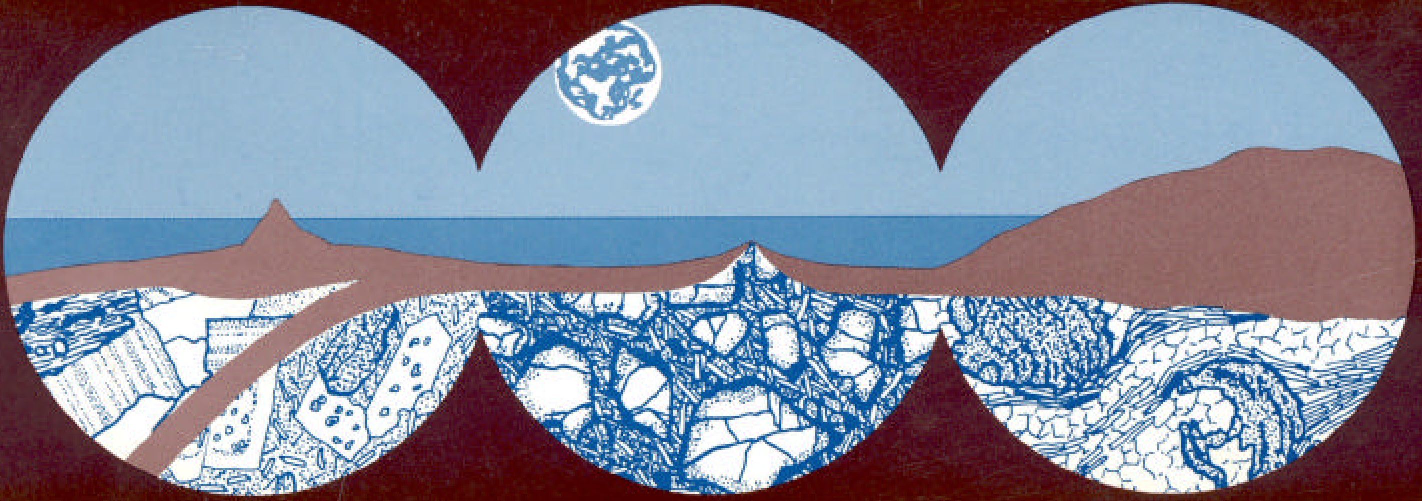
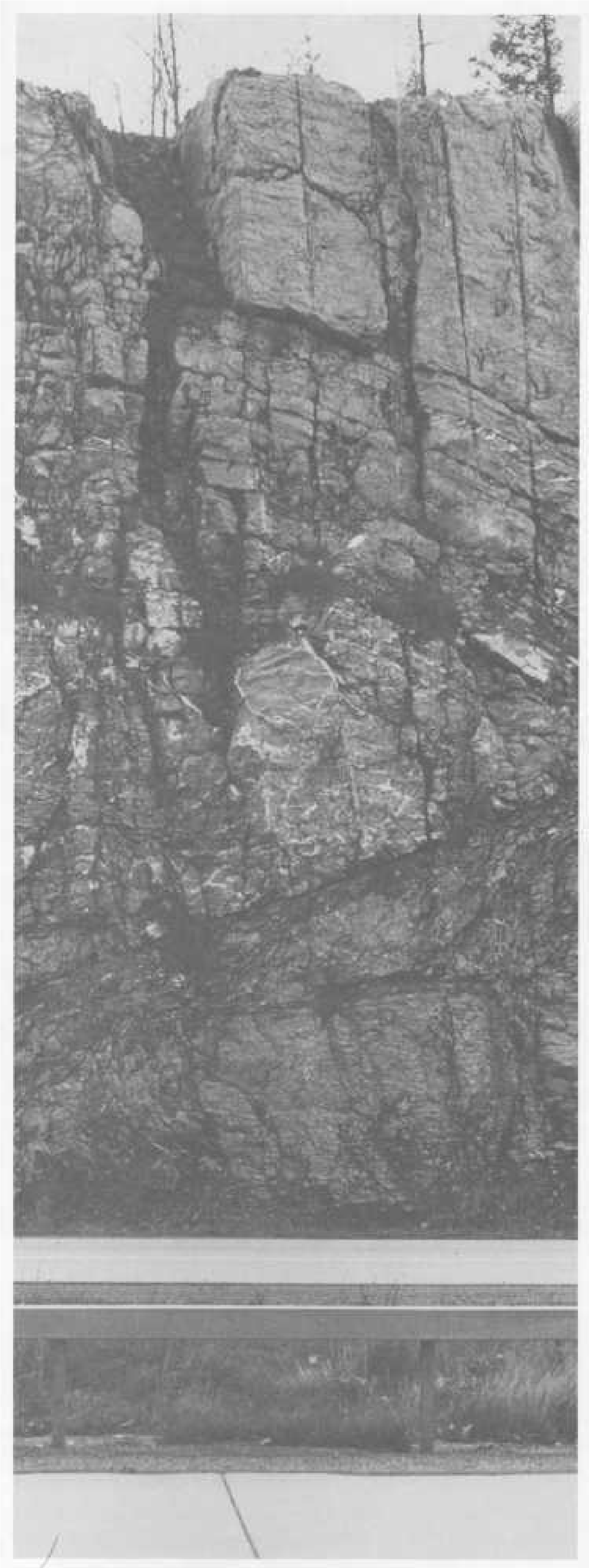


## Graduate Programs in

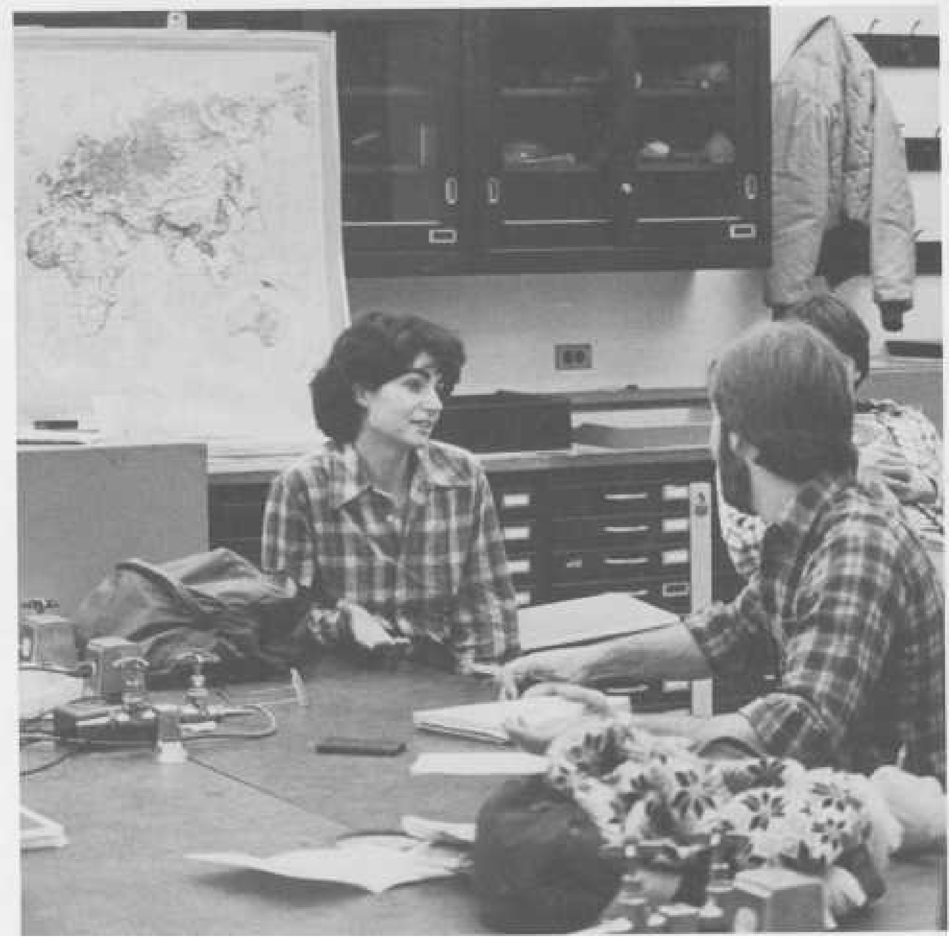
# Geological Sciences

## State University of New York at Albany



# Contents

# The Department



During the 1970s faculty in this department played an important role in developing the geological corollaries of plate tectonic theory. Their contributions in this area have earned an excellent international reputation one unusual for a department so small. As a graduate student here, you will have the chance to join this small but influential group of scholars in exploring a variety of exciting research frontiers.

While tectonics is still a department specialty, we currently offer four areas of equal emphasis tectonics, structural geology, petrology, and geochemistry in programs leading either to the Doctor of Philosophy or the Master of Science. In general, about half our 30 students are enrolled in the Ph.D. program.

Graduate study here is comfortable. You'll have the chance to develop close working relationships with faculty in a pleasant, informal atmosphere. Student participation in research usually begins immediately on entering graduate study. At the same time you'll share the excellent resources and facilities of a large university. You'll also benefit from the fact that faculty research projects are well funded, supported by federal grants from the National Science Foundation, the Department of Energy, and the National Aeronautics and Space Administration, as well as by funds from industrial, private, and University sources.

In short, we offer you the opportunity to work closely with a select group of scientists in a well-equipped, well-funded, and attractive setting. We hope this book, particularly the section in which faculty members describe their research, will help you to decide whether the Department of Geological Sciences at State University of New York at Albany is the right place for you.

