. A96.

Enrique Merino

Geochemistry and Petrology

Associate Professor, Geological Sciences; Ingeniero, School of Mining Engineering, Madrid, Spain; Ph.D. University of California at Berkeley, 1973.

Merino's general field of interest is low- and high-temperature alteration and mechanisms, combining petrological, water-chemical, kinetic, and theoretical approaches. Current research deals with working out the geochemical factors and mechanisms that produce different crystalline textures, with the igneous origin of agates, with the genesis of many self-organizational textures in igneous, metamorphic, and sedimentary rocks, with the dynamic and geochemistry of weathering in tropical and semi-arid countries, with the geochemistry of rift-basin clastic sediments in west Africa and Connecticut, and with the physics and textural attributes of wind-blown sand.



Fibrous-quartz layers in a Brazilian agate. Profiles are aluminum and potassium contents, in the 10-to-100-ppm range, in the layers shown. Agates have amazing quartz textures: the fibers in every other layer are fine and twisted and relatively rich in Al and K. Fibers in the intervening layers are coarser, untwisted and Al, K-poor.

Much of this work (funded by NSF, the Petroleum Research Fund, and CNRS of France) is carried out in collaboration with D. Nahon (Marseille), E. Deloule (Nancy), B. Werner (Scripps, La Jolla), J.-P. Girard (Case Western Reserve), and graduate student Y. Wang.

Representative Publications

Merino, E. (1990). The geochemistry of habits and textures of authigenic quartz. *Chem. Geol.*, **84**, p. 233-234.

Wang, Y. and E. Merino (1990). Self-organizational origin of agates: Banding, fiber twisting, composition, and dynamic crystallization model. *Geochimica et Cosmochimia Acta* **54**, p. 1627- 1638.

Wang, Y. and E. Merino (1992). Dynamic model of oscillatory zoning of trace elements in calcite: double layer, inhibition, and self- organization. *Geochimica et Cosmochimia Acta*, **56**, p. 587-596.

Werner, B. and E. Merino (1992). Quantitative model for concavity formation in eolian sand grains. Scripps Institution of Oceanography Reference Series No. 92-2, 6p.

Merino, E. (1992). Self-organization in Stylolites. *American Scientist*, **80**, p. 466-473.

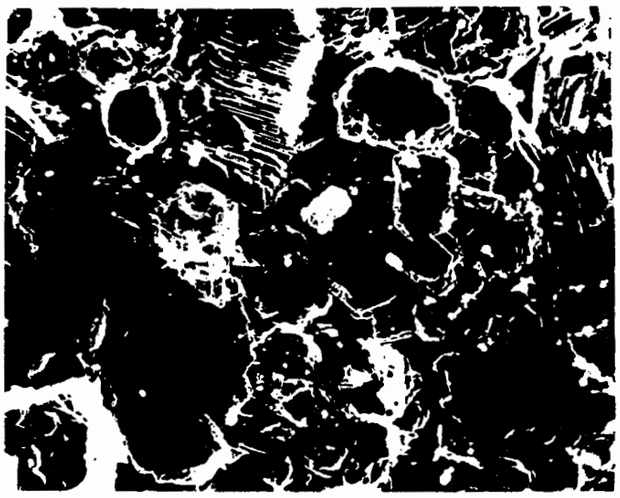
Merino, E., D. Nahon, and Y. Wang (in press). Kinetics and mass transfer of pseudomorphic replacement: application to replacement of parent minerals by Al, Fe, and Mn oxides during weathering. *American Journal of Science.*

Haydn Murray

Economic Geology, Clays and Industrial Minerals

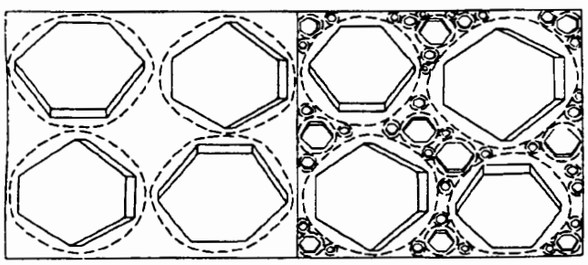
Professor, Geological Sciences; B.S., M.S., Ph.D. Illinois, 1951.

Murray's research interests focus largely on the origin, depositional environments, geochemistry, and applications of the various clay minerals. Petrology of clay and hydrothermal deposits is an integral part of this research. Determination of crystallinity and oxygen isotopic compositions of kaolinite, smectite and bauxite minerals leads to a clearer understanding of the origin of these deposits and to predictions of the occurrence and quality of economically important deposits. Researchers from all over the world work in Murray's laboratories, and are funded primarily by industrial grants.



Electron micrograph showing kaolinite plates and stacks from Dry Branch, Georgia.

Current projects are listed as follows:
A. Genesis and properties of the kaolin clays along the Minnesota River near Redwood Fall, Minn. Collaborator: Dr. Peter Brandlein, post-doctoral research associate from Germany.
B. Genesis and characterization of a hydrothermal clay deposit in Argentina. Collaborator: Dr. Silvana Bertolino, post-doctoral research associate from Argentina.
C. Relationship between kaolinite crystallinity and overlying bauxite deposits in Brazil, Suriname, and Australia. Collaborator: Dr. Eva Kocsardy, post-doctoral research associate from Hungary.
D. Oxygen isotope composition of residual, hydrothermal, and sedimentary kaolins and smectites. Collaborator: Tim Johnson, who has set up a new laser ablation fluorination system.



Representation of the relationship between particle packing and viscosity.

Representative Publications

Solomon, D.H. and H.H. Murray (1972). Acid-Base Interactions and the Properties of Kaolinite in Non-Aqueous Media. *Clays and Clay Minerals*, **20**, p. 135-141.

Murray, H.H. (1976). Benefication of Selected Industrial Minerals and Coal by High Intensity Magnetic Separation. *IEEE Transactions on Magnetics*, MAG-12, **5**, September.

Patterson, Sam H. and H.H. Murray (1984). Kaolin, Refractory Clay, Ball Clay, and Halloysite in North America, Hawaii, and the Caribbean Region. *Geol. Survey Professional Paper 1306*, 56p.

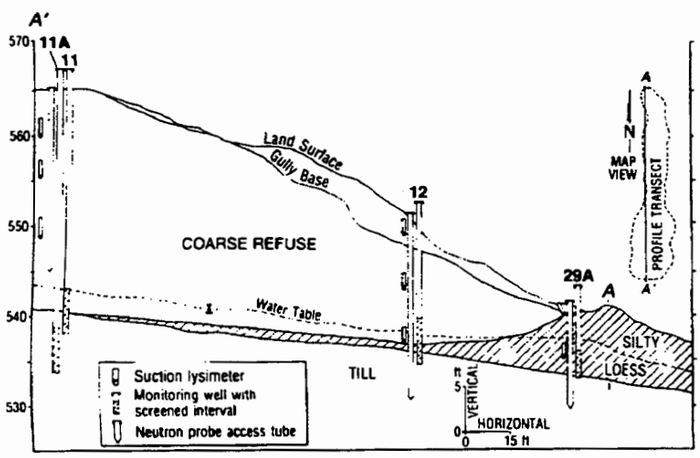
Murray, H.H. (1989). Clay Minerals for Advanced Ceramics. *Mining Eng.* p. 1123-1125.

Murray, H.H. (1991). Overview — Clay Minerals Applications. *Appl. Clay Sci.*, **5**, p. 379-395.

Greg A. Olyphant — Hydrogeology, Quaternary Geology and Geomorphology

Associate Professor, Geological Sciences and Geography; B.A. Cal State; M.A., Ph.D. Iowa, 1979.

Olyphant's emphasis is on monitoring and computer modeling of surficial processes. Current geomorphologic research focuses on aspects of erosion and sediment yield at abandoned strip mining sites in southwestern Indiana, and mechanics of eolian sand transport and the role of eolian processes on the sediment budget of southern Lake Michigan. Other research interests include geomorphic response to Holocene climatic changes in alpine areas and temporal and spatial dynamics of fluvial systems.



Section across the instrumented watershed showing subsurface monitoring installations, stratigraphy, and average water table. Such profiles are a routine part of detailed investigations of hydrologic and geomorphic conditions at sites in southern Indiana and elsewhere.

Hydrologic research consists of monitoring and computer modelling of rainfall-runoff relationships, unsaturated groundwater flow, and acid drainage in strip mined areas with the goal of evaluating the feasibility of direct revegetation as a method of reclamation. He recently completed a study of hydrologic conditions in an area experiencing mine subsidence. The study focused on the hydrologic response of abandoned, flooded, underground mines to natural and human induced stresses, and provided inference for the existence of pathways of rapid subsurface water movement into the abandoned mine works.

He has had a long-term interest in watershed hydrology, especially the role of snowmelt in the generation of runoff from mountainous areas. Recent publications on this topic have emphasized the effects of radiation and turbulent heat fluxes in the generation of snowmelt- runoff from late-lying snowfields in the Colorado Rockies.

Representative Publications

Olyphant, G.A. and S.I. Isard (1988). The role of advection in the energy balance of late-lying snowfields: Niwot Ridge, Front Range, Colorado. *Water Resources Research*, **24 (11)**, p. 1962-1968.

Morris, S.E. and G.A. Olyphant (1990). Alpine Lithofacies Variation: Working Toward a Physically Based Model. *Geomorphology*, **3**, p. 73-90.

