# The University of Texas at Austin

# UTIG


# Institute for Geophysics

# What's Inside




***Publication Coordinator: Patricia E. Ganey-Curry***
***Editorial Assistants: Mark H. Dorsett, Lisa M. Gahagan, Kathryn A. Moser***

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INSTITUTE FOR GEOPHYSICS
THE UNIVERSITY OF TEXAS AT AUSTIN

# About UTIG

The University of Texas at Austin Institute for Geophysics (UTIG), a leading academic research group in geology and geophysics, founded in 1972 by geophysicist/oceanographer, Maurice Ewing, conducts geophysical investigations of the history, structure, and dynamics of the earth's crust and of earthquake phenomena. UTIG is an Organized Research Unit within the College of Natural Sciences and serves the basic and applied geophysical research and graduate student training needs of The University of Texas at Austin.

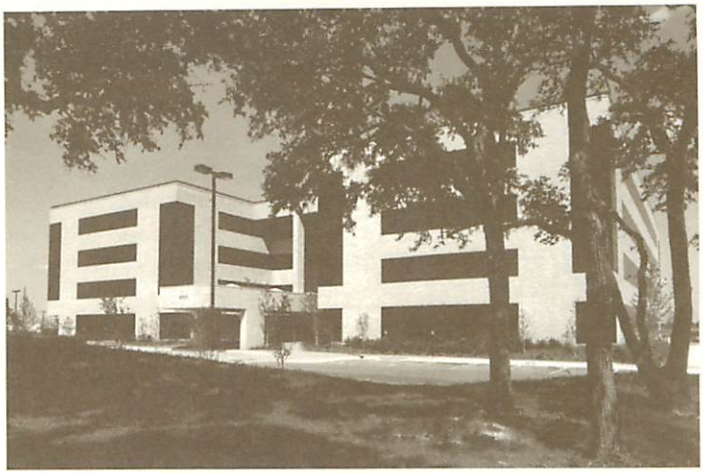
The Institute for Geophysics provides research and educational opportunities to gain new insights into geological and geophysical phenomena. The Institute's basic research, which emphasizes the ocean basins and continental margins, not only enhances fundamental understanding of the physical structure and evolution of the solid earth, but also is relevant to geological exploration for natural resources, environmental problems related to resource extraction and waste disposal or other man-made conditions, problems of earthquake prediction and the phenomena of acoustic transmission in the ocean and solid earth. Many of the resource-related and environmental problems which confront society require a global perspective in order to be properly understood and addressed, and the Institute for Geophysics offers unique capabilities in this regard.

The common research goal among the scientists at UTIG is a desire to increase our understanding of the earth's structure and processes through the use of advanced geophysical observations. Scientists at UTIG propose, conduct and report on their research activities as individual principal investigators or as groups of investigators whose expertise depends on the geologic problem, and/or geophysical techniques being employed. Research scientists often work as part of international and national teams in large, multi-disciplinary research programs. Disciplinary areas of research interests include seismic reflection and refraction, earthquake seismology, geothermal studies, gravity, geomagnetism, aerogeophysics, laser altimetry, geodesy, and theoretical geophysics. Geographic areas of research are worldwide. Funding is provided by federal agencies (principally the National Science Foundation, the U.S. Office of Naval Research, and the U.S. Air Force) and by the State of Texas, with additional support from The University and major oil companies.

Institute capabilities in geophysical research extend from problem definition to data acquisition, processing and, finally, interpretation of results. Development of new methodology and instrumentation for these studies is an integral part of the Institute's activities. To support research activities, UTIG provides a technical support staff to help with data processing, programming, drafting, design and engineering, and to maintain equipment which includes computers, low-fold multichannel systems, an array of active or passive ocean bottom seismometers, magnetometers, gravimeters and geothermal probes.

Graduate student training is an important component of the research activities of the Institute. Many geophysics graduate students at UT and other universities take advantage of the opportunity to work with the staff and facilities of the Institute for Geophysics on projects related to funded research programs. Office space and computational resources are made available to students in the Institute laboratory. There are at present more than 30 graduate students associated with the Institute.

The Institute's laboratory is in north Austin near the University's J. J. Pickle Research Campus.



# History

As early as 1892, the University of Texas Board of Regents recognized the need for a marine education program and marine station in Texas. The first University of Texas Marine Station was established in 1900 in the University Medical School at Galveston. Regent George W. Brackenridge provided a steam vessel to serve as its first research vessel. Both the vessel and the station were destroyed in a hurricane in 1900. Later in 1915, Regent Brackenridge made a second attempt at establishing a marine program by donating his 38-meter schooner, the *Navidad*, but again the program was halted by a tropical storm. In 1941 the Marine Science Institute at Port Aransas was founded.

The organization that was to become the Institute for Geophysics was established in 1972 when Maurice Ewing, a native of Texas and founder of the Lamont-Doherty Geological Observatory at Columbia University, moved back to his home state. With a group of his colleagues, he formed the Earth and Planetary Sciences Division of the Marine Biomedical Institute at the University of Texas Medical Branch in Galveston (UTMB).

Research vessel Ida Green docked in front of UT-MSI facility in Galveston circa 1978.

Before his death in 1974, Dr. Ewing established a recognized center of lunar and earthquake seismology and created the first academic program in marine multichannel seismic research.

Building on the solid foundation left by Dr. Ewing, the University of Texas Board of Regents developed a plan to provide the opportunity to conduct advanced research and teaching programs in areas related to Texas natural resources, particularly the Gulf of Mexico and coastal zone. The administration of the Earth and Planetary Sciences Division was transferred to the Marine Science Institute (MSI) at The University of Texas at Austin in September 1974. Dr. Ewing's Galveston group was renamed the Geophysics Laboratory and joined with the Port Aransas Marine Science Lab, also of UT Austin. At the same time, the Department of Marine Studies was established.

