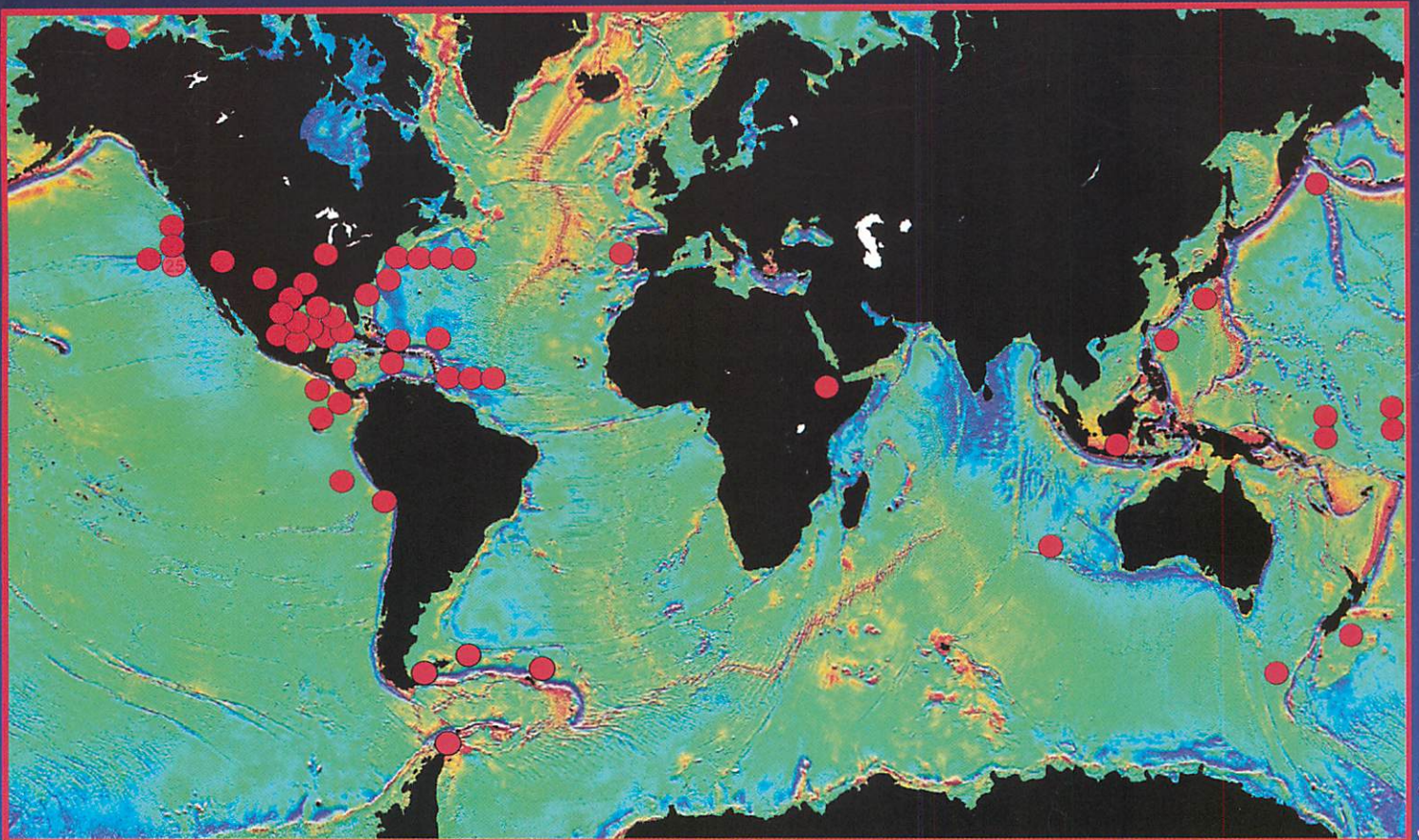


# UTIG World Wide Presence in the 21st Century



The University of Texas at Austin  
Institute for Geophysics



# A LETTER FROM THE DIRECTOR

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As the Institute for Geophysics enters the new millennium, we have plans for expansion beyond the already robust collection of research, training, and outreach projects overviewed in these pages. Most exciting, a generous gift from the G. Unger Vetlesen Foundation will fund a new research effort in quantitative climate modeling based on the climate variations preserved in the geologic record. This initiative takes advantage of UTIG's existing expertise in climate change observations and computational modeling; it also provides a unique opportunity to develop more powerful and more accurate climate prediction models. As part of this new initiative Charles Jackson, a talented paleoclimate modeler, joined UTIG's research staff in September 2000 and we seek to hire a second expert this year.

Looking forward to 2003, when the Integrated Ocean Drilling Program (IODP) will replace the current ODP, we expect several UTIG scientists to play central roles in both designing and managing the new program's geophysical facilities and in related data acquisition and processing efforts. Two of our senior research scientists and I serve on the committees planning the IODP's management structure and scientific program. As the IODP reconfigures existing drilling activities for regional geologic contexts and defines new riser and riserless drilling sites, the Institute's expertise in 3-D seismic imaging will be more valuable than ever. This expertise and the rewards of such international collaboration are currently manifest in a joint U.S.-Japanese investigation of subduction processes in the Nankai Trough offshore Japan. Led by two UTIG scientists, the research team has surveyed and is currently processing images of the Nankai seismogenic zone in an effort to better understand earthquake genesis and in preparation for post-2003 drilling.

The Nankai survey was the largest-ever academic 3-D survey of its type. Scientists at UTIG are striving to match such record-breaking data acquisition with comparable breakthroughs in dissemination. The massive archive of marine seismic reflection data collected worldwide by UTIG investigators since 1974 will soon be available online to the international marine geophysical community and industry. We expect that the Institute's Seismic Reflection Data Search (SRDS) web site will not only facilitate access to this 26-year archive but also serve as the prototype for an international equivalent.

Finally, having worked out of rented space for nearly two decades, we anticipate that UTIG will be housed permanently in The University of Texas's Pickle Research Center in the near future. The Institute's planned new location will provide the advantage of proximity to UT's Bureau of Economic Geology, a natural collaborator in research projects related to resource exploration.

Sincerely,



**UTIG**  
**WORLD WIDE PRESENCE IN**  
**THE 21ST CENTURY**

JULY 2001

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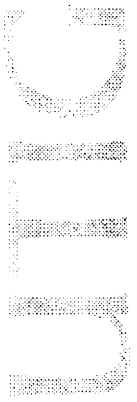
We gratefully acknowledge the assistance of Patty Ganey-Curry, Janet Everett and Gwen Watson with the design and layout of this document.

**PAUL STOFFA**  
**Director of UTIG**



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# WHO WE ARE

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The University of Texas Institute for Geophysics (UTIG) is known internationally as a leading academic research group in geology and geophysics. Founded in 1972, it is an Organized Research Unit within The University of Texas System, operating under the auspices of the flagship College of Natural Sciences in Austin. UTIG research activities are carried out all over the world and include large-scale, multi-investigator, multi-institutional field programs. The importance of geophysical measurements and their mathematical interpretation in the exploration for petroleum and economically useful minerals has also led to valuable partnerships between UTIG and industry.

The Institute for Geophysics currently hosts 24 research scientists, four post-doctoral fellows, and two emeritus professors. The support staff of about 30 people includes engineers, systems analysts, technicians, and administrative personnel. UTIG maintains a close working relationship with the University's Department of Geological Sciences (DGS), in which four Institute scientists serve as faculty. During any given semester, between 20 and 30 graduate students, mostly from DGS, engage in UTIG research as partial fulfillment of their Masters and Ph.D. degree requirements; about ten undergraduate students assist researchers each year. The Institute for Geophysics also plays a role in K-12 education through formal teacher-training programs and informal outreach efforts.

*Texas—given its historical association with the energy industry, its large and economically important continental shelf and slope, and its direct access to the world's oceans through the Gulf of Mexico—is a natural location for an Earth sciences research institute of global scope with emphases in geophysics and marine geology.*

## A BRIEF HISTORY OF UTIG

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The organization that was to become the Institute for Geophysics was established in 1972 when Maurice Ewing, one of the most highly acclaimed Earth scientists of the twentieth century and a native of Texas, returned to his home state. Ewing, who also founded the present-day Lamont-Doherty Earth Observatory of Columbia University, established and served as the first director of the Earth and Planetary Sciences Division of the Marine Biomedical Institute at The University of Texas Medical Branch in Galveston. During his lifetime, Ewing used exploration geophysics to help lead the world into the post-WWII era of global research in the ocean basins. By the time of his death in 1974, the Earth and Planetary Sciences

*Founded in 1972 by geophysicist and oceanographer MAURICE ("Doc") EWING, The University of Texas Institute for Geophysics is situated in Austin, the state capital of Texas.*

*"Drilling 17 holes at ten sites, the scientists [on DSDP Leg 3] made the most significant discovery in the history of scientific ocean drilling and helped evolve our understanding of Earth's processes" —The Ocean Drilling Program, Celebrating 30 Years of Scientific Ocean Drilling: 1999 Calendar.*

*In 1998 the Board of Directors of the Offshore Energy Center inducted The University of Texas Institute for Geophysics into the Center's Hall of Fame as a Technology Pioneer in the field of "Search for Oil and Gas: Marine Exploration". This honor is in recognition of UTIG's 25-year history of contributions in two-dimensional and three-dimensional marine seismic data acquisition, processing, and interpretation.*

Division had become an established center of lunar and seismology research, and had initiated the first academic program in marine multichannel seismic research.

Building on this solid foundation, The University of Texas Board of Regents developed a plan to promote advanced research and teaching programs in areas related to the state's natural resources, particularly the coastal zone. To facilitate this plan, the administration of the Earth and Planetary Sciences Division was transferred to the Marine Science Institute of The University of Texas at Austin in 1974 and the Division was renamed the Galveston Geophysics Laboratory.

In 1982, to promote closer interaction with the Department of Geological Sciences and to augment its role in graduate education, the Laboratory was renamed The University of Texas Institute for Geophysics (UTIG) and moved to Austin. Arthur E. Maxwell assumed the directorship. Maxwell had made his mark in the annals of Earth science by serving as co-chief scientist of Leg 3 of the Deep Sea Drilling Project (DSDP) in 1968. The scientists on DSDP Leg 3 confirmed seafloor spreading and thus substantiated the now widely accepted hypothesis of plate tectonics, an accomplishment that has been called the most significant discovery in the history of scientific ocean drilling. DSDP Leg 3 also led to the validation of the paleomagnetic time scale, giving geophysicists a powerful tool for estimating the age of the ocean floor. Between 1982 and 1994, UTIG expanded its role in marine geophysics and seismology and developed major research programs in polar regions, particularly Antarctica and the southern oceans.

In 1994, Maxwell retired as director and was succeeded by Paul Stoffa, who also holds the Shell Distinguished Chair in Geophysics in the Department of Geological Sciences. Stoffa is a marine seismologist with expertise in multichannel seismic acquisition, the use of parallel computers in seismic processing, and the modeling and inversion of geophysical data. He has strengthened his administrative team at UTIG by naming two senior scientists, Ian Dalziel and Cliff Frohlich, as associate directors, and by hiring Katherine Ellins to serve as program manager. Stoffa's primary goals as Director are to ensure that UTIG retains its place as a premier geophysical research institution and that its scientists have the resources to allow them to continue to expand the frontiers of knowledge in their study of Earth science. Under Stoffa, UTIG's scope has broadened still further to include a wider range of geophysical projects, a new climate modeling initiative, and a program of K-12 educational outreach. To meet these challenges the space requirements of the Institute have increased. Efforts are underway to expand the financial resource base of the Institute.

# UNIQUE IN THE UNIVERSITY OF TEXAS SYSTEM

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UTIG research projects often involve large interdisciplinary research teams of scientists, graduate students, engineers, and other technical personnel, and are usually collaborative efforts that include investigators from other national and international academic institutions, as well as industry partners. Such projects are regularly undertaken during the academic year to take advantage of optimal local weather, sunlight, sea state, and, at times, the availability of specialized equipment and research platforms (e.g., ships, airplanes, and jack-up rigs). The ability for UTIG's researchers to organize and participate in complex field projects that require weeks, or even months, at sea or in the field sets UTIG apart from academic departments at The University of Texas at Austin.

## WHERE TO LEARN MORE

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UTIG is expanding virtual frontiers, as well. The Institute for Geophysics has an ever-growing, continuously updated web site at [www.ig.utexas.edu](http://www.ig.utexas.edu). There, anyone with access to the Internet will find comprehensive information and the latest news about:

- ★ field projects and research facilities;
- ★ research staff, students, and alumni;
- ★ seminars, meeting abstracts, and technical reports;
- ★ K-12 educational projects and other forms of public outreach;
- ★ UTIG's institutional history.

*Set apart within The University of Texas System as a unique center for research, UTIG can afford its talented scientific staff the flexibility to fulfill its commitment to carry out pioneering research in Earth science at the highest academic standards.*

# FUNDING FOR RESEARCH

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## *SCHOLARSHIP*

## *COLLABORATION*

## *RESOURCE EXPLORATION*

## *GRADUATE EDUCATION*

## *POSTDOCTORAL TRAINING*

## *PUBLIC OUTREACH*

Throughout its history UTIG has received financial support from a diverse variety of sources. While the State of Texas provides funding for the core operating expenses, the majority of UTIG's support has always come from contracts and grants. Federal agencies, principally the National Science Foundation and the Office of Naval Research, together with a large number of industry sponsors (oil and oil service companies) support most of the research activities at UTIG. Since 1995 gifts from Advanced Microdevices, BP, Gale White, the Palisades Geophysical Institute, Paradigm Geophysical Corporation, Schlumberger Technology Corporation, the Shell Oil Company Foundation, and the Vetlesen Foundation have provided seed money for new initiatives, essential computational equipment and software, and fellowship support for graduate students and postdoctoral research scientists.

# WHAT WE DO

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UTIG strives to conduct research that expands the frontiers of knowledge in Earth science, has societal and economic relevance, and is of human interest. Dedicated to both basic and applied research, the Institute aims to enhance humanity's fundamental understanding of the dynamic geophysical processes that have influenced and continue to influence Earth's structure and climate. Geographically, UTIG's scope includes the ocean basins, continental margins, Antarctica, and all sites of seismic activity. Chronologically, its scope is no less vast: from the development of tectonic evolution models that reconstruct continental arrangements as much as a billion years ago to predicting how future climatic scenarios would impact sea-level changes and thus the habitability of densely populated coastal regions. The Institute's research has been and will continue to be highly relevant to natural resource exploration, the assessment of geologic hazards, and the mitigation of environmental damage. The development of new mathemat-

ical models, data processing and imaging techniques, and geophysical instrumentation is also an integral part of UTIG's ongoing research and future goals.

In addition to such research—reviewed in detail under the “Research Projects” heading below—UTIG's program includes five other essential elements:

- \* the publication of its findings in scholarly journals and conference presentations;
- \* partnerships in academia through participation in national and international research organizations;
- \* partnerships with industry, especially in the area of natural resource exploration;
- \* postdoctoral training and graduate education;
- \* public outreach including K-12 educational training.

## SCHOLARSHIP

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The dialogue that is international science is carried out principally through the publication of research results in respected academic journals. UTIG's scientists, postdoctoral fellows, and graduate students have always been committed to sharing the fruits of their research and analysis with the scientific community and lay public.

*Since 1990, individuals supported by UTIG publish about 40 papers each year in peer-reviewed scientific journals; papers authored by UTIG researchers now collectively receive more than 1000 citations each year.*

## PARTNERSHIPS IN ACADEMIA

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With the desire to conduct research on a global basis comes the need for multi-institutional cooperation. To this end, UTIG scientists often work on teams in large, collaborative research programs. Beyond the participation of its scientists in national and overseas programs as necessary for individual field projects (see

*Many UTIG scientists participate as individuals in national and international geoscience initiatives that correspond to their particular focused disciplinary interests.*



**INTERRIDGE (THE INITIATIVE FOR INTERNATIONAL COOPERATION IN RIDGE-CREST STUDIES)** is an international, interdisciplinary initiative concerned with all aspects of mid-ocean ridge crest research from biology to geophysics.