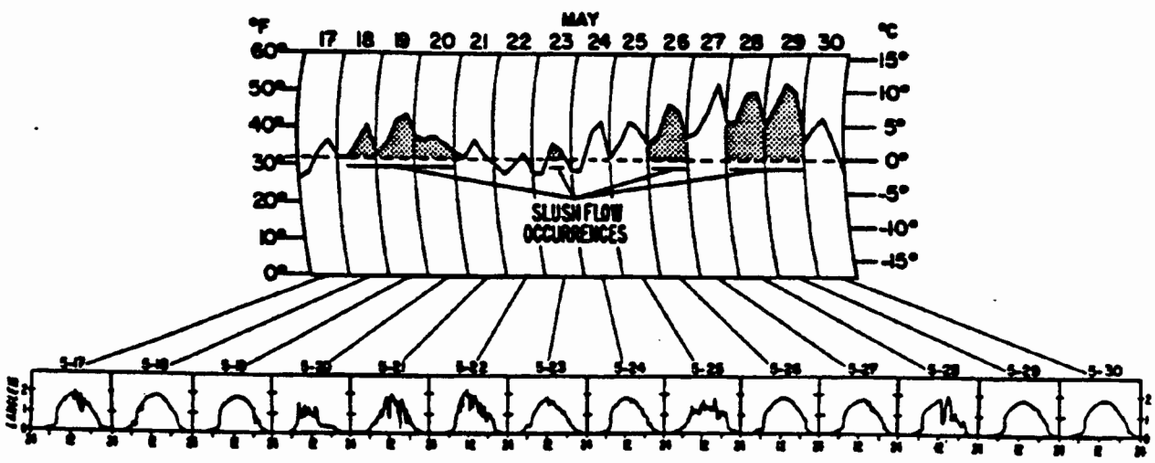
Olyphant, G.A., C.P. Carlson and D. Harper, (1991). Seasonal and Storm-related Aspects of Sediment Yield from a Rapidly Eroding Coal Refuse Deposit in Southwestern Indiana. *Water Resources Research*. 27(11): p. 2825-2833.

Olyphant, G.A., E.R. Bayless and D. Harper, (1991). Seasonal and weather-related controls on solute concentrations and acid drainage from a pyritic coal-refuse deposit in southwestern Indiana, U.S.A. *Journal of Contaminant Hydrology*, **7**, p. 219-236.

Lawrence J. Onesti — Quaternary Geology and Geomorphology

Associate Professor, Geological Sciences, B.S. Northwestern; M.A. Michigan State; Ph.D. Wisconsin, 1973.

Onesti's research is in geomorphology and Quaternary geology, with applications to environmental geology. He has particular interests in Arctic-Alpine regions, fluvial systems, snow and ice hydrology, and natural hazards and neotectonics. Recent research has focused on release mechanisms, debris entrainment processes, depositional environment and impact pressure of slush avalanches in the central Brooks Range, Alaska, Rana District north Norway, and Khibiny Mountains Kola Peninsula (USSR). He also studies alluvial river response and Pleistocene depositional terrace systems response to neotectonic activity in southern Indiana, and Wind River Basin, Wyoming. Finally, he is working on river channel migration history and changes in channel geometry characteristics as indicators of climatic change.



Air temperature and mechanical pyranograph records during slushflow occurrences at Atigun Pass, Central Brooks Range, 17-30 May 1981.

Representative Publications

Onesti, L.J. (1983). Hydrologic Characteristics of Six Small Arctic-Alpine Watersheds, Central Brooks Range, Alaska. *Proceedings IVth International Conference on Permafrost, Fairbanks, Alaska*, p. 957-961.

Onesti, L.J. (1985). Meteorological Conditions that Initiate Slushflows in the Central Brooks Range, Alaska. *Annals of the International Glaciological Society, Sapporo, Japan*, **6**, p. 23-25.

Onesti, L.J. (1986). Slushflow Release Mechanism: A First Approximation. *Proceedings International Symposium on Avalanche Formation, Movement and Effect: Proceedings International Association of Scientific Hydrology, Swiss Institute for Snow and Avalanche Research, IAHS Publication, Davos, Switzerland*, **16**, p. 331-336.

Onesti, L.J. and T.K. Miller (1987). Interregional Comparison of Alluvial Stream Channel Morphology: Great Plains vs. Central Lowlands. *Water Resources Bulletins, American Water Resources Association*, **24 (6)**, p. 1207-1217.

Onesti, L.J. (1989). Suspended Sediment Load Variation of Arctic-Alpine Watersheds in Alaska. *Symposium on Headwater Hydrology, American Water Resources Association, Missoula, Montana.*

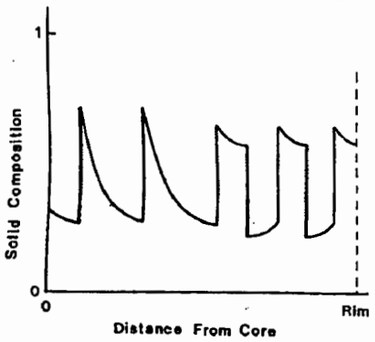
Onesti, L.J., T.E. Concl, O.A. Chadwick (1992). River Terraces in the Wind River Basin, Wyoming: Modelled Flexure from Yellowstone Uplift. *Chapman Conference on Tectonics and Topography, American Geophysical Union, Snowbird, Utah, Program Abstracts*, p. 27.

Peter Ortoleva

Theoretical Geochemistry

Professor, Geological Sciences and Chemistry; B.A., Renesselaer Polytechnic Institute; Ph.D. Cornell, 1970.

A unified approach to the modeling of a range of phenomena from intracrystalline zoning to basin diagenesis is adopted. The emphasis is on the challenging problem of strongly coupled systems. These systems are analyzed for their self-organization and other nonlinear dynamical behavior; models are developed for exploration and waste and environmental analysis.

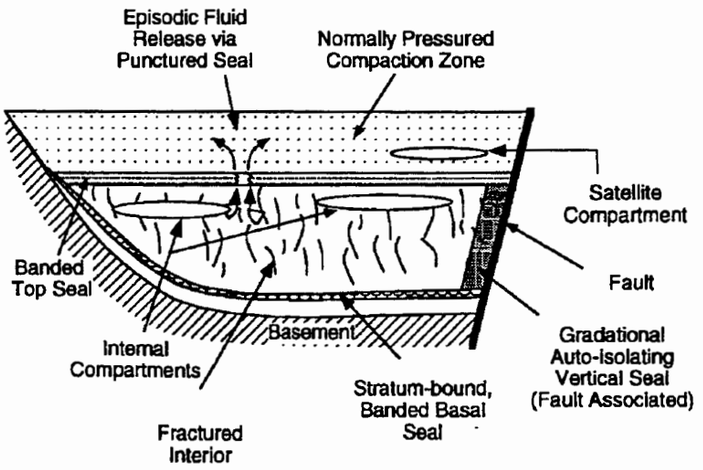


Oscillatory crystal zoning is predicted via a surface attachment feedback model. Oscillation is shown to be associated with a cusped nonequilibrium fractionation surface.

Models are under development for oscillatory and sector crystal zoning (figure at left), differentiated diagenetic and metamorphic layering, stylolites, banded and mosaic agates and temporally oscillatory fluid migration in sedimentary basins.

Petroleum and mineral exploration is being facilitated by the development of a basin diagenesis code which accounts for a complete suite of mechanical, reaction and transport processes (figure below). The code is used to predict the distribution of diagenetic, structural and petroleum traps within the basin and the development of over- and under-pressures and reservoir rock. Another code focuses on the imposition of reactive fluids on a rock over geological or engineering time scales.

This research is supported by grants from the US DOE, Gas Research Institute, NSF and the petroleum and computer industries. The Indiana University Laboratory for Computational Geochemistry under Ortoleva's supervision provides an interdisciplinary research environment and supports about 12 students from computer science, chemistry, geology, mathematics and physics, one half being from the Department of Geological Sciences.



A sedimentary basin is shown to be rich in self-organization and other nonlinear phenomena.

Representative Publications

Meshri, I. and P. Ortoleva, eds. (1990). Prediction of Reservoir quality through chemical modeling. *AAPG Memoir 49*, 175p.

Ortoleva, P., B. Hallet, A. McBirney, I. Meshri, R. Reeder, and P. Williams, eds. (1990). Self-organization in geological systems: Proceedings of a workshop held 26-30 June 1988, University of California, Santa Barbara. *Earth Science Reviews 29*, Amsterdam, Elsevier, 417p.

Ortoleva, P. (1992). Nonlinear chemical waves. *Chichester, John Wiley and Sons*, 302p.

Dewers, T. and P. Ortoleva (1990). Geochemical self-organization III: A mean field, pressure solution model of spaced cleavage and metamorphic segregational layering. *Am. J. Sci.*, **290**, p. 473-521.

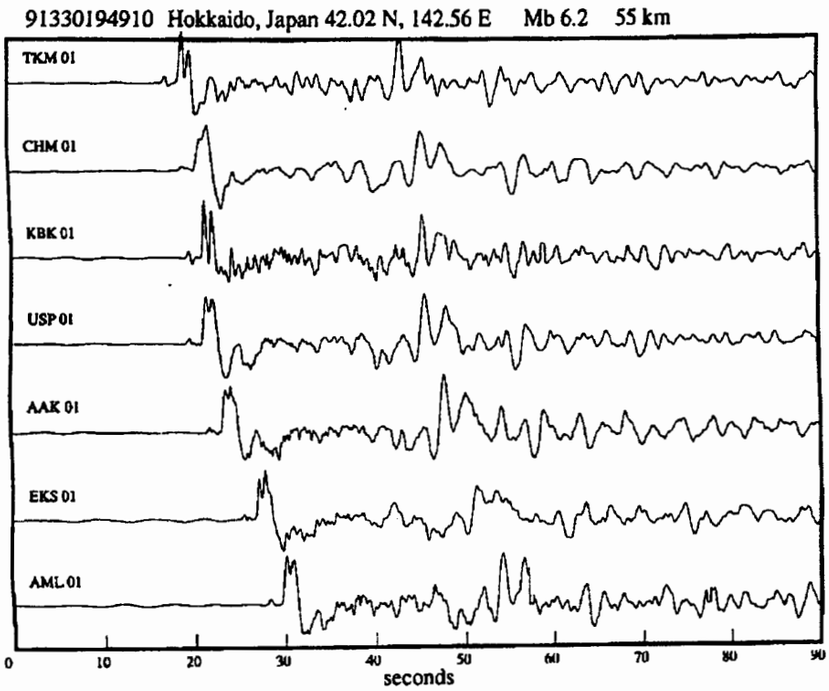
Ortoleva, P. (in press). Geochemical self-organization. *Oxford University Press.*

Gary Pavlis

Geophysics and Tectonics

Associate Professor, Geological Sciences; B.S. South Dakota State; Ph.D. Washington, 1982.