Dr. Creighton A. Burk, formerly Chief Geologist of Mobil Oil Company, was the first Director of the Marine Science Institute and the first Chairman of the Department of Marine Studies, both of which he directed from Austin. Dr. Peter T. Flawn, who later became President of The University of Texas at Austin, briefly assumed directorship through March 1979. J. Robert Moore led the Marine Science Institute during the period of March 1979 thru December 1981.

In July of 1975, after the establishment of the Marine Science Institute, J. Lamar Worzel was named Director of the Galveston Geophysics Laboratory. Dr. Worzel expanded the laboratory staff and widened its areas of research until his retirement in September 1979.

On January 1, 1982, Dr. Maxwell came to The University of Texas at Austin as the first director of the newly formed Institute for Geophysics. The Galveston-based group was separated from MSI and renamed the Institute for Geophysics to better reflect the group's interests. His efforts helped to develop the Institute into one of the leading geology and geophysical research institutions in the world.

The need for closer proximity to other University groups involved in earth sciences necessitated a move of most of the Institute's activities to Austin. Dr. Maxwell was instrumental in relocating the research staff from Galveston to Austin, which led to an increase in research staff from 14 to 31; an increase in graduate student involvement from 10 to 49; increased interaction with other UT Austin departments and other universities, both national and international, and an increase in seismic data processing capabilities from a dedicated minicomputer system to supercomputer based commercial seismic data processing software and workstation based geophysical interpretation. He was also responsible for an increase in NSF funding to the Institute during his tenure from less than $500K to a high of $3.5M.

UTIG has been built into a leading academic research group in geology and geophysics. It is now an Organized Research Unit under the direction of the Dean of the College of Natural Sciences and the current Director, Dr. Paul L. Stoffa.

Established to serve the basic and applied geophysical research needs of The University of Texas at Austin the Institute fulfills its mission as stated:

> "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 which 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 program of global scope, including a strong effort in marine geophysics and marine geology."

# Data Processing

Advances in network technology continue a trend away from centralized computer systems toward distributed systems that can grow selectively in the areas of greatest need. The UTIG computer system now includes personal computers, workstations, and supercomputers. Fast networks interconnect these systems to give each user access to the most suitable level of processing power required for any given task.

At the desktop, Macintosh personal computers are used which handle almost all word processing and publication tasks, optical character recognition, graphic design, and administrative data processing. Every office is equipped with a at least one Macintosh, so they have become nearly as important as telephones for mail and messaging. Used as terminals to faster systems, the Macintosh can access data from other computers and process it with a wide variety of inexpensive software. Networked PostScript laser printers distributed throughout the building give rapid turnaround for normal black and white graphics and text output. Each office has both a slow Appletalk connection for older Macs, as well as a faster Ethernet. These are seamlessly interconnected to the University's Ethernet, FDDI networks and to the Internet.

The next higher level in computing capability is a network of over 20 mostly Sun workstations that are used for seismic data processing and interpretation, numerical modeling, software development, and any tasks that require faster processing than the Macintoshes currently achieve. The Suns offer the general advantages of faster network attachments and more disk space, with larger screens that allow more detailed graphics. An SGI Power Indigo 2 was installed in fall 1995 to speed both graphics and computation in visualizing complex three dimensional seismic volumes. Two core servers provide for general department wide computation and data storage. Peripheral equipment attached to the servers include two Versatec plotters and a D size digitizer. The servers handle electronic mail, network news service, and other core services for both Macintoshes and workstations.

Interactive seismic data processing, interpretation and related tasks using IES from GeoQuest™ Systems and Geovecteur Plus™ from Compagnie Générale de Géophysique (CGG) is performed at UTIG. Geovecteur™ the most comprehensive 2D and 3D seismic data processing system available for the Cray, also runs in interactive or batch modes on local workstations and provides all types of pre- and post-stack techniques currently in commercial production use. These include various sophisticated static routines for dip move-out, tau-p transformations, pre-stack depth migration and full 3D migration in time or depth. UTIG is using Geovecteur for conventional and deep penetration crustal programs and several 3D surveys. Software written to perform 3D depth migrations runs on our workstations or larger machines, depending on the problem size.

The most powerful systems we commonly use are at The University of Texas at Austin's High Performance Computing Facility (HPCF), where two Cray J90's were installed in summer 1995. The batch mode machine is a 16 processor/512 Mbyte system with approximately 216 Gbytes of disk. A smaller 5 processor machine provides an interactive and testing environment. Both run Geovecteur™ and UTIG locally developed codes.

Computational resources are made available to students in the Institute laboratory.

# UTIG Sponsored Projects

The University of Texas at Austin encourages faculty and research staff members to seek support for sponsored projects related to teaching, research and public service. The University recognizes that research under sponsored projects contributes significantly to the academic stature, achievement, and capability of the faculty and research staff in fulfilling its responsibilities as teachers and public servants. The University seeks to insure the close integration of research and teaching, including the employment of students in sponsored projects and the use of research facilities for instructional purposes. The principal investigator (or project director) has many Institute resources available to assist in the preparation of proposals and fulfillment of project goals. The following is a list, organized by funding agency, of currently sponsored projects at UTIG.

## State of Texas (THECB)

### Hybrid Linear/Nonlinear Methods of Seismic Waveform Inversion

*Principal Investigator: Mrinal K. Sen*

Inversion of geophysical data to obtain subsurface material properties is critical to increasing quantitative understanding of geologic structures and lithology and has direct application in hydrocarbon exploration and exploitation. Seismic waveform inversion seeks to determine compressional wave velocity, Poisson's ratio and impedance contrasts by minimizing the differences between observed and synthetic seismic data based on proposed subsurface structures and a particular type of wave propagation. This problem is nonlinear and can be solved using nonlinear optimization procedures such as simulated annealing (SA) and genetic algorithms (GA). However, depending on the seismic data actually used and the *a priori* information available, seismic waveform inversion can be made approximately linear so that solution by iterative linear approaches is possible. Experience with iterative linear and nonlinear inverse methods shows that each approach has its unique merits and disadvantages. The elements of nonlinear optimization and iterative linear methods can be combined to achieve two important goals: increase the rate of convergence and thereby lower the computational cost; and, improve resolution without significantly increasing the computational burden. If these objectives can be achieved, seismic waveform inversion could be routinely applied, thereby, significantly improving estimates of material properties.