**LIPS** is an initiative to study the origin and evolution of large igneous provinces (LIPS) and their role in continental break-up, mantle convection, and climate dynamics.

**MARGINS** is a U.S. program dedicated to understanding the complex interplay of processes that govern continental margin evolution globally.

**SEIZE (THE SEISMOGENIC ZONE EXPERIMENT)** comprises scientists who coordinate experiments—including geophysical surveys, ocean drilling, and borehole observations—designed to study the seismogenic zone.

**STRATAFORM (STRATAL FORMATION)** is a project funded by the Office of Naval Research (ONR) to study continental shelf sediment dynamics, slope geologic processes, and stratigraphic sequences resulting from shelf and slope sedimentation offshore New Jersey and California.

sidebar), UTIG is directly involved in the activities of several international and U.S. academic research alliances.

The OCEAN DRILLING PROGRAM (ODP) is a major international effort to explore the geological and geophysical structure of the ocean floor through a systematic program of ocean drilling. Since 1972, twelve UTIG scientists have served as Chief Scientists for the ODP. UTIG has played the leading role in the acquisition and processing of multichannel seismic data for ODP drill-site selection and evaluation; it was the first academic institution to collect such data and, later, the first to collect and process three-dimensional seismic data. UTIG scientists are heavily involved in the planning of the Integrated Ocean Drilling Program (IODP), which will replace the ODP in 2003.

The JOINT OCEANOGRAPHIC INSTITUTIONS INC. (JOI) is a consortium of 14 major U.S. oceanographic institutions that oversees the organization, management, and scientific planning structure of the ODP. UTIG is the institutional representative for The University of Texas at Austin in JOI, and UTIG's director, Paul Stoffa, is currently Chairman of the JOI's Board of Governors. Under his leadership, JOI will bid on the contract to manage the IODP.

The JOINT OCEANOGRAPHIC INSTITUTIONS FOR DEEP EARTH SAMPLING (JOIDES) is the international organization responsible for providing advice to JOI on the scientific and technical planning of the Ocean Drilling Program. The U.S. representatives on JOIDES panels and committees are chosen by the U.S. Science Advisory Committee (USSAC). UTIG scientists serve on several advisory panels.

The CONSORTIUM FOR OCEAN RESEARCH AND EDUCATION (CORE) is an association of 63 U.S. oceanographic research institutions, universities, laboratories, and aquaria with the shared goal of promoting all aspects of marine science research and education. UTIG is UT-Austin's representative in CORE.

The INTERNATIONAL SEISMOLOGICAL CENTRE (ISC) undertakes the final collection, analysis, and publication of standard earthquake information from all over the world.

The SUPPORT OFFICE FOR AEROGEOLOGICAL RESEARCH (SOAR) is the research facility created by the NSF Office of Polar Programs (OPP) for the purpose of executing NSF/OPP-sponsored aerogeophysical work in Antarctica. Based at UTIG from 1994 to 2002, SOAR has been responsible for scheduling and carrying out the acquisition of all airborne geophysical data required by U.S. investigators to study the Antarctic ice sheet.

The INCORPORATED RESEARCH INSTITUTIONS FOR SEISMOLOGY (IRIS), a consortium of U.S. universities with research programs in seismology, seeks to develop and operate the infrastructure needed for the acquisition and distribution of high quality seismic data.

The UNIVERSITY-NATIONAL LABORATORY SYSTEM (UNOLS) is the organization responsible for scheduling and oversight of the U.S. academic fleet.

The SOUTHEAST CONSORTIUM FOR OCEAN RESEARCH (SECOR) is a consortium of academic institutions in the southeastern U.S. formed to foster marine science programs and facilities in that region.

## PARTNERSHIPS WITH INDUSTRY: NATURAL RESOURCE EXPLORATION

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Geophysicists currently lead the effort to explore marine reserves of oil, natural gas, gas hydrates, and minerals. Although geophysical techniques do not eliminate the need for exploratory drilling, they minimize this expensive process by detecting and delimiting prospects. In addition to accruing new data through field research, UTIG scientists synthesize and disseminate the scientific knowledge and technical information crucial to natural resource exploration.

Geophysical conditions favorable for the occurrence of frozen methane, known as **GAS HYDRATES** or clathrates, have been identified from seismic data. In 1996, drilling on Ocean Drilling Project (ODP) Leg 164 off the southeast coast of the United States provided evidence that gas hydrate resources trapped in sediment layers on the continental shelves worldwide are greater than previously estimated. This discovery prompted the U.S. Department of Energy and national oil companies in India and Japan to launch programs to identify reserves and to determine how to exploit this enormous untapped energy resource. Several UTIG scientists are pursuing geophysical projects to further characterize the marine environments where gas hydrates occur.

The **GULF BASIN DEPOSITIONAL SYSTEMS (GBDS) PROJECT**, supported by 22 oil companies, aims to provide the foundation for a detailed, comprehensive synthesis of the Gulf basin that merges the basin-floor succession (understood largely

*The **ONR GEOCLUTTER PROGRAM** seeks to develop models that will help distinguish geologic structures from artificial targets in the seafloor's shallow subsurface. Initial work will focus on the mid-outer continental shelf offshore New Jersey because bathymetry and portions of the shallow subsurface have already been mapped in detail as a result of STRATAFORM.*

*Hydrocarbons and economically useful minerals will remain essential commodities in the global economy well into the 21st century. Oil and mining industries therefore seek to further capitalize on innovative geophysical techniques as they extend their exploration efforts ever deeper into the ocean basins.*

*In the summer of 2000, scientists from UTIG, Oregon State University, and Columbia University conducted a high-resolution seismic reflection and refraction survey at Hydrate Ridge, offshore Oregon. ODP will drill Hydrate Ridge in 2002 to study the occurrence of gas hydrates at convergent margins.*

## **INDUSTRY SPONSORS**

**(1995-2001):**

*Alberta Energy*  
*AMOCO Production Co.*  
*AGIP Petroleum Co. Inc.*  
*Anadarko Petroleum Corp.*  
*Arco*  
*BHP Petroleum (Americas) Inc.*  
*BP*  
*British Gas Technology*  
*Burlington Resources*  
*Chevron*  
*Conoco Inc.*  
*Elf Exploration Production, Inc.*  
*Exxon Exploration Co. (Now*  
*ExxonMobil)*  
*Japan National Oil Company*  
*Kerr McGee Oil and Gas*  
*Marathon Oil Co.*  
*Mobil Exploration & Producing*  
*NEXEN Inc.*  
*Norsk Hydro ASA*  
*Oryx Energy*  
*Pemex Exploracion y Prod.*  
*Pennzoil*  
*Petroleos de Venezuela, S.A.*  
*Phillips Petroleum Co.*  
*Shell*  
*Statoil*  
*Texaco USA*  
*TOTAL USA,*  
*UNOCAL (Spirit Energy)*  
*Vastar Resources (now BP)*

through seismic data) with the coastal plain, shelf, and upper-slope succession (defined mainly by well data) for the last 65 million years. Project scientists have customized ARC/INFO GIS software for regional mapping and analysis to produce a UTIG Gulf of Mexico database.

**The GULF OF MEXICO INTRASLOPE BASINS PROJECT (GIB)**, initiated with industry support in June 1998, entails a detailed, comprehensive, and integrated synthesis of the late Quaternary depositional facies in intraslope basins. Participating scientists seek to document the influence of sea-level change in controlling depositional facies and processes.

UTIG researchers are also interpreting faults and sedimentary sequences from a 3-D seismic survey of the southern part of Venezuela's MARACAIBO BASIN, one of the world's premier petroleum provinces. The Venezuelan National Oil Company, Petroleos de Venezuela, S.A. (PDVSA), has acquired 3-D seismic data for the entire basin as part of their oil exploration effort. One of UTIG's graduate student researchers is analyzing the depositional history of the Maracaibo Basin. This analysis will help to select sites for future petroleum wells in the basin.

**The PLATES PROJECT**, supported by a consortium of oil companies, develops software that reconstructs past and present tectonic plate movement. Scientists worldwide use models generated by PLATES to examine geological problems of global and regional extent and to identify the potential occurrence of mineral and petroleum reserves. PLATES provides powerful tools for reconstructing historical geologic environments, particularly if the underlying plate motion model is accurate and detailed. For this reason, PLATES is especially useful to groups engaged in exploration for hydrocarbons or minerals on global and regional scales. PLATES maintains an up-to-date oceanic magnetic and tectonic database. New paleomagnetic, hot spot, geological, and geophysical data are continuously added to extend the span and accuracy of global plate reconstructions. PLATES reconstructions are built around a comprehensive database of finite-difference poles of rotation, derived both from extensive plate motion research at UTIG, using the PLATES interactive plate modeling software, and from published studies.

Because geophysical measurements and their mathematical interpretation are crucial when exploring for petroleum and minerals, the **SLOSEIS (SLOWNESS ANALYSIS WAVEFORM INVERSION AND UNCERTAINTY ESTIMATION IN VTI MEDIA) PROJECT** seeks to develop velocity analysis, imaging, and seismic waveform inversion software for use by supporting industry partners.

**The TECHNICAL ALLIANCE FOR COMPUTATIONAL STRATIGRAPHY (TACS)**, supported by a consortium of nine oil companies and directed by UTIG's Hilary Olson and scientists at the University of Utah's Center for Industrial Imaging, developed biostratigraphic and quantitative stratigraphic software. The primary emphasis was on

technology development that contributes to multidisciplinary geologic studies but was not available to the industry user from existing commercial software applications. UTIG researchers used TACS's Integrated Paleontologic System (IPS) to rapidly synthesize the geologic record's wealth of paleontologic data and discern patterns that all geoscientists can access and interpret. The technology addressed petroleum-related issues such as the recognition of genetic sequences and techniques for the creation of optimal multi-well, composite stratigraphic sequences, the correlation of reservoir rocks, the establishment of a climate/sea-level framework of the rock column, and depositional setting of sedimentary units.

## POSTDOCTORAL TRAINING & GRADUATE EDUCATION

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The Institute for Geophysics provides research and educational opportunities for postdoctoral fellows and graduate students from the U.S. and countries all over the world. By participating in large field programs, fellows and students not only gain field experience and new insights into geological and geophysical phenomena, they also develop professional associations with other scientists who may become lifetime colleagues. By contributing to UTIG's excellent record of research and scholarship, they help maintain the Institute's high scientific standing. UTIG's postdoctoral training and graduate education has an impact on industry insofar as two-thirds of all graduate degree recipients go on to begin their geoscience careers in the industrial sector.

Many UTIG fellows and graduate students have received support from the Palisades Geophysical Institute (PGI). Since PGI's inception in 1994, its Postdoctoral Fellowship fund has supported ten postdoctoral fellows at UTIG, three of whom have since joined the scientific staff as research associates. To date, UTIG has also hosted over 50 different graduate students sponsored by PGI's Ewing-Worzel Graduate Fellowships. A recent endowment from the late Gale White ensures that UTIG will be able to offer support to additional graduate students. UTIG research staff members have served as principal research advisors or co-advisors to over 150 Ph.D. and Masters students.

### **FELLOWSHIPS AND SCHOLARSHIP SUPPORT**

*PGI Ewing Worzel Graduate Fellowships*

*Gale White Graduate Fellowships*

*PGI Postdoctoral Fellowships*

*BP Scholarships*

*Phillips Petroleum Scholarships*

*Located in a salt mine 470 meters beneath the surface, HKT is among the most sensitive stations in the world, especially since July 1995 when UTIG installed modern, broadband, digital seismometers whose recorded signals are continuously relayed to the global network by satellite*

*Visit the TexSeis web site at [www.ig.utexas.edu/texseis](http://www.ig.utexas.edu/texseis).*

*UTIG staff visit local schools, youth organizations, and other community centers to assist with science education and to make presentations about current research.*

## **PUBLIC OUTREACH**

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All of UTIG's research in the Earth sciences has, as its ultimate goal, to improve the welfare of the planet's occupants. But UTIG scientists also benefit the public—at local, state, and international levels—more directly through various outreach efforts related to safety and education.

### **EARTHQUAKE HAZARDS: KEEPING THE PUBLIC INFORMED**

UTIG scientists have always led efforts to monitor earthquakes and advise state officials, the media, and the general public about appropriate safety measures. Most of the information about local earthquakes is derived from data recorded at the Hockley Seismic Station (HKT), operated and maintained by UTIG. Since 1997, when rapid demographic changes were seen to warrant a state-supported program, UTIG scientists have been engaged in a major reassessment of Texas seismicity and resulting hazards.

Recently, scientists at UTIG and Texas Tech University collaborated to upgrade the seismic station in Junction, Texas (JCT). As funding becomes available, UTIG and Texas Tech will continue to install other stations at various in-state sites as part of the Texas Regional Seismic Network (TexSeis). The new TexSeis web site provides continuous public access to seismograms recorded by its own and other networks, a global seismicity database, and many other useful resources.

### **K-12 EDUCATIONAL INITIATIVES**

UTIG's K-12 educational initiatives include four major projects: two aimed at professional enhancement for K-12 science teachers—the "Geology, Meteorology, and Oceanography" teacher training workshops and the "Teachers in the Field" project—as well as an "Adopt-a-School" project and a planned "Seismology in Schools" project. These educational endeavors are part of a unified program of educational outreach and development that represents a coordinated vision for UTIG as a whole. They draw upon the work of all UTIG scientists, although individual researchers are involved at different levels. UTIG's educational outreach and development activities are an important investment in the future of Texas and the nation.

The Institute's educational outreach projects not only help students to understand geoscience, but also engage them in the fundamental scientific disciplines (physics, chemistry, and biology) and mathematics by appealing to their immediate, day-to-day experiences with the physical world around them. The first two projects fuel the enthusiasm of K-12 teachers for science and help them become better instructors. Because UTIG's projects reach out to teachers and students at ethnically and economically diverse schools, we expect to engage and inspire youth from traditionally underserved and under-represented groups. UTIG's contributions to K-12 science education will enrich the lives of K-12 students, provide a foundation for understanding the prudent development and use of natural resources, and help to create good stewards of the environment.

#### TEACHER TRAINING IN THE GEOSCIENCES

During the spring of 2000, UTIG scientists conducted a series of five-day leadership-training sessions for teachers of the Texas high school course "Geology, Meteorology, and Oceanography" (GMO). The GMO course is offered as a high school science elective and as such is part of the Texas State Board of Education's "distinguished" high school program. The course incorporates the scientific principles outlined in Texas Essential Knowledge and Skills, the National Science Education Standards, and the AAAS Benchmarks for Science Literacy in America into learning experiences organized within eight contemporary Earth science themes. The eight themes selected for the GMO course were based on research conducted at UTIG. All of the themes emphasize the concept of Earth as a system characterized by the complex interaction of processes, including biogeochemical and energy cycles. This theme-oriented approach realistically conveys how geoscientists study the history and changing nature of our planet and how they investigate environmental and energy-resource concerns. In addition, the approach illustrates the interdisciplinary nature of geoscience—specifically, how an integrated knowledge of physics, chemistry, biology, and mathematics is required to develop conceptual, mathematical, and computer models to explain the natural world.