Pavlis's early work focused on geophysical inversion techniques. He has written several papers on theoretical and computational aspects of earthquake location and velocity inversion from seismic travel time data. More recently his research has broadened to include two new areas. First, through association with IRIS (Incorporated Research Institutions for Seismology) he has become involved in fundamental research in wave propagation through data collected by passive seismic arrays. His principal interest is in improving understanding of how seismic waves are scattered and attenuated within the earth and how this limits capabilities for using seismic waves radiated by earthquakes in a variety of practical problems. These practical aspects include understanding earthquake sources and detection and discrimination of underground nuclear explosions. His second current research interest is the seismotectonics of Central Asia. This interest was born through collaborations with Michael Hamburger and has yielded several recent papers.



Vertical component records of a magnitude 6.2 earthquake in Japan recorded by Kirghistan broadband array. The waveforms show enormous variations across this array due to complicated scattering of seismic waves in the crust and upper mantle beneath the array. This observation illustrates an important new frontier in seismology, which is to use data like this to image the deep interior of the earth.

Representative Publications

Pavlis, G.L. (1986). Appraising earthquake hypocenter location errors: a complete, practical approach for single event locations. *Bull. Seis. Soc. Amer.*, **76**, p. 1699-1717.

Pavlis, G.L., M.W. Hamburger, and I.L. Nersesov (1989). Anomalies in the magnitude-frequency relation of earthquakes in the Garm region, Soviet Central Asia. *Bull. Seism. Soc. Amer.*, **79**, p. 1913-1926.

Meyerholtz, K.A., G.L. Pavlis, and S.A. Szpakowski, (1989). Convolutional quelling in seismic tomography. Geophysics, **54**, p. 570-580.

Pavlis, G.L., P. Anderson, and B. Kaplan (1990). Visualization technique for seismic array data. *Leading Edge*, **9**, p. 26-29.

Pavlis, G.L. and M.W. Hamburger (1991). Aftershock sequences of intermediate-depth earthquakes in the Pamir-Hindu Kush Seismic Zone. *Journal of Geophysical Research*, **96 (18)**, p. 107-117.

Pavlis, G.L. (1992). Appraising relative earthquake location errors. *Bull. Seism. Soc. Am.*, **82**, p. 836-859.

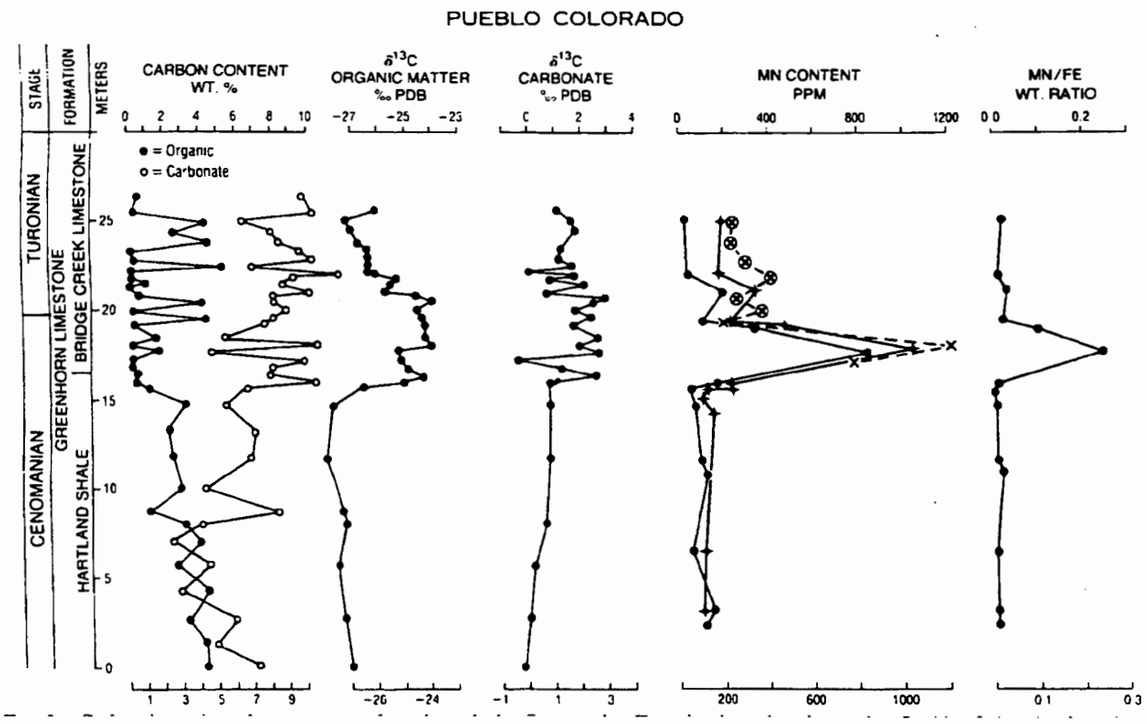
Lisa M. Pratt **Sedimentary and Organic Geochemistry, Stratigraphic Interpretation**

Associate Professor, Geological Sciences, B.A., M.S. North Carolina; M.S. Illinois; Ph.D. Princeton, 1981.

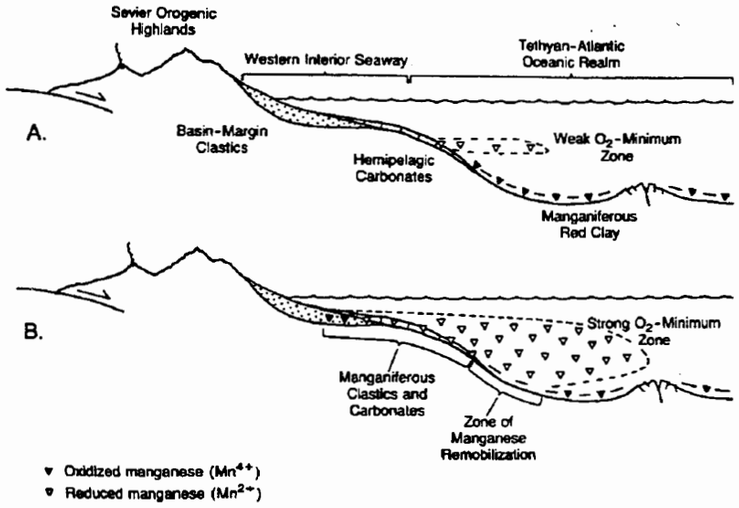
Pratt and her students are involved in geochemical, stratigraphic, and sedimentologic studies of fine-grained sediments and sedimentary rocks with particular emphasis on reconstruction of paleoclimatic and paleoceanographic conditions during deposition of black shales. Recent studies have focused on strata ranging in age from the Precambrian Nonesuch Formation, Ordovician Maquoketa Shale, Miocene Monterey Formation, to modern sediment in Santa Monica basin, offshore California.

Concentrations and stable isotopic ratios of organic carbon and sulfide sulfur indicate that the Nonesuch Formation was deposited in a marine embayment, in contrast to the prevailing interpretation of a lacustrine origin. Biomarker compounds (organic molecular fossils) in the Nonesuch are derived largely from primitive eukaryotic algae and bacteria with small contributions from prokaryotic algae (Pratt, et al., 1991). Although concentrations of organic carbon are generally less than 1 wt % in the Nonesuch, levels of thermal maturity are modest and the type of organic matter is hydrogen rich, indicating that deeper water facies with restricted input of siliciclastic sediment may have significant petroleum source potential (Hieshima and Pratt, 1992).

Detailed isotopic studies of oxidized and reduced sulfur species in the Monterey Formation have shown that both iron and organic matter can provide reactive sites for trapping of sulfide



Carbon isotopic and manganese values through the Cenomanian-Turonian boundary interval at Pueblo, Colorado. Organic-matter $\delta^{13}C$ from Pratt and Threlkeld (1984). Manganese values from Arthur et al. (1985) are shown by "x," the circled values representing 10-point averages. Large dots represent XRF values; crosses are AA values.



Schematic diagram of manganese remobilization during expansion of oxygen minimum zones.

formed during sulfate reduction (Zaback and Pratt, 1992; Zaback et al., in press). Most previous studies of ancient sulfur budgets have failed to incorporate data on elemental sulfur, monosulfides, and organic sulfur compounds (OCS). When large quantities of highly metabolizable organic matter accumulate below the oxic/anoxic boundary, rates of sulfate reduction can outpace rates of sulfate renewal to the pore water system. High concentrations of hydrogen sulfide can develop under these circumstances, leading to black shales containing pyrite and OCS with anomalous enrichment of ^{34}S.

Upcoming projects in this research group are directed toward understanding the distribution of nutrients and primary productivity in the circum-Caribbean region during the Cretaceous. Marine sequences now exposed in Costa Rica, Columbia, Venezuela, and Trinidad record the influences of discharge from major river system and upwelling into a westward-flowing equatorial current. The prolific petroleum provinces of northern South America are sourced by pelagic and hemipelagic mid-Cretaceous shales deposited prior to closure of the Panamanian isthmus.

Representative Publications

Pratt, L.M. and C.N. Threlkeld (1984). Stratigraphic significance of $^{13}C/^{12}C$ ratios in mid-Cretaceous rocks of the western interior, USA, *in* Scott, D.F. and D.J. Glass (eds.) *The Mesozoic of Middle North America*: Canadian Society Petroleum Geologists, Mem. 9, p. 305-312.

Pratt, L.M., R.E. Summons, and G.B. Hieshima (1991). Sterane and triterpane biomarkers in the Precambrian Nonesuch Formation, North American Midcontinent Rift. *Geochimica et Cosmochimica Acta*, **55**, p. 911-916.

Hieshima, G.B. and L.M. Pratt (1992). Sulfur/carbon ratios and extractable organic matter of the Middle Proterozoic Nonesuch Formation, North American Midcontinent Rift. *Precambrian Research*, **54**, p. 65-79.

Zaback, D.A. and L.M. Pratt (1992). Isotopic composition and speciation of sulfur in the Miocene Monterey Formation: Reevaluation of sulfur reactions during early diagenesis in marine environments. *Geochimica et Cosmochimica Acta*, **56**, p. 763-774.