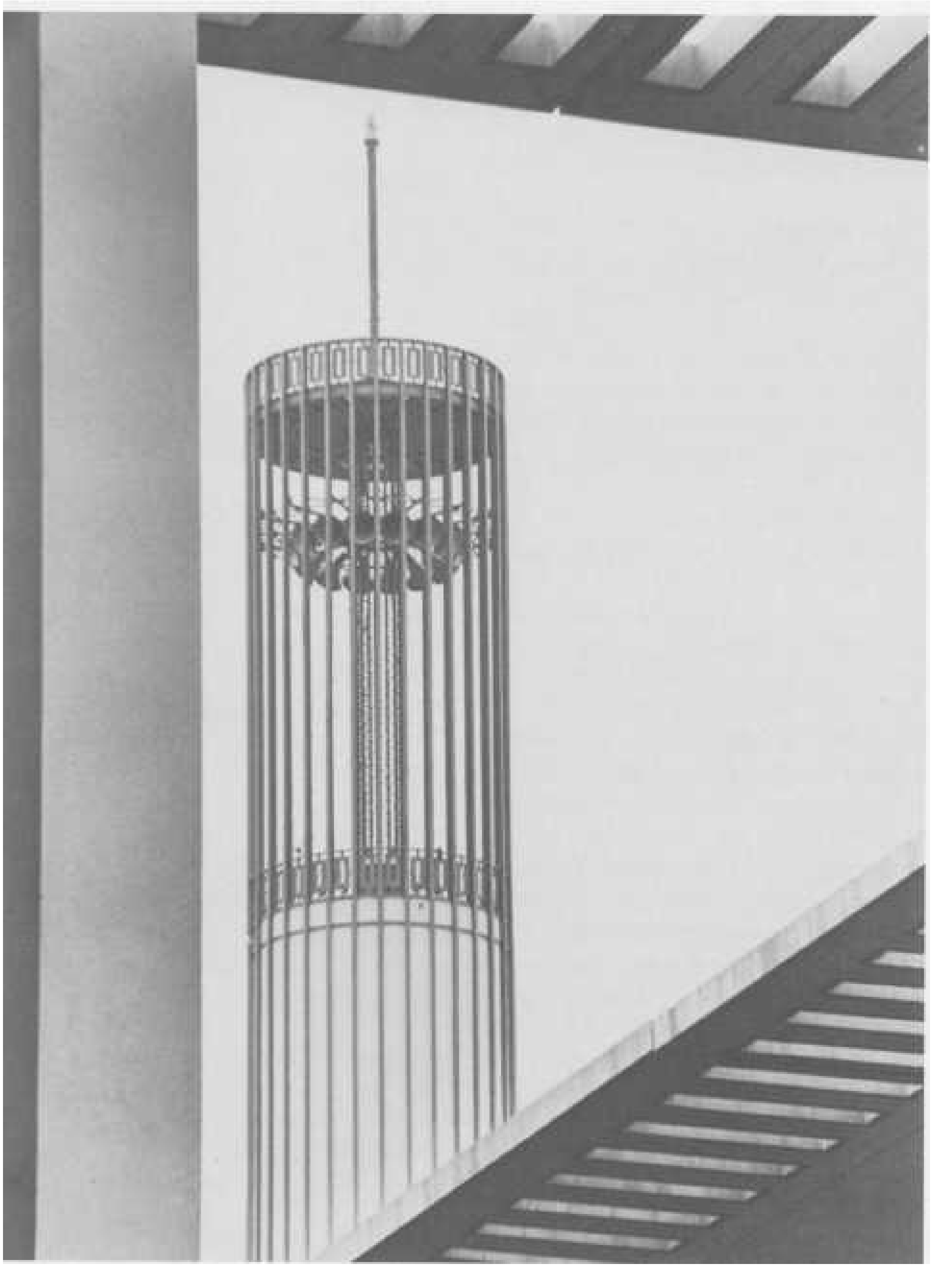
Stephen E. DeLong, Chairman

# The University

State University of New York at Albany is the senior campus of the largest centrally managed system of public higher education in the nation.

Founded in 1844, it is one of four university centers in the New York State system. The main campus is housed in a modern complex designed by Edward Durell Stone and first opened in 1966. The complex occupies a 400-acre site at the western edge of the city of Albany. The University also maintains a recently renovated downtown campus with free, easy access between the two. The Department of Geological Sciences is located on the uptown campus.

Albany currently enrolls 16,000 students, 30 percent of whom are graduate students. It is organized into nine degree-granting schools and colleges offering a range of programs in the humanities and fine arts, science and mathematics, social and behavioral sciences, business, criminal justice, education, library and information science, public affairs, and social welfare. The University offers the master's degree in 50 areas, the certificate of advanced study in 12, and the doctoral degree in 24.



# Research Facilities and Equipment

The Department has excellent laboratory and field equipment for a variety of geological investigations. Because much of our research is field-oriented, we have both on- and off-road vehicles as well as a small boat for coastal mapping. And because detailed understanding of geological material often requires laboratory analysis, we strive to maintain state-of-the-art research equipment for experimental geology.

**Material Deformation Laboratory**
The laboratory features several kinds of transmitted light deformation apparatus for study of microstructural evolution in deforming polycrystalline materials. Associated equipment for photomicrography and optical fabric measurement is available.

**Rare Gas Mass Spectrometry** This facility is primarily designed as an $^{40}$Ar $^{39}$Ar age analysis system, but is also used for a variety of other rare gas studies. The mass spectrometer is a 12-cm radius Nuclide Corp. instrument with simultaneous collection by both Faraday cup and electron multiplier. Special features of the gas extraction system include a very low blank and rapid sample throughput. Data acquisition and reduction are performed on-line with final results available within minutes of the completion of a run. We are presently acquiring a VG Micromass 1200S mass spectrometer which features state-of-the-art sensitivity and background to complement our existing system.

**Electron Microprobe**
The Department has an ETEC Autoprobe with a Tracor-Northern energy dispersive analysis system attached. It is used routinely for small-area (1 10 micron diameter) analysis of fused whole rocks, rock-forming minerals, and experimental products. In addition, the recent acquisition of two crystal spectrometers has expanded our capabilities to include the determination of trace and minor elements in natural samples and experimental runs. The microprobe is also equipped with secondary and backscattered electron detectors which allow the use of scanning electron microscopy in conjunction with chemical analysis. This has been useful to students of structural geology as well as those of geochemistry and petrology.

**Experimental Petrology**
The Department has one-atmosphere furnaces for trace-element and petrological studies. One furnace is equipped with zirconium electrolyte oxygen fugacity sensors to measure intrinsic $fo_2$ of natural samples. Our researchers also have access, through cooperation with Bruce Watson of Rensselaer Polytechnic Institute, to a variety of high-pressure devices including hydrothermal bombs, an internally-heated pressure vessel, and piston-cylinder presses.

**Additional Facilities**
Additional facilities available in the Department for graduate student use include a Siemens x-ray fluorescence spectrometer and diffractometer, a Perkin-Elmer atomic absorption spectrometer, research level microscopes with photomicrography and television systems, and a well-equipped darkroom.

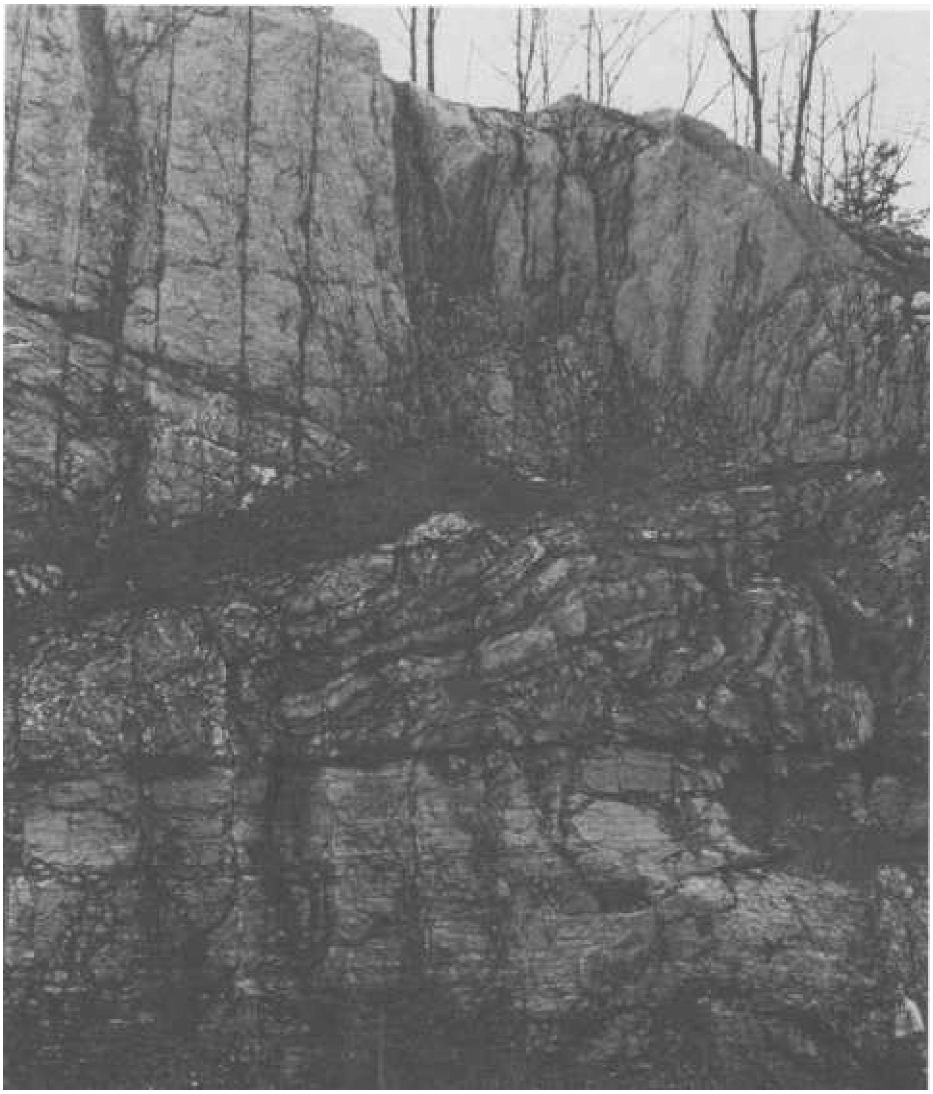
**Research Support Facilities** The Department machine shop is well-equipped for production of precision research instruments. We also use the services of the

University's glass blowing shop, central machine shop, and electronics shop.

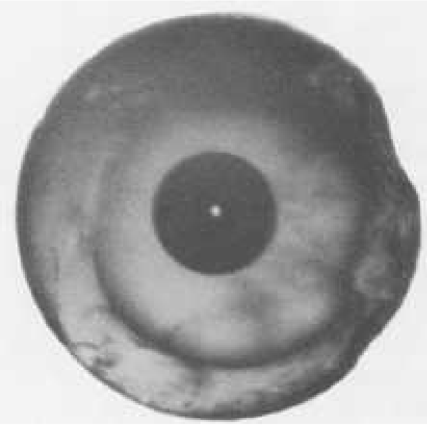
We have excellent facilities for preparing thin sections and for crushing and sawing rocks, and we are well-equipped with a variety of devices for drafting, reduction, and reproduction of maps and figures.

The University Computing Center operates a Sperry 1100/83 3 x 2 processor computer to which the department has on-line access. The Center supports an academic services unit with experts available to provide advice to research users. In addition, microcomputers are available in the department.

The one-million-volume University Library contains an excellent collection of geological periodicals and books and provides a computerized bibliographic service.



Thrust faults in folded early Devonian limestones of the Helderberg Group, forming the outer edge of the Acadian orogenic belt in eastern New York. N.Y. Route 23, near Catskill, N.Y.



Transmitted light photomicrograph showing a sphere of Apollo 15 volcanic green glass enclosing a sealed vesicle (138 microns diameter). This mafic magma was erupted onto the lunar surface 3300 million years ago and was derived from a source region located 500 kilometers within the moon.

# Faculty

Faculty research focuses on four relatively broad areas: tectonics, structural geology, geochemistry, and petrology. This focus allows us to develop vitality and substance within each area, plus interaction between each, that is unusual for a department this size, and recent faculty appointments and plans for the future reinforce this commitment. All of us share a strong interest in field-based programs, and we strive to keep direct links between them and our lab-based work in geochemistry and experimental structural geology.