#### THE "TEACHERS IN THE FIELD" PROJECT

Teachers in the Field provides K-12 science educators with authentic, first-hand research experience by allowing them to participate in field programs headed by UTIG scientists. Scientists at UTIG work with the Charles A. Dana Center and the Science Education Center at The University of Texas at Arlington to prepare K-12 science teachers for, and guide them through, an authentic geoscience project, including a field program, laboratory work, data analysis and synthesis, technical writing, and the development of curriculum materials for the classroom and the web. Scientific results and all the educational materials that are developed are shared electronically with the K-12 science education community. In addition, participants make presentations describing their experiences at national, regional, and

*More than fifty Texas school teachers participated in the GMO training courses during the spring of 2000.*

*Their enthusiasm is represented by this participant's comment: "Thank you so much for the best professional growth experience I've ever had."*

*The training project is part of the TEXTEAMS certification program of professional development and leadership training for K-12 teachers, sponsored by the National Science Foundation and the Texas Education Agency; a grant from the Charles A. Dana Center for Educational Innovation supported UTIG's involvement.*

*In April 2000, UTIG launched its "Teachers in the Field" pilot project. Stanly Treanor, a high school physics and computer science teacher from Merkel High School in Merkel City, Texas, sailed aboard the icebreaker R/V Nathaniel B. Palmer on an NSF-sponsored marine geophysical cruise as a member of a UTIG science party.*

*The goal of the cruise was to use UTIG's suite of ocean-bottom seismographs in a seismic refraction experiment to investigate geologic structures in the Bransfield Strait offshore of the Antarctic Peninsula. Mr. Treanor has since participated in a GMO training session to share his experiences and newly gained knowledge.*

*For more information about "Teachers in the Field" and to see Mr. Treanor's onboard photo-journal, please visit UTIG's "K-12 Education" web pages.*

*Effie Jarrett, a summer intern during 1993, returned to UTIG after earning a degree in computer science and worked with the SOAR group in Antarctica for three years. She is now a systems analyst in the Department of Geological Sciences.*

state educational and geoscience meetings. By providing teachers with a "once-in-a-lifetime" opportunity to be fully integrated into the scientific enterprise itself, to engage in scientific research, and to work in a collegial environment with scientists on a significant project, UTIG aims to fire their enthusiasm and to help them achieve a deeper understanding of contemporary geoscience.

#### **THE "ADOPT-A-SCHOOL" PROJECT**

The Institute for Geophysics is particularly proud of its achievements regarding its "Adopt-a-School" project, through which UTIG scientists make presentations about their research to fifth-grade classes at the Emma Galindo and Bertha Casey Elementary Schools and Liberty Hill Elementary School, as well as many other local schools. Since 1998, UTIG researchers have worked closely with teachers to convey interesting science concepts and to recreate the excitement of scientific discovery in the classroom. Testimony of the project's tremendous success is provided by two consecutive first-place wins in 1998 and 1999 for the UTIG/Galindo fifth grade's entry at Austin Science Fun Day, a competitive science fair staged annually at the Texas Memorial Museum by The University of Texas at Austin's College of Natural Sciences. On both occasions, students from Galindo Elementary, a bilingual school, impressed judges and fair visitors with their ability to clearly explain their projects in English and Spanish. Liberty Hill and Bertha Casey Elementary students both won Excellence Awards for their projects in 2000 and 2001.

#### **THE "SEISMOLOGY IN SCHOOLS" PROJECT**

While earthquakes present dire hazards to human society, they also offer opportunities to study the composition and dynamic processes of the entire Earth. The Institute for Geophysics plans to enrich secondary-school science education by establishing a "Seismology in Schools" project in conjunction with the Texas Regional Seismic (TexSeis) network. Each station in the TexSeis network, including the Hockley seismographic station maintained by UTIG, will be associated with a nearby host school. The project will engage students in the acquisition and manipulation of seismological data, help teachers bring relevant science into the classroom, and motivate and enable scientists to spread their knowledge and activities beyond the boundaries of their departments.

#### **THE U.S. DEPARTMENT OF DEFENSE SCIENCE AND ENGINEERING APPRENTICESHIP SUMMER PROGRAM**

UTIG is one of five laboratories at UT Austin that participates in this apprenticeship program to provide recent high school graduates with hands-on experience in a stimulating research environment. Each summer since 1993, UTIG has hosted two to four students as part of this initiative.

## MUSEUM EXHIBITS & OTHER PRESENTATIONS

As experts in their field, UTIG scientists contribute and review material used in local and international exhibits as well as national broadcasts. For example:

- \* UTIG researchers participated in planning and generating material for the Smithsonian traveling exhibition "Ocean Planet."
- \* Material for the daily National Public Radio series "Earth and Sky" is prepared in Austin and reviewed by the UTIG research staff.
- \* Don Blankenship contributed to the BBC program HORIZON-ANATARCTICA: "The Ice Melts" (first broadcast in October 1997).
- \* Don Blankenship also contributed to the NOVA program on Antarctica, "Warnings from the Ice" (first broadcast in April 1998).
- \* UTIG's PLATES research staff regularly contribute educational material for public presentations regarding plate tectonics. One such exhibit is "Our Dynamic Earth," a UK Millennium Project that opened in Edinburgh, Scotland, in May 1999.
- \* The PLATES research staff also contributed to the public television science program NOVA's documentary on the Seychelles, "Garden of Eden" (first broadcast nationally in November 2000).
- \* "Waltz Across Time," an exhibit at The University of Texas at Austin's Texas Memorial Museum (Feb.-Dec. 2000), featured a computerized PLATES animation that chronicles the tectonic plate movement of Texas over the last 750 million years.

*PLATES's "Waltz Across Time" animation is publically available at [www.ig.utexas.edu/research/projects/plates/movies/txant.ppt](http://www.ig.utexas.edu/research/projects/plates/movies/txant.ppt).*

*For information about any of these outreach efforts, please visit UTIG's web site at [www.ig.utexas.edu](http://www.ig.utexas.edu), then select "Outreach."*



# RESEARCH

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Geoscience is by nature interdisciplinary, integrating knowledge of geology, physics, biology, chemistry, and mathematics to shed light on the dynamic history of our planet and on some of humankind's most pressing environmental and energy-resource concerns. UTIG research scientists apply geophysical methods to a wide range of investigations from studies of the entire Earth to the exploration of localized areas in the upper crust. The variety of subjects studied includes the dynamics of the Western Antarctic Ice Sheet, climate change, plate tectonics, continental margin morphology, sea-level fluctuations, and seismology. UTIG scientists also develop new methodologies and quantitative techniques for analyzing and processing geophysical data. The many projects underway at UTIG provide information crucial to our understanding of the geophysical processes that have shaped our planet and affected its climate in the past, enabling us to prepare for the future.

*UTIG's capabilities in geophysical research extend from problem-definition through data acquisition and processing to the interpretation of results. To meet the requirements of each step, the Institute for Geophysics uses state-of-the-art equipment and technologies. The development of new methodologies and instrumentation for research projects is an integral part of UTIG's activities.*

## PROVIDING THE MEANS

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### RESEARCH PLATFORMS: SHIPS & AIRCRAFT

UTIG research scientists conduct marine research on ships that are part of the U.S. academic (University-National Oceanographic Laboratory) fleet, including The University of Texas's own ship, *The Longhorn*, and the U.S. Antarctic Research Program. They also go to sea on Coast Guard and U.S. Navy vessels, and on the Ocean Drilling Program's drillship, the *JOIDES Resolution*. Collaborations with Australia, Canada, France, Germany, Great Britain, Japan, Norway, and Taiwan also provide UTIG scientists with opportunities to sail on other international vessels. Research ships are generally outfitted with the highly specialized instruments and acquisition systems necessary for geophysical surveying. Specific ships are selected to match the scientific objectives of each research problem.

The Support Office for Aerogeophysical Research (SOAR), based at UTIG from 1994 to 2002 and funded by the NSF, is the national facility responsible for

all U.S. aerogeophysical research in Antarctica. Aerogeophysical surveying is rapid and cost-effective; vast areas of the ice sheet can be surveyed rapidly without the risk of sending a field party into the survey area. SOAR uses a ski-modified deHavilland Twin Otter aircraft fitted with a suite of airborne geophysical instruments to provide high-quality, integrated observations of ice thickness, surface elevation, magnetics, and gravity. The instrument package includes ice-penetrating radar and a laser altimeter, magnetometer, and gravimeter. State-of-the-art logging systems record the data on-board. Data processing requires calculating the aircraft's trajectory to a high precision, using the U.S. Global Positioning System (GPS), while real-time navigation is accomplished using the Russian GLONASS system in combination with GPS.

## MARINE GEOPHYSICAL SURVEYING

UTIG investigators apply seismic refraction and reflection surveying to a wide range of problems: from large-scale experiments designed to study the structure of the Earth's entire crust to investigations of targeted geologic settings.

### SEISMIC REFRACTION

Seismic refraction surveying uses seismic energy that returns to the surface after traveling through the ground along refracted ray paths. Because this energy travels at different speeds through different types of rocks, refracting interfaces separate layers of different seismic velocity. Seismologists use seismic refraction data to develop detailed images of the crust and the upper mantle below the seafloor.

To carry out seismic refraction work on the seafloor, UTIG has developed a specialized ocean-bottom seismograph (OBS) contained in a glass ball seated in a polyethylene hemisphere. Experiments using OBS instruments may be "passive", in which the energy generated by earthquakes is detected and used to create an image of the Earth's interior, or "active", in which seismic sources (high-energy sound waves) are generated from research ships.

### SEISMIC REFLECTION

Seismic reflection surveying uses seismic energy initially generated from a sound source on board a research ship that returns to the surface after being reflected from subsurface rock and sediment layers. The reflected sound provides an image of sub-seafloor layers as the speed and direction of the sound waves are altered by the physical properties of the sediments or rocks. Seismic reflection surveys provide a specified depth of penetration and a particular degree of resolution of the subsurface geology in both the vertical and horizontal dimensions. A conventional reflection detector system consists of an array of geophones or

*UTIG researchers and their colleagues have used gravimeters, like those on SOAR's instrument suite, to identify sedimentary streams beneath the Western Antarctic Ice Sheet and to delineate the structure of the Chicxulub impact crater.*

*More than two-thirds of the Earth's surface is covered by ocean, so there are many scientific applications for an underwater seismograph.*

*UTIG's OBS instruments have been used to obtain seismic refraction data at hundreds of sites all over the world.*

*UTIG Senior Scientist Tom Shipley has created the UTIG Seismic Reflection Data Search (SRDS) web site to facilitate access to the Institute's 26-year global archive of seismic reflection data and to serve as the prototype for an international equivalent.*

hydrophones arranged in a specific pattern and connected together. The assembly, known as a streamer, is towed behind the research vessel.

In 1986, UTIG became the first academic institution to collect and process three-dimensional (3-D) marine seismic data. The collection of such data involves very detailed seismic reflection profiling in combination with satellite navigation to produce a detailed portrait of the Earth's interior. With 3-D seismic data, investigators can select specific surfaces within the surveyed zone that are of special interest and use sophisticated visualization software programs to generate maps of them.

#### **MULTIBEAM BATHYMETRY**

UTIG researchers also use sidescan sonar and high-resolution, multibeam bathymetric systems to image seafloor morphology and texture. The multibeam bathymetric systems available on some UNOLS vessels consist of two hull-mounted instrument arrays. One array transmits a succession of sonic pulses in a swath; the sound reflected from the seafloor is received by a second array. Advances in data acquisition and image processing have made it possible to generate mosaiced topographic maps of the seafloor in real time. Such maps provide a regional view of the geologic framework, fundamental for research and sound management of the coastal ocean. The simultaneous collection of conventional high-resolution seismic reflection profiles of the structure beneath the seafloor and high-resolution sidescan data provides a four-dimensional view of the seafloor. The interpretation of these data yields insight into past and present processes responsible for shaping the seafloor.

#### **EARTHQUAKE DETECTION**

UTIG maintains the Hockley Seismic Station (station code HKT) in Hockley, Texas, which has used modern three-component broadband digital equipment since 1995. Data acquired from Hockley is forwarded to the Global Seismic Network (GSN) operated by the Incorporated Research Institutions for Seismology (IRIS). The Hockley Seismic Station is also a cooperating member of the United States National Seismic Network (USNSN). All data are archived continuously 24 hours a day regardless of the earthquake.

#### **GLOBAL POSITIONING**

The U.S. Global Positioning System (GPS) satellites provide data that are used in a broad spectrum of Earth science disciplines, including geodesy and geodynamics. Currently, there are 24 satellites, each travelling in a 12-hour, circular orbit 20,200 kilometers above Earth. The satellites are positioned so that at least six are

*UTIG's Hockley seismometer, located in a chamber 470 meters below the surface in an active salt mine (owned by United Salt Corporation), is largely removed from the noise of natural and human activities that affect instruments on the surface.*

*Researchers at UTIG study the motions of tectonic plates, displacements associated with earthquakes, sea-level fluctuations, and Earth orientations by monitoring very precisely the change in the receiver locations over time. With the technology currently available, an accuracy of a few millimeters can be achieved.*

nearly always observable from any point on Earth. The GPS satellites transmit ranging codes on two radio frequency carriers at L-band frequencies, which can be detected by ground-based GPS receivers. Special ground-based stations perform satellite monitoring that permits the locations of GPS receivers to be determined with a high degree of accuracy.

## COMPUTING & DATA PROCESSING

The large amounts of data gathered by UTIG's researchers require a matching data-processing capability. The Institute for Geophysics is dedicated to acquiring state-of-the-art technology to keep pace with innovations in industry and academia and to maintain its preeminence in the field of geophysics. UTIG's computing facilities encompass a broad range of hardware and software components which are seamlessly networked to allow for the sharing of resources in a heterogeneous environment. For many demanding numerical and graphically-intensive tasks, UNIX workstations are the tool of choice due to their computational speed, sophisticated image-rendering capabilities, and inherent networking facility as well as the rich availability of tools for software development. For its most computationally demanding data-processing tasks, UTIG also employs several multi-processor computers, including its most powerful system, an 8-processor SGI Origin-2000 parallel computer. Recently, clustered workstations have been shown to rival the performance of supercomputers at a fraction of the cost, and researchers at UTIG have endeavored to apply this innovative approach to solving the most complex numerical problems.

UTIG researchers use high-end graphic workstations with visualization software to process and analyze seismic refraction, seismic reflection, and multibeam bathymetric data sets. They can take advantage of numerous graphical input and output devices for the visual presentation of research results: high-resolution color scanners, slide makers, and printers and large-format plotters capable of outputting to various media types. Primary data storage consists of approximately 4000 GB of data configured in several RAIDs (Redundant Arrays of Independent/Inexpensive Disks) attached to UNIX servers, and made available through the network to UNIX and NT desktop systems alike. The Institute maintains a presence on the Internet with a web site ([www.ig.utexas.edu](http://www.ig.utexas.edu)) that highlights current research projects and provides biographical and research information on its personnel.

*The centerpiece of UTIG's seismic processing capabilities include the SGI Origin-2000 parallel computer system. The SGI, which is used primarily for pre-stack seismic imaging, was purchased in 1998 with funds from NSF's Major Research Instrumentation (MRI) Program and contributions from ARCO, Mobil, Shell, CONOCO, Petroleum Geoservices, Norway and the Vetlesen Foundation. Use of the SGI reduces the turn-around time and cost of complex imaging of multichannel seismic data.*

# ANTARCTIC ICE SHEET DYNAMICS

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*The vast continent of Antarctica is one of the least known regions of the world. This is changing, however, with the application of increasingly sophisticated technologies and coordinated research programs. The Institute for Geophysics is home to one such effort called SOAR, the Support Office for Aerogeophysical Research.*

*Building on their aerogeophysical expertise in Antarctica, UTIG scientists have become involved in the planning of an unmanned space mission to Europa, one of Jupiter's largest moons. Europa is thought to have an ocean that may possibly host exotic life under its icy surface. The orbiting spacecraft that is scheduled to be sent to Europa in 2006 will be equipped with a suite of geophysical instruments, including ice-penetrating radar.*

The Antarctic ice sheets, which hold 90% of the world's fresh water, are vital components of the world's climatic system and have a major influence on global sea levels. Indeed, if the current ice sheets melted, sea level would rise by about 70 meters. At present, knowledge of the history of the Antarctic ice sheets is fragmentary, making it impossible to predict whether the present ice sheets will grow or diminish with global warming.