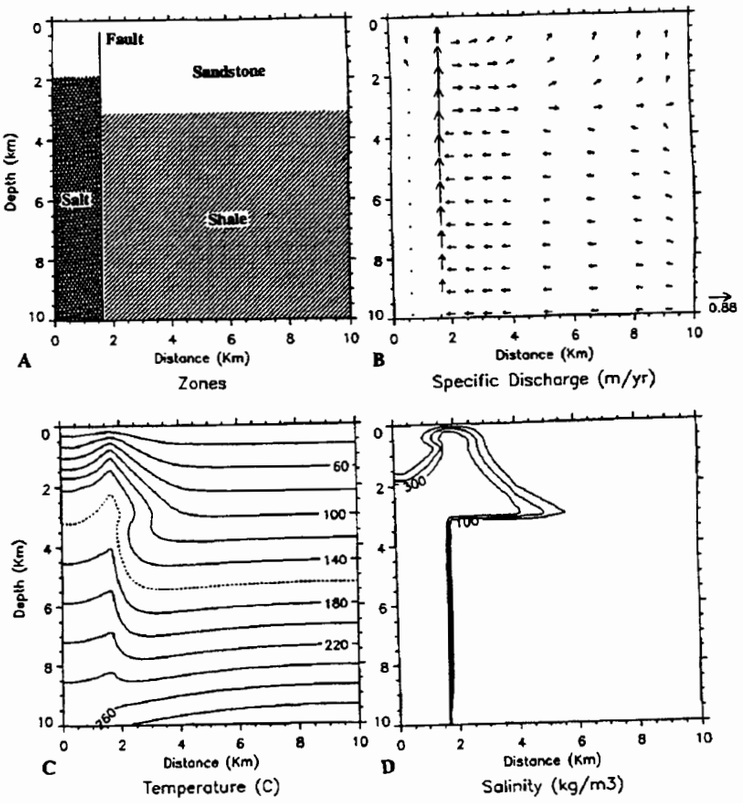
Zaback, D.A., Pratt, L.M., and Hayes, J.M. (in press). Transport and reduction of sulfate and immobilization of sulfide in marine black shales. *Geology*.

Vishnu Ranganathan — Hydrogeology and Aqueous Geochemistry, Basin Analysis

Assistant Professor, Geological Sciences; B.S. Bombay; M.S. Cincinnati; Ph.D. Louisiana State, 1988.

Recent research has centered on the dynamics of fluid-, mass-, and heat transport in sedimentary basins over time scales of 10,000 years to 100 Ma and distance scales of kilometers to hundreds of kilometers.

Ranganathan has just begun a project in which he is using a computer model to estimate the rates at which interstitial brines in intracratonic sedimentary basins such as the Illinois Basin are flushed out by recharging groundwaters. The study may help contrain field scale permeabilities of rocks in such basins. A second project he is working on entails mapping salinity plumes and thermal plumes of groundwaters around salt domes in the Gulf of Mexico Basin using geophysical well logs and using computer models of groundwater flow, coupled with heat and mass transport, to simulate the behavior of brine plumes under a variety of subsurface P-T-X conditions and permeability distributions. This research has been funded by grants from the National Science Foundation, the American Chemical Society, and by private industry.



Groundwater flow model coupled with energy and solute transport. A) Radial Symmetric model of a salt dome surrounded by a fault and thick section of geopressured, anisotropic shale. B) Fluid flow pattern after 20 thousand years (vectors are log scaled). C) Isotherms are perturbed by hot water flowing up the fault. D) Brine plume is created from halite dissolution as fluids flow up the flanks of the salt dome.

Representative Publications

Ranganathan, V., and J.S. Hanor (1989). Perched brine plumes above salt domes and dewatering of geopressured sediments, *Journal of Hydrology*, **110**, p. 63-86.

Ranganathan, V. (1991). Salt diffusion in interstitial waters and halite removal from sediments — examples from the Red Sea and Illinois Basins, *Geochimica et Cosmochimica Acta*, **55**, p. 1615-1625.

Ranganathan, V. (1992). Basin dewatering and formation of brine plumes near salt domes. *Journal of Geophysical Research.*, **97**, B4, p. 4667-4683.

Cassidy, D.P. and V. Ranganathan (1992). Groundwater upwelling near Bay St. Elaine Salt dome in South Louisiana, as inferred from fluid property variations. *American Association of Petroleum Geologists Bulletin*, **76**, p. 1550-1568.

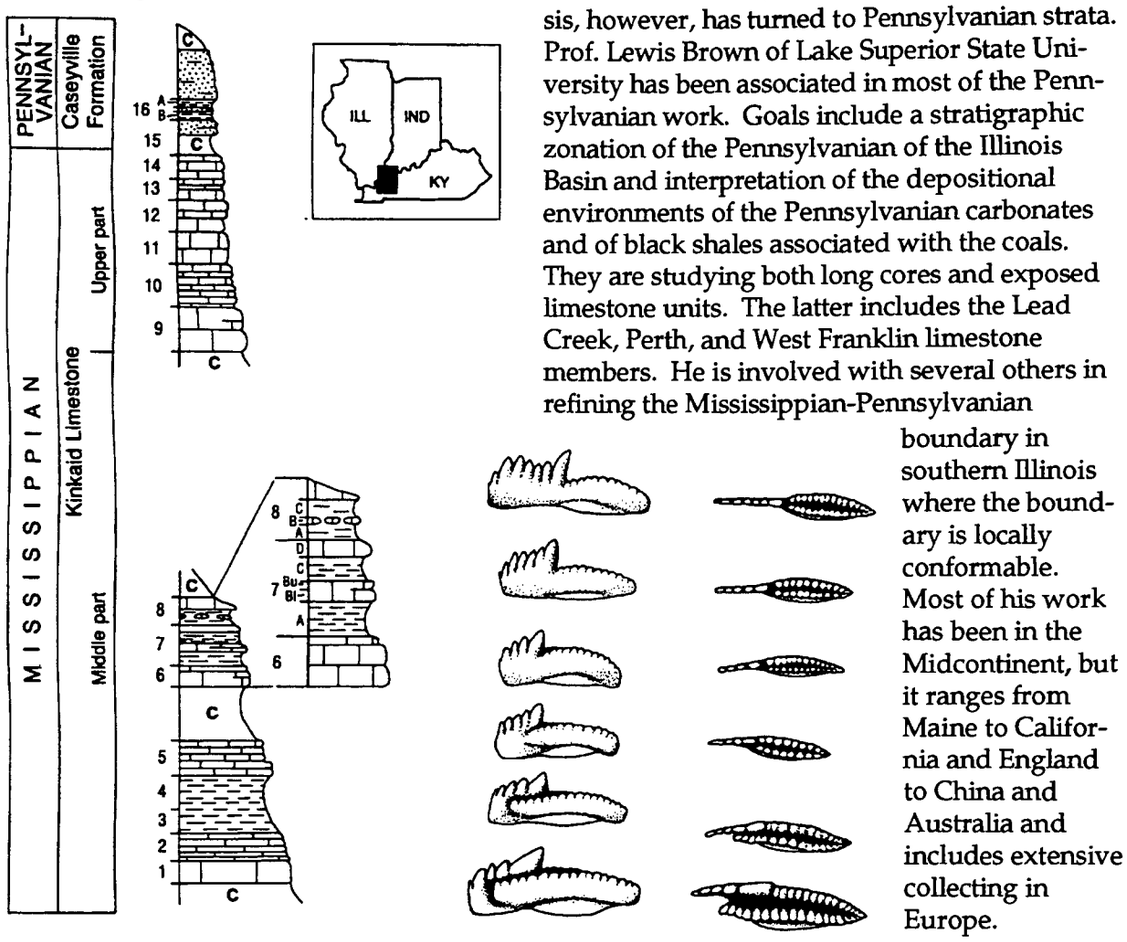
Ranganathan, V. (1992). Dissolved salt removal from Illinois Basin waters, in: Kharaka, Y.K. and Maest, A.S., (eds.), Water-Rock Interaction, Proceedings of the Seventh International Symposium on Water-Rock Interaction, Park City, Utah, July 13-18, 1992, **2**, p. 1051-1054.

Carl B. Rexroad

Geobiology and Paleontology

Senior Scientist, Indiana Geological Survey and Professor, part-time, Geological Sciences; B.A., M.S. Missouri; Ph.D. Iowa, 1955.

Conodont biostratigraphy and paleontology, including paleoecology, comprise Rexroad's primary interest. He has worked mostly with Mississippian and Silurian faunas and currently is completing a study of conodonts from the Reelsville Limestone (Chesterian). Recent emphasis, however, has turned to Pennsylvanian strata. Prof. Lewis Brown of Lake Superior State University has been associated in most of the Pennsylvanian work. Goals include a stratigraphic zonation of the Pennsylvanian of the Illinois Basin and interpretation of the depositional environments of the Pennsylvanian carbonates and of black shales associated with the coals. They are studying both long cores and exposed limestone units. The latter includes the Lead Creek, Perth, and West Franklin limestone members. He is involved with several others in refining the Mississippian-Pennsylvanian boundary in southern Illinois where the boundary is locally conformable. Most of his work has been in the Midcontinent, but it ranges from Maine to California and England to China and Australia and includes extensive collecting in Europe.



Left, columnar section showing general lithology, sample intervals, and stratigraphic terminology of the section collected at Buzzard Roost Bluff (inset). Right, schematic diagram showing the transition from Cavusgnathus unicornis, *the specimen at the bottom, to* C. monocerus, *the specimen at the top, through* C. tytthus *n. sp., the four intermediate specimens.*

Representative Publications

Rexroad, C.B., and A.S. Horowitz (1990). Conodont paleoecology and multielement associations of the Beaver Bend Limestone (Chesterian) in Indiana. *Courier Forschungsinstitut Senckenberg*, **118**, p. 493--537.