In the following descriptions of our individual interests, you can see how our current projects can be categorized among one or more of the four areas of research activity in the department. Additionally, there is considerable collaboration across these four areas. Some cooperative arrangements are specifically described (e.g., the relationship between volcanism and tectonics in Turkey), while others are now being planned (e.g., geochronology and tectonism of the northern Appalachians). Still other possibilities might be catalyzed by a graduate student who wants to develop an interface between two areas (e.g., changes in mineral chemistry associated with growth of microstructures).

# Cosmochemistry

**John W. Delano; B.S., Upsala College; Ph.D., State University of New York at Stony Brook; Assistant Professor**

Basaltic liquids are used by geochemists and petrologists as probes of planetary interiors. The mineralogic and petrologic constraints derived from study of those melts can, however, be less than unique if the basalts have had any history of crystal liquid fractionation during emplacement. Igneous rocks fulfilling the essential requirement for little or no differentiation subsequent to leaving the source regions within the planetary interior are rare on both the earth and the moon. Such melts are termed "primary." Debates have persisted for nearly 20 years among terrestrial petrologists as to the chemical characteristics of primary basaltic melts derived from the upper mantle. Comparable arguments have persisted among lunar scientists since 1969.

Advances have been made in the last three years toward resolving the lunar debate through the discovery and analysis of 23 varieties of volcanic glass from the six Apollo landing sites. Due to the chemical systematics that persist among all of these glass compositions, these lunar volcanic glasses are thought to be samples of primary magmas derived from about 300 miles within the moon's interior.

During eruption of these primary lunar magmas in fire-fountains, indigenous lunar gas was trapped in rare vesicles. Since data from the other laboratories suggest that these lunar volatiles were derived from primordial reservoirs (4.56 billion years old) within the deep lunar interior, additional vesicles are being sought in volcanic glasses from Apollo 15 and Apollo 17. These vesicles will be analyzed by a consortium of research groups and will likely contribute new constraints on the moon's origin.

The planetary research program also involves the analysis of impact glasses from the earth (i.e., tektites) and the moon. The purpose is to learn to interpret better the chemistries of impact glasses so as to constrain the nature of the target materials. Tektites are being used to develop the necessary principles. Since impact glasses are abundant in planetary regoliths, we expect that those samples have considerable potential for providing chemical petrological information about remote areas of a planet. The ability to properly interpret these impact glasses from the moon and other regolith-bearing bodies will make those samples valuable tools of planetary exploration.

The final component of our research involves experimental petrology to determine the intrinsic oxidation state of mantle-derived xenoliths. This research provides data bearing on the nature of the earth's initial atmosphere and on the composition of the earth's core.

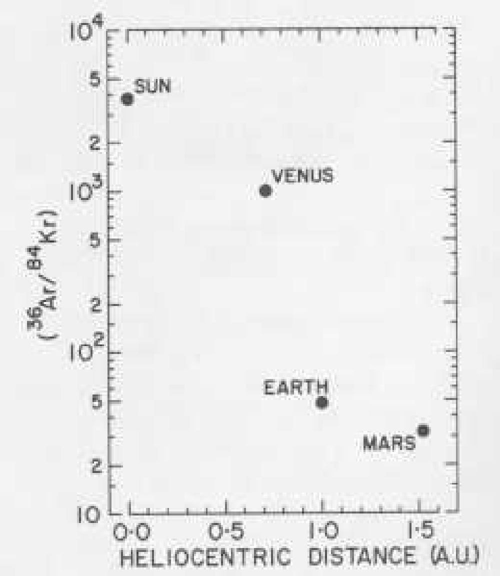
**Recent Publications**

Delano J. W. and Lindsley D. H. ( 1982). Chemical systematics among the moldavite tektites. Geochim. Cosmochim. Acta, 46, 2447-52.

Delano J. W., Lindsley D. H., Ma M. S., and Schmitt R. A. (1982). The Apollo 15 yellow impact glasses: Chemistry, petrology, and exotic origin. *Proc. 13th Lunar Planet. Sci. Conf.,* A159-A170.

Chen H. K., Delano J. W., and Lindsley D. H. (1982). Chemistry and phase relations of VLT volcanic glasses from Apollo 14 and Apollo 17. *Proc. 13th Planet. Sci. Conf.,* A171-A181.

Delano J. W. and Lindsley D. H. ( 1984). Mare glasses from Apollo 17: Constraints on the Moon's bulk composition. *Proc. 14th Lunar Planet. Sci. Conf.,* Part 1, J. *Geophys. Res.* 88, B3-B16.



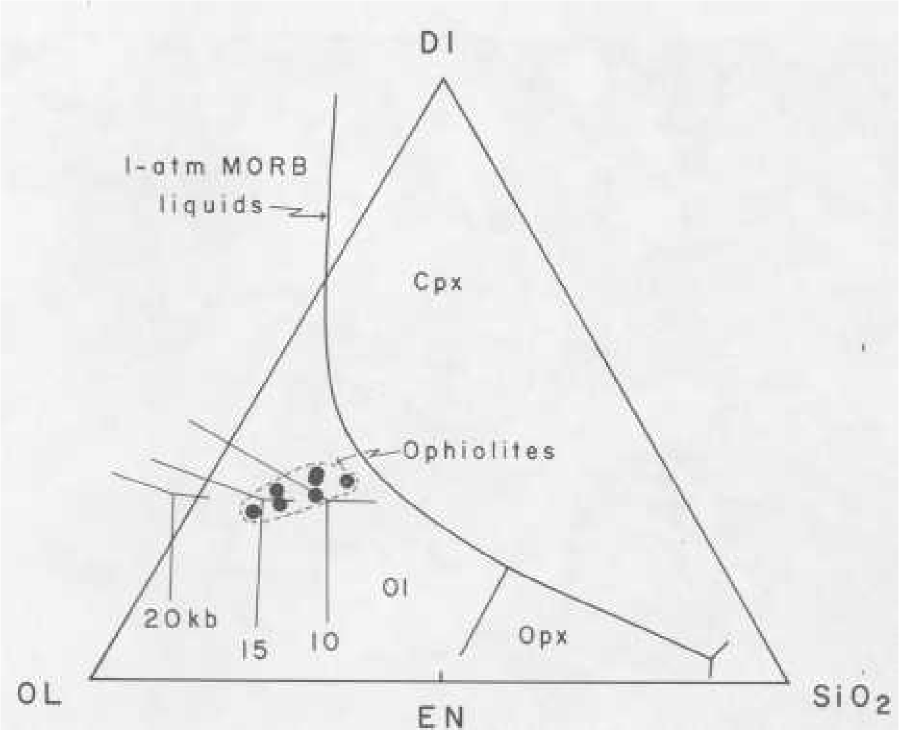
The matter that accreted to form the various terrestrial-type planets contains $^{36}$Ar $^{84}$Kr ratios that vary according to distance from the sun. This parameter, when measured in lunar glasses, should be capable of testing whether the moon formed in close proximity to the earth or was formed elsewhere in the Solar System and subsequently captured by the earth. Experiments at State University of New York at Albany are being planned that will utilize this relationship to constrain the origin of the moon.

# Geochemistry and Igneous Petrology

**Stephen E. DeLong; A.B., Oberlin College; M.A., Ph.D., University of Texas at Austin; Associate Professor and Chairman** The chemistry of igneous rocks carries information on the physical environment in which they formed, ranging in scale from tectonic setting to the boundary layer of a magma chamber. My recent research has explored this chemical physical interrelationship at both extremes of the scale, applying results from mineral chemistry, trace-element and isotope geochemistry, and experimental petrology to rock suites from the ocean floor (including ophiolites) and subduction collision zones.

Two current projects (in collaboration with William Kidd) focus on the relation of magmatism and tectonic setting. In one, we are studying a suite of basalts and gabbros emplaced in an Ordovician arc-trench gap in the Notre Dame Bay area of north-central Newfoundland in an attempt to elucidate the reasons for their presence in what would normally be a nonmagmatic terrain. We expect that the trace-element geochemistry of these rocks can be used to establish their setting by comparison to those formed in known environments. In a second project, we have made a traverse across eastern Anatolia (Turkey) to observe the structural and chemical relationship of young volcanism in the area to the ongoing continental collision between the Arabian and Eurasian plates. We anticipate that trace-element and isotopic analyses will be especially helpful in estimating the degree of interaction of continental crust in melting and volcanism on a regional basis.

On a smaller scale, I am interested in defining the extent to which the chemistry of magmatic rocks that are demonstrably related in space and time can be explained by near-surface (i.e., magma-chamber or post-crystallization) processes. The remaining, "unexplained" aspects of their chemistry may then be more confidently attributed to prior processes in the mantle. Current projects that derive from this interest and on which graduate students are currently working with me include: (1) olivine-clinopyroxene-orthopyroxene geothermometry of tectonized harzburgites from a 7-km-thick section at the base of Table Mountain in the Bay of Islands ophiolite complex, Newfoundland; (2) detailed mineral chemistry and trace-element geochemistry of andesites and dacites from Little Sitkin volcano in the Aleutian arc (a parallel study to that just completed for the adjacent volcano, Semisopochnoi); and (3) magmatic vs. metamorphic evolution of the brown green blue-green



Bulk ophiolite compositions [calculated by a modification of the method of Elthon (1979)] presumably represent the average magma composition from which each sample of oceanic crust was formed. Comparison of these compositions with the high-pressure cotectics of Stolper (1980) suggests that the parental magma available at mid-ocean ridges last equilibrated with an upper mantle assemblage of olivine orthopyroxene clinopyroxene at 10 15 kilobars.

amphibole transitions (at the thin section scale) in gabbros from the Oceanographer Fracture Zone, Mid-Atlantic Ridge.

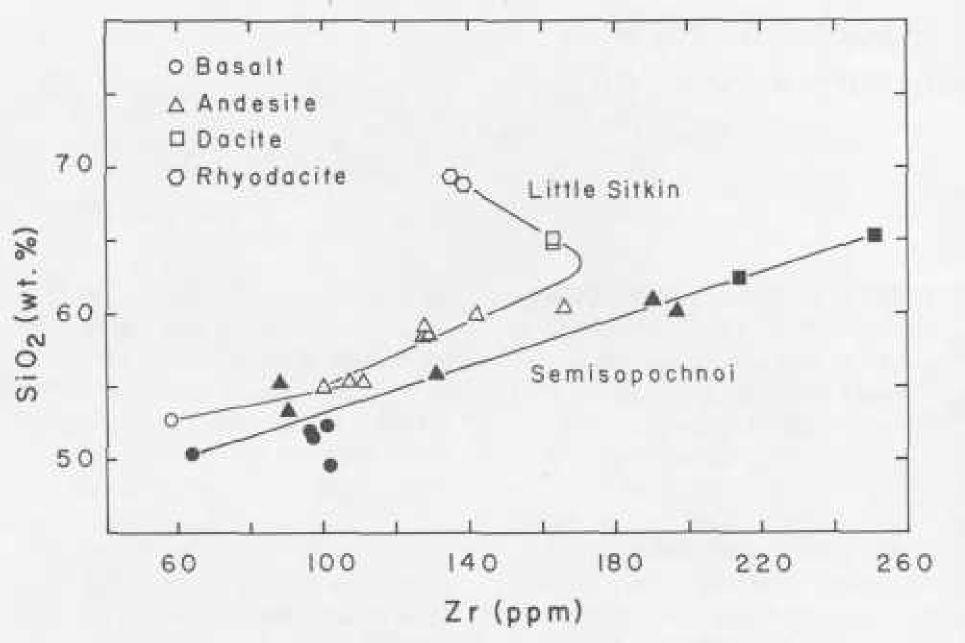
**Recent Publications**

DeLong S. E. and Lyman P. (1982). Water-capture in rapid silicate analyses. *Chemical* Geology 35, 173-76.