The West Antarctic Ice Sheet (WAIS) is one of the Earth's most dynamic systems. It is particularly vulnerable to warming trends because its base lies below sea level and large sections of it, such as the unstable Ross ice shelf, are not grounded on continental rocks but instead extend out over the ocean. "Marine" ice sheets are characterized by rapidly moving streams of ice that penetrate and drain a slowly moving ice reservoir. Evidence left by past marine ice sheets indicates that they have a strongly non-linear response to long-term climate change; thus, massive and rapid discharges of ice are possible. Understanding the evolution of the ice stream system and its interaction with the interior ice is the key to understanding the dynamics of the WAIS.

In recent times, the flow rates of some West Antarctic ice streams have varied markedly, causing increased concern over the long-term stability of the WAIS. In order to test models of ice sheet and ice stream behavior, UTIG's Support Office for Aerogeophysical Research (SOAR) has collected many thousands of kilometers of data using a suite of airborne geophysical instruments for the NSF-sponsored CASERTZ (Corridor Aerogeophysical Survey of the Ross Transect Zone)/WAIS project.

Data from such aerogeophysical and ground-based experiments suggest to UTIG scientist Donald Blankenship that the fast-moving ice streams glide on a lubricating layer of water-saturated sediment and that their behavior may be controlled by the geology of the underlying West Antarctic rift system. This system's easily eroded fault-bound basins provide the sediment for the slurry; overlying ice provides the water, melted by elevated heat flux associated with lithospheric extension. Blankenship and his UTIG colleagues also interpreted magnetic and radar measurements which revealed that there was volcanic activity beneath the ice surface.

# CLIMATE DYNAMICS

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UTIG is home to several researchers who are involved in studying global climate on annual, suborbital (10-to-100-year), orbital (1000-to-10,000-year) and tectonic (greater than 100,000-year) time scales. Donald Blankenship and David Morse, for example, are collaborating with colleagues elsewhere on the WAIS-CORES Project to select a site for an ice core to be drilled from the West Antarctic Ice Sheet starting in 2002. This ice core will provide a detailed, high-resolution record of the WAIS's role in global climate change and in the Earth's climate history over a period of several thousand years.

Jamie Austin, Craig Fulthorpe, and Hilary Olson study marine cores collected by the ODP and data from seismic surveys to decipher the complex record of geologically and climatically induced sea-level fluctuations contained within continental-margin sediments on time scales greater than 100,000 years.

The PLATES Project, led by Lawrence Lawver and Ian Dalziel, reconstructs Earth's tectonic plates and geological environments as far back in geologic time as one billion years. Their unique modeling tools provide a better understanding of the way in which large-scale topographic features (the Himalaya Mountains and oceanic gateways, for example) interact with atmospheric dynamics and global ocean circulation to influence climate.

Fred Taylor is involved in two paleoclimate programs to document the temperature history in the Western Pacific Warm Pool region of the Pacific Ocean, an area that is critical to the Earth's climate and weather. One program involves analyzing cores drilled from living corals to obtain a record of climate extending back several hundred years; the other involves analyzing cores of fossil corals from uplifted reefs to obtain climate records for times back through the last glacial maximum about 22,000 years ago. Variations in the isotopic ratios in tiny samples taken along the growth direction in a coral skeleton reflect how temperatures have changed over time so precisely that the seasonal cycle is very clear.

UTIG's quantitative geophysical group, led by Paul Stoffa and Mrinal Sen, is actively engaged in the development of unique algorithms for modeling geophysical data. An important part of this research has been the development of quantitative ways to estimate the probability and covariance of a model's parameter without the need for limiting assumptions based on Gaussian statistics, which are often violated in geophysical problems. These quantitative measures of model parameter resolution and inter-correlation are vital to improving the uncertainty analysis that should be an integral part of all climate research.

*One of the most challenging scientific problems is to understand how and why Earth's climate has changed over the broad spectrum of geologic time.*

*Fortunately for paleoclimate studies, chemical variations in the calcium carbonate forming annual density bands in corals (similar to tree rings) precisely record sea-surface temperatures. Taylor and his colleagues use the coral's isotopic records to compare the temperature records of various times in the past with the present and are thus able to resolve El Niño cycles from the present as far back in time as 15,000 years ago.*

*UTIG's new climate initiative seeks to promote knowledge of the climate system by using mathematical methods to characterize its uncertainties. As part of this new initiative, climate modeler Charles Jackson joined the UTIG staff in September 2000.*

**TEXAS AND ANTARCTICA - WERE THEY ONCE NEIGHBORS?**

*While conducting NSF-sponsored fieldwork in Antarctica, UTIG Associate Director Ian Dalziel was struck by the similarity of rock outcrops in the Transantarctic Mountains to the pink granite rocks of the Llano uplift in Texas. This observation prompted him to propose that ancestral North America, known to geologists as Laurentia, was connected to South America, Africa, and Antarctica between 1,100 and 750 million years ago by a large promontory, the "Texas plateau." Using PLATES software, UTIG researcher Lisa Cahagan has demonstrated that Dalziel's hypothesis is reasonable.*

*The results of this work were published in the January 1997 issue of Geological Society of America Bulletin for which Dalziel received the Best Research Paper Award (1997-98) presented by The University of Texas University Cooperative Society.*

Although understanding global climate change has been the focus of intense study in recent years, the ability to predict future climate change is still very uncertain. To assess the uncertainties in climate prediction, UTIG has received a generous gift from the George Unger Vetlesen Foundation to initiate a new research program in quantitative climate modeling. This initiative will combine UTIG's existing expertise concerning observations of climate variations preserved in the geologic record with its expertise in computational modeling. UTIG will thus contribute to the development of more powerful and robust climate prediction models.

## PLATE TECTONICS

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The formation, break-up, and dispersal of continents are the main processes that affect Earth's surface geology. The ever-changing distribution of continents and oceans is not only responsible for some of the planet's most dramatic geologic features, it also governs the occurrence and distribution of minerals, influences the climate, and is fundamental to life on Earth.

### MODELING PLATE CONFIGURATIONS & MOVEMENTS

UTIG's global plate reconstruction project, known as PLATES, is an industry-supported program that has developed software to model past tectonic plate movements. The software is used to study paleotectonics on a regional and global scale. Reconstructions are built around a comprehensive database of poles of rotation, derived both from extensive plate motion research at UTIG as well as published studies. The PLATES software can animate the motion of the major plates for up to the last 600 million years, yielding time-varying tectonic scenarios that enable analyses of evolutionary Earth processes.

Lawrence Lawver and Ian Dalziel are the project's principal investigators. Lawver's research focuses on the tectonics of the Arctic, Antarctic, and East Asian regions as well as the development and evolution of paleoseaways. Dalziel has devoted his research career to reconstructing the tectonic plates that covered the surface of Earth prior to the existence of the last supercontinent, Pangea, which began to break apart 200 million years ago. Until recently, Dalziel's research focused on the southern continents (Africa, South America, Australia, and Antarctica) which, together with India, were assembled into a single, major continent known as Gondwana. Today Dalziel, working with colleagues from the U.K. and Australia, has turned his attention to unraveling the complicated tectonic history of his Scottish homeland. The northwest foreland of Scotland is a small frag-

ment of the ancestral core of North America, known as Laurentia, which became detached during the opening of the North Atlantic Ocean basin in the Cenozoic era. The geologic history of this part of Scotland is important to understanding paleogeography and tectonics 500 to 600 million years ago. Work carried out over the past forty years has given rise to hypotheses of a very complicated past history. Dalziel and his colleagues' interpretation, however, leads to a substantial simplification of this history.

Lisa Cahagan manages the PLATES project and maintains its database by adding new paleomagnetic, hot spot, geological, and geophysical data to extend the span and enhance the accuracy of reconstructions.

## LARGE IGNEOUS PROVINCES

Large igneous provinces (LIPs) are the products of a significant type of planetary volcanism found on Earth, the Moon, Venus, and Mars. On Earth, LIPs occur in many geologic settings, including every ocean basin. The two largest LIPs are enormous: the Ontong Java Plateau in the Pacific Ocean, with an area of 1.86 million square kilometers, is nearly three times the size of Texas; the Kerguelen Plateau in the Indian ocean is almost as large at 1.78 million square kilometers. Both lie mostly below sea level. Such LIPs provide information about mantle composition and dynamics that is not reflected by volcanism at spreading ridges.

The production of oceanic plateaus and other LIPs is associated with major transfers of heat and material to Earth's surface, possibly associated with decompression melting of an ascending hot mantle plume. LIPs currently account for only 5 to 10 percent of the heat and magma expelled from the Earth's mantle. By contrast, in Early Cretaceous time (145 to 85 million years ago) giant LIPs apparently accounted for as much as 50 percent. Since LIPs punctuate the oceanic crust, which is produced steadily at seafloor spreading centers, the magma eruptions that create the LIPs must occur sporadically. The episodic nature of LIP production documented in the geologic record, especially between 150 and 50 million years ago, is evidence that a more dynamic, unpredictable mode of mantle circulation existed during Earth's past.

The study of LIPs is important for several other reasons, as well. The intense igneous activity associated with their production profoundly affects oceanic and atmospheric temperatures. The resulting global environmental changes influence biological evolution and species diversity. Moreover, because oceanic LIPs appear to resist subduction, they may serve as future building blocks of continental crust. Despite their huge size and distinctive morphology, oceanic LIPs remain among the least understood features in the ocean basins.

*Recently, Lawver and Cahagan have worked with scientists from the Naval Research Lab (Washington, D.C.) to reinterpret the Cenozoic tectonic evolution of the Eastern Arctic, including revising the motion of Greenland.*

### **THE LOST CONTINENT:**

*In 1999, former UTIG scientist Mike Coffin served as co-chief scientist on Ocean Drilling Program Leg 183 to the Kerguelen Plateau. Cores retrieved by drilling into the underwater plateau indicated that for eons it had existed as a continent above sea level before subsiding below the waves 20 million years ago.*

*This startling discovery generated a flurry of media interest. Science writer Alexandra Witze's Dallas Morning News article on the subject—"Paradise submerged: Sunken plateau provides clues to Earth's history"—earned her the American Geophysical Union's prestigious Walter Sullivan Award for science journalism in April 2000.*



*In September 2001, Mike Coffin left UTIG to become Professor of Marine Geophysics at the Ocean Research Institute, University of Tokyo, and Senior Researcher, Institute for Frontier Research on Earth Evolution (IFREE), Japan Marine Science and Technology Center. While at UTIG, Coffin became an international leader of research investigating LIPS. In Japan he will be involved in the new Integrated Ocean Drilling Program.*

#### **THE FIRST OYSTER BAR:**

*UTIG scientist Richard Buffler and UT graduate student Berhane Negassi Gherbretensae were part of an international team that unearthed ancient stone tools from a raised Pleistocene coral reef on the Red Sea coast of Eritrea, Africa. These findings push back by 10,000 years the date for the earliest known human consumption of shellfish and thus record the onset of a new human feeding strategy. The team's article in the journal Nature (4 May 2000) spawned widespread media interest in "humanity's first oyster bar."*

UTIG scientists have collectively participated in a series of international research cruises to acquire marine geophysical data with which to better characterize the dimensions and structure of the Ontong Java and Kerguelen Plateaus. In addition, they have participated on three ODP cruises to drill into both plateaus. High-quality multichannel seismic (MCS) data acquired during three research cruises—two Australian expeditions aboard R/V *Rig Seismic* in 1997, and a French campaign aboard the R/V *Marion Dufresne* in 1998—were used to locate five primary drill sites on the Kerguelen Plateau for ODP Leg 183. In the fall of 2000, Mike Coffin participated in ODP Leg 192, this time to investigate the origin, age, and post-emplacement history of the Ontong Java Plateau.

## **DIVERGENT MARGINS**

Rifting occurs at divergent margins where tectonic plates are moving apart. "Active rifting" requires the presence of an upwelling mantle plume at the base of the lithosphere prior to crustal extension. As plates separate, magma erupts along the faults and fissures that result.

Richard Buffler has embarked on a major field investigation in the southern Red Sea/northern Danakil regions of Eritrea, Africa. This NSF-sponsored study examines the interplay of tectonics, volcanism, and sedimentation in an active rift boundary setting. Established in 1992 after a 30-year struggle for independence, Eritrea is the newest African country, located in the continent's northeast lobe, just north of Ethiopia along the southern Red Sea. Because the area is the setting of a potentially important early hominid migration route, a secondary objective is to establish a geological framework for paleontological and archaeology studies, including early hominid evolution.

Antarctica also affords an excellent location to investigate tectonism, magmatism, and the onset of sea-floor spreading in a continental extension zone. Indeed, this remote continent is almost completely surrounded by actively spreading ridges. In April and again in November 2000, Jamie Austin, Ian Dalziel, and Yosio Nakamura led a team of UTIG researchers onboard the U.S. icebreaker R/V *Nathaniel B. Palmer* to study the deep structure of another small piece of the global crustal jigsaw puzzle: Bransfield Strait, an actively extending "marginal" basin sandwiched between the Antarctic Peninsula and the South Shetland Islands. Widespread crustal extension, accompanied by recent volcanism along the Strait's axis, is associated with slow underthrusting of oceanic crust at the South Shetland Trench. About 130-200 million years ago, similar "back-arc" extension occurred in basins along the entire Pacific margin of the supercontinent known as Gondwana. Approximately 100 million years ago, deformation of these basins initiated uplift of the Andes. Sponsored by the NSF Office of Polar Programs, UTIG

researchers investigated the deep structure beneath the Bransfield Strait by collecting and analyzing high-quality, high-density OBS profiles both along and across the Strait. Understanding the Bransfield Strait's deep crustal structure is the key to resolving its transitional stage of evolution as a rift basin and a crucial step toward understanding the complex tectonic evolution of this part of the Southern Ocean. Such knowledge will provide a foundation for comprehensive models of the origin and evolution of the Andes Mountains, with important implications for similar mountain-building processes everywhere.

Fred Taylor and Ian Dalziel, working with colleagues at the University of Hawaii and the University of Memphis, have started a three-year study that uses the U.S. Global Positioning System (GPS) to measure tectonic plate motions between South America, Antarctica, and Africa. This study, the Scotia Arc GPS Project (SCARP), uses a new geodetic approach known as a multi-modal occupation strategy (MOST). Taylor and his colleagues have installed five permanent GPS receivers at selected sites in the Scotia arc region. Temporary stations on the South Sandwich, Falkland, South Georgia, and South Orkney Islands have been tied to permanent GPS sites in South America, Antarctica, and Africa. One aim of the SCARP network is to measure the present motion of the Scotia Plate, which is located between Antarctica and South America. A second objective is to determine if extension is occurring across the Bransfield Strait. While velocity resolutions of less than 1.0 millimeter/year are not expected in the initial three-year project, SCARP will establish the baseline necessary for the acquisition of subsequent measurements in six to eight years. The sequel project will characterize the slow motions and deformations that occur across and within the boundaries of the Scotia Plate.

Plans are underway to extend the SCARP network from the Antarctic Peninsula into other parts of West Antarctica. Linking to other networks in Antarctica operated by the Jet Propulsion Laboratory and the University of California at Santa Barbara will allow investigators to distinguish displacements due to the West Antarctic rift system from those caused by isostatic rebound since the last glacial maximum.