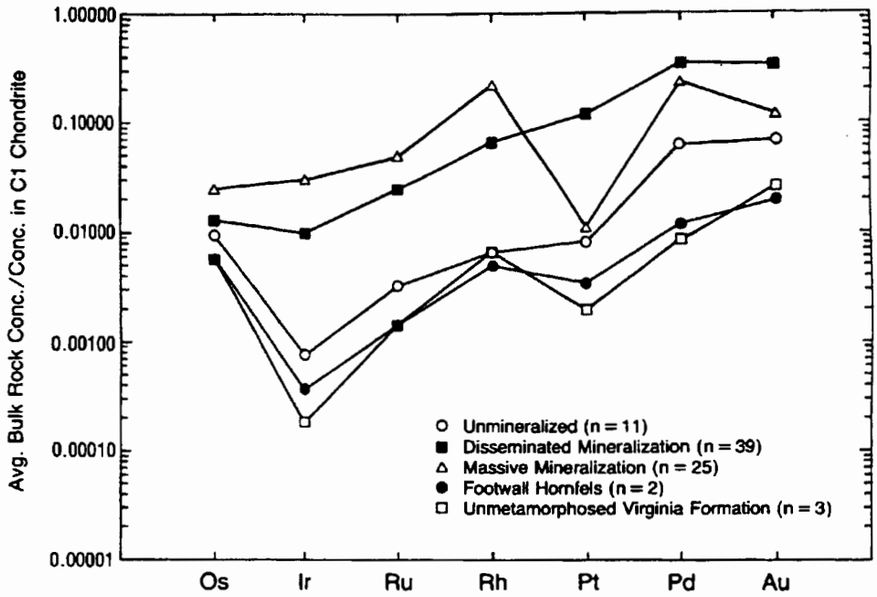
Rexroad, C.B., and W.J. Varker (1991). The new Mississippian conodont genus *Synclydognathus*. *Journal of Paleontology*, **66**, p. 945-957.

Rexroad, C.B. (1992). A summary of Chesterian conodonts in the Illinois Basin, *in* Horowitz, A.S., and J.R. Dodd, eds., *Chesterian sections (Late Mississippian) along Interstate 64 in southern Indiana.* Department of Geological Sciences, Indiana University, Bloomington, p. 25-35.

Edward M. Ripley **Petrology of Metallic Ore Deposits, Isotopic Geochemistry**

Professor, Geological Sciences; B.S. Illinois State, M.S. Minnesota, Ph.D. Penn State, 1976.

Ripley's research interests include the genesis of metallic ore deposits and the application of stable isotopic geochemistry to petrologic problems. Primary research goals center on the understanding of both igneous and hydrothermal processes that control the concentration of metals in a variety of geologic settings. Techniques employed in his research program include field mapping, transmitted and reflected light microscopy, fluid inclusion microthermometry, major and trace element analyses, stable isotopic measurements, a variety of microbeam analytical techniques, and thermodynamic/kinetic modeling. Examples of research currently in progress include studies of the genesis of copper, nickel and platinum group elements in mafic igneous rocks of the Duluth Complex and hydrothermal beryllium mineralization in rhyolitic volcanic rocks. Specific topics of concern include the relative roles of fractional crystallization and assimilation of country rocks in the formation of immiscible sulfide melt, the origin of hydrothermal fluids involved in the sub-solidus redistribution of platinum, palladium and gold, and both magmatic and meteoric waters in hydrothermal beryllium mineralization. Other work is on the controls of copper sulfide deposition in Permian red beds in Kansas.



Chondrite normalized diagram showing platinum-group element distribution of igneous and metasedimentary rocks at the Babbitt Cu-Ni deposit, Duluth Complex, Minnesota.

Representative Publications

Branam, T.D., and E.M. Ripley (1990). Genesis of sediment-hosted copper mineralization in south-central Kansas: I. S/C and sulfur isotopic relationships. *Econ. Geol.*, **85**, p. 601-622.

Lira, R. and E.M. Ripley (1990). Fluid inclusion studies of the Rodeo de los Molles REE and Th deposit, Las Chacras Batholith, Central Argentina. *Geochim. et Cosmochim. Acta*, **54**, p. 663-673.

Ripley, E.M. (1990). Platinum-group element geochemistry of Cu-Ni mineralization in the basal zone of the Babbitt deposit, Duluth Complex, Minnesota. *Econ. Geol.*, **85**, 830-842.

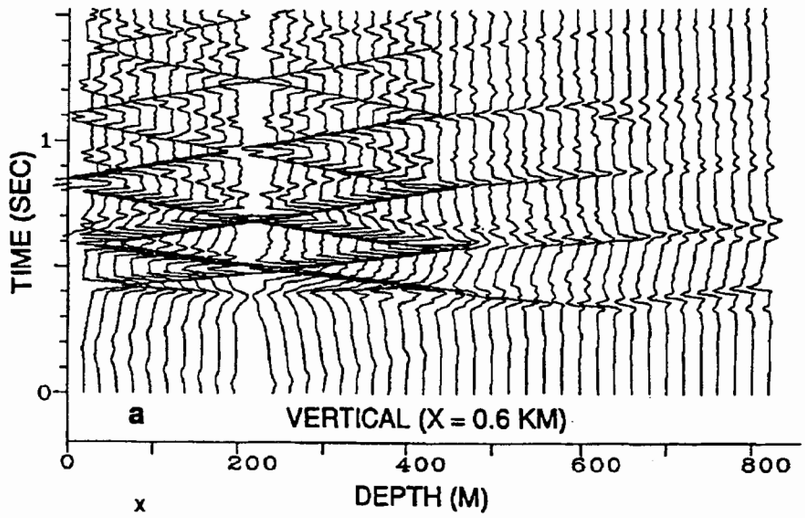
Ripley, E.M., N.R. Shaffer and M.S. Gilstrap (1990). Distribution and geochemical characteristics of metal enrichment in the New Albany Shale (Devonian-Mississippian), Indiana. *Econ. Geol.*, **85**, p. 1790-1808.

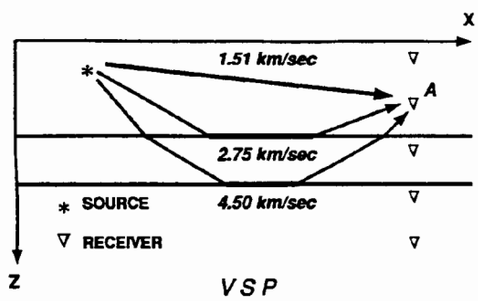
Albert Rudman

Geophysics

Professor, Geological Sciences; B.S., M.A., Ph.D. Indiana, 1963.

Rudman's research career has centered on computer applications in exploration geophysics. His work in potential fields includes analysis of gravity magnetic field data and heat flow modeling of magmatic processes in Hawaii. In addition, his recent work in seismic methods includes: (1) seismic array analysis of earthquake location errors in the New Madrid seismic zone, (2) inversion of potential field data, (3) time series analysis of travel time anomalies in Soviet Central Asia, (4) development of new codes for calculating synthetic seismograms based on collaborative work with Neil Frazer at Hawaii, and (5) application of neural networks for identification of first-breaks in seismic reflection data.





Above, a VSP test case with vertical seismograms at offsets of 0.6 km. Left, schematic of direct and refracted head wave paths from source to a common receiver, using the velocity model. (Rudman et al., in press)

Representative Publications

Rudman, Albert J., and David Epp (1983). Conduction models of the temperature distribution in the east rift zone of Kilauea Volcano, *Jour. of Volcanology and Geothermal Res.*, **16**, p. 189-203.

Sarwar, A.K.M., and Albert J. Rudman (1985). Inversion of a normally incident reflection seismogram by the Gopinath-Sondhi integral equation, *Geophys. Journ. Roy. Astro. Soc.*, **81**, p. 551-562.

Frazer, L. Neil, and Albert J. Rudman (1988). Seismic modeling in the Tau-p Domain, Indiana Geological Survey Occasional Paper 54, Geophysical Computer Program Series 12.

Murat, Michael M., and Albert J. Rudman (1992). Automated first annual picking: A neural network approach: *Geophys. Prospecting*, **40, (6)**, p. 587-604.

Bear, G.W., Al-Shukri, H.J. and Albert J. Rudman (1992). Three-dimensional linear gravity inversion using an iterative stochastic least squares method, EOS, *Trans. Am. Geophys. Union*, **73**, p. 82.

Rudman, Albert J. and others (in press). Workstation computation of synthetic seismograms for vertical and horizontal profiles: A full wavefield response for a two-dimensional layered half-space: *Computer & Geosciences*, **19, (3)**.

Michael Savarese

Geobiology and Paleontology

Assistant Professor, Geological Sciences; B.S., M.S., Rochester; Ph.D. California/Davis, 1989.

Savarese's primary research effort over the last few years has been directed to the interpretation of the paleobiology of an enigmatic group of fossils, the Archaeocyatha. Archaeocyathans were the most abundant constituent of the Early Cambrian fauna and were principal reef framebuilders. Despite this, many fundamental paleobiological questions have remained unanswered. By incorporating evidence from functional morphology, comparison with modern analogs, stratigraphic and paleoecological analyses, and cladistic studies, he has corroborated a hypothesis of sponge affinity for archaeocyathans and has shown that their skeletons were capable of generating flows needed for suspension feeding. A better understanding of the tempo and mode of the metazoan radiation at the base of the Phanerozoic requires that the temporal and geographic distribution of taxa be well documented. The paleoecology of Early Cambrian bioherms is still relatively unstudied. The Flinders Ranges of South Australia contain well preserved archaeocyathan bioherms and are ideal for such a study. A project to work on these bioherms, funded by the Petroleum Research Fund, commenced with a field expedition in August, 1992. This work should continue for the next two to three years.

Functional Morphology and Ecology of Modern Reef Sponges: If archaeocyathans were indeed sponges, the functional morphology and ecology of living sponges in modern reef environments should be instructive. The biomechanics of fluid flow through tropical demosponges and the effects gross morphology and ontogenetic variability have on those flows are presently being studied in situ on reefs in the Florida Keys and Jamaica.

Biomechanics of Benthic Marine Invertebrates: A second aspect of Savarese's research considers the effects morphology of free-lying benthic organisms has on fluid-induced forces and substrate stability, and the effects morphology has on taphonomic processes. Marine life in the Paleozoic was dominated by epifaunal, soft substrate animals. Many of these, namely brachiopods and rugose corals, possessed no means of attachment, and, therefore, were susceptible to disturbance caused by currents. These flow-induced forces are partly a function of organism size, shape, and orientation. Consequently, morphology and behavior may have an adaptive significance to these epifaunal animals. Finally, these forces may operate during the life of an animal or after its death. Taphonomic and functional hypotheses are being tested experimentally in a flume, designed and built in the Department, and in the image analysis laboratory. This facility is designed for the study of boundary layer phenomena and for measurement of forces benthic organisms experience. In addition, field based paleoecologic studies are being conducted to corroborate results from biomechanical experimentation.