### Anisotropic Earth Model Calculations

*Principal Investigator: Mrinal K. Sen*

Most of what is known today about the Earth's interior has been derived from seismology. The seismograms from earthquakes recorded at stations all over the world are analyzed to derive compressional and shear wave velocity and density as a function of depth. In laboratory experiments, rocks and minerals are subjected to high pressure and temperature simulating conditions in the earth's deep interior. These data are used in conjunction with seismological data to infer the chemical composition of the materials in the earth's interior. Most of these calculations have been done assuming very simple earth models such as a 1D isotropic earth.

Researchers are developing algorithms for the calculation of synthetic seismograms for anisotropic earth models in spherical coordinates. These will be used to derive constraints on the anisotropic parameters of the earth's deep interior. The result will enable the earth science community to either validate the existing models of the mantle and inner core, or to derive new models. Such results will have far reaching implications in terms of chemical composition of materials, global tectonics, mantle convection and the generation of the Earth's magnetic field.

### Development of an Economical Technology to Measure Geothermal Heat Flow on Shallow Seafloors

*Principal Investigator: Kenneth H. Griffiths*

Researchers will develop a new, cost-effective technology to measure geothermal heat flow in shallow (100 to 500m) seafloors. The design will include an expendable, thin (1-inch diam.), long (10 m) seafloor penetrator which contains a number of temperature sensors. When deployed the penetrator will free-fall through the water column and, with its momentum, penetrate deep into the sediments below the zone of seasonal disturbance. The Institute for Geophysics will design and construct the interior electronics assembly. This will include the temperature sensors, analog to digital conversion and the control microprocessor. In addition to providing high accuracy measurements; the design will focus on high-volume, low-cost manufacture of these sensors.

## U.S. Air Force

### Observational Analysis of the Origin of Non-Double Couple Seismic Sources

*Principal Investigator: Cliff Frohlich*

Radiation from many earthquake sources cannot be explained solely as being due to slip along a simple planar fault. These "anomalous" sources are most likely caused by multiple events occurring on appropriately oriented, nonparallel faults or can be attributed to systematic problems with the source determination process, e.g., errors caused by near-source structure. Understanding these events is of special importance both because it may elucidate the mechanics of the earthquake source process, and also because events with such anomalous sources might be misidentified as explosions, or, explosions might be misidentified as earthquakes with anomalous sources. This project is to investigate the nature of these anomalous earthquake sources by investigating earthquakes in pairs—for each anomalous event one or more nearby event with a well determined double-couple source mechanism is found.

### Seismic Event Location Using Both Traveltime Inversion and Broadband Waveform Modeling

*Principal Investigators: Lian-she Zhao/Cliff Frohlich*

This project investigates how accurately matching observed and synthetic seismograms constrains event locations, even when data is available from only a single station. For this research, broadband digital seismograms are collected for events having magnitudes of 3.5 to 6.0 or larger in three geographic areas: 1) Western United States; 2) Tibet/China; and 3) The Middle East. The procedure will be to model the larger of these events to determine appropriate regional crustal structure, then, to determine the

range of hypocentral and source property parameters consistent with observations of the smaller events. The project will develop robust methods to determine the hypocenters and sources of the smaller events as efficiently as possible. These events are also located using traditional travel-time based methods so as to evaluate when waveform-based location methods are superior.

### Quantitative Characterization of Crustal Heterogeneity: Implications for Seismic Wave Propagation

*Principal Investigator: John A. Goff*

Projected plans are: 1) to stochastically analyze fine-scale geologic maps in order to build a statistical database of structural and seismic properties (seismic velocity and density) of the crust and upper mantle in different tectonic environments, 2) to develop models which contain lithospheric seismic velocity heterogeneity which is both deterministic (long wavelength) and stochastic (short wavelength), 3) to relate the statistics of the stochastic models to the statistics of synthetic seismic wavefields in the 0.5-40 Hz seismic band using full waveform methods for computing synthetic seismograms and using theoretical methods for analyzing wave scattering, and 4) to conduct parallel research on seismic field data from different tectonic environments. The crustal scale models will be useful for predicting long range propagation of crustal and upper mantle phases associated with earthquakes or large explosive sources, as well as for estimating the complexity in teleseismic signals introduced by heterogeneities in the lithosphere.

## U.S. Office of Naval Research

### Sequence Stratigraphic Geometries and Neogene Evolution of the Middle Atlantic Continental Margin

*Principal Investigators: Craig S. Fulthorpe/James A. Austin, Jr.*

Researchers have gathered available oil industry multichannel seismic (MCS) data from the middle Atlantic margin encompassing prospective Ocean Drilling Program (ODP) drilling sites across the mid-outer shelf to interpret and map the upper interval of those data. The 3-D geometries of seismic sequences will be defined to investigate the morphology and evolution of the prograding Neogene shelf sediment prism. The work constitutes an extension of ONR-funded 2-D and 3-D Huntec DTS™ (deep-towed seismic) surveying deeper into the subsurface and is related to ONR's long-term plan to develop a natural laboratory on this part of the middle Atlantic continental shelf.

### Swath Mapping of the New Jersey and Northern California Margins and Statistical Characterization of the Shelf and Slope Bathymetry

*Principal Investigator: John A. Goff*

This project is designed principally in support of swath mapping field programs for both the New Jersey and Northern California STRATAFORM (STRATA FORmation on Margins) natural labs. It has entailed participation in survey planning, operations, data processing and data interpretation. The swath mapping field program is a primary support for all aspects of the STRATAFORM program (shelf dynamics, slope processes, and sequence stratigraphy). A top priority of this work will be to disseminate to the STRATAFORM community digital and map forms of bathymetric and sonar data and provide preliminary geologic interpretation.