## CONVERGENT MARGINS

Convergent margins mark the collision of two tectonic plates. If one plate is capped by continental crust and the other is composed of oceanic crust, the denser oceanic plate will descend beneath the more buoyant continental plate along a subduction zone. Earth's surface is covered by about 43,500 kilometers of active subduction zones. These are particularly dynamic regions because the great forces associated with subduction generate the largest and most frequent earthquakes on Earth. In addition to triggering tsunamis, rapid subsidence, and uplift in coastal

### **PALMER SEA TRIALS:**

*In September 2000, UTIG's Jamie Austin led a 30-member team on two phases of sea trials to test new, cutting-edge geophysical equipment recently added to the U.S. icebreaker RV Palmer. The new equipment complements the ship's icebreaking capacity to give the United States a unique asset for marine research offshore of Antarctica, the world's last continental frontier.*

*Since 1988, UTIG scientists have used GPS technology to study tectonic plate motion. GPS is so precise that it is possible to determine the distance between sites hundreds of kilometers apart to less than one centimeter. By repeating these measurements, researchers can calculate the horizontal motions of tectonic plates and deformation within crustal blocks.*

*The NSF-sponsored MARGINS program has created two initiatives to promote advanced research at convergent margins.: SEIZE and the Subduction Factory initiative.*

*SEIZE, or the SEismogenic Zone Experiment, is dedicated to understanding the properties and processes of subduction plate boundary fault zones. SEIZE research will contribute to knowledge about the nature of earthquakes and their hazards in this environment.*

***NANKAI 3-D STUDY***

*The Nankai survey covered 640 square kilometers, making it the largest-ever academic 3-D survey of its type.*

*Processing the Nankai survey's huge volume of data would be impossible without the generous support of Schlumberger Technology Corporation and the Shell Oil Company. Schlumberger donated software for the processing, and Shell funded the computer configurations necessary for sophisticated 3-D imaging.*

areas, convergent margins produce lines of active volcanoes both on land and on the seafloor. As the human population in coastal areas near subduction zones grows, the threat to human life and property from earthquake- and volcano-related hazards grows as well. Thus, marine geological and geophysical research at convergent margin settings is of societal relevance.

One of UTIG's most scientifically intriguing projects currently is an international, multi-institutional collaboration to study subduction zone processes in the Nankai Trough offshore of Japan. For two months in 1999, researchers Nathan Bangs and Tom Shipley led a team of students, technicians, and scientists on a 3-D seismic survey of the Trough. Participants in this NSF-sponsored survey included scientists from two other U. S. and five Japanese academic and governmental institutions. The project's results will be used to determine drilling sites for a new Japanese academic riser drillship, which will sample the seismogenic zone at a collisional plate boundary fault. The new ship is currently under construction for the Integrated Ocean Drilling Program (IODP), which will begin in 2003.

The Southwest Pacific is characterized by the most rapid plate motions on Earth. For this reason, it is an exceptional natural laboratory for the study of active tectonics. Fred Taylor, Paul Mann, and colleagues in the Department of Geological Sciences at The University of Texas at Austin have examined the record of vertical tectonism preserved in coral reefs in the New Georgia Islands, part of a 900-kilometer-long double chain of volcanic islands in the convergent zone between the Pacific and Australian Plates. The barrier reefs that encircle the coastlines of the New Georgia Islands are characteristic of the first stage of atoll development. As Charles Darwin proposed in 1842, barrier reefs form around subsiding volcanic islands as coral reefs grow upward to keep pace with the apparently rising sea level. Eventually, the core of the island sinks entirely beneath the ocean leaving a near-circular coral island known as an atoll.

The New Georgia Islands also host emergent barrier reefs at elevations as great as 25 meters above sea level, the occurrence of which indicates the interruption of Darwin's reef-to-atoll subsidence sequence by subsequent tectonic uplift. Earthquakes provide evidence of tectonic uplift due to the subduction of the recently active Woodlark Spreading Center beneath the New Georgia Islands. Taylor, Mann, and colleagues calculated rates of tectonic uplift by combining elevation data with Carbon-14 dating of the emergent reef terraces. By dating distinct notches in the reef terraces that reflect uplift associated with individual earthquakes, the researchers were also able to document when these occurred and the amount of uplift each effected.

In 1997-98, Paul Mann, Tom Shipley, and Mike Coffin participated in a joint U.S.-Japanese multichannel seismic study to map crustal and upper-mantle structures in the Solomon Islands convergent zone. The primary objective of this study,

and of an OBS study independently proposed by Kiyoshi Suyehiro and colleagues at the Ocean Research Institute in Tokyo, was to test two models for the formation of the Malaita anticlinorium — the deformed wedge of Cretaceous-Cenozoic limestone, basalt, and clastic rocks that is the emergent part of the Ontong Java Plateau. The seismic reflection and OBS refraction data collected revealed that only about the upper 20% of the Plateau's crust is accreted to the Solomon Islands, whereas the remaining lower crust is subducted at the convergent margin. This result suggests that thick plateaus may not be the key building blocks of continental crust and that other oceanic sources must be investigated. The study contributed to the understanding of the role of oceanic plateaus in the growth of continents and of how subduction zones are initiated by polarity reversal.

In 1995, UTIG scientists Yosio Nakamura and Kirk McIntosh participated in a collaborative seismic imaging project that involved researchers from the U.S. and Taiwan. The goal of the project was to study mountain-building processes associated with the Taiwan arc-continent collision. There, the closure of a forearc basin is occurring during the accretion of a volcanic arc to the Asian continent. The joint U.S.-Taiwan program focused on collision processes and the structure of eastern Taiwan and the Ryukyu Arc northeast of Taiwan. Deep multichannel seismic profiling and seismic refraction studies with a suite of UTIG's OBS instruments were conducted from the R/V *Ocean Researcher I* of the National Taiwan University and the R/V *Ewing*. Land-based seismographs were also established in order to record the large airgun shots from the ships. This program significantly increased the understanding of crustal deformation in critical regions of a modern mountain-building zone.

The southern Middle-America Trench (MAT) off Nicaragua and Costa Rica is a key site of geochemical, seismological, and tectonics research as well as an area of special interest for both the Subduction Factory and SEIZE MARGINS initiatives. In 1999, Kirk McIntosh participated in a multinational (German, U.S., French, British, and Costa Rican) project aimed at understanding processes related to the subduction of the Cocos Plate at the MAT. The primary focus of this project, called PAGANINI, was the acquisition and analysis of seismic refraction data in order to characterize the various domains of the Cocos Plate, including the Cocos Ridge hotspot track and numerous seamounts.

In 2000, McIntosh led the NicSeis project aboard the R/V *Ewing* and recorded deep-penetration seismic reflection and refraction data offshore Nicaragua and northern Costa Rica. These data provided images of most of the seismogenic zone of the plate boundary to depths of 20-30 kilometers off Nicaragua as well as information about fluid and sediment fluxes into the subduction system. These fluxes will

*The term Subduction Factory is used to encompass the fluxes of material into and out of subduction zones, together with the thermal, chemical and mechanical processes that shape convergent plate boundaries, the deep mantle below, and the air and water above. The MARGINS Subduction Factory initiative aims to measure fluxes of mass and fluids from the oceans to their destinations in volcanic arcs or deep into the Earth's mantle.*

*UTIG scientists are making significant contributions to the SEIZE and Subduction Factory initiatives at two of the locations that have been designated special focus areas — the Nankai trough and the Costa Rica/Nicaragua MAT.*

*THE PAGANINI PROJECT involved a series of cruises onboard the R/V Sonne (Germany) to collect geophysical data of the Cocos Plate and the adjacent Nazca Plate. Results from the project aided the development of crustal velocity models for the Cocos Plate; these models will bear directly on estimates of subducted crustal mass and on the nature and morphology of the seismogenic plate boundary.*

be compared to products of the volcanic arc to help determine the processes and properties of the Subduction Factory.

## TRANSFORM PLATE BOUNDARIES

Transform plate boundaries are sites where continental and oceanic plates slide horizontally past one another on long, straight strike-slip faults like the San Andreas Fault in California. Like convergent margins, transform plate boundaries are the site of some of Earth's most dramatic and hazardous geological events. Beyond the obvious societal motives for gaining an improved understanding of such faults, UTIG scientists are also challenged by the complex stratigraphy typical of transform boundaries.

UTIG senior research scientist Paul Mann and former graduate students Jean-Paul van Gestel and Stefan Muszala collaborated with scientists from the University of North Carolina and the University of Southern California on an NSF-funded, 1996 cruise to map faults and tectonic structures in the deep-water area north of Puerto Rico. Having collected single-channel seismic reflection, bathymetric, and sidescan sonar data, they discovered an important strike-slip fault less than 100 kilometers north of Puerto Rico. The regional pattern of faulting apparent in these data yielded fresh insights into the mechanisms responsible for the regional deformation of the island. In a follow-up study funded by the National Earthquake Hazards Reduction Program (NEHRP) of the U.S. Geological Survey, Mann and colleagues from the University of North Carolina collected high-resolution single channel seismic reflection data and sidescan sonar data from the shallow shelf areas west and south of Puerto Rico. These data revealed several suspected but previously undocumented late Holocene faults that correlate with onshore structures. In a parallel onland study Mann and a colleague from the U.S Geological Survey used fault trenching to document two Holocene earthquakes on a fault scarp in southwestern Puerto Rico. This is the first documented Holocene earthquake fault in Puerto Rico and provides valuable input into seismic hazard maps being produced for Puerto Rico by the U.S. Geological Survey.

Since 1991, Paul Mann and Fred Taylor have worked with colleagues from the U.S. Geological Survey and the University of Arizona to study a strike-slip fault at the main North America-Caribbean plate boundary in the Dominican Republic. Using a combination of stratigraphy and radiocarbon dating from several trenches that cross the fault, they discovered that the main fault in northern Hispaniola, the Septentrional Fault, has not experienced a major earthquake in more than 800 years. Geologic evidence, however, indicates that movement has occurred along the fault over the past several thousand years. This movement is equivalent to an average rate of about ten millimeters of slip per year. According to Taylor and

*Located above the active North America-Caribbean plate boundary, Puerto Rico and the U.S. Virgin Islands are subject to earthquakes and tsunamis generated both by subduction and strike-slip-related faults. Because the islands have some of the densest populations in the Western Hemisphere with many people living near the coast, the potential hazards from earthquakes and tsunamis are considerable.*

*GPS is a particularly powerful tool for determining how elastic strain accumulates within tectonic plates and is released by earthquakes. Using GPS to investigate the relationship between plate motion and seismic activity, UTIG scientists gain insight into the growth of island arcs, the earthquakes generated among them, and the factors that influence these earthquakes' size, distribution, and timing.*

Mann's calculations, this corresponds to five millimeters of stored slip that could be released catastrophically during an earthquake. Because of this potential hazard, they are using GPS measurements to carefully monitor the plate boundary fault along its length.

To quantify the rates and directions of interplate motion between the North America and Caribbean Plates, Mann and colleagues at the University of Miami, the University of Wisconsin, and the University of Puerto Rico obtained NSF support to establish a GPS network in the northeastern Caribbean. In 1998, Mann completed the installation of 25 new GPS sites in the Dominican Republic. With 31 sites in all, the Dominican network now approaches the density of GPS networks along better-known active margins such as the San Andreas Fault. This project, known as CANAPE (Caribbean North American Plate Experiment), is beginning to yield valuable insights into the nature of fault-related motions and the earthquake potential of specific faults in the northeast Caribbean. In the future, the network will expand to include Puerto Rico, Haiti, Jamaica, and northern Central America; that is, the entire land area of the North American Caribbean transform boundary.

*The CANAPE network will allow a complete view of the behavior of the North America-Caribbean plate boundary zone and will complement data from GPS networks established in northern South America and southern Central America.*

## CONTINENTAL MARGIN MORPHOLOGY

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Many UTIG researchers are involved in rigorous, quantitative investigations of the morphology of the continental shelf seafloor. With the aid of high-resolution imaging, they are able to link modern seafloor features to sedimentary structure and processes recorded in the stratigraphic record.

Jamie Austin, Craig Fulthorpe, John Goff, and Hilary Olson played a leading role in the Office of Naval Research's multi-institutional STRATAFORM initiative, which was aimed at better understanding the morphology of U.S. continental margins and their processes. STRATAFORM research is concentrated on the New Jersey margin and the Eel River Basin off northern California, two locales that the ONR has designated as natural laboratories. UTIG scientists have collected very high-resolution boomer single-channel seismic profiles, including three-dimensional data off New Jersey, and high-resolution multichannel seismic data and swath bathymetry data from both margins. A key objective of STRATAFORM was the collection of seismic data at a variety of overlapping scales of resolution and penetration in order to understand how short-term processes relate to the deeper, preserved stratigraphic record. The ultimate goal is to link modern processes to the

*STRATAFORM's overarching goal was to link short-term event stratigraphy—biological and physical processes currently affecting sedimentation—to the preserved stratigraphic record on continental shelves representing the past million years.*

*Individual projects were aimed at studying: 1) shelf sediment dynamics and the development of lithostratigraphy; 2) slope geological processes and resultant geomorphology; and 3) stratigraphic sequences resulting from shelf and slope sedimentation.*

seismically imaged and sampled (preserved) record through a series of increasingly sophisticated models.

#### **EAST COAST TSUNAMIS:**

*In May 2000, UTIG scientist John Goff, together with colleagues at the Woods Hole Oceanographic Institution and the Lamont-Doherty Earth Observatory, conducted an NSF-sponsored geophysical survey of the Atlantic continental shelf on the R/V Hatteras. This was a follow-up to previous research to determine whether cracks on the shelf had the potential to trigger tsunamis that might endanger cities in the eastern United States.*

*Goff's research received widespread media coverage, including articles in the New York Times and the Washington Post as well as interviews on National Public Radio and NBC. Preliminary results from the May cruise indicate that the cracks may be a system of large depressions excavated by eruptions of natural gas. The scientists speculate that the ongoing process of such blowouts could contribute to submarine landslides, which may cause tsunamis.*

#### **NEW JERSEY MARGIN**

Sand ridges are the largest and most pervasive features on the seafloor of the northeast U.S. Atlantic shelf. They form in the nearshore environment in response to storm driven currents. As a consequence of the Holocene marine transgression, sand ridges are now located farther offshore in a different hydrodynamic regime where currents are not constrained by the coast and storms do not influence bottom currents as frequently or as strongly. A recent UTIG high-resolution swath sonar survey mapped a portion of the New Jersey shelf from about 20 meters water depth to the shelf break at about 120 meters, imaging both sand ridges and smaller-scale dunes and ribbons in far greater detail than had been previously possible. The purpose of the study was to examine the morphology of offshore sand ridges and smaller-scale features in an effort to better understand bedform development in deeper waters. A robust statistical analysis of the data revealed that the gross morphology of ridges does not change with depth. Changes in ridge orientation do occur, however, and they generally mirror changes in regional contour orientation. Thus, while there is evidence that sand ridges undergo some important modifications on the inner shelf, they do not continue to grow once they have transgressed into the offshore hydrodynamic regime. Ridges found on the mid-shelf tend to have higher backscatter at the crests, implying that these are winnowed, relict features. Lineated, smaller features are also present in the seafloor morphology of the New Jersey margin. Analysis of such features in combination with super-high-resolution seismic reflection data provides the primary control for understanding the geologic sequence associated with the latest sea-level rise.

#### **EEL RIVER BASIN, CALIFORNIA**

To address STRATAFORM objectives on the northern California margin, UTIG collaborated with scientists of the University of New Brunswick to conduct a swath sonar survey with the R/V *Pacific Hunter* in the spring of 1995. The survey collected multibeam bathymetry and sidescan sonar data. John Goff analyzed the high-resolution swath sonar data collected on the Eel River Shelf to investigate seafloor morphology and acoustic backscatter patterns. The Eel Shelf, which lies within an active compressional tectonic margin, is a dynamic region that receives abundant terrigenous sediment input from the Eel River. The results of the study showed that although the bathymetry of the Eel Shelf is subtle, several structures can be discerned. Some of these shelf structures are related to depositional processes, whereas others appear connected to tectonic processes. Analysis of the

data also revealed a series offshore-perpendicular striations, or ribbons, spaced about 0.2 to 1.0 kilometer apart. Some aspects of the morphology of the ribbons suggest that they may be associated with down-slope flows.