Representative Publications

Savarese M. and P.W. Signor (1989). New occurrences of archaeocyathans in the upper Harkless Formation of Esmeralda County, Nevada, and their paleoecological significance. *Journal of Paleontology*, **63**, p. 539-549.

Savarese, M. (1991). Effects of moving fluid on the paleobiology of Paleozoic bottom-dwelling, marine animals. *Geological Society of America Abstracts with Programs* **23 (3)**, p. 15.

Savarese, M. (1992). Functional analysis of archaeocyathan skeletal morphology and its paleobiologic implications. *Paleobiology*, **18 (4)**, p. 464-480.

Savarese, M. (in review). A cladistic analysis of archaeocyathan phylogenetic affinities. *Journal of Paleontology*.

Savarese, M. (in review). Taphonomic and paleoecologic implications of flow-induced forces on concavo-convex brachiopods: An experimental approach. *Palaios*.

Robert H. Shaver

Paleobiology and Stratigraphy

Professor (ret.), Geological Sciences, B.S., M.S., Ph.D., Illinois, 1951.

Shaver's research interests have focussed mostly in three areas: in earlier years, especially in Carboniferous biostratigraphy and ostracod paleontology; in later years, in midwestern Siluro-Devonian stratigraphy, Illinois Basin to Michigan Basin, and in Silurian carbonate sedimentation and reef paleoecology of the same area. Some of this work has been applied to the current debates on the relative efficacy of eustasy and tectonism to account for third-order cyclical deposition in Silurian carbonate rocks. Another impact has been toward a revolution of thought on the relationship between evaporite- and reef-bearing Silurian rocks in the Midwest.

Three current projects are:

(a) Sedimentological, paleoecological, and tectono-eustatic events across the Wenlockian-Ludlovian (Silurian) boundary, midwestern craton, U.S.A. This work has been requested from two sources, the Estonian Institute of Geology for the Estonian Academy of Science *Proceedings* and the Subcommission on Silurian Stratigraphy of the International Union of Geological Sciences (for IGCP project 216, publication managed by Otto Walliser, Germany).

(b) Book for popular consumption on the geology of Indiana, requested by the Indiana Geological Survey.

(c) Symposium paper on Silurian sequence stratigraphy in the craton, midwestern U.S.A. and southwestern Ontario, requested by scientists at the Iowa Geological Survey for their forthcoming volume on *Paleozoic Sequence Stratigraphy: North American Perspectives*, to be published by the Geological Society of America.

Representative Publications

Shaver, R.H. (1984). Atokan Series Concepts with Special Reference to the Illinois Basin and Iowa, in Sutherland, P.K., and Manger, Walter, editors, The Atokan Series and Its Boundaries: *Oklahoma Geological Survey Bulletin*, **136**, p. 101-113.

Shaver, R.H. (senior author), and 30 others (1985). Midwestern Basins and Arches Region, in Lindberg, F.A., editor, Correlation of Stratigraphic Units of North America (COSUNA) Project: Tulsa, Oklahoma, *American Association of Petroleum Geologists COSUNA Chart MBA*.

Droste, J.B., and R.H. Shaver (1987). Paleoceanography of Silurian Seaways in the Midwestern Basins and Arches Region: *Paleoceanography*, **2**, p. 213-227.

Droste, J.B., and R.H. Shaver (1987). Upper Silurian and Lower Devonian Stratigraphy of the Central Illinois Basin: *Indiana Geological Survey Special Report*, **39**, 29p.

Shaver, R.H., and J.A. Sundeman (1989). Silurian Seascapes: Water Depth, Clinothems, Reef Geometry, and Other Motifs — A Critical Review of the Silurian Reef Model: *Geological Society of America Bulletin*, **101**, p. 939-951.

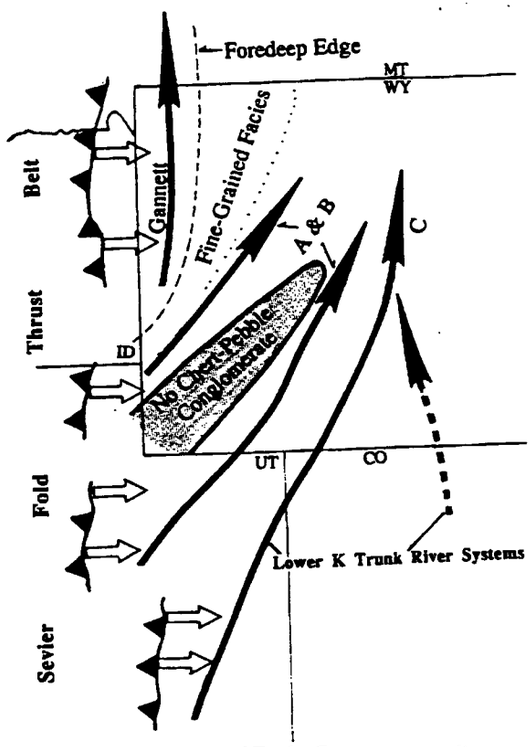
Shaver, R.H. (1991). A History of Study of Silurian Reefs in the Michigan Basin Environs, in Catacosinos, P.A., and Daniels, P.A., Jr., editors, Early Sedimentary Evolution of the Michigan Basin: *Geological Society of America Special Paper*, **256**, p. 101-138.

Lee J. Suttner

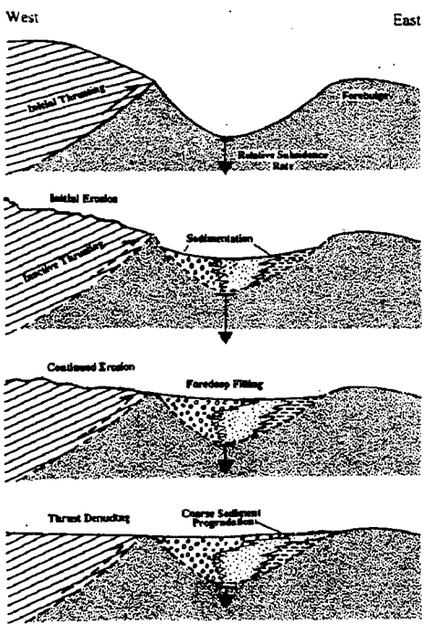
Sedimentary Petrology, Basin Analysis, Sedimentology

Professor and Chairman, Geological Sciences; B.S. Notre Dame; M.S., Ph.D. Wisconsin, 1966.

Lee J. Suttner's research centers on field-based studies of Cretaceous fluvial systems in the Rocky Mountain foreland basin of Colorado, Wyoming, and Montana. Traditional models of foreland-basin evolution emphasize the importance of fold-thrust belt tectonics along the basin margin in controlling stratigraphic patterns within the basin. Suttner's work elucidates the role of intra-basin lithosphere deformation, in all probability forced by plate-margin tectonic events, in influencing the location, morphology, and direction of flow of river systems and their associated deposits within the foreland basin. Currently, field work is taking place in the northeast Powder River Basin and around the Flanks of the Black Hills uplift. This area is of special interest because it is one of a rare number of sites where it is possible to study the complex interrelations in a foreland basin between rivers which flowed off the craton and those that originated in the fold-thrust belt. Deciphering age relations among the major river systems is an important part of the study because it is crucial to understanding both the mechanisms and rates of migrations of the systems. These age relations are being established through a combination of magnetrostratigraphy, fission track dating and subsurface correlation, the latter made possible with the Department's library of geophysical logs. A number of faculty from other institutions are involved in this study including Gary Johnson at Dartmouth University (paleomagnetic and fission-track stratigraphy), Peter DeCelles at Rochester University (Jurassic/Cretaceous fluvial-systems analysis in the Wyoming-Idaho thrust belt), James Schmitt at Montana

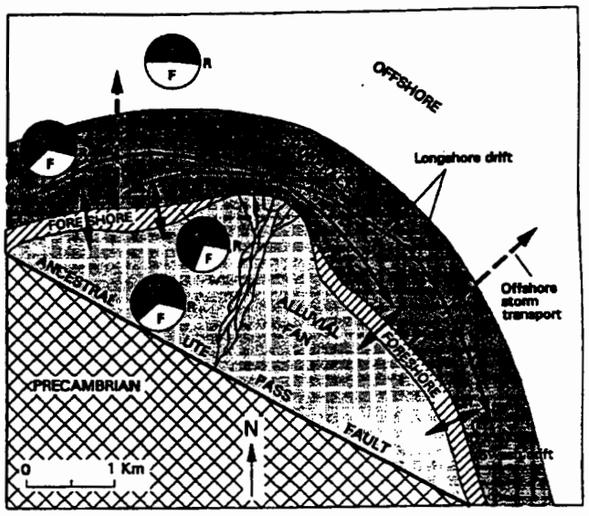


Arrows represent patterns of Early Cretaceous sediment dispersal in the Rocky Mountain foreland basin. Trunk river systems were confined within graben-like structures caused by intra-basin lithosphere deformation. River system C formed approximately 10 million years after systems A&B, perhaps in response to a later tectonic event in the Sevier fold-thrust belt.



Schematic cross-sections illustrating the temporal and spatial association among foreland-basin margin thrusting, erosion, and basin filling.

State University (Cretaceous fluvial-systems analysis in outcrop belts along the flanks of the Bighorn Mountains), and James Meyers at Winona State University (Jurassic Cretaceous non-marine facies analysis in Montana). This work is being supported by grants from NSF.



Schematic representation of processes affecting sandstone composition in the Fountain Formation. Pie diagrams illustrate variation in composition as a function of environment. Sediment was derived from a Precambrian source terrane located southwest of the ancestral Ute Pass Fault and transported northeastward across a broad fan or alluvial plain. Sand initially bypassed the foreshore enroute to a shoreface zone. Later it was reworked by swash processes in the foreshore. Feldspar, winnowed from foreshore sand, was transported into the offshore/ transitional environment during storms. These processes enriched the foreshore sand in quartz and the offshore/ transition sand in feldspar.