### Ocean Science Education in Quantitative Marine Seismology

*Principal Investigator: Paul L. Stoffa*

The investigator is one of two recipients of the Ocean Science Educator Award for fiscal year 1994. The program identifies and supports distinguished academic scientists who are recognized researchers in the ocean sciences and who have an excellent record of educating high quality doctoral and/or postdoctoral students and who will, under this program, draw postdoctoral scientists from other disciplines into the ocean sciences. Fellows selected by the educator and institution for training and research must be trained in a field outside the ocean sciences, must have published research experience and documented superior academic and research achievements.

### High-Resolution Seismic Surveying for Pleistocene Sequence Stratigraphy, New Jersey Continental Shelf and Upper Slope, in Support of STRATAFORM

*Principal Investigator: James A. Austin, Jr*

STRATAFORM's (STRATAFORmation on Margins) primary goal is to understand how the complex array of depositional processes on continental margins translates into the preserved stratigraphic record. The primary scales of interest are ~$10^6$ years into the past, and ~hundreds of meters into the seafloor. Nested arrays of geophysical data on the shelf and upper slope are the primary means to imaging stratigraphic successions and associated facies architecture. Low resolution (20-100 Hz) multichannel seismic and very high-resolution (500-3500 Hz) single-channel Huntec™ profiles have already been collected offshore New Jersey. This project supported a cruise to collect profiles in the intervening frequency band (~30-500 Hz) and to complete detailed grid surveys and assess potential hydrocarbon hazards in the vicinity of proposed ODP drill sites. These sites will comprise a critical segment of the Mid-Atlantic Transect (MAT) that is designed to understand the history of Neogene sealevel on this margin. ODP drilling could also provide valuable ground truth for the geophysical profiles collected in support of STRATAFORM. All of these data support designation of this part of the New Jersey margin as a natural laboratory for marine geology/geophysics and shallow water acoustics.

### Huntec 3-D Surveying and Piston Coring Off New Jersey

*Principal Investigator: James A. Austin, Jr.*

Regional seismic reflection surveys have delineated a wedge of late Quaternary sediment extending 150 km south from the Hudson apron along the edge of the continental shelf off New Jersey. The bottom of the sediment wedge is defined by a prominent reflector (R), assumed to represent an erosional surface carved during a low-stand of sea level, probably corresponding to the Wisconsin Maximum glaciation.

A 3-D reflection survey of a 5 x 0.5 km area of the southern part of the wedge was carried out in October 1989. Line spacing was 10 m and shot spacing 2.5 m. Navigation achieved position accuracies to <5 m. A series of cores both within and near the survey area yielded sedimentological and faunal data for ground-truth of the seismic results.

The survey shows that the outer shelf sediment wedge has a complex internal structure unrelated to the present seafloor morphology. Continued studies on the data are in progress.

# National Science Foundation Division of Ocean Sciences

## Three-Dimensional Seismic Reflection Investigation of Fluid Flow and Structural Evolution: Northern Barbados Ridge

*Principal Investigators: Thomas H. Shipley/Paul L. Stoffa*

A three dimensional seismic reflection survey and a novel pilot OBS program was conducted in the frontal part of the accretionary prism in the northern Barbados Trench. This experiment was designed to fully image a 170 square kilometer area from the seafloor to the top of the oceanic plate, and encompassing all of the existing and proposed drill sites.

## Collaborative Research: Pacific to Bering Shelf Deep Seismic Reflection Experiment

*Principal Investigator: Nathan L. Bangs*

The growth of continents since Archean time is dominated by two major processes—arc magmatism and terrane accretion. Magmatism at convergent margins is the primary mechanism by which new crust is generated. Terrane accretion is the mechanism by which fragments of previously generated crust are amalgamated into an existing continental nucleus. Many of these fragments are fundamentally oceanic in their origin and become a component of the continental crust through the process of terrane accretion. While we now accept that magmatism and accretion are phenomena that are axiomatic to continental growth, major questions remain concerning the mechanics of these phenomena. These range from the details of arc structure and terrane boundaries, to fundamental questions such as the reason for the continental crust's bulk chemical composition and the mechanism of terrane emplacement. In progress is a deep multichannel seismic reflection survey of a region where both processes are recently active or occurring today, the Aleutian Arc and the extensive continental shelf of Alaska.

## Rock Property Estimation by AVO Inversion of Marine Seismic Data

*Principal Investigators: Mrinal K. Sen*

The contrasts in the elastic properties of rocks are manifested in seismic waveform data as variations in arrival times and amplitudes of reflection events recorded in the seismograms. One example is the amplitude variation with offset (also called AVO effect) which has been used by exploration seismologists as a diagnostic in the direct detection of hydrocarbons. Several academic multichannel seismic datasets also show significant AVO effects. The bottom simulating reflectors (BSR), whose primary effect in the stacked CDP section is a bright spot, also show a continuous increase in amplitude with offset. Researchers will develop a more rigorous technique of AVO inversion for the application to marine multi-channel seismic data.

Typically, AVO inversion is a two-step procedure. The first step is to compute the background (or low frequency component) velocity model and the second step is to compute the high frequency components of the material property, e.g., compressional wave velocity, shear wave velocity, fluid factor, porosity, etc. Researchers will use global optimization methods such as simulated annealing and genetic algorithms to estimate the background velocity field which will be coupled with a linearized inversion to derive estimates of the high frequency material property component

## Structure of the Chicxulub KT Impact Crater, Yucatan

*Principal Investigators: Richard Buffler/Gail Christeson/Yosio Nakamura*

The Chicxulub structure occurs along the northern coast of the Yucatan peninsula in the Gulf of Mexico. It is buried beneath up to a kilometer of Tertiary carbonates. Its upper boundary has been drilled, and it has been mapped on the basis of potential field and Landsat data. It is now widely believed that the structure represents a large meteorite impact that was responsible for mass extinctions at the Cretaceous-Tertiary(KT) boundary. The purpose of this joint project is to image in detail the internal crustal structure and morphology of the Chicxulub impact crater and to quantify its dimensions. The project will involve the collection, processing and interpretation of a series of deep penetration seismic reflection profiles, wide-angle seismic measurements, and refraction measurements from the offshore portion of the crater. It represents a joint collaborative effort between UTIG, Imperial College (UK), the British Institutions Reflection Profiling Syndicate (BIRPS), Universidad Nacional Autonoma de Mexico (UNAM) and the Canadian Geological Survey.