## GULF OF MEXICO

As oil and gas exploration has moved into deeper waters in the last decade, the Gulf of Mexico has become the focus of several UTIG projects that aim to learn more about the deeper areas, as well as to understand the Gulf's complete depositional history. To that end, the UTIG team of Richard Buffler, William Galloway, and Patricia Ganey-Curry have completed two phases of the Gulf Basin Depositional Systems (GBDS) Project. The project goals are to refine sequence correlation between the shelf and basin, understand slope processes, identify major sedimentary transport axes, explain the role of submarine canyons, and determine the major controls on deposition. Phases I and II yielded the foundation for a detailed, comprehensive synthesis of the Gulf basin that merges the basin-floor succession (understood largely through seismic data) with the coastal plain, shelf, and upper slope succession (defined largely by well data) for the last 65 million years. The project customized ARC/INFO GIS software for regional mapping and analysis to produce a UTIG Gulf of Mexico database that is an important contribution to geographic information systems in geology. Support for the project, provided by a consortium of petroleum companies, has been extended through 2002 (Phase III).

## SEA-LEVEL FLUCTUATIONS

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Sea level fluctuates as a result of the complex interaction of processes that operate both locally and globally. These fluctuations profoundly influence the flux of particles, chemicals, and nutrients into the ocean, the distribution and character of nearshore ecosystems, and air-sea-land interactions and their relationship to global climate. By understanding the relationship between sea level and past climate, researchers provide data essential to analyzing both natural and human-induced changes in our current climate system. Sediments deposited on continental margins comprise a sensitive record of the history of sea-level change on geologic time scales ranging from tens to millions of years. For this reason, several UTIG studies are focused on extracting the global sea-level signal locked in the sedimentary record of the continental shelf and slope in key regions of the world.

*The GBDS Project has developed as the ultimate framework for new exploration in the Gulf of Mexico.*

*In April 2001 Patty Ganey-Curry was awarded a College of Natural Sciences staff excellence award in recognition of her successful management of the GBDS project, role as industry liaison, work with students and alumni, and outstanding achievements in K-12 educational outreach.*

*The New Jersey margin is an excellent locale for sea-level investigations for a number of important reasons. First, there have been few local tectonic disturbances in this well-studied region. Second, its mid-latitude setting maximizes the chance for excellent age control built on the integration of biostratigraphy and chemical isotope, chemical, and magnetic stratigraphies. Finally, high rates of sedimentation over the last 30 million years have provided a high-resolution record of ice growth and decay.*



*The success of ODP Leg 174A rested on the application of new logging-while-drilling (LWD) technology developed by industry in the mid-1990s to measure in situ properties in boreholes. Unstable sand sequences hampered coring and thus rendered conventional logging unfeasible. At two sites, LWD enabled the documentation of shallow sequence boundaries, thought to result from rapid sea-level fluctuations.*

*Fred Taylor's work using geochemical dating to establish the timing of Late Quaternary climate changes has resolved some of the more controversial aspects of the Late Quaternary sea-level curve.*

*UTIG's Hockley Seismic Station (station code HKT) is part of the Global Seismic Network.*

The approach involves "stacking" continental margin transects from different global locations to differentiate local controls—including tectonism, changes in sediment supply, and current activity—from global (eustatic) causes of sea-level change.

Most notable of the UTIG sea-level studies is the ongoing work on the continental shelf offshore New Jersey, which began in earnest in 1990 with the collection of a grid of high-quality seismic data aboard the R/V *Ewing* in preparation for ODP Leg 150 drilling in 1994. In 1995, the *Ewing* data were augmented by high-resolution profiles collected aboard the R/V *Oceanus* in preparation for ODP Leg 174A. In June 1997, Co-Chief Jamie Austin, Hilary Olson, and Craig Fulthorpe participated on this second drilling leg, which sampled and dated unconformity-bounded prograding sequences of Miocene to Pleistocene sediments on the New Jersey shelf. The results of Leg 174A revealed there was a lagoonal or estuarine environment on the outer shelf during the late Miocene, suggesting sea-level falls exposed almost the entire shelf.

In January 2000, UTIG scientist Craig Fulthorpe led an NSF-sponsored cruise on the R/V *Ewing* to collect high-resolution, multichannel seismic data in the Canterbury Basin offshore of New Zealand. Researchers will combine forward stratigraphic modeling with MCS data interpretation to distinguish between the local and global controls on the sea-level record contained in the sediments. Understanding global sea level is important to the world's future, as any sea-level rise that may occur in the 21st century could affect hundreds of millions of people, including inhabitants of the Gulf Coast of Texas.

## SEISMOLOGY

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The Institute for Geophysics has been active in earthquake seismology since 1972. Earthquake research is motivated in part by the concern to determine where active tectonic movement is taking place today. This involves obtaining accurate locations for small earthquakes and relating the pattern of these locations to the regional geology. In 1997, for example, UTIG seismologists led by Cliff Frohlich completed an analysis of earthquakes along the Macquarie Ridge south of New Zealand. This study complemented a cruise to study the origin of the central Macquarie Ridge. An important question concerned whether the central Macquarie Ridge was a product of both transform motion and incipient subduction; both the earthquake investigations and the data collected on the cruise suggested that, con-

trary to previously published accounts, the area was not undergoing incipient subduction.

## MODELING EARTH'S INTERIOR—SEISMIC INVERSIONS

Portions of the lowermost mantle nearly 3000 km beneath the Earth's surface may have a preferred orientation (anisotropy). UTIG scientists Jay Pulliam and Mrinal Sen observed split shear waves, which are diagnostic of anisotropy along the waves' path, arriving at UTIG's Hockley Seismic Station from deep earthquakes in the southwest Pacific. These waves just grazed the core-mantle boundary beneath the central Pacific Ocean at the deepest extent of their travels. Sen and Pulliam developed and applied an innovative technique to produce a model of the lowermost mantle beneath the Central Pacific by matching the split waves with theoretical seismograms synthesized by a numerical technique called the reflectivity method. The modeling method holds the model's upper layers fixed but adjusts the lowermost layers using a global optimization technique called very fast simulated annealing (VFSA) until they match the specific properties of the portion of the lowermost mantle sampled by the data. Pulliam and Sen's modeling has shown that the mechanism producing anisotropy beneath the Central Pacific is different from the one at work beneath the Caribbean and Alaska, for which split shear waves have also been observed. This result has important implications for the style and geographical pattern of convective flow in the mantle. Since this flow is an important component of plate tectonics, the investigation of a remote region halfway to the center of the Earth is significant to those of us living on the Earth's surface.

## UTIG'S NEW BROADBAND OBS

Since seismic waves generated by earthquakes offer the most direct means for sampling the Earth's deep interior, seismologists exploit the energy produced by large-magnitude, deep earthquakes to the greatest extent possible. Unfortunately for imaging purposes, earthquakes tend to happen repeatedly in the same few locations, and most seismograph stations are located on continents. Although a few stations are scattered through the ocean basins on isolated islands, the current collection of stations does not provide the experimental geometry required to image the deep Earth fully given the distribution pattern of earthquakes. To achieve the needed geometry, UTIG scientists Jay Pulliam and Yosio Nakamura and engineer Ben Yates are developing a broadband seismograph that can be temporarily deployed on the ocean bottom for up to a year at a time to record earthquakes .

*While the VFSA method is computationally intensive, it has proven feasible using prudent choices of reflectivity parameters and fast computers. An added benefit of the global optimization approach is that it explores the range of acceptable models rather than producing only a single model that explains the data adequately.*

*Besides basic research into solid Earth structure, UTIG's new broadband ocean bottom seismograph (OBS) will find applications in studies of acoustical properties of the ocean bottom, monitoring natural hazards, improving exploration methods in shallow and deep water, monitoring of producing oil and gas fields, providing design criteria for large structures, such as oil production platforms, that are rooted in marine sediments, and ensuring compliance with the Comprehensive Test Ban Treaty.*

## TEXAS EARTHQUAKES

*The largest recent Texas earthquake was a magnitude 5.8 event near the West Texas town of Alpine in 1995.*

*"Seismology in Schools" will allow K-12 science teachers and their students to learn about earthquake processes and hazards, explore the Earth through seismology, and practice steps to prepare for and respond to earthquakes when they happen nearby.*

Earthquake monitoring and studies of seismic risk are hampered in Texas by the small number of seismograph stations operating in the state. While earthquakes have not been a major danger to Texans historically, earthquakes do occur here and in neighboring regions. Our current understanding of seismicity in Texas derives largely from reports of earthquakes felt by people, rather than from quantitative measures of earthquake size and characteristics. Current monitoring cannot provide accurate estimates of potential damage or loss of life due to earthquakes. With the population of Texas expanding rapidly, the potential for injury to people and damage to structures increases proportionately, so Jay Pulliam and Cliff Frohlich, together with Harold Gurrola of Texas Tech University, are establishing a statewide network of digital broadband seismographic stations for real-time monitoring of earthquakes. This network, called TexSeis, will comprise thirteen stations distributed around the state. Data from the TexSeis network will be available to interested researchers, as well as the public, and will form the basis of a program called "Seismology in Schools".

Because earthquake monitoring methods are also useful for monitoring massive explosions, seismic research may play an important role in preventing nuclear escalation and warfare. The Comprehensive Test Ban Treaty, drafted in 1996 and signed by many countries including the U.S. and Russia, implies that signatory nations, even as they await its ratification, will not undertake nuclear testing with devices corresponding to seismic magnitudes larger than about 3.0. Many nations are unwilling to sign or ratify the treaty unless there are methods to monitor small seismic events, at least in politically sensitive regions. Most current methods locate events by comparing the travel times of seismic phases arriving at several monitoring stations. Unfortunately, explosions with magnitudes as small as 3.0 are often recorded by only one or two stations and go unreported. To address this problem, UTIG scientists are currently developing methods that use seismic waveforms to more accurately locate earthquakes or explosions with data from a single broadband digital station. Whereas conventional seismic analysis focuses on phase arrivals only, this approach exploits the informational wealth of the entire waveform, against which the scientists attempt to match synthetic waveforms generated by sophisticated models.

# COMPUTATION AND INVERSE THEORY

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UTIG's very active sea-going program generates large volumes of two-dimensional (2-D) and three-dimensional (3-D) seismic reflection data and offset 3-D ocean-bottom seismograph (OBS) data, which together provide the best available information about significant structures beneath the seafloor. In addition, UTIG scientists collect high-resolution near-offset 3-D data for mapping very shallow subsurface structures. While conventional data processing is carried out using commercial software, UTIG's quantitative geophysics group develops unique algorithms and innovative processing techniques for use by UTIG researchers and other marine geologists and geophysicists in academia and industry. The group's 3-D prestack migration methods, used to yield more robust estimates of velocity, and post-stack processing procedures have been found particularly effective for subsurface imaging. UTIG researchers have also developed a special-purpose migration code, based on the Kirchhoff integral formula and ray tracing, to handle large volumes of seismic data. This code is designed to run on parallel machines and a cluster of workstations using message-passing software.

Seismic modeling has become an essential companion of data processing as it plays an important role in data analysis and survey design. UTIG researchers have developed several innovative seismic modeling tools that are applicable for assessing 1-D, 2-D, and 3-D Earth models. Each tool iteratively compares a trial Earth model's computations to recorded data and updates the model until an acceptable fit is obtained. This automated model-fitting procedure is based on a general mathematical technique, called inverse theory, which helps to determine model perturbations based on the mismatch between the theoretical and recorded data. There are four basic types of difficulties encountered inverting these data: 1) The data are generally noisy and data sets can be very large. A multichannel reflection line, for example, will usually contain many gigabytes of data. 2) The possible models are highly complex, typically involving many different structural layers that vary geographically. The corresponding mathematical functions may involve thousands of different variable parameters. 3) The so-called inverse problem is highly non-linear. 4) Most inverse problems are ill-posed and thus result in several solutions that may explain the data equally well. Of these four difficulties, the last two—the non-linearity and the non-uniqueness problems—are the most troublesome, especially since they complicate efforts to determine the uncertainties of important model parameters. One would like to sample all possible crustal models and choose the best, but this is computationally impossible.

*An early approach to the difficulties of matching theoretical to recorded data was the so-called Monte Carlo method in which models were selected completely at random. Only by increasing the number of models tested could analysts improve the chance that any one model would correspond closely to the data. The non-directed Monte Carlo approach wastes a lot of time testing bad models, however. Genetic algorithm and simulated annealing methods developed at UTIG are much more efficient.*

*Paul Stoffa and Mrinal Sen are affiliated with The Texas Institute for Computational and Applied Mathematics (TICAM)*

*TICAM is an organized research unit that is linked with the Mathematics Department and the College of Engineering.*

In response to this dilemma, UTIG scientists have utilized two 'directed' random methods, the so-called genetic algorithm (GA) and simulated annealing (SA) methods. Both of these methods allow a considerable degree of randomness in the model selection process, particularly as the inversion begins. But as it proceeds, the allowable class of models becomes more and more restricted to favor those that most nearly match the data. Genetic algorithms are evolutionary: the vectors representing model parameters are combined over many iterations just as genes on biological chromosomes recombine over many generations. The algorithms favor vectors that best fit the data just as natural selection favors organisms that best fit their environments. Simulated annealing methods operate instead according to a thermodynamic metaphor: a so-called temperature parameter controls how large the random variation between subsequent models can be. The temperature is initially set high and many different model types are explored; as the calculation proceeds, the temperature is gradually lowered so that only models that fit the data closely are evaluated. Several other new methods have been developed to compute travel times and ray paths in laterally inhomogeneous media.

UTIG scientist Mrinal Sen and Director Paul Stoffa are currently adapting some of the UTIG-developed modeling tools mentioned above to provide for anisotropy. Most crustal rocks of interest to exploration geophysics are either inherently anisotropic or behave as anisotropic materials when sampled by seismic waves. Thin layering in sedimentary rocks, fractures in subsurface rocks, and orientation preferences in crystals all cause anisotropic propagation, which is manifested in seismic data as anomalies in travel times, amplitudes, and waveforms. Ultimately, Sen and Stoffa hope to learn what sort of data are needed to best determine anisotropy parameters, how uniquely such parameters can be determined, and, most generally, how important it is when modeling data to provide for anisotropy at all. Committed to investigating the range of models that fit a given data set acceptably rather than a single best-fitting model, they have applied a forward modeling technique based on the reflectivity method and global optimization methods like simulated annealing. They have also cast the inverse problem in a Bayesian framework and estimated the marginal posterior probability density function, the posterior covariance, and the correlation matrices using the Gibbs' sampling technique.



# RESEARCH STAFF

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**Jamie Austin** uses 2-D and 3-D MCS reflection and refraction data to examine the structure and stratigraphy of passive margins around the world, including the east coast of the U.S. and Canada, the Iberian Peninsula, and most recently along the northern Antarctic Peninsula. He is especially interested in the application of seismic stratigraphic principles to understanding the significance of seismic unconformity in both shallow- and deep-water environments and of the uniformity of seismic facies in carbonate versus clastic depositional provinces. A second major thrust of Austin's research is the study of the deep structure of continental lithosphere and the response of continental crust to deformation processes associated with plate fragmentation and convergence. Austin serves the marine geoscience community as a strong proponent of scientific ocean drilling and is currently a member of an international planning committee, IPSC, which will plan the post-2003 program of scientific ocean drilling under the new Integrated Ocean Drilling Program (IODP).