Suttner's other research centers in sandstone petrology. The composition of sandstone is a response to a complex interplay of variables related to its derivational, transportational, depositional and diagenetic history. Suttner is currently attempting to isolate and evaluate the role and relative importance of just one of the variables, depositional process, in affecting the framework and authigenic composition of sandstone. To do so, his research group is conducting comparative studies of facies-controlled differences in composition of first-cycle detritus within both river and wave-dominated coarse-grained deltas of Pennsylvanian age in Colorado. Standard petrographic, chemical and x-ray analysis is supplemented with SEM, electron microprobe, and isotopic study of selected components. This work is significant in that it permits them to (1) characterize the extent of compositional modification due to mechanical disaggregation and hydrodynamic sorting in high relief settings characterized by high rates of sedimentation and rapid burial, and (2) document how sandstone maturation varies as a function of different energy regimes associated with wave and river-dominated shoreline settings. This work is being jointly conducted with Prodip Dutta at Indiana State University and Suzanne Kairo, Exxon Production Research. Funding from PRF-ACS has supported this work.

Representative Publications

May, M., L.J. Suttner and E.P. Kvale (1990). Evidence of complex age relations and dispersal patterns in lower Cretaceous conglomerates, Wind River Basin, Wyoming: *Geol. Soc. Amer. Abst. with Programs*, **22**, p. 322.

Malone, A. and L.J. Suttner (1992). Evidence against recurrent movement along the Willow Creek fault zone during deposition of the Morrison Formation (Jurassic), Northern Tobacco Root Mountains, Montana: *Rocky Mountain Geologist*, **28**, p. 47-64.

May, M.T., L.C. Furer, J.H. Meyers, L. J. Suttner, E.P. Kvale, and P.G. DeCelles (1992). Complexities in Fluvial stratigraphic sequences in medial to distal portions of a developing foreland basin: An example from the Lower Cretaceous of Wyoming and Montana: *Absts. with Program; Am. Association of Petroleum Geologists Annual Meeting (Calgary)*, p. 84.

May, M.T., L.J. Suttner, L.C. Furer and J.H. Meyers (1992). Early Cretaceous basin partioning — fact or fiction? — Evidence from the Wind River Basin, Wyoming: Soc. of Sedimentary Geology theme meeting — Mesozoic of the Western Interior (Fort Collins); Absts. with Program, p. 46.

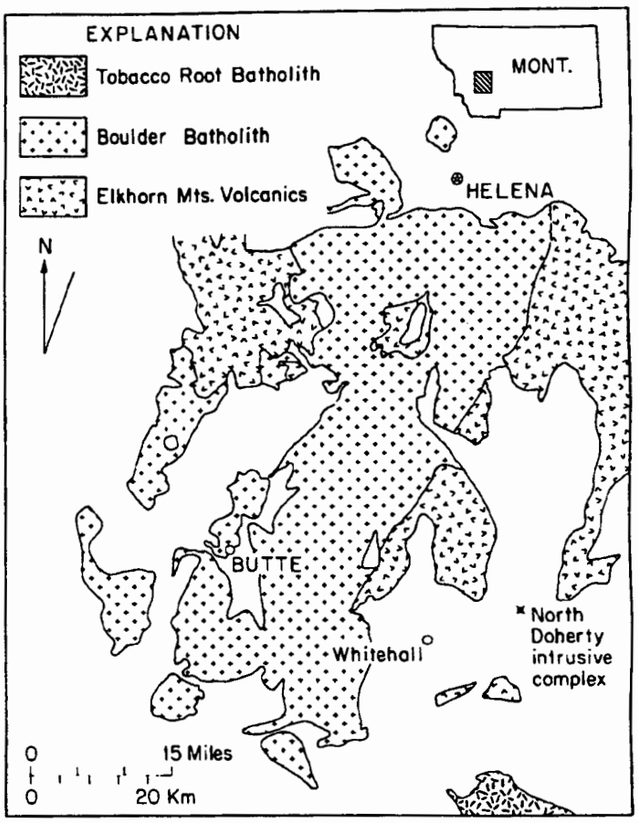
Meyers, J.H., L.J. Suttner, L.C. Furer, and M.T. May (in press). Intra-basin tectonic control of fluvial sandstone bodies in The Cloverly Formation (Early Cretaceous), west-central Wyoming, U.S.A., *Basin Research*.

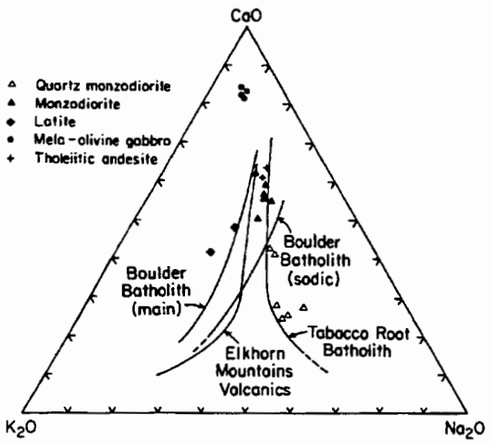
David G. Towell

Trace-Element and Isotope Geochemistry

Associate Professor, Geological Sciences; B.S. Penn State; Ph.D. M.I.T., 1963.

Towell's major research goals and interests lie in the application of geochemical techniques to the solution of petrologic problems. The primary focus of his work is on plutonic and volcanic igneous rocks but also includes metamorphic and sedimentary rocks as well. The principal aspect of his research is the application of major and trace element geochemistry to modeling magmatic differentiation processes (*e. g.*, partial melting, fractional crystallization, magma mixing, *etc.*) Field mapping and sample collection (right) are combined with extensive chemical (below) and mineralogical analysis including petrography, inductively coupled plasma emission spectroscopy and electron microprobe analysis. Specific investigations have included studies in the Boulder and Tobacco Root batholiths, the North Doherty Intrusive Complex, and the Elkhorn Mountains Volcanic Series, all located in southwest Montana. Attempts are also being made to relate these intrusive and extrusive bodies on a regional basis in terms of both igneous and tectonic history.





Representative Publications

Vitaliano, C. J., S. Kish and D. G. Towell (1980). Potassium-argon dates and strontium isotopic values for rocks of the Tobacco Root batholith, Southwestern Montana. *Isochron West*, **28**, p. 13-15.

Bean, C. L. and D. G. Towell (1981). A geochemical study of the North Doherty Intrusive complex, Jefferson County, Montana. *Geol Soc Amer Abstr w Prog*, **13**, p. 190.

Towell, D. G. and C. G. Vitaliano (1983). Late Cretaceous volcanic and intrusive rocks near the eastern margins of the Boulder and Tobacco Root batholiths. *Montana State University Department of Earth Sciences Publication*, **10**, 28p.

Charles J. Vitaliano

Petrology and Petrography

Professor (ret.), Geological Sciences; B.S., College of the City of New York, M.A., Ph.D. Columbia University, 1944.

Research has focussed mainly on Economic Geology of non metallic minerals; field mapping and petrology of igneous, volcanic and metamorphic rocks. Currently Vitaliano is involved in the study of petrography of archaeological artifacts. Previous and current projects include:

(a) Magnesium-bearing deposits of Nevada, Utah and California,
(b) Low-grade metamorphic rocks of New Zealand,
(c) High-grade Precambrian Metamorphic rocks in Montana, U.S.A.
(d) volcanic rocks of Nevada and Santorini, Greece, and
(e) Petrography of artifacts from Israel, Greece, the Mississippi Valley and the Eastern Mediterranean.

Representative Publications

Vitaliano, C.J. and Brian H. Mason (1953). The mineralogy of the antimony oxides and antimonates. *Min. Mag.*, **30**, p. 100-112.

Vitaliano, C.J. and R.D. Harvey (1964). Wallrock alteration in the Goldfield District, Nevada. *Jour. of Geol.*, **72**, p. 564-579.

Vitaliano, C.J. and J.H. Cleveland (1966). Magnesium mineralization, Gabbs, Nevada, Symposium on the geology of cement raw materials, 2nd forum on Geology of Industrial Materials. *Acta*, Bloomington, Ind.

Vitaliano, C.J. (1968). Petrology and structure of south-eastern Malborough Sounds, New Zealand. *New Zealand Geol. Survey Bull.*, **74**, 40p.

Vitaliano, C.J. and D.B. Vitaliano (1971). Plinian eruptions, earthquakes, and Santorini — a review: *Acta of the First International Scientific Congress on the Volcano of Thera, Greece*, 15-23 September 1969, p. 88-108.

Vitaliano, C.J. and D.B. Vitaliano (1974). Santorini tephra on Crete, *Amer. Jour. Archeology*, **78 (1)**, p. 9-13.

Vitaliano, C.J. and D.B. Vitaliano (1978). Tephrochronological evidence for the time of the Bronze Age eruption of Thera; *Acta of the 2nd International Scientific Conference*: Thera and the Aegean World I.

Vitaliano, C.J., J. Wooden, S.W. Koehler, and P.C. Ragland (1978). The late Precambrian mafic dikes of the southern Tobacco Root Mountains, Montana: Geochemistry, Rb/Sr geochronology, and relationship to belt tectonics. *Canadian Jour. of Earth Sciences*, **15 (4)**, p. 467-479.

Jeffrey R. White — Aquatic Chemistry, Biogeochemistry, Limnology

Associate Professor, Geological Sciences; B.A. Gettysburg College, M.S. Rutgers University, Ph.D., Syracuse University, 1984.

White and his group are interested in processes controlling the cycling of elements in aquatic and terrestrial systems and in the potential impact of human activity on element cycles. They study cycling of elements at sediment/water interfaces in fresh water systems and within soils of agricultural systems. They also contribute to interdisciplinary research on changes in the biology and chemistry of lake/watershed systems.

Increased deposition of atmospheric sulfate is affecting the cycling of sulfur, iron, manganese, and carbon in lake ecosystems of northeastern North America. They have been investigating these effects by measuring chemical changes over short distances (1 cm) at the sediment/water interface of acidic lakes in the Adirondack Mountain region of New York State. Evidence of changes in element cycling is drawn from chemical diffusion gradients, chemical mass balances, sediment geochemistry, and stable isotopic analyses. White's group have accumulated evidence of profound changes in the importance of sulfate reduction – and, thus, the cycling of carbon – in remote lakes, and have found that the cycling of trace metals has also been altered.