## Time-Transgressive Deformational Effects of Oblique Underthrusting of Aseismic Ridges on the Puerto Rico Trench and Island Margin

*Principal Investigator: Paul L. Mann*

This is a cooperative project involving the University of Puerto Rico, UTIG and the University of Southern California. The Puerto Rico Trench and northern margin of the island of Puerto Rico occupy a zone of tectonic transition between subduction tectonics of the Lesser Antilles island arc and strike slip fault system to the west. The Main Ridge area of the Puerto Rico Trench is selected as the focus of this study as it appears to be the zone of active collision between elevated fracture zones on the downgoing North America plate and the Puerto Rico island slope of the overriding Caribbean plate. The plan for this project is to map this area with sidescan/bathymetric(MR1) and geophysical (magnetic, gravity and 4-channel seismic.)

## Geological Record of Southern Ocean Sedimentation

*Principal Investigator: Thomas A. Davies*

Work in progress is directed toward the preparation and interpretation of palinspastic maps that show the patterns of sediment distribution in the oceans at various times through the Cenozoic. Such maps clearly delineate the principal depocenters and show how the sedimentary record has responded on an oceanwide scale to changes in paleogeography, paleocirculation and climate. The time-slice approach exemplified by the maps has become applicable on a wide scale only recently, as both the

number and geographic coverage of continuously cored deep-sea drillsites have increased. This approach complements the contributions of time-series and model studies to identifying and understanding significant events in the Cenozoic history of the oceans and the changing global environment.

### Collaborative Research: The Temperature History of the Western Pacific Warm Pool Over the Last 30 Ka

*Principal Investigator: Frederick W. Taylor*

The main objective of this project is to obtain seasonal and mean annual records of sea surface temperature in the Western Pacific Warm Pool over portions of the last 30,000 years. The Western Pacific Warm Pool has the highest mean annual sea surface temperatures on earth ranging from 28°C to greater than 29.5°C. Because of the high temperatures, the Warm Pool supplies the earth's atmosphere with a large portion of its water vapor and heat, largely in the form of latent heat. The rate of ocean-atmosphere heat and water vapor transfer increases with increasing temperature, reaching particularly high values as temperatures rise above ~28° C. Thus, the earth's climate is very sensitive to changes in Warm Pool temperature. Despite its importance, the history of Warm Pool temperatures on glacial-interglacial time scales is not well known. Existing data are discrepant and controversial.

In order to address this controversy, three new and promising sea surface thermometers will be applied to fossil corals drilled from sites in the Warm Pool. Drilling will be done in conjunction with the French research organization, ORSTOM, which has already committed ship time for drill rig transport, purchased a new $120,000 drill rig, committed an experienced driller, and committed research scientists who will contribute toward analysis of samples and interpretation of results. As tectonic uplift minimizes depths to glacial maximum material, localities undergoing tectonic uplift have been chosen as drilling sites. The absolute ages of recovered corals will be established. The results will have important implications regarding our understanding of glacial climate, transitions from glacial to interglacial climate, and millennial-scale climatic events during deglaciation.

### Collaborative Research: US-ROC Deep Seismic Imaging Study of the Taiwan Arc Continent Collision

*Principal Investigators: Kirk McIntosh/Yosio Nakamura*

This project represents a collaborative seismic imaging program between geoscientists of the United States and The Republic of China (ROC) to study orogenic processes associated with the Taiwan arc-continent collision. Uplift rates measured along the collision suture in southeastern Taiwan are among the fastest in the world. Little is known about the crustal structure beneath this region or the mechanisms responsible for uplift at the critical transition from subduction to collision located in the offshore south and east of Taiwan. The US-ROC program will significantly increase understanding of crustal deformation in critical regions of a modern orogenic belt, which has served as an important model for the mechanics of fold and thrust-belts worldwide. This investigation will provide the necessary regional information for ODP drilling proposed to study the closure of a forearc basin during arc accretion to a continent.

### Accretionary Prism Plumbing in 3D: Fluid Pathways and Fluid-Structure Interaction Using the Costa Rica 3D Seismic Volume

*Principal Investigators: Kirk McIntosh/Thomas H. Shipley/Nathan L. Bangs*

Researchers are studying fluid pathways in accretionary prisms by using existing two-dimensional and three-dimensional seismic reflection data sets from the Costa Rica convergent margin in an integrated, three part project. A large effort will be undertaken to map the network of potential fluid conduits as indicated by the system of faults in the 2D and 3D seismic data sets. A model is in development to show the seismic response of prism reflectors to interpret where fluids may be present along conduits, and how and where fluids are involved in the structural development of the prism. Researchers will seek to improve velocity estimates and seismic images of selected, critical pieces of the data needed for interpretation of fluid sources and migration pathways within the prism. Collectively these objectives will comprise a comprehensive effort to delineate the mechanics of fluid migration and dewatering activity in the Costa Rica accretionary prism. By integrating the results from these efforts, a detailed image of this prism's fluid pathways will be produced. Results will be used to make testable hypotheses regarding fluid source regions and migration paths and place constraints on the behavior of fluids that govern thrusting and trigger underplating.