**Nathan Bangs** is interested in structural development and tectonic processes along convergent margins. He uses advanced MCS methods to acquire 3-D images of structure and stratigraphy within subduction zones in order to examine tectonic activity and deformational styles and to study fluid migration in accretionary prisms. His expertise also includes the processing, inversion, and modeling of seismic reflection data. Recently, Bangs has studied the accretionary complexes of Barbados, Chile, and the Aleutians. He is currently the U.S. co-leader of a major U.S.-Japan project to characterize changes in the physical properties of a portion of the Nankai Trough subduction zone offshore Japan. The project aims to determine how these changes relate to earthquake activity. Three-dimensional seismic data collected during summer 1999 will be used to determine the depths at which sediments have sufficient strength to store the large stress energies that could be released in tsunamagenic earthquakes.

**Don Blankenship** uses both airborne and ground-based geophysical techniques—including laser altimetry, radar sounding, seismic reflection and refraction, and potential fields methods—to investigate dynamics of large ice sheets and subglacial geology. Much of his current research is focused on understanding the West Antarctic rift system (including the flanking Transantarctic Mountains) and the marine-based West Antarctic Ice Sheet. Blankenship's recent aerogeophysical investigations have verified that there is a strong correlation between subglacial sediments and ice streaming; these

**SENIOR RESEARCH SCIENTIST**

*Marine geology and geophysics; Ph.D., Massachusetts Institute of Technology/Woods Hole Oceanographic Institution (1979); B.A., Amherst College (1973)*

**RESEARCH SCIENTIST**

*Marine geology and geophysics; Ph.D., M.Phil., M.A., Columbia University (1990, 1987, 1986); B.A., Williams College (1983)*

**RESEARCH SCIENTIST;  
DIRECTOR, SUPPORT OFFICE FOR  
AEROGEOPHYSICAL RESEARCH**  
*Airborne geophysics, seismology, and ice sheet dynamics; Ph.D., M.S., University of Wisconsin, Madison (1989, 1982); B.A., Eastern Illinois University (1978)*

airborne experiments also give indications of active subglacial volcanism near the critical region where ice streams begin. The airborne platform that he developed to simultaneously acquire ice-penetrating radar, laser altimetry, airborne gravity, and aeromagnetic measurements has become the foundation for an NSF-sponsored national facility for airborne geophysics in Antarctica (SOAR) operating from UTIG. Building on his expertise in radar sounding and ice sheets, Blankenship has become involved in the planning of an unmanned space mission to Europa, one of Jupiter's moons, which is thought to have an ice-covered ocean that may host exotic life. He has served on several definition teams for NASA's Europa Orbiter Mission, currently planned to launch in 2006.

**SENIOR RESEARCH SCIENTIST**  
**PROFESSOR, DEPARTMENT OF**  
**GEOLOGICAL SCIENCES**  
*Marine geology and geophysics, seismic sequence stratigraphy; Ph.D., University of California, Berkeley (1967); B.S., The University of Texas at Austin (1959)*

**RESEARCH ASSOCIATE**  
*Seismology, marine geophysics; Ph.D., Massachusetts Institute of Technology/Woods Hole Oceanographic Institution (1994); B.S., Texas A&M University (1988)*

**Richard Buffer** studies ocean basins and their margins using marine geological and geophysical tools. He is especially expert in the application of principles of seismic sequence stratigraphy to the study of marine depositional systems and their adjacent margins. With UTIG/DGS colleague William Galloway, Buffer currently supervises the industry-sponsored UT Gulf Basin Depositional Synthesis Project (GBDS). He is also involved with other UTIG scientists in the study of the structure of the Chicxulub impact crater, which lies buried beneath 1000 meters of sediment straddling the northern boundary of the Yucatan Peninsula and the Gulf of Mexico. The impact is associated with the catastrophe that marked the abrupt end of the Cretaceous period and the start of the Tertiary period (K/T). Most recently, Buffer and Canadian and African colleagues have initiated a major field investigation in the southern Red Sea/northern Danakil region of Eritrea, Africa, in order to address scientific problems related to active geological rift processes in the northern part of the Afar triple junction. A major secondary objective of this project is to establish a geological framework for further paleontological and archaeology studies, including early hominid evolution.

**Gail Christeson** is a seismologist with special expertise in marine geophysics, mid-ocean ridge structure and emplacement processes, oceanic crustal structure, and ocean-bottom seismology. Her work frequently involves using UTIG's OBS instruments in a variety of settings, most recently to study the structure of the subducting crust near Costa Rica and Barbados, the size and morphology of the Chicxulub impact crater, and the nature of the crust within Bransfield Strait. She is currently planning a joint project with scientists from the UK and Mexico to learn more about the Chicxulub impact crater, the site of meteorite impact at the end of the Cretaceous that was responsible, at least in part, for the mass extinctions at the Cretaceous/Tertiary (K/T) boundary. Expanding upon work on the East Pacific Rise (EPR) she had done as a graduate student, Christeson recently participated in a NSF-sponsored expedition to Hess Deep, a steeply plunging rift that cross-cuts the EPR and slices through a slowly-moving treadmill of recently created crust produced at one of the planet's fastest-spreading mid-ocean ridges, providing a window into the Earth's crust-making processes.

**Ian Dalziel**, one of two associate directors of UTIG and Professor of Geological Sciences at The University of Texas at Austin, has dedicated most of his career to understanding global tectonic processes and to mapping out the geography of ancient times on a dynamic Earth. His 35 years of field experience have been devoted to work in the British Caledonides, the Canadian Shield, the Andes, and Antarctica. NSF-sponsored fieldwork in Antarctica between 1995 and 1998 led Dalziel to propose that ancestral North America, known to geologists as Laurentia, was connected to South America, Africa, and Antarctica one billion years ago by a large promontory, which he named the "Texas Plateau." The results of this work were published in the January 1997 issue of *GSA Bulletin*. Recently, working with colleagues from the U.K. and Australia, Dalziel has turned his attention to unraveling the complicated tectonic history of Scotland, his homeland. Dalziel was President of the International Division of the Geological Society of America from 1996 to 1997; he has served as delegate to the Scientific Committee on Antarctic Research of International Union of Geological Sciences since 1987, and has also served as the International Secretary of the American Geophysical Union since 1996.

**Kathy Ellins** is program manager at UTIG. She has combined her background in the geosciences with her experience in K-12 and university-level education to launch two significant K-12 outreach projects: Teacher leadership training workshops for the Texas high school course, *Geology, Meteorology, and Oceanography*, and *Teachers in the Field*. Kathy collaborates with the University of Texas' Charles A. Dana Center and the College of Natural Science's UTEACH program on K-12 projects. She also serves as the Institute's primary public information officer and oversees all development efforts.

**Cliff Frohlich**, one of two associate directors of UTIG, is an earthquake seismologist with a particular interest and expertise in the study of "deep" earthquakes. One component of his research supports objectives of the Comprehensive (Nuclear) Test Ban Treaty, which many nations are reluctant to sign until better technologies are available for detecting violations. With other researchers at UTIG, Frohlich seeks to develop methods that use inverse theory to more accurately locate small earthquakes or massive explosions with data from a single broadband digital seismograph station. Whereas conventional seismic analysis focuses on phase arrivals only, this new approach exploits the informational wealth of the entire seismic waveform, against which synthetic waveforms generated by sophisticated models may be matched. Recently, Frohlich and fellow UTIG seismologist Jay Pulliam carried out a thorough review of Texas earthquake activity; the two scientists are working with the Texas Department of Emergency Management to develop an earthquake hazard policy that will be appropriate for the state.

**ASSOCIATE DIRECTOR; SENIOR RESEARCH SCIENTIST; PROFESSOR, DEPARTMENT OF GEOLOGICAL SCIENCES**  
*Geology, Earth history, and global scale tectonic processes; Ph.D., University of Edinburgh (1963); B.Sc., University of Edinburgh (1959)*

**PROGRAM MANAGER**  
*K-12 education, development, public information; Ph.D., Columbia University (1988); B.A., Skidmore College (1973)*

**ASSOCIATE DIRECTOR; SENIOR RESEARCH SCIENTIST**  
*Solid Earth geophysics, earthquake seismology, tectonics, synthetic stratigraphy, statistics, classical physics, waveform modeling by global optimization methods; Ph.D., M.S., Cornell University (1976, 1973); B.A., Grinnell College (1969)*



**RESEARCH SCIENTIST**

*Marine geology, sedimentary geology and architecture, seismic and sequence stratigraphy, sea-level variation; Ph.D., M.S. Northwestern University (1988, 1979); B.S. University of Leeds (1975)*

**RESEARCH SCIENTIST**

*Marine geophysics, statistical morphology; Ph.D., Massachusetts Institute of Technology/Woods Hole Oceanographic Institution (1990); B.S., Brown University (1985)*

**RESEARCH ASSOCIATE**

*Antarctic data acquisition, airborne geophysics, tectonics; Ph.D. California Institute of Technology (1997); B.S. Rice University (1988)*

**Craig Fulthorpe** seeks to better understand the origins of the sequence stratigraphic record by evaluating the relative roles of local geological processes and global sea level (eustasy) in creating depositional geometries. Though sequence stratigraphy has gained general acceptance as an interpretive tool, the theory that sequences are globally synchronous and caused by eustatic cycles has proved difficult to confirm, partly because both sequence architecture and timing are influenced by local controls (e.g., rates of subsidence and sediment supply, isostasy, compaction, and current activity) in addition to eustasy. Fulthorpe's projects focus on three key margins in different parts of the world: offshore New Jersey, northern California, and the Canterbury Basin offshore New Zealand. His New Jersey and California projects are components of a broad sea-level and stratigraphic initiative funded by the ONR's STRATAFORM project. His work offshore New Jersey also involves the integration of data from ODP Legs 150 and 174A.

**John Goff** uses swath sonar mapping to investigate the large- and fine-scale morphology of the seafloor and its pattern of acoustic reflectivity. As part of the STRATAFORM initiative, he is conducting shallow-water surveys of active and passive continental margins (in northern California and New Jersey, respectively) in order to compare and contrast the margin morphologies and geologic processes operating in these settings. Goff also uses the statistical analysis of geophysical fields associated with shelf bathymetry, sea ice draft, crustal heterogeneity, and oil reservoirs to relate their complex morphology to the geological processes which form or interact with them. His active areas of research include the use of multibeam bathymetry on the New Jersey margin to investigate the quantitative properties of sand ridge and sand ribbon morphology; the quantitative characterization of stratigraphic architecture for the purpose of simulation/interpolation in regions of incomplete data coverage; and the combined use of geostatistical and non-linear inversion techniques to produce an oil reservoir simulation constrained by several different kinds of data. Most recently, Goff has investigated lithologic and velocity variations recorded in the German Continental Drilling Program super-deep drill hole.

**Jack Holt** studies subglacial geology and rift processes. His work takes him to Antarctica for months each winter (austral summer), where he leads UTIG's multi-instrumented airborne geophysics program. Holt's airborne team of 10 to 15 researchers maps the Earth's crust buried beneath the Antarctic ice using a deHavilland Twin Otter plane equipped with ice-penetrating radar, a laser altimeter, a gravity meter, a towed magnetometer, and GPS and inertial navigation systems. The team's data is valuable to interdisciplinary studies of glaciology and geology, generating maps of subglacial topography, ice surface elevation, and gravity and magnetic anomalies. Holt is currently using his Antarctic data to study geological structures associated with the formation of the Transantarctic Mountains, located along a flank of the Western Antarctic Rift. Holt is also examining clues related to the movement of the Baja California peninsula from the North American plate to the Pacific plate.

He uses paleomagnetism and geochronology techniques to determine the age of marine and volcanic deposits associated with the peninsula; the deposits' age and distribution help Holt to construct models of rifting, contributing to the discipline's understanding of this basic geological process.

**Charles Jackson** is interested in the interpretation of paleoclimate records in terms of the physics of the atmosphere, ocean, cryosphere, and their coupling. More particularly, he seeks to identify how glacial cycles occur and the processes that caused or amplified the episodes of extreme climate variability during the last glacial cycle (~120 to 10 thousand years ago). His primary research tools are complex computer models of the climate system and various simplified models that are sometimes more useful for isolating processes of interest. Jackson has examined how the collapse of part of the Laurentide ice sheet, which covered Canada during the last glacial cycle, could facilitate episodes of climate variability on millennial time scales through its control over the atmosphere's circulation. He worked closely with researchers at NOAA's Geophysical Fluid Dynamics Laboratory to model the climate system's response to continuous changes in Earth's orbital geometry over the last 165 thousand years.

**Lawrence Lawver** currently focuses his research on paleogeographic reconstructions of the Polar Regions, East Asia, and the Western Pacific, the development of paleo-seaways and their impact on climate, and the aerogeophysics of the Arctic region. He is particularly interested in two of the remaining problems in the study of plate tectonics: understanding the timing and process of the opening of the Canada Basin of the Arctic region, and the impact of plate tectonics on long-term climate change. Lawver uses marine magnetic anomaly, heat flow, and aerogeophysical data, as well as computer graphics, to aid in understanding the break-up and evolution of the polar regions. He has acquired heat flow, marine magnetic, and seismic data during cruises to the Antarctic Peninsula and the Ross Sea region of Antarctica. Recent work with his colleague Marta Ghidella of the Instituto Antartico Argentino has led to a new understanding of the early break-up history of the Weddell Sea region of Antarctica. As one of the principal investigators of UTIG's PLATES project, Lawver uses the PLATES global databases as an investigative tool in carrying out his research.

**Paul Mann** has focused his latest research on geophysical studies of strike-slip and convergent margins, the integration of offshore MCS and sidescan data with onshore field observations, and the application of GPS and satellite remote-sensing data to tectonic problems. He has worked in a number of geologically diverse environments, including the collisional settings of island arcs with continents, seamounts, and oceanic plateaus in Cuba, Hispaniola, Puerto Rico trench, Kamchatka, Venezuela, Panama, Costa Rica, and the Solomon Islands; transform boundaries and associated basins in the circum-Caribbean and southwest Pacific; and subduction zones in the circum-Caribbean and southwest Pacific. Mann's overarching research goal is to relate plate-margin structure and sedimentation to relative plate motions. For studies carried out

**RESEARCH ASSOCIATE**

*Paleoclimate modeling and analysis; Ph.D., University of Chicago (1998); B.S., Haverford College (1992)*

**SENIOR RESEARCH SCIENTIST**

*Marine geophysics; plate tectonics; magnetics; gravity, heat flow, and seismic studies; Ph.D., University of California at San Diego/Scripps Institution of Oceanography (1976); B.S., Stanford (1970)*

**SENIOR RESEARCH SCIENTIST**

*Tectonics, marine geophysics; Ph.D., State University of New York at Albany (1983); B.A., Oberlin College (1978)*

**RESEARCH SCIENTIST**

*Marine geology, geophysics, structural geology, convergent margin processes, seismic methods; Ph.D., University of California, Santa Cruz (1992); B.Sc., Colorado School of Mines (1980)*

**RESEARCH ASSOCIATE**

*Glaciology, observational glaciology, ice core studies, paleoclimatology, geophysical data inversion; Ph.D., University of Washington (1997); M.S., University of Washington (1990); B. Sc., California Polytechnic (1987)*

**SENIOR RESEARCH SCIENTIST;**

**PROFESSOR, DEPARTMENT OF GEOLOGICAL SCIENCES**

*Geophysics, terrestrial and extraterrestrial seismology, properties of inner solar system bodies, marine seismic instrumentation;*

in the offshore environment, he has used sidescan sonar, MCS reflection, refraction, gravity, and magnetic data. His methods of onshore study include structural and sedimentologic field mapping, studies of late Quaternary coral reefs, GPS surveys, trenching of active faults, and satellite imagery interpretation.