Walker D. and DeLong S. E. (1982). Soret separation of mid-ocean ridge basalt magma. *Contrib. Mineral. Petrol.* 79, 231-40.

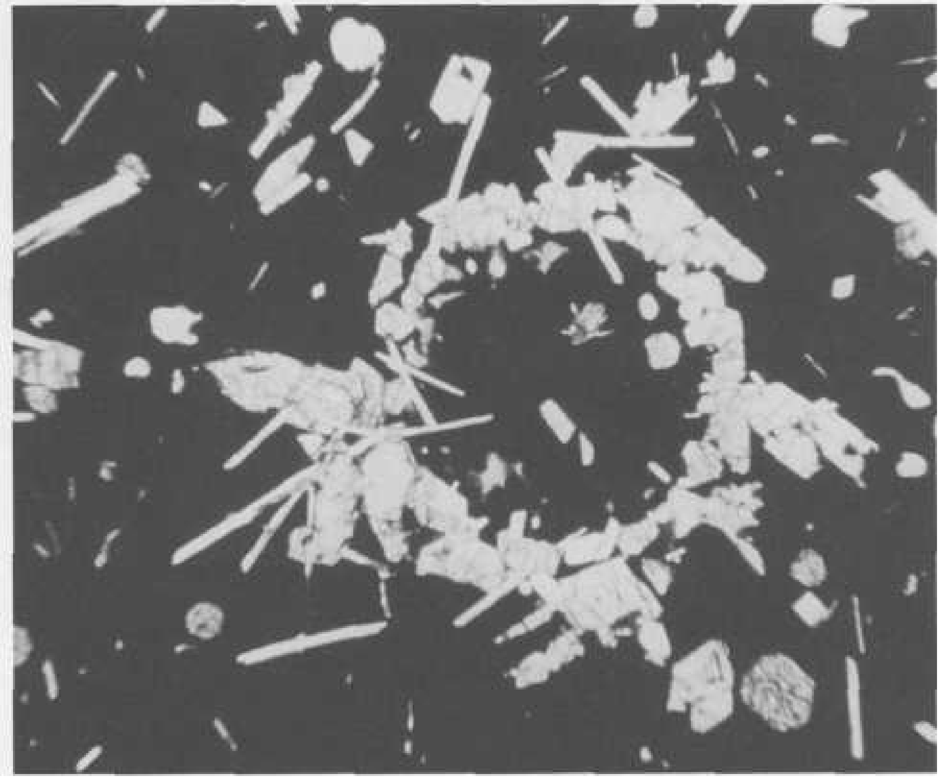
Karson J. A., Elthon D. L., and DeLong S. E. (1983). Ultramafic intrusions in the Lewis Hills massif, Bay of Islands ophiolite complex, Newfoundland: Implications for igneous processes at oceanic fracture zones. *Geol.* Soc. *America Bull. 94,* 15-29.

DeLong S. E., Perfit M. R., McCulloch M., and Ach J. (1984). Magmatic evolution of Semisopochnoi Island, Alaska: Trace-element and isotopic constraints. *Jour. Geol.* (submitted).



Variation of $SiO_2$ and Zr in volcanic rocks from Little Sitkin and Semisopochnoi volcanoes in the Aleutian Island arc. Magmatic evolution on Semisopochnoi is dominated by magma mixing; crystal fractionation is more important on Little Sitkin (e.g., zircon saturation is evident in this figure).

A crystal-ring microstructure in a basalt from the Oceanographer Fracture Zone on the mid-Atlantic Ridge (Walker, DeLong, and Shibata, *1980, Contrib. Mineral. Petrol.* 74, 1-6).



# Tectonics and Structural Geology

**Gregory D. Harper; B.S., Nebraska; M.A., Ph.D., California Berkeley; Assistant Professor**

The study of the tectonic evolution of ancient orogens is an exciting and rapidly evolving field. Tectonic interpretation requires integration of field observations and mapping, geochronology, stratigraphy, structure, and petrology. My research has emphasized a multidisciplinary approach toward solving tectonic problems of structurally complex ophiolitic and island arc terranes.

My recent research has focused on the Josephine ophiolite and its overlying metasedimentary rocks of northwestern California. Projects related to the ophiolite include regional tectonic setting and generation in a back-arc basin, recognition of fossil fracture zone complexes, trace element geochemistry, hydrothermal metamorphism, and sedimentary petrology and structure of metasedimentary rocks overlying the ophiolite. Related research involves understanding the formation of oceanic lithosphere at slow-spreading centers with emphasis on normal faulting and related tilting.

One of the new directions of my research concerns Archean tectonics, which is currently highly controversial. I am now working on a 2.7 Ga greenstone belt in Wyoming that appears to contain a dismembered and multiply deformed ophiolite. The lack of Archean ophiolites has traditionally been cited as evidence that tectonics in the Archean was different from today. The occurrence of an Archean ophiolite thus has profound implications and suggests that perhaps tectonic processes in the early history of the earth were more similar to those of the present than previously thought.

I am particularly interested in M.S. and Ph.D. students who would like to use an integrated approach in attacking tectonic problems in the Appalachians, Canadian greenstone belts, or other areas. M.S. students will probably want to emphasize structure or sedimentation and tectonics, whereas Ph.D. students are encouraged to adopt a broader approach utilizing the geochronology facilities available in the department.

**Recent Publications**

Harper G. D. (1980). The Josephine ophiolite   The remains of a Late Jurassic marginal basin in northwestern California. *Geology 8,* 333-37.

Harper G. D. (1982). Evidence for large-scale rotations at spreading centers from the Josephine ophiolite. *Tectonophysics 82,* 25-44.

Saleeby J. B., Harper G. D., Snoke A. W., and Sharp W. (1982). Time relations and structural-stratigraphic patterns in ophiolite accretion, west-central Klamath Mountains, California. J. *Geophys.* Res 87, 3831-48.

Harper G. D. (1984). The Josephine ophiolite, northwestern California. Geol. *Soc. Am. Bull.* (in press).

# Isotope Geochemistry

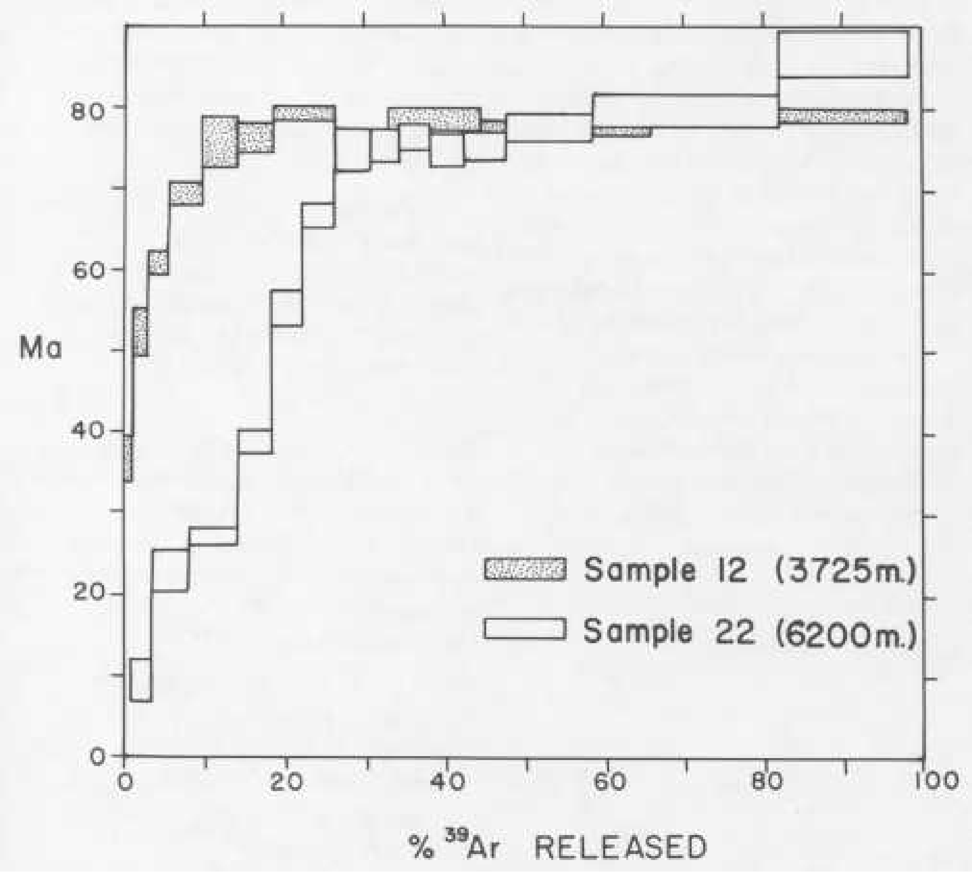
**T. Mark Harrison; B.Sc., University of British Columbia; Ph.D., Australian National University; Assistant Professor**

Since virtually all geological processes involve the transfer of heat, understanding the thermal evolution of rocks helps us to understand better both the geological history of crustal material and the physical mechanisms behind the earth-forming processes. My interest in this field follows two paths; 1) use of the $^{40}$Ar $^{39}$Ar and allied dating methods to reveal tectonothermal histories of igneous, metamorphic, and sedimentary terranes, and 2) the development and application of "fundamental accessory phase parameters" in granitoid systems with a view to understanding the origin and evolution of crustally derived melts.

The $^{40}$Ar $^{39}$Ar age spectrum technique has the demonstrated potential to reveal the distribution of $^{40}$Ar (produced by the radioactive decay of $^{40}$K) within mineral grains. Because the daughter product is a noble gas, it has the tendency to diffuse out of natural crystals in response to temperature disturbances. As we now understand the systematic behavior of a number of minerals with very different retentivities of $^{40}$Ar, it is possible to not only reconstruct cooling histories of simple cooling systems, but also to "see through" polymetamorphic events as well.