### Investigation of Upper Plate Response to Subducting Plate Morphology and Seamounts as Subduction Zone Asperities

*Principal Investigator: Kirk McIntosh*

Data has been acquired to investigate the upper plate response to three different morphological segments of the Cocos plate that subduct beneath Costa Rica. The smooth, seamount-dominated, and Cocos Ridge segments of the Cocos plate were surveyed using a large marine airgun source, 20-30 ocean bottom instruments (seismometers and hydrophones), 30+ land instruments, and selected land shots to obtain wide aperture and near vertical seismic data along the three regional transects. The wide aperture data will be used to establish crustal structure/velocity models across the arc and forearc areas, which are poorly known at present. The resulting models can also be used to process (i.e., migrate) near-vertical data recorded by the ocean bottom and land instruments to image the plate boundary zone reflections landward into the zone of seismogenic subduction and seaward to tie with existing seismic reflection data. Along all three transects a primary goal is to construct accurate velocity models so that the images of the plate boundary zone produced in this project can be tied to relocated earthquake hypocenters. Integration of these two data sets could provide a missing link in understanding the transition from aseismic to seismogenic plate motion.

### Transform and Subduction Tectonics Along the Macquarie Ridge: Sidescan, Seismic Reflection, Earthquake & Gravity Studies

*Principal Investigators: Millard F. Coffin/Clifford A. Frohlich/Paul W. Mann*

How subduction is initiated is an outstanding unsolved problem in plate tectonics. The Macquarie Ridge Complex, a ~1500 km long plate boundary south of New Zealand, appears ideal for studying this process. Seismicity and global plate motion studies define the plate boundary as obliquely convergent. It is one of the most seismically active and unusual regions in the world—the world's largest earthquake of the 1980's, and the largest strike-slip earthquake ever recorded, occurred along it on 23 May 1989—and the complex is deformed on a large scale. Overthrusting zones are observed and manifested as large departures from local isostasy in the form of large free-air and geoid anomalies. A subduction zone with a well-defined Wadati-Benioff zone lies along strike under the South Island of New Zealand. The complex is entirely submarine and most of it lacks significant sediment cover, allowing igneous basement to be readily imaged.

Plans are to: 1) determine modes and mechanisms of deformation along the Macquarie Ridge Complex; 2) test the "paired-bend" model of transform boundary evolution, which predicts restraining bends characterized by oblique subduction alternating with releasing bends marked by pull-apart basins; 3) test two models for subduction initiation, the "diffuse" thrusting model, which predicts widespread thrusting which eventually coalesces into a single major thrust fault, and the "discrete" thrusting model, which predicts nucleation of thrust faults along a pre-existing fracture zone.

### US-Japan Marine Geophysical Study of the Solomon Island Arc—Ontong Java Convergent Zone, Southwest Pacific Ocean

*Principal Investigators: Paul W. Mann/Thomas H. Shipley/ Millard F. Coffin*

This is a U.S.-Japan cooperative program to map crustal and perhaps upper mantle structures in the Solomon Islands convergent zone. The primary objective of the MCS study and an independently proposed OBS study by Dr. K. Suyehiro and colleagues at the Ocean Research Institute in Tokyo, Japan, is to test two models for the formation of the Malaita anticlinorium—the deformed wedge of Cretaceous-Cenozoic pelagic limestone, basalt, and clastic rocks that most previous workers agree to be an emergent part of the Ontong Java Plateau. One model predicts tectonic wedging of the Solomon Island Arc beneath the Ontong Java Plateau. A second alternative model predicts a more familiar oceanic accretionary wedge geometry with northeastward (plateauward) offscraping and thrust imbrication of plateau rocks. The proposed MCS-OBS study focusing on the Malaita anticlinorium and North Solomon Trench will use state-of-the-art data acquisition and processing techniques to address fundamental questions concerning the subduction/accretion/fragmentation of oceanic plateaus at subduction zones and their deformational effects on the overriding island arc—including collision-related arc polarity reversal. Answers to these questions are important for understanding how oceanic plateaus may contribute to growth of continents through time and how subduction zones initiate by polarity reversal.

## National Science Foundation Office of Polar Programs

### Geologic Studies in the Shackleton Range Coats Land, and Dronning Maud Land, East Antarctica: A North American Connection

*Principal Investigator: Ian W. D. Dalziel*

E. Moores and I. Dalziel (Geology, May and June 1991) have suggested that the Pacific margins of the East Antarctic and North American Precambrian cratons were formerly juxtaposed, and that they drifted apart to initiate the Pacific Ocean during the fragmentation of a Neoproterozoic supercontinent. Investigators plan to conduct geologic, geochemical, geochronometric, and paleomagnetic studies of the Antarctic rocks in question, in order to compare them with those adjacent to the Grenville front in the southwestern United States. The work will include a detailed stratigraphic study of the only undisturbed Neoproterozoic sedimentary sequence in the Antarctic continent.

### Support Office for Aerogeophysical Research

*Principal Investigator: Donald D. Blankenship*

The Support Office for Aerogeophysical Research (SOAR) is a research facility chartered by the National Science Foundation (NSF) Office of Polar Programs (OPP) expressly for the purpose of supporting NSF/OPP-sponsored aerogeophysical work in Antarctica. The goal of the facility is to develop, maintain, and operate a suite of geophysical systems aboard a Twin Otter aircraft.The facility's airborne platform is capable of supporting the need for high-quality, integrated observations of gravity, magnetics, surface elevation, and ice thickness from continental Antarctica. The geophysical systems carried aboard the SOAR airborne platform include a gravimeter, magnetometer, a laser altimeter, and an ice-penetrating radar. Positional information is provided by GPS (both real-time differential pseudo range and post-processed carrier-phase), supplemented by inertial navigation and precision pressure altimetry data. The technical goal of the facility is to integrate these geophysical and positioning systems to obtain the highest quality observations consistent with their simultaneous operation.

### Lithospheric Controls on the Behavior of the West Antarctic Ice Sheet; Corridor Aerogeophysics

*Principal Investigator: Donald D. Blankenship*

West Antarctica is characterized by two of the earth's most dynamic systems, the extending lithosphere of the West Antarctic rift system and the marine-based West Antarctic ice sheet. This is an interdisciplinary aerogeophysical study to

characterize the lithosphere of the West Antarctic ice sheet. The objective is to trace the effects on the ice stream system of the rift architecture as manifested by the distribution of sedimentary basins and volcanic constructs. The research tool is a unique multi-instrumented geophysical aircraft developed specifically to address coupled geological and glaciological problems. It is capable of imaging both the surface and bed of the ice sheet while simultaneously measuring the gravity and magnetic signature of the subglacial lithosphere.