**Kirk McIntosh** is interested in the structure and development of continental margins along convergent and transpressive plate boundaries. His work investigates the structures and processes ranging from crustal scale to (large) outcrop scale that can be studied using seismic reflection and refraction data, sidescan sonar, and other geological and geophysical tools. Among these processes are sediment accretion, subduction, and erosion at convergent margins, forearc and backarc extension and compression, fluid dynamics in accretionary prisms, and shallow-subduction seismicity. McIntosh's primary research sites are currently the Middle America Trench system offshore Costa Rica and Nicaragua (where seamount subduction, the subduction of the Cocos Ridge, backarc thrusting, forearc extension, and a migrating triple junction pose exciting challenges) and Taiwan's continent-collision zone (one of the world's few sites of an ongoing continent/island-arc collision). To address a paucity of deep-structure data from this region, McIntosh and UTIG colleague Yosio Nakamura participated in a collaborative U.S.-Taiwan seismic imaging project on which deep MCS profiling and seismic refraction studies were carried out with a suite of UTIG's OBS instruments.

**David Morse** carried out research at UTIG for two years as a Palisades Geophysical Institute Postdoctoral Fellow before being appointed Research Associate in fall 1999. The focus of one of his current research projects involves the selection of ice core drilling sites for CASERTZ/WAIS (Corridor Aerogeophysical Survey of the Ross Transect Zone/Western Antarctic Ice Sheet), a collaboration between UTIG and the University of Washington Geophysics program. The U.S. ice core research community's WAISCORES project calls for an ice core to be drilled from the WAIS's inland flow divide region. The project aims to assist in the site selection process by performing ice flow calculations to provide time-scale and layer thickness estimates, identifying source regions of deep ice, and interpreting the existing CASERTZ/WAIS radar internal layer morphology for evidence of flow disturbance or basal melting in the deep ice. Morse will use existing radar data and ice dynamics models to identify potential sites where the climate record will be well preserved throughout its long history.

**Yosio Nakamura** is a geophysicist with special interests in terrestrial and extraterrestrial seismology and expertise in seismic instrumentation. He was among the pioneering researchers who, during and following the Apollo Lunar Landing project in the 1970s, used the extensive data collected by a network of seismic stations on the Moon to make the first direct seismic observations of an extraterrestrial object. This research in lunar seismology has led to an invaluable understanding of the dynamics and internal structure of the Moon. It also provides valuable information about tectonism not available on Earth due to the particularities of our planet's size, composition, and stage of

evolution. Under Nakamura's direction, researchers at UTIG have developed a fleet of ocean-bottom seismograph (OBS) instruments in order to acquire high-quality seismic data in targeted marine geologic settings. With UTIG colleague Kirk McIntosh, he used a suite of these OBS instruments in a collaborative U.S.-Chinese project that involved the seismic imaging of Taiwan's continent-collision zone. The collected data have permitted Nakamura and McIntosh to study the crustal-thickening processes that both precede and accompany the collision and to examine the triple junction along eastern Taiwan. More recently, with colleagues Jamie Austin and Ian Dalziel, he led a team of UTIG researchers onboard the U.S. icebreaker R/V *Palmer* to study the deep crustal structure of Bransfield Strait.

**Hilary Olson** integrates the biostratigraphic and paleoenvironmental analysis of foraminifera with core and seismic data. She is particularly interested in the quantitative analysis of foraminiferal census data to improve paleoenvironmental and biostratigraphic interpretations. As a principal investigator for the Technical Alliance for Computational Stratigraphy (TACS) project, Olson worked with colleagues at the University of Utah and in industry to develop a biostratigraphic workstation application targeted at a sequence-stratigraphic solution. Currently, she is applying these techniques to study the latest Quaternary depositional processes and faunas of the intraslope basins of the Gulf of Mexico and the latest Quaternary shelf and slope processes along the New Jersey continental margin. Using a high-resolution data set composed of box cores, piston cores and seismic data, Olson and her colleagues are testing and calibrating the sequence-stratigraphic model from various sites around the world. From 1999-2000 Olson served as President of the North American Micropaleontological Section of the Society for Sedimentary Geology.

**Ingo Pecher** is primarily interested in the application of modern seismic methods to detect and quantify methane gas hydrate in sediments. Methane hydrate is stable under the pressures and temperatures that exist in the world's oceans at water depths below about 500 meters, where it occurs frozen within the cavities of molecules of ice in seafloor sediments. Pecher has investigated seismic field data from gas hydrate provinces offshore Peru, Costa Rica, South Carolina, and in the Gulf of Mexico. His current research includes an analysis of the high-resolution velocity structures across bottom-simulating reflectors, which are thin gas layers underlying the gas hydrate stability zone in sediments. He is also investigating the compressional-to-shear wave conversion that is most likely caused by the stiffening of sediments in association with a partial replacement of pore water by solid gas hydrate. In conjunction with researchers at the U.S. Geological Survey's gas hydrate laboratory, he is working to develop and calibrate rock-physics models of gas-hydrate-bearing sediments. Recently, Pecher has applied tomographic inversion techniques to analyze OBS data from the Cascadia subduction zone.

*Ph.D., Pennsylvania State University (1963); M.S., B.S., Tohoku University (1958, 1956)*

**RESEARCH ASSOCIATE**

*Biostratigraphic and paleoenvironmental analysis using foraminifera, quantitative biostratigraphy, seismic stratigraphy, seismic facies analysis and basin analysis; Ph.D., Stanford University (1988); B.S., University of Notre Dame (1983)*

**RESEARCH ASSOCIATE**

*Marine geology and geophysics, gas hydrates, convergent margins, seismic processing, waveform and traveltime inversion, ocean-bottom seismometry; Ph.D., GEOMAR, U. Kiel, Germany (1995); "Diplom" (M.Sc.), Institute for Geophysics, U. Kiel, Germany (1991)*

**RESEARCH ASSOCIATE**

*Earthquake Seismology, solid earth geophysics, seismic tomography, waveform modeling by global optimization methods, Ph.D., University of California, Berkeley (1991); A.B., Cornell University (1983)*

**RESEARCH ASSOCIATE**

*Optimization, imaging and visualization algorithms for application to seismic data; Ph.D., Baku State University (1979), M. Sc. Baku State University (1975).*

**SENIOR RESEARCH SCIENTIST**

*Seismology and exploration geophysics, seismic wave propagation, inverse problems, seismic imaging, anisotropy, computational physics; Ph.D., University of Hawaii at Manoa/Hawaii Institute of Geophysics (1987); M.Sc., B.Sc., Indian School of Mines (1979;1977)*

**Jay Pulliam** is currently studying the structure of the deep Earth using earthquake sources, developing seismic methods based on ray perturbation theory, and developing a broadband ocean-bottom seismograph (BBOBS) suitable for recording earthquakes on the ocean floor. He has worked with UTIG's Mrinal Sen to model shear-wave splitting on seismograms recorded at the Hockley Seismic Station from deep-focus earthquakes in the southwest Pacific. They interpreted this splitting to be caused by anisotropy in the lowermost mantle beneath the central Pacific. If this interpretation is correct, the anisotropy may indicate chemical heterogeneity in that region of the Earth, which could be caused by mixing of mantle and core materials. Pulliam is also interested in evaluating the effects of seismic data errors on models of Earth structure and exploring the bias introduced by the model parameterization, smoothing and regularization, and the bending of seismic rays. With UTIG's Cliff Frohlich, he is devising ways to monitor compliance with the Comprehensive Test Ban Treaty and is helping the Texas Department of Emergency Management to develop a state-wide earthquake hazard policy.

**Roustan Seifoullae**v is a mathematician who specializes in the application of numerical and optimization methods to a variety of problems, including those encountered in oil and mineral exploration. He is widely acknowledged for his important contributions to the theory of analytical potential theory, boundary value problems, and singular integral equations. Seifoullae's current research focuses on the development of new algorithms for advanced geophysical imaging and inversion techniques for seismic processing and imaging. He utilizes his expertise in computer simulation, nonlinear optimization, and parallel computing to help carry out this research.

**Mrinal Sen** is primarily interested in developing techniques for seismogram synthesis and imaging and the inverse problems of estimating rock properties from geophysical data. Over the years, he has developed several asymptotic, numerical, and hybrid numerical-analytic techniques for modeling wave propagation, travel time computation, and imaging. In addition to demonstrating the effectiveness of genetic algorithms (GA) and simulated annealing (SA) to geophysical inversion, Sen has demonstrated that the Gibbs sampling technique and the Metropolis rule can be applied to characterize uncertainties and estimate the posterior probability density (PPD) function in model space. He is actively pursuing the application of such research to seismic reflection data from gas hydrates, global seismology, seismic tomography, and anisotropic parameter estimation. Sen also develops parallel algorithms for seismic processing and models earthquake seismograms for large-scale earth structures. With UTIG's Jay Pulliam, he has interpreted shear-wave splitting on seismograms from deep-focus earthquakes in the southwest Pacific to be caused by anisotropy in the core-mantle transition zone.

**Tom Shipley** is a marine geologist who specializes in the application of seismic reflection methods to the study of convergent margin processes. He is particularly concerned with understanding the crucial role of fluids in accretionary prisms and how they influence the distribution of low-shear-strength fault zones. He heads a team of UTIG researchers who have pioneered the academic use of 3-D seismics to image subduction zone processes. Most recently, Shipley participated in a major U.S.-Japanese project to characterize changes in the physical properties of a portion of the Nankai Trough subduction zone in order to determine how these changes relate to earthquake activity. This program provided the background information for two legs of ODP drilling and a proposed deep hole into the seismogenic zone using a new Japanese drilling vessel currently under construction. Shipley believes that the combination of drilling experiments and seismic reflection data will significantly improve our understanding of the relationship between hydrologic and tectonic processes at accretionary margins. He is also responsible for creating UTIG's Seismic Reflection Data Search (SRDS) web site, which will soon make the Institute's massive 26-year archive of marine seismic reflection data available online to the international marine geophysical community and industry.

**Fred Taylor** integrates research in geology, biology, and chemistry to address geologic and environmental problems. He has expertise in the study of corals, in which sea-surface temperatures are precisely recorded as chemical variations in the calcium carbonate that forms their annual density bands. He is currently involved in two paleoclimate programs to document the temperature history in the Western Pacific Warm Pool region, an area that is critical to the Earth's climate and weather. One program involves analyzing cores drilled from living corals from New Caledonia, Vanuatu, the Solomon Islands, and Papua New Guinea to obtain a record of climate extending back several hundred years; the other involves analyzing cores of fossil corals from uplifted reefs to obtain climate records for times back through the last glacial maximum about 22,000 years ago. On another project, Taylor is investigating Quaternary climate and sea-level changes using combined  $^{230}\text{Th}$  and  $^{231}\text{Pa}$  dating of fossil corals. He is also studying Quaternary and contemporary crustal motions in the Southwest Pacific using coral reefs as recorders of tectonic deformation. Taylor also uses the Global Positioning System to measure the horizontal plate motions that drive earthquakes and crustal deformation at the edges of tectonic plates in the Southwest Pacific, the South Shetland Islands of Antarctica, and South America and the bedrock beneath the WAIS.

**SENIOR RESEARCH SCIENTIST**

*Marine geology and geophysics; Ph.D., Rice University (1975); B.S. California State University at Hayward (1971)*

**SENIOR RESEARCH SCIENTIST**

*Neotectonics, paleoseismology, paleoclimatology; Ph.D., Cornell University (1978); M.S., Brown University (1974); B.S., University of North Carolina (1971)*

# MISSION

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Geoscientists view Planet Earth from core to upper atmosphere in terms of global systems, and the economic, environmental and intellectual needs to undertake geoscience studies on a global scale are steadily increasing. Thus, to contribute effectively to research and education in the Earth sciences, a major public university must have a substantive program that treats the earth as a planet. Such a program should investigate not only the continents, but also the continental margins, the oceans and the polar regions, since the latter, when taken together, cover three-quarters of the surface of the globe. Investigations of these diverse regions, including the study of the deep earth structure beneath them, are vital to understanding the tectonic development and resources of our planet. Furthermore, Texas, with its historical association with the energy industry, with its large and economically important continental shelf and slope, and with its direct access to the world's ocean through the Gulf of Mexico, is a natural location for a research organization with a global scope, including a strong effort in marine geophysics and marine geology."

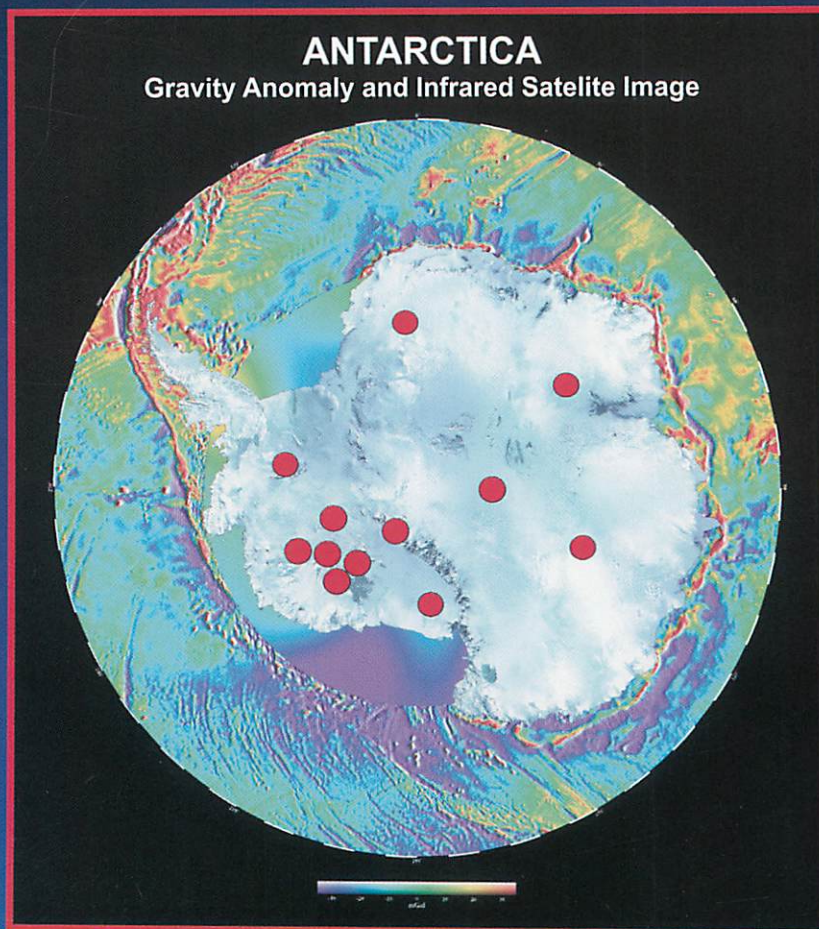
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**DIRECTOR; SENIOR RESEARCH  
SCIENTIST; SHELL DISTINGUISHED  
CHAIR IN THE DEPARTMENT OF  
GEOLOGICAL SCIENCES**  
*Marine seismology, computa-  
tional geophysics, the use of  
parallel computers in seismic  
processing; Ph.D., Columbia  
University (1974);  
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**Paul Stoffa**, UTIG's Director since 1995, applies his expertise in multichannel seismic acquisition, signal processing, acoustic and elastic wave propagation, modeling and inversion of geophysical data, along with his knowledge of parallel computers, to developing new seismic data acquisition and processing methods that can be used to address complex geologic problems. Working with other researchers at UTIG, Stoffa has developed 2-D and 3-D seismic acquisition techniques that can be combined with pre- and post-stack migration methods to form images of the subsurface. To define the subsurface velocity structure, he has designed nonlinear optimization procedures such as genetic algorithms and very fast simulated annealing based on the 'misfit' of migrated subsurface images and reflection tomography. These optimization procedures and the seismic migration algorithms can be implemented on parallel computer architectures so that solving practical problems in geology is within reach. Stoffa is Chairman of the Board of Governors of the Joint Oceanographic Institutions, a member of the Board of Governors of the Consortium for Ocean Research and Education, and a Society of Exploration Geophysicists District 3 Representative. He also serves on the JOIDES Executive Committee of the ODP.

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