We are currently applying this technique to a number of different geological environments for a variety of purposes. Research involves 1) a batholith in British Columbia, Canada that has been peripherally affected by a post-crystallization thermal event related to the tectonic emplacement of an adjacent terrane results of this study provide a surprisingly short time scale ( $10^5$ years) for this process; 2) the thermal evolution of two juxtaposed "suspect terranes" in Alaska; and 3) the thermal evolution of sedimentary basins using detrital microcline feldspar. These analyses provide thermochronological information in the temperature-time range of petroleum maturation and give this technique potential as a useful exploration tool and as a means of probing the geodynamic processes of basin evolution. Active research includes basins of the Rio Grande Rift, New Mexico, San Joaquin Valley, California, and North Sea. Research students are currently being supervised in field projects in Alaska, Barbados, and California, but we welcome structure tectonics students to use our facility to obtain time constraints and tectonothermal information for their field-based studies.

Our present understanding of the evolutionary pathways taken by magmas before their appearance at the earth's surface has been considerably enhanced by the application of techniques that employ the discriminating nature of trace elements in mineral melt systems. A substantial proportion of the rare earth elements (REE) and U in rocks of the continental crust are concentrated in accessory minerals such as zircon, apatite, sphene, allanite, and monazite, giving these phases the potential to provide considerable information regarding conditions during partial fusion events in the crust. However, to understand fully the redistribution of these elements amongst accessory phases during anatexis requires knowledge of both the stability and partition behavior of the participating minerals and elements. In collaboration with Bruce Watson, Rensselaer Polytechnic Institute, we are experimentally determining the following "fundamental accessory phase parameters": 1) the solubility of the accessory mineral in crustal melts; 2) the partition characteristics of REE and parent (U) and daughter (Pb) isotopes between mineral and melt; and 3) the diffusivities of the species of interest in the accessory mineral. This information is required before we can make full use of trace-element modeling techniques to understand the origin and evolution of crustally derived magmas. Field oriented studies anticipated in the near future to complement the experimental data offer opportunities for graduate students.



Distribution of apparent $^{40}$Ar $^{39}$Ar age (in millions of years) within two crystals of detrital microcline from deep drill cores taken in the southern San Joaquin Valley, California. The sample obtained from 6.2-km depth reveals evidence of a recent thermal episode that has caused radiogenic $^{40}$Ar to be lost from the sample. This result allows calculation of the temperature-time history of this portion of the sedimentary basin.

**Recent Publications**

Harrison T. M. and McDougall I. (1982). The thermal significance of microcline K-Ar ages inferred from $^{40}$Ar $^{39}$Ar age spectrum results. *Geochim. Cosmochim. Acta 46,* 1811-20.

Watson E. B. and Harrison T. M. (1983). Zircon saturation revisited: Temperature and composition effects in a variety of crustal magma types. Earth *Planet. Sci. Lett.* 64, 295-304.

Harrison T. M. and Watson E. B. (1983). Kinetics of zircon dissolution and zirconium diffusion in granitic melts of variable water content. *Contrib. Mineral. Petrol.* 84, 66-72.

Harrison T. M. and Be K. (1983). $^{40}$Ar $^{39}$Ar age spectrum analysis of detrital microclines from the southern San Joaquin Basin, California: An approach to determining the thermal evolution of sedimentary basins. Earth *Planet. Sci. Lett.* 64, 244-56.

Harrison T. M. (1983). Some observations on the interpretation of $^{40}$Ar $^{39}$Ar age spectra. *Isotope* Geoscience 1, 319-38.

# Tectonics and Structural Geology

**William S. F. Kidd; B.A., Ph.D., Cambridge University; Associate Professor**

My research is directed toward understanding aspects of the tectonics of orogenic belts, which are dominated by continental and island arc microcontinent collisional events. Studies largely consist of fieldwork, making detailed geological maps of the distribution of lithologies in conjunction with structural and sedimentological observations. At present, studies of the Northern Appalachians include the rocks of the Taconic Allochthon and adjacent related units; 1) examining the history of its emplacement and the deformation of the continental margin through the detrital evidence in coeval flysch; 2) looking at aspects of the structures of the Allochthon and adjacent rocks in order to try to understand their development; 3) studying the stratigraphy and sedimentation of the continental rise sediments of the Allochthon in order to elucidate the development of the rise and the variations that occur in it along strike. A project to investigate some aspects of the thermal history of the western New England part of the orogen is planned in collaboration with Mark Harrison. Projects in western Newfoundland are aimed at understanding the structural development of the early Ordovician allochthons, and some structural and tectonic aspects of the adjacent island arc terrane that collided with North America in the middle Ordovician.

Studies in Turkey, in collaboration with Stephen DeLong and faculty at other universities, concern the tectonics and magmatism of the zone of collision between the Arabian and Eurasian continents. Reconnaissance work has been completed; some more detailed studies of the tectonics and the geochemistry of the Neogene volcanics related to the collision may be initiated soon (in collaboration with Turkish colleagues).

I have also been involved in studies of the tectonics of oceanic transform faults using the submersible ALVIN and deep-towed oceanographic instruments. A similar study of a transform on the fast-spreading segment of East Pacific Rise is anticipated in the next year or two.

geochemical work to shed light on the tectonic processes of formation of the oceanic crust.

The tectonics of the early (Archean) earth how much or how little they differed from present plate tectonic behavior are also of interest to me. Field studies to investigate some aspects of this subject are planned for the future in Canada.

**Recent Publications**

Rowley D. B. and Kidd W. S. F. (1981). Stratigraphic relationships and detrital composition of the medial Ordovician flysch of western New England: implications for the tectonic evolution of the Taconic Orogeny. *Jour. Geol.* 89, 199-218.

Casey J. F. and Kidd W. S. F. (1981). A parallochthonous group of sedimentary rocks uncomformably overlying the Bay of Islands Ophiolite Complex, North Arm Mountain, Newfoundland. *Canadian Jour. Earth Sci*. 18, 1035-50.

Dewey J. F., Kennedy M. J., and Kidd W. S. F. (1983). A geotraverse through the Appalachians of Northern Newfoundland. *Profiles of Orogenic Belts* (ed., N. Past) Geodynamics series, v.-10, 205-41, American Geophysical Union.

Fox P. J., Karson J., Kidd W. S. F., Kastens K., MacDonald K., Gallo D., and Crane K. (1983). Tectonics of the Tamayo Transform East Pacific Rise intersection. *Marine Geophysical Research* (in press).

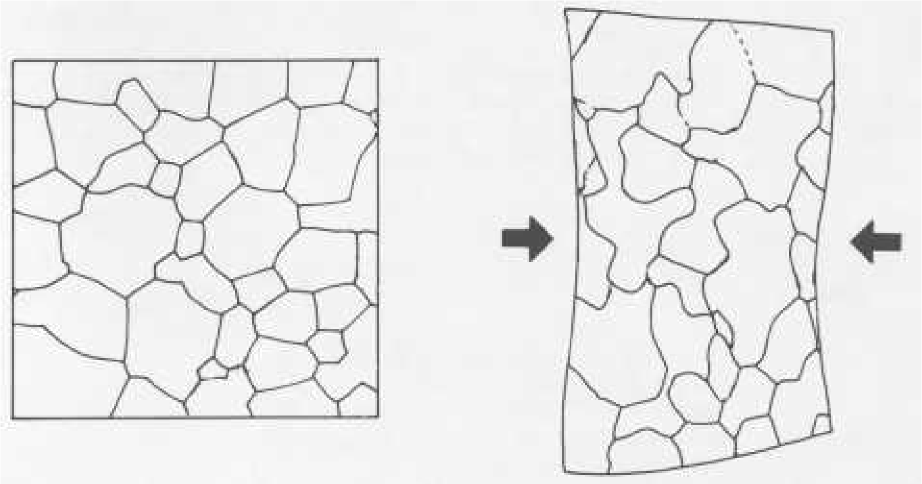
# Structural Geology

**Winthrop D. Means; A. B., Harvard University; Ph.D., University of California at Berkeley; Professor**

The structures of deformed rocks provide a beautiful but somewhat cryptic record of the patterns and rates of internal motions in the earth. A fundamental problem in structural geology, if not the fundamental problem, is to decipher the code linking structure to motion. My research, like that of many other structural geologists at universities around the world, centers on this venerable but still largely unsolved problem. We aim to provide field workers with improved techniques for inferring tectonic motions from structures, and we hope to provide material scientists in general with new insights on the behavior of deforming crystalline materials. My work divides somewhat between attempting to understand motion and attempting to understand structural evolution, particularly microstructural evolution.

To understand motion, and its efficient description and analysis, one has to determine what authorities in continuum mechanics already know about the purely geometrical theory of flow and deformation. Part of my time is spent learning this theory and translating and extending it into forms usable by geologists. This has resulted in a small book *(Stress and Strain)* and some papers cited here that deal with new graphical techniques for representing and manipulating tensor quantities. I have never had a graduate student who could assist with this work because, understandably, students with good geological background (which we require) rarely have the necessary theoretical background. I do however attempt, via coursework and seminars, to bring all of my students up to whatever level of understanding I have reached. I look forward to the possibility of student work in this field in the future, probably at the Ph.D. level.

To understand microstructural evolution there is no substitute for experiments in which a thin section of crystalline material is deformed under direct microscopic observation. This new approach to microstructural problems, developed by geologists and metallurgists just a few years ago, is opening up many new lines of research. My own version of a "see-through" deformation apparatus is described in Means and Xia (1981). We are using it at present to investigate the microstructural evolution of materials undergoing simultaneous deformation and recrystallization. Other attractive applications are to problems of microstructural evolution in materials that undergo phase changes or interphase reactions during deformation. Such problems lie at the heart of what must be the next major development in metamorphic petrology discovery of the principles linking mineralogical to structural adjustments in deforming rocks. See-through experiments provide an attractive first approach to discovering these principles, even given the fact that various analog materials must be used in the experiments in place of minerals. Experimental studies like these are wholly appropriate for thesis research, so long as a student has reasonable prior petrographic and field-structural experience, and so long as an attempt is made to study comparable naturally deformed rocks along with the experimental materials. These requirements, taken together, make the work more suitable for Ph.D. than for M.S. projects. However, I am also interested in M.S. students with little previous structural experience. For such students an apprenticeship in detailed structural



Polycrystalline octachloropropane sample before (left) and after (right) experimental deformation and recrystallization. Some of the original grains have grown larger, some smaller, but no new grains have been introduced.

and microstructural mapping is usually required as a thesis project. This can lead on, if talent and inclination permit, to the types of more fundamental Ph.D. studies described above.