## Neotectonic Evolution of Antarctic Peninsula/Scotia Sea Region: Multi-Beam, Sidescan Sonar, Seismic, Magnetics and Gravity Studies

*Principal Investigator: Lawrence A. Lawver*

The neotectonic evolution of the Antarctic Peninsula and Scotia Sea is extremely complex. Understanding the recent evolution of the Drake-Scotia-Antarctica-South America plate intersections will provide important information as to how major plate boundaries reorganize after demise of a long-lived spreading center and consequential reduction in the number of plates. The plate reorganization probably resulted in the uplift of the Shackleton Ridge which may have affected the sedimentary patterns in the southwest Scotia Sea. If the break of the Shackleton transform fault can be traced with multibeam and sidescan sonar as it intersects the southern end of South America, then the orientation and geometry of the faults, fractures and deformation as the transform fault intersects the South American continent will help to interpret the structures in that complex region.

## Penrose Conference on "Tectonic Development of the Canada Basin, Arctic Ocean"

*Principal Investigator: Lawrence A. Lawver*

The tectonic history of the Arctic region is still extremely controversial and of great importance not only to our understanding of global tectonics, but also to understanding the framework of the known and conjectured oil and mineral resources of the Arctic. The movement of the tectonic plates involved in the evolution of the Arctic region have not all been identified, even 25 years after the plate tectonic revolution. In particular, how and when the Canada Basin section of the Arctic developed during the Mesozoic and Cenozoic is still debated in papers and proposals. In order to facilitate understanding of the present geological and geophysical knowledge of the Arctic, and to plan coordinated, cooperative future work in the Arctic a Geological Society of America Penrose Conference, titled "The Tectonic Development of the Canada Basin and Surrounding Regions" was held September 28-October 3, 1995 in Banff, Alberta and was supported by this project.

## The Bransfield Strait-South Shetland Islands Trench: Structural & Stratigraphic Evolution of a Linked Back-arc/Fore-arc System

*Principal Investigators: Ian W. D. Dalziel/James A. Austin, Jr.*

University of Texas Institute for Geophysics (UTIG) multichannel seismic (MCS) data has enabled detailed analysis of structural style and rifting processes in Bransfield Strait to be carried out. This analysis has brought new insight to the ongoing extensional processes in Bransfield Strait. Researchers plan to expand this study to consider Bransfield Strait in the full context of a fore-arc/arc/back-arc system. Primarily this will use UTIG MCS data, but will also incorporate as necessary other geophysical data from the region that are available from the UK and Italy.

## Collaborative Research: Seismic Traverse of the Byrd Subglacial Basin - Field Test

*Principal Investigators: Ian W. D. Dalziel/ Donald D. Blankenship/Paul L. Stoffa*

A seismic survey was conducted in the Byrd Basin area in Central West Antarctica during November 1994-January 1995. One of the principal aims of this survey was to study different shooting techniques in ice-covered areas and identify the problems that may typically arise during the processing of seismic data acquired in similar situations. The experiments were conducted by researchers from the University of Texas at Austin, the Pennsylvania State University and the British Antarctic Survey. The location of the survey area in the deep interior of Antarctica provided unique challenges in terms of logistics and technology and the field parties operated from a camp maintained by the United States Antarctic Program with financial support from the National Science Foundation. A 63 kilometer long multichannel seismic profile acquired using a 60-channel snow streamer, will be analyzed to create an image of the middle to lower crust. In addition to the main profile, two shorter wide angle surveys (that overlapped with sections of the main line) were also conducted along with a shallow refraction experiment (aimed at determining velocities in the firm layer) and a reshoot of a part of the main profile using detonating cord. Moreover, a 15 kilometer long profile was acquired in a direction perpendicular to that of the main line with the intention of studying the crossline dip.

## Collaborative Research: Quaternary Paleoclimatic Evolution, Larsen Basin, Offshore Seymour Island, Eastern Antarctic Peninsula

*Principal Investigators: Martin B. Lagoe/Benjamin J. Sloan*

Quaternary glacial marine deposits of the Larsen Basin are uniquely suited for study of the modern environmental setting and recent paleoclimatic evolution of the northeastern Antarctic Peninsula continental shelf, an area thought to exhibit pronounced sensitivity to climatic changes. Microfossils and their stable isotope signatures from these deposits provide information on varying oceanographic conditions, ice mass extent, and sediment dispersal. Questions to be answered include: 1) What are the faunal and isotopic responses to glaciation, both proximal and distal to the variety of small and medium ice masses in the area? 2) What is the relationship between physical evidence of ice position, as expressed in sediments and seismic data, and the faunal and isotopic signatures thereof? 3) To what extent is an environmental model of the highly variable interglacial Modern shelf applicable to describing and understanding late Quaternary environments representative of different climatic regimes?

# National Science Foundation Division of Earth Sciences

## Neural Computing in Geophysics

*Principal Investigator: Mrinal K. Sen*

The purpose of this project is to develop and implement inversion methods based on neural networks for application to geophysical inversion problems, particularly, seismic inversion. The motivation for investigating this approach is as follows: for geological interpretation, the mapping of elastic properties (impedance, Poisson's ratio, etc.) along a seismic line is required. GA inversion for each point along a seismic line is currently computationally expensive. However, for a selected number of points along a line, Genetic Algorithms to derive the elastic properties can be used. During that process a neural network can be trained, i.e., derive the connection weights. After training, seismic gathers from the intermediate points can be input to the network to estimate depth-dependent elastic properties for those surface points resulting in a complete map. The most difficult part of the problem is to train the network. Global optimization methods such as Simulated Annealing and Genetic Algorithms are used for the network training since the methods have been proven robust in application to geophysical inversion.