Additionally, they have begun work on methane cycling in wetlands. Freshwater wetland environments are particularly conducive to methanogenesis because they are often rich in organic matter and depleted in O_2 and sulfate. On a molar basis, each increment of CH_4 emitted to the atmosphere is 25-fold more efficient at energy retention than are corresponding additions of CO_2. With atmospheric methane concentrations increasing at a rate of 1% per year, the role of methane as a greenhouse gas is of major concern. To improve understanding of natural sources of atmospheric methane, they are currently investigating a number of wetland types. The role of local climate (temperature, insolation, and water level) in controlling methane budgets is being studied using chemical mass balances, stable isotopic analyses, isolation of specific bacterial populations, and continuous records of climatic variables. They aim to develop mechanistic models that will describe methane cycling in detail and which will allow prediction of responses of natural rates of methane production to climatic change.

Other areas of research include: the development of stable isotopes of nitrogen as a "fingerprinting" tool to identify the sources of ammonia and nitrate in surface water; improvement of sampling and analysis techniques for trace metals in gravel sediments; and development of new isolation techniques for microbial communities inhabiting wetland sediments.

Representative Publications

White, J.R., and C.T. Driscoll (1987). Manganese Cycling in an Acidic Adirondack Lake, *Biogeochemistry*, **3**, p. 87-103.

White, J.R., C.P. Gubala, B. Fry, J. Owen and M.J. Mitchell (1989). Sediment biogeochemistry of iron and sulfur in an acidic lake, *Geochimica et Cosmochimia Acta*, **53**, p. 2547-2559.

Charles, D., J. White, D. and 11 others (1990). Paleoecological Investigation of Recent Lake Acidification in the Adirondack Mountains, N.Y., *Journal of Paleolimnology*, **3**, p. 195-241.

Gubala, C.P., D.R. Engstrom, and J.R. White (1990). Effects of Iron Cycling on 210Pb Dating of Sediments in an Adirondack Lake, U.S.A. *Can. J. Fish. Aquat. Sci.*, **47**, p. 1821-1829.

Shannon, R.D. and J.R. White (1991). The Selectivity of a Sequential Extraction Procedure for Iron Oxyhydroxide and Sulfides in Freshwater Sediments. *Biogeochemistry*, **14**, p. 193-208.

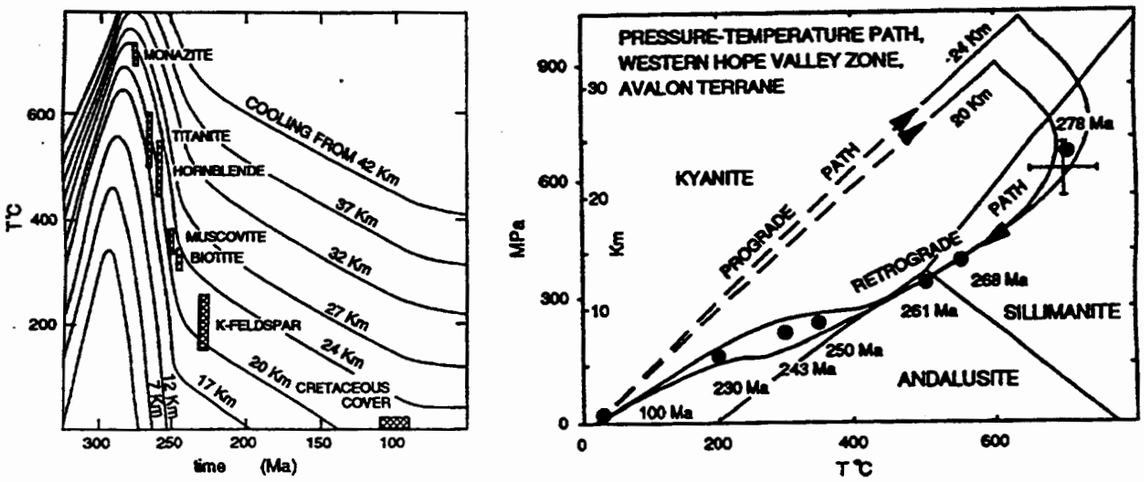
Robert P. Wintsch

Metamorphic and Sedimentary Petrology, Structural Geology, Tectonics

Associate Professor, Geological Sciences; B.A. Beloit; Ph.D. Brown, 1975.

Wintsch's research interests span several aspects of metamorphic geology, from low grade rocks and diagenesis to high grade rocks and partial melting. Much of the research is focused on identifying the relationships between deformation and petrology, from the grain scale and pressure solution, to the plate scale at convergent plate margins.

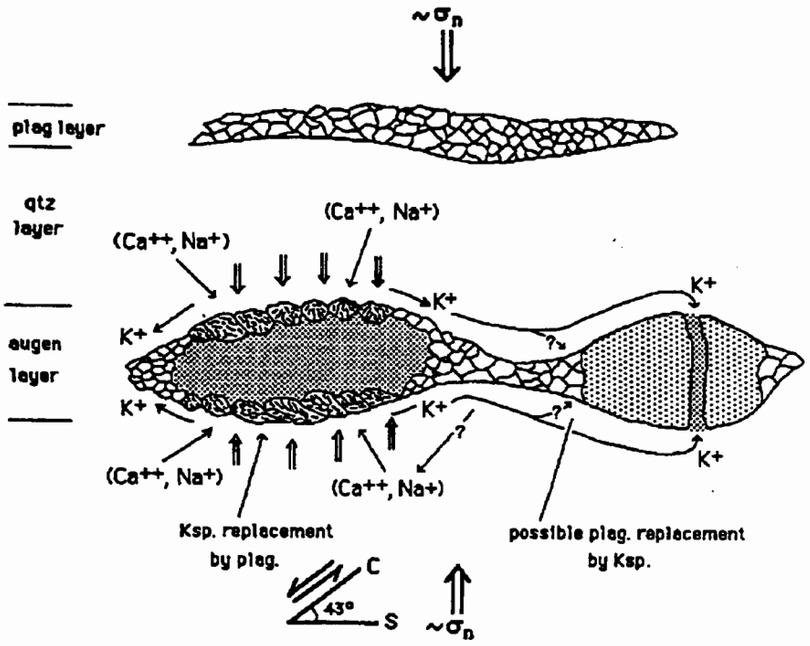
Pressure-Temperature-Time Paths and Terrane Analysis: Much of Wintsch's recent work is directed toward integrating thermal histories into metamorphic petrology and structural petrology. The ultimate goal of this work is to unravel the history of exotic terrane accretion in ancient mountain belts. The work uses mineral 'thermochronometers' to date the temperature and define cooling histories, and in some rocks establish the degree of heating when the age of a relic mineral is not reset by the metamorphism. The results lead directly to identifying whether terranes have been assembled before, during, or after peak regional metamorphism, and help in the commonly difficult identification of high grade, ductile fault zones at terrane boundaries. This work has been focused in Paleozoic rocks of the northern and central Appalachians, but we are planning to expand this work to more modern mountain belts.



Pressure-temperature (time) and temperature-time (pressure [depth]) paths for the Avalon terrane southeastern New England. (from Wintsch et al., 1992)

Low Grade Rocks and Slaty Cleavage: Wintsch is working on low grade rocks with the goal of identifying the reactions that occur during diagenesis, and determining if these reactions occur in environments closed or open on the scale of a hand specimen. The degree of openness is being inferred through determining whether the progress of these reactions correlates with changes in the bulk composition of the whole rock. A related study is looking at the mudstone to slate transition, to determine of pressure solution of mudstones could release, or "mobilize" major components for recycling in the upper crust. Collaborative work on fission track ages in apatite and zircon helps to inductively reconstruct the loading and unloading history of sedimentary basins.

Mylonites and Fault Rocks: Wintsch is exploring the relationships among chemical and mechanical processes in metamorphism, and especially in fault zones, where mechanical processes are relatively important. Chemical processes turn out to have a relatively large role in the evolution of fault rocks, from pressure solution-like dissolution/precipitation reactions in a near closed system, to reaction softening and reaction hardening in relatively open systems. He has identified ductile processes in very shallow fault zones where brittle deformation is expected, and evidence for brittle (seismic?) deformation is rocks as high grade as the sillimanite zone, where ductile deformation is expected. Wintsch has been working on fault rocks from the Moine thrust, Scotland, Insubric line southern Swiss Alps, and the northern and central Appalachians.



Model for the development of myrmekite in high-grade fault rocks. (from Simpson and Wintsch, 1989)

Representative Publications

Wintsch, R.P., and M.S. Andrews (1988). Deformation induced growth of sillimanite: "Stress" mineral revisited. *J. of Geology*, **96**, p. 143-161.

Simpson, C. and Wintsch, R.P., 1989, Evidence for deformation- induced K-feldspar replacement by myrmekite: *J. Metamorphic Geol.* **7**, p. 261-275.

Dipple, G.M., R.P. Wintsch, and M.S. Andrews (1990). Identification of the scales of differential element mobility in a ductile fault zone through multi-sample mass balance. *J. Meta. Geology*, **8**, p. 645-661.

Wintsch, R.P., M.S. Andrews and C. Ambers (1990). The case for thrust napping and against fold napping in the Avalon terrane of southeastern Connecticut: *in* Socci, A.D., Skehan, S. J., J.W., and Smith, G.W., eds., Geology of the composite Avalon terrane of southern New England. *Geol. Soc. America, Spec. Paper* **245**, p. 209-233.

Wintsch, R.P., C.M. Kvale, and H.J. Kisch (1991). Open system, constant volume development of slaty cleavage, and strain induced replacement reactions in the Martinsburg Formation, Lehigh Gap, PA. *Geological Soc. Am. Bull.*, **103**, p. 916-927.

Wintsch, R.P., J.F. Sutter, M.J. Kunk, J.N. Aleinikoff, M.J. Dorais (1992). Contrasting P-T-t paths: Thermochronologic evidence for a Late Paleozoic final accretion of the Avalon terrane in the New England Appalachians. *Tectonics*, **11**, p. 672-689.