**Recent Publications**

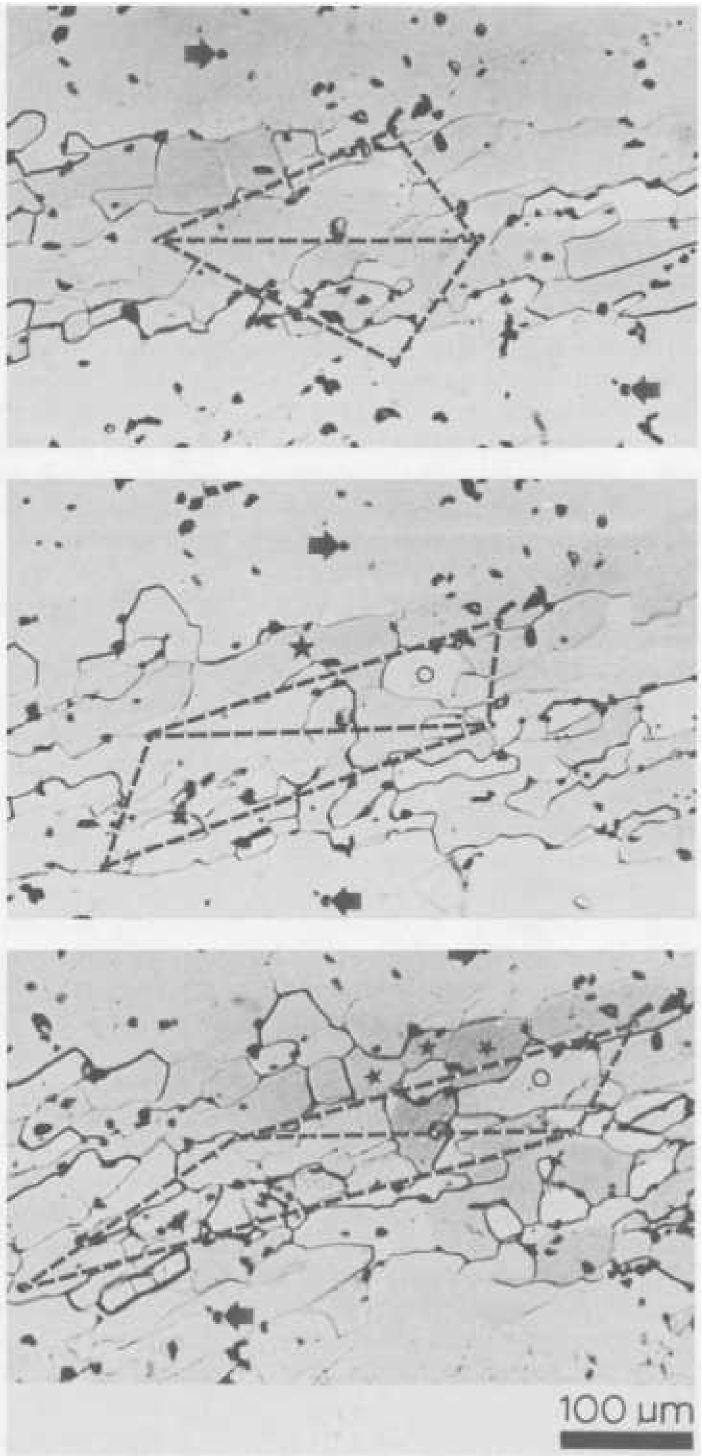
Means W. D., Hobbs B. E., Lister G. S., and Williams P. F. (1980). Vorticity and non-coaxiality in progressive deformations. *Jour. Structural Geology 2,* 371-78.

Means W. D. (1981). The concept of steady-state foliation. *Tectonophysics* 78, 179-99.

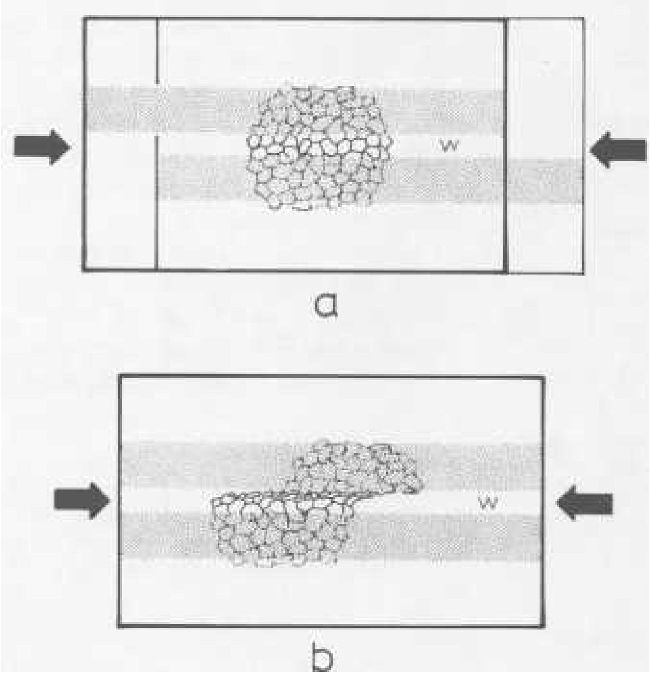
Means W. D. and Xia Z. G. (1981). Deformation of crystalline materials in thin section. *Geology 9,* 538-43.

Means W. D. (1982). An unfamiliar Mohr circle construction for finite strain. *Tectonophysics* 89, T1-T6.

Means W. D. (1983). Application of the Mohr circle construction to problems of homogeneous deformation. *Jour. Structural Geology* 5, 279 86.



Progressive development (top to bottom) of a dextral shear zone in polycrystalline para-dichlorobenzene. The broken lines connect the same material particles in each picture.



Technique for shearing polycrystalline samples between two glass microscope slides. The sample in (a) is gripped by frosted strips on the slides and sheared as in (b) when the slides are moved over one another.

# Metamorphic Petrology

**Akiho Miyashiro; B.Sc., Ph.D., University of Tokyo; Professor**
Between 1947 and 1967, I worked in the fields of metamorphic petrology and x-ray crystallography at Tokyo University. The major aim of my work during this period was to clarify the nature and extent of the diversity of regional metamorphism. This led to my proposal in 1961 of a three-fold classification of regional metamorphism and of the concept of paired metamorphic belts. In connection with the petrological study, many metamorphic minerals were investigated, including a detailed study of cordierite and related minerals. This resulted in my discovery of the low (orthorhombic) and high (hexagonal) polymorphs due to order-disorder transformation in cordierite and a new hexagonal mineral, osumilite.

In the course of the 1960s, I came to be increasingly interested in tectonics. In order to carry out petrological studies related to tectonics, I moved to Lamont-Dohert Geological Observatory of Columbia University in 1967, and then to Albany in 1970. I worked on igneous and metamorphic rocks of mid-oceanic ridges and then on a great variety of petrological problems related to tectonics, such as the diversity of island arc volcanic rocks and the origin of ophiolites. My proposal in 1973 of an island arc origin for the Troodos ophiolite was disputed by many authors, but its validity has been established by recent studies.

Toward the end of the 1970s, my interest in metamorphic petrology proper was revived. I am now working on various problems of metamorphic reactions and chemical models of regional metamorphism.

**Selected Publications**

Miyashiro A. (1957). Cordierite-indialite relations. *Amer. Jour. Sci.* 255, 43-62.

Miyashiro A. (1961). Evolution of metamorphic belts. *Jour. Petrol. 2,* 277-311.

Miyashiro A. (1964). Oxidation and reduction in the earth's crust with special reference to the role of graphite. *Geochim. Cosmochim. Acta,* 28, 717-29.

Miyashiro A., Shido F., and Ewing M. (1970). Crystallization and differentiation in abyssal tholeiites and gabbros from mid-oceanic ridges. *Earth Planet.* Sci. Lett. 7, 361-65.

Miyashiro A. (1972). Metamorphism and related magmatism in plate tectonics. *Amer. Jour.* Sci. 272, 629-56.

Miyashiro A. (1973). *Metamorphism and Metamorphic Belts.* Allen Unwin, London.

Miyashiro A. (1973). The Troodos ophiolitic complex was probably formed in an island arc. *Earth. Planet. Sci. Lett.* 19, 218-24.

Miyashiro A. (1978). Nature of alkalic volcanic series. *Contrib. Mineral. Petrol.* 66, 91-104.

Miyashiro A., Aki K., and Sengor A.M.C. (1982). *Orogeny.* John Wiley Sons, Chichester and New York.

# Petrology and Neotectonics

**George W. Putman; B.S., Union College; M.S., Ph.D., Pennsylvania State; Associate Professor**

Continental collisions commonly result in a thickened crust (up to 2x or more) where anatexis may occur in the deeper portions. With a normal crustal geothermal gradient the melts will tend to be granitic minimum temperature types with a high water (or $H_2O$ F) content as appropriate to pegmatites, certain migmatites, and S-type granites. Comparisons of several collision terranes, or portions thereof, subjected to similar peak temperatures and lithostatic pressures reveal distinct differences in both the scale and products of melting not explained by gross variations in host rock lithology. Exposures of a variety of granitic rocks in the Adirondacks of New York and in parts of New England provide an opportunity for study of the controls on melting and magma emplacement in both deep and intermediate crustal levels.

My current interests in this topic are: 1) temperature and pressure estimation based on saturated melts; 2) distributions of mineral assemblages and Grenville period anatexis in paragneiss units of the Adirondacks.

Another aspect may be the possible influence of major ductile shear zones on anatexis, and I am also interested in determining the configurations of, and sense of displacement on, these features of Adirondack geology.

A different area of my current interest concerns the neotectonics of northeastern New York, including: 1) possible reactivation patterns of major Adirondack boundary faults as suggested by study of the McGregor fault zone; 2) possible post-glacial or Holocene fault displacements as investigated by shallow trenching; 3) the relationships of geodetic changes linear block faulting and carbon dioxide discharges in the upper Hudson Valley.

**Selected Publications**

Putman G. W. and Alfors J. T. (1969). Geochemistry and Petrology of the Rocky Hill stock, Tulare County, California. GSA Sp. Paper 120, 109 pp.

Putman G. W. (1975). Base metal distribution in granitic rocks, II: Three-dimensional variation in the Lights Creek Stock, California. *Econ. Geol.* 70, 1225-41.

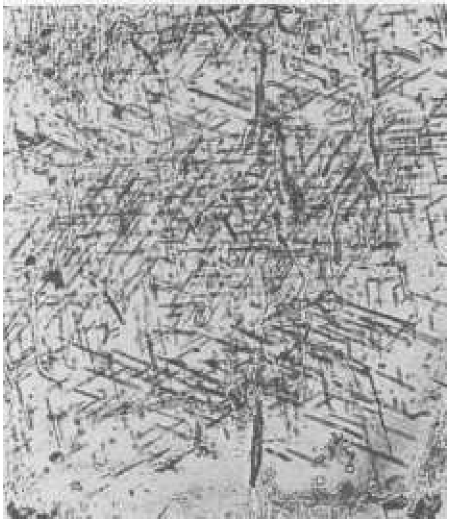
Putman G. W. and Sullivan J. R. (1979). Granitic pegmatites as estimators of crustal pressures; a test in the eastern Adirondacks, New York. *Geology* 7, 549-53.

Putman G. W. and Young J. R. (1984). The bubbles revisited; an account of the geology and chemistry of carbonated mineral waters of eastern New York, *Jour. Northeastern Geology* (in press).

# Related Staff

## Geochemistry and X-Ray Methods

**Karleen E. Davis; B.S., Oregon State University; M.S., Massachusetts Institute of Technology; Nonteaching Professional**
Much of our understanding of the origin and evolution of igneous rocks is based on the modeling of trace element behavior during anatexis, mixing, and crystallization. Poorly constrained assumptions about the partitioning, solubility, and mobility of these elements, however, are incorporated into all of these models, and it has become evident that further application of the approach will be limited without accurate values for these parameters. To this end, I am currently involved in a program of experimental work with Mark Harrison (Albany) and Bruce Watson (Rensselaer Polytechnic Institute) to obtain data for a carefully chosen subset of the commonly employed trace elements. My current focus is the partitioning of Zr between amphibole and silicate melts.



Magnetite rods in plagioclase from the Rocky Hill stock, California. This is an example of the ubiquitous occurrence of single-domain magnetites in plutonic rocks.

This work meshes neatly with my primary departmental responsibility as a nonteaching professional, the development and maintenance of the x-ray analytical equipment, as we are using our microprobe at the limits of its sensitivity. Analysis for Zr, Ni, Sr, and the REE at the level of a few hundred ppm (by weight) is generally the task of x-ray fluorescence or some other bulk sample analysis method. Only rarely has the electron microprobe been applied in this way. We are limited, however, by the size of the experimental charges and have had to optimize our analysis system for each element of interest.

Another application of specialized microprobe technique, which I have undertaken with William Kidd and several students, is the determination of provenance from the detrital mineralogy of greywackes from the Taconic Allocthon. Recently, we were able to prove the existence of chromite in some of these rocks, suggesting that at least some ophiolitic material was obducted in New England during the Taconic Orogeny. Ongoing work will attempt to determine the timing of this obduction event.

A separate aspect of my interest in igneous rock systems is the work I have done on the magnetic mineralogy and signal intensity of ocean floor gabbros. Early models of the source of marine magnetic anomalies accounted for their intensity with a 0.5 km-thick layer of highly magnetic basalt. This was based largely on measurements made on fresh basalt samples dredged from mid-ocean ridges. These are now recognized to be typically high values. Thus, a thicker layer of magnetic source rock must be invoked, and the layer of the gabbros beneath the sheeted dikes seems a likely source. My work (in cooperation with Stephen DeLong) has involved measurement of the magnetic properties of a suite of ocean-floor gabbros dredged from the Mid-Cayman Rise Spreading Center. These measurements suggest that not only is the gabbro layer a potentially important source, but also that it is in fact necessary to incorporate this thick, moderately intense magnetic layer in modeling marine magnetic anomalies.

**Recent Publications**

Hart S. R. and Davis K. D. (1978). Nickel partitioning between olivine and silicate melt. *Earth Planet. Sol. Lett.,* Volume 40, 203-19.

Davis K. E. (1981). Magnetite rods in plagioclase as the primary carrier of stable NRM in ocean-floor gabbros. *Earth Planet. Sci. Lett. 55,* 190-98.

# Metamorphic Petrology

**Karen L. Kimball; B.A., Carleton; M.S., Michigan Technological University; Ph.D., Wisconsin; Research Associate**

In recent years the goals of metamorphic petrology have undergone significant change. The techniques of geothermometry and geobarometry, phase equilibria, kinetics, fluid inclusion studies, geochronology, and other procedures have been greatly improved. Instead of providing only snapshot views of 'peak' metamorphic conditions, these techniques can be used to decipher complex tectonic histories and to determine the origins and compositions of metamorphic fluids, thus increasing our understanding of the evolution of the earth's crust. I am interested in characterizing the fluid phase present during metamorphism because a great deal can be learned about tectonic processes if we understand the mechanisms and extent of fluid flow in rocks. With these goals in mind I have been concentrating on three projects: the study of hydrothermally altered abyssal ultramafics, metamorphosed iron formations, and amphibolites.

By studying altered ultramafic rocks from fracture zones I hope to develop new insights into the hydrothermal circulation cells present in the earth's crust (manifest for example by the hot smokers in the Pacific Ocean), the earth's heat flow budget, and the deposition of hydrothermal ore deposits. Altered ultramafic samples have been dredged from oceanic fracture zones all over the world; a prerequisite for this work is good "sea legs." Once the samples are in hand, detailed petrographic study, electron microprobe analysis, scanning electron microscopy, and x-ray diffraction are all used to understand the textures and phase equilibria in the rocks. The reaction textures can establish the alteration sequence, and the phase equilibria of reactions involved in the alteration sequence can be used to calculate alteration temperatures, the composition of the fluid responsible for the alteration, and changes in the fluid composition with time. $^{87}$Sr $^{86}$Sr ratios are used to constrain the character (e.g., seawater vs. mantle) of the hydrating fluid, and perhaps even ages of alteration veins.

Another aspect of my research involves the study of metamorphosed iron formations. In those rocks I am considering fluid movement and compositional variations on a thin section, rather than a global, scale. Because the chemistry of iron formations is relatively simple, it is possible, in some cases, to map chemical potential gradients in the fluid as functions of silicate mineral compositions. Small scale variations in fluid composition may provide information about the mechanism involved in creating the gradients. An important result of this study was a workable two-site solution model for Fe-Mg amphiboles.

A third research project involves the study of amphibolites in northern New England. One goal of this research is to develop a theoretical basis which will allow calculation of the pressure-temperature-time (P-T-t) path a rock has undergone, in much the same manner as phase relations in pelites and zoned garnets are used now. Toward this end I am developing both orthoamphibole and calcic amphibole solution models. A pleasant aspect of the amphibolite studies is the opportunity to do field work.

The long-range goal of understanding tectonic processes and orogenic histories requires a wide range of research topics and techniques. My research interests encompass field work, theoretical treatment, and an analytical approach in the study of rocks from various tectonic environments, but I am interested in becoming involved in experimental hydrothermal studies, heat flow modeling, structural geology, and fluid inclusion work.

**Recent Publications**

Kimball K. L. and Spear F. S. (1984). Metamorphic petrology of the Jackson County Iron Formation, Wisconsin. *Can. Mineral.* (in press).

Spear F. S. and Kimball K. L. (1984). RECAMP A FORTRAN IV program for estimating Fe$^{3}$ contents in amphiboles. *Comp. Geos.* (in press).

Kimball K. L., Spear F. S. and Dick H. J. B. (1984). High temperature alteration of ultramafics, Islasorcadas Fracture Zone. *Contrib. Mineral. Petrol.* (submitted).

# Adjunct Faculty

Our adjunct professors maintain ties with the department through teaching, research, and frequent informal contacts. Thesis supervision by an adjunct professor in an area not central to our program goals is possible in some cases. The following adjuncts have had recent and extensive interaction with our students:

**Robert L. Fleischer, Ph.D. (Harvard), Staff Scientist, General Electric Research and Development Co.**
Research interests include studies of $^{222}$Rn directed at uranium, petroleum, and natural gas exploration as well as industrial and home exposure hazards. Dr. Fleischer was central to the development of fission track dating of geological material and maintains an interest in the geochronological application of nuclear tracks.

**Ed Landing, Ph.D. (Michigan), Senior Scientist, New York State Geological Survey**
Current research involves biostratigraphy and sedimentology of pre-orogenic units in the Taconic allochthons, eastern New York ,and Quebec; eustatic history and related faunal and lithostratigraphic developments of the Cambrian through Early Ordovician; and biostratigraphy and systematics of Early Cambrian small shelly faunas of Laurentia and the Avalon Platform.

**Walter Mitronovas, Ph.D. (Columbia), Senior Scientist, New York State Geological Survey**
Current research activities are 1) the study of historical earthquakes, 2) investigating the nature and causes of secular variation in seismicity, 3) the determination of crustal velocity structure using quarry blasts and earthquakes, and 4) the study of unusual seismic phenomena (e.g., cryoseisms, seismic booms, etc.).

# Visitors

Our faculty is supplemented by guest scholars who visit the department for periods ranging from several weeks to a year. Recent visitors include:

**P. R. Cobbold** (Visiting professor, June August 1983) C.N.R.S., University of Rennes, France

**D. G. DePaor** (Visiting professor, January May 1983), University College, Galway, Ireland, now at Johns Hopkins University

**C. F. Miller** (Visitor, June August, 1984), Department of Geology, Vanderbilt University

**I. McDougall** (Visitor, September 1983), Research School of Earth Sciences, Australian National University, Australia

**J. L. Urai** (Postdoctoral fellow, 1984), State University of Utrecht, The Netherlands

Our central location in the Northeast allows us to draw speakers from a pool of more than 20 excellent geology programs within a 200-mile radius of Albany, plus others for our Friday afternoon seminar series. Recent speakers include:

**Roger Bilham,** Columbia University
**Harry Bradbury,** Yale University
**Robin Brett,** U.S. Geological Survey
**John Cisne,** Cornell University
**John Dickey,** Syracuse University
**John Edmonds,** M.I.T.
**Phillip England,** Harvard University
**Richard George,** Exxon Production Research
**Roger Mason,** University of London
**James Monger,** Geological Survey of Canada
**Nobu Shimuzu,** M.I.T.
**Carol Simpson,** Virginia Tech
**Fouad Tera,** Carnegie Institute of Washington
**David Walker,** Columbia University
**Francis Wu,** State University of New York at Binghamton

# Doctor of Philosophy

The general aim of the program is to prepare qualified students for research careers in the geological sciences in universities, industry, and governmental research agencies. This program offers advanced training in four fundamental and interrelated areas of geological science: tectonics, structural geology, petrology, and geochemistry. It requires at least three academic years of full-time study and research, or the equivalent over a longer period beyond the baccalaureate, and may typically involve as many as four years.

**Program of Study and Research (60 credits, minimum)**

Each student's course of study is planned with a graduate committee that takes into account previous preparation, area of specialization, and professional objectives. Students must complete a minimum of 60 credits of advanced courses, seminars, independent study, and research. In addition to taking other courses as advised by the graduate committee of the department, you must complete Geo 510 and 517 and four courses from among the following: Geo 518, 520, 530, 545, 650, 675. As well as the normal 60 credits of graduate courses, students are required to take Geo 500 each semester of their registration.

**Dissertation**

Each student must submit an acceptable dissertation which represents a significant and original research contribution in the area of specialization chosen.

**Department Examinations**

1. A proficiency examination in optical mineralogy and petrography will be given at the beginning of the first semester of graduate study.
2. You must pass a written qualifying examination in one of the following fields: structural geology, tectonics, igneous petrology, metamorphic petrology, or geochemistry. This examination is normally taken during the third or fourth semester of graduate study.
3. You must pass an oral examination focused on presentation and defense of an original research proposal. This examination will normally be taken during the fourth or fifth semester of graduate study.
4. You must satisfactorily complete an oral defense of the dissertation.

**Research Tool Requirement**

A foreign language may or may not be required for the Ph.D. depending on the relevance of such a language to the student's thesis. The relevance of a foreign language is to be decided by the student's committee. If a decision for no foreign language is made, then an alternative research tool proposal must be made by the committee. The acceptance of this alternative is to be made by a majority vote of the departmental faculty. If a decision for a foreign language is made by the committee, then this must also be submitted to the departmental faculty for ratification. The advisory committee may, at its discretion, require a second foreign language.

**Admission to Candidacy**

You are admitted to candidacy for the degree of Doctor of Philosophy upon the following:

1. Satisfactory record in course and research study.
2. Completion of the University residence requirements.
3. Satisfactory completion of research tool requirement.
4. Satisfactory completion of the comprehensive and qualifying examinations.
5. Approval of proposed dissertation topic.

**Ancillary Duties**

In addition to the completion of course requirements, satisfactory performance in some ancillary teaching, research, or practicum duties contributing to academic development is required, whether or not you receive financial support from this institution. These duties are assigned with educational objectives in mind.

# Master of Science

The general aim of the program is to prepare qualified students for further studies toward the doctoral degree or for careers as geologists in industry or governmental agencies. As with the Ph.D., this program offers training in four fundamental and interrelated areas of geological science: petrology, structural geology, tectonics, and geochemistry. It requires at least three semesters and one summer of full-time study and research, or the equivalent over a longer period beyond the baccalaureate. Two of the three semesters are needed for classwork. The third semester is normally required following the summer research program and is generally devoted to a synthesis of data gathered during the summer program.

**Program of Study and Research (30 credits, minimum)**

1. A proficiency examination in optical mineralogy and petrography will be given at the beginning of the first semester of graduate study.
2. Geology (18 30 credits)
    a. Geo 510 and Geo 517 are required for the degree, plus one course from each of the following two groups:
        (a) Geo 520, 530, or 650;
        (b) Geo 518, 545, or 675. Other courses as advised
    b. Independent research in a specialization (Geo 699 for 6 credits) with the results of the research reported in an acceptable thesis
    c. In addition to the normal 18 credits in geology, students are required to take Geo 500 each session of their registration

3. Supporting courses (0 12 credits). Selected courses in related fields as advised.
4. Satisfactory completion of a major field examination in geology.
5. Foreign language requirement. A reading knowledge of French, German, or Russian is desirable before entrance to the program and must be demonstrated before its completion. An alternative research tool (e.g., computer programming) may be substituted for a foreign language at the discretion of the department.

**Ancillary Duties**

In addition to the completion of course requirements, satisfactory performance in some ancillary teaching, research, or practicum duties contributing to the academic development is required, whether or not you receive financial support from this institution. These duties are assigned with educational objectives in mind.

# Graduate Courses

Course offerings at the graduate level reflect the four inter-related strengths in the department: geochemistry petrology and structural geology tectonics. Advanced courses in geophysics and sedimentology are available to students at nearby Rensselaer Polytechnic Institute. Course credits are shown in parentheses.

**Geo 505**

**Optical Mineralogy and Petrography (3)**
Systematics of mineral optics for the common rock-forming minerals and the properties of various mineral groups; microscope techniques and the examination of important igneous and metamorphic rock suites.

**Geo 510**

**Geochemical Thermodynamics (3)**
Basic principles of thermodynamics with applications to crystallization and fusion processes and mineral reactions. Treatment of silicate crystalline solutions. Analysis of phase diagrams of geological importance.

**Geo 511**

**Analytical Geochemistry (3)**
Theoretical and practical introduction to the use of geochemical instrumentation and methods; x-ray spectrometry diffraction, electron-beam microanalysis, mass spectrometry, and high-temperature experimental petrology.

**Geo 516**

**Marine Geology (3)**
Geology of the ocean basins with emphasis on the morphology, sediments, sedimentary processes, crustal structure, and evolution of the ocean floor.

**Geo 517**

**Tectonics (3)**
Seismologic basis for plate tectonics, kinematics of plate motion, geometry, and evolution of plate mosaics. Analysis of the structure and history of shields, platforms, rift valleys, plateaux, continental margins, island arcs, transcurrent fault zones, and orogenic belts.

**Geo 518**

**World Historical Geology (4)**
An integrated survey of the geologic history of the earth.

**Geo 520**

**Igneous Petrology (3)**
Basic concepts in igneous petrology, including differentiation mechanisms, the reaction principle and partial melting. Properties and tectonic relations of the main igneous rock associations with study of selected examples.

**Geo 530**

**Metamorphic Petrology (3)**
Basic concepts in metamorphic petrology, including progressive metamorphism, metamorphic facies, and facies series. Tectonic relations of regional and ocean-floor metamorphism. Regional metamorphism in North America.

**Geo 540**

**Geophysics (4)**
Introduction to geophysical characteristics of the earth and basic geophysical techniques such as seismic refraction and gravity, magnetic and thermal measurements. General survey of current geophysical models of the interior of the earth.

**Geo 545**

**Structural Geology III (4)**
Structural analysis, mechanisms of rock fracture and flow, interpretation of regional stress and strain history from structural features.

**Geo 610**

**Geochemical Kinetics (3)**
Principles and application of diffusion theory to nonequilibrium geological processes. Methods of solution of the diffusion equation, rate laws, thermochronology, irreversible thermodynamics, and solid state properties of minerals.

**Geo 620**

**Tectonics II (3)**
Study of the tectonic evolution of the earth's crust from the Mesozoic to recent.

**Geo 630**

**Phase Equilibria (3)**
Principles of phase equilibria applied to advanced topics in geochemistry, including liquid immiscibility, critical phenomena, volatile-rich systems, exsolution and inversion processes, and geothermometry geobarometry.

**Geo 640**

**Cosmochemistry (3)**
Cosmic abundances (elemental and isotopic); their usefulness in constraining the origins of major chemical systems on planets. Specific topics include the following: (a) core mantle equilibrium within the earth; (b) origin of atmosphere hydrosphere on Venus, Earth, and Mars; (c) origin of the earth's moon; and (d) origin of differentiated meteorites.

**Geo 650**

**Isotope Geochemistry (3)**
Chemical evolution of the earth, including nucleosynthesis, nebular condensation, and development of the crust mantle core. Emphasis on evidence from trace-element and isotope geochemistry.

**Geo 670 Topics in Mineralogy (1 4)**
**Geo 671 Topics in Igneous Petrology (1 4)**
**Geo 672 Topics in Metamorphic Petrology (1 4)**
**Geo 673 Topics in Geochemistry (1 4)**
**Geo 674 Topics in Stratigraphy-Sedimentation (1 4)**
**Geo 675 Topics in Structural Geology (1 4)**
**Geo 676 Topics in Tectonics (1 4)**
**Geo 677 Topics in Marine Geology (1 4)**
**Geo 678 Topics in Geophysics (1 4)**

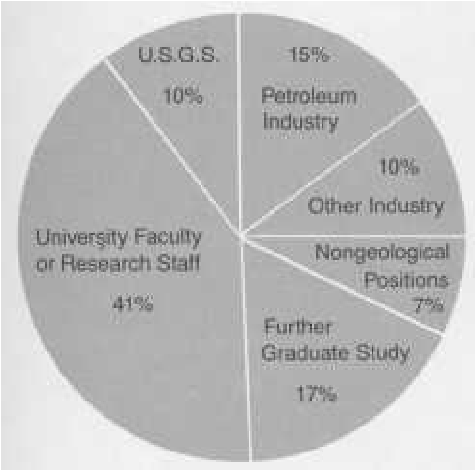
**Geo 740**

**Tectonics III (3)**
Study of the tectonic evolution of the earth's crust from Precambrian to late Paleozoic.

**Geo 500 Seminar (0)**
**Geo 694 Directed Readings in Geology (2 6)**
**Geo 699 Thesis Research (2 6)**
**Geo 894 Directed Readings in Geology (2 6)**
**Geo 898 Doctoral Research (2 9)**
**Geo 899 Dissertation (3 2)**

# Career Placement

Our graduates have had excellent job placement records. Over 40 percent have taken jobs as University faculty or research staff. Among the institutions at which they work are Cornell University, Woods Hole Oceanographic Institution, the University of Houston, University of Chicago, Johns Hopkins University, and the University of Texas at Austin. Many others take jobs with oil companies, including Amoco, Texaco, Sunoco, and Cities Services. About 40 percent of our master's students go on to further study.



# The Area

The Capital District is at the crossroads of a region remarkable for its natural and cultural resources and especially suitable for geological fieldwork.

Within a short distance of the campus are the Berkshires, the Catskills, and the Adirondacks the largest wilderness area east of the Mississippi, and Lake Placid, site of the 1980 Winter Olympic Games. Skiers will find the full range of opportunities for cross-country or for Alpine activity, with major areas such as Killington, Gore, Hunter, Bromley, Stratton, and Mt. Snow within commuting distance. Saratoga Springs is internationally known as a sports and cultural center with the famous racetrack active in August and the New York City Ballet, the Philadelphia Orchestra, and the City Center Acting Company in residence each summer. Nearby Williamstown, Jacob's Pillow, Tanglewood, and Woodstock are also alive with theatre, music, arts, and crafts.

The Capital District, which also includes the cities of Schenectady and Troy, has a population of approximately 750,000. New York City is 150 miles to the south, Boston 175 miles to the east, and Montreal 225 miles to the north. The New York State Thruway and two major interstate highways intersect within a mile of the main campus. There are bus, rail, and air terminals within five miles of the University.

## Financial Support

Financial support is available to graduate students on a competitive basis. The main source of support is through teaching assistantships which carry a stipend of approximately 6,000 for the academic year, plus a waiver of tuition for up to 10 credits per semester. Grant-supported research assistantships are also available which carry a comparable stipend and may be accompanied by a tuition waiver. You can supplement these during the summer through research and teaching appointments.

The University offers a number of three-year Presidential Fellowships in the amount of 7,000 per year plus a tuition waiver. You are encouraged to apply for other fellowships, such as the National Science Foundation Graduate Fellowships.

Some support for student-initiated research is available both through the Department and the SUNYA Benevolent Foundation. You are encouraged to apply for research funding from external sources (e.g., Geological Society of America, Sigma Xi) from which funds have been regularly obtained in the past.

## Admissions

**Doctor of Philosophy**
You must have a bachelor's degree from an accredited college or university with a specialization in one of the physical sciences or engineering. Although the program is designed primarily for students who have majored in geology at the undergraduate level, there may be instances in which a science student with other than a major in geology may be admitted to the doctoral program provided that the deficiencies in undergraduate geology are made up during the first year of graduate study. Test scores of the Graduate Record Examinations are required.

**Master of Science**
You must have a bachelor's degree from an accredited college or university with a specialization in one of the physical sciences, mathematics, or engineering. Although the program is designed primarily for students who majored in geology at the undergraduate level, there may be cases where science majors are admitted provided they make up deficiencies during the first year of graduate study.

You must submit scores on the Aptitude Test of the Graduate Record Examinations. This program is not open to students completing qualifications for a secondary school teaching certificate.

## More Information

Please do not hesitate to write or call for more information we'd be happy to answer your questions or send you an application. Write or call:

Professor W. D. Means
Department of Geological Sciences
Earth Science 351
State University of New York at Albany
1400 Washington Avenue
Albany, New York 12222
(518) 457-3975

State University of New York at Albany does not discriminate on the basis of age, color, creed, disability, marital status, national origin, race, or sex. Inquiries concerning this policy should be directed to the Affirmative Action Office.

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