## Collaborative Research on the Sumatran Subduction Zone and Great Sumatran Fault

*Principal Investigator: Frederick W. Taylor*

This research investigates the two great plate-boundary faults of Sumatra. Though geographically restricted, our three-year investigation will address fundamental questions concerning both the repeatability of great earthquakes and the kinematics of obliquely convergent plate boundaries. This work could also lead to a firmer basis for seismic hazard evaluation, not just in Sumatra, but in other seismically vulnerable regions as well.

## Was Laurentia the "Southeast Pacific Continent?"

*Principal Investigator: Ian W. D. Dalziel*

A new scenario for global Paleozoic paleogeography began to emerge with the publication of the "SouthWest US - East Antarctica" ("SWEAT") hypothesis that East Antarctica-Australia had been juxtaposed with the Pacific margin of North America in the late Precambrian. It was also suggested at that time that the proto-Appalachian margin of Laurentia might have been juxtaposed with the Pacific margin of South America, the opening of the Pacific Ocean basin between Laurentia and East Antarctica in the late Precambrian to Cambrian being balanced on a globe of constant radius by the closure of pan-African and Brazilide ocean basins during assembly of Gondwana.
Paleomagnetic data are in keeping with the idea that Laurentia made an "end-run" around the proto-Andean margin during the Paleozoic, perhaps colliding with it more than once.
The hypothesis that the proto-Appalachian margin of Laurentia rifted from the proto-Andean margin of South America at the end of the Precambrian, and that the Appalachian and Andean orogens were initially a single mountain system resulting from Paleozoic Laurentia-Gondwana interaction, has many and far-reaching implications. The work proposed in Chile, Argentina, and possibly Peru is designed to test the "Laurentian end-run" hypothesis, but will make significant contributions to the understanding of the origin and development of the Pacific margin of South America regardless of its validity.

## Structural, Stratigraphic and Volcanic Response of the Kamchatka Arc to Neogene Shallow Subduction of the Emperor Seamount Chain

*Principal Investigator: Paul W. Mann*

The Kamchatka Peninsula is the site of shallow subduction of the Hawaii-Emperor seamount chain, one of world's longest (6000 km) and best studied hotspot chains. A compilation of geologic and geophysical data from the Kamchatka Peninsula suggests that shallow subduction and/or accretion of seamounts may be responsible for several regional tectonic effects including a double Neogene volcanic arc separated by an intra-arc basin, the presence of alkaline volcanic rocks in the outer volcanic arc, forearc indentation of the Pacific margin of Kamchatka, constriction and shoaling of the Kamchatka trench, and uplift of marine forearc basins of Neogene age. This is a multidisciplinary program to assess the structural, stratigraphic, and geochemical effects and history of shallow subduction/accretion of seamounts in the forearc region of the Kronotskiy Peninsula - the Pacific promontory immediately adjacent to the hotspot chain.

## Seismological Study in the Southern Eurasian Collision Zone

*Principal Investigator: Fumiko Tajima*

The deep structure along the southern Eurasian collision zone has long been a subject of debate as to whether the lithosphere of the Indian plate is underthrusting beneath Tibet all the way to Tarim basin, or downwelling in southern Tibet. Teleseismic data residual spheres are sensitive to relatively narrow vertical anomalies near source structure and decrease in sensitivity for more horizontal anomalies. P-wave travel-time data read from the seismograms recorded by WWSSN, Canadian and digital (IRIS/GSN, GEOSCOPE and GDSN) network stations were analyzed using the differential residual sphere approach to check the gross features of velocity anomalies along this collision zone. The differential travel-time residuals of the event in southern Tibet vs. north central and Himalayan events show consistently fast arrivals at the stations in the northwest - southeast direction. Simulational results with simple velocity anomaly models indicate that a narrow, nearly vertical and high velocity zone beneath the southern plateau can account for the observed fast arrivals, and thus a region of cold downwellings predicted by the convective model for the continental convergence.

## Seismic Structure of the Transition Zone Associated with the Japanese Subduction Zones

*Principal Investigators: Fumiko Tajima and Stephen P. Grand*

The seismic structure of the upper mantle transition zone, from 400 to 700 km depth, is of fundamental importance for understanding the mode of convection within the Earth's mantle as

well as the chemical composition of the Earth. In this project plans are to delineate upper mantle seismic structure associated with the transition zone near Japan Islands using (triplicated) P and S waveforms recorded at regional stations. Three major issues debated recently will be considered: (1) what velocity anomalies are associated with the subduction zones in the transition zone; (2) whether the subducting slabs flatten at the bottom of the transition zone or extend into the lower mantle; and (3) whether the seismic structure derived for the upper mantle supports a model of chemical layering or one with discontinuities due to temperature-dependent phase transitions approximately at 410 km (alpha to beta in olivine), possibly at about 525 km (beta to gamma).

# U.S. Geological Survey

### Paleo-seismic Investigation of the North American-Caribbean Strike-Slip Plate Boundary, Dominican Republic

*Principal Investigator: Paul W. Mann*

The islands of Puerto Rico and Hispaniola are within the seismically active North America-Caribbean plate boundary zone. Marine geophysical surveys of the offshore area north of Puerto Rico and on- and offshore mapping in the Dominican Republic have shown this plate boundary to be a mainly submarine, left-lateral strike-slip fault system that extends over 3200 km from the Lesser Antilles arc in the east to the Middle America trench in the west. A large earthquake on this fault in the Puerto Rico-Hispaniola segment of the plate boundary fault could severely affect this densely populated and rapidly developing area.

This project funded by the USGS National Earthquake Hazards Reduction program aims to better understand the longterm, geologic record of earthquakes and strain accumulation along this potentially hazardous plate boundary fault zone. Five trenches have been excavated across the critical subaerial segment of the plate boundary fault in the Cibao Valley of the Dominican Republic. These excavations combined with radiocarbon dating of soil horizons in the trench have revealed the occurrence of three, large prehistoric (pre-1492) earthquakes that ruptured this segment of the fault zone. Researchers also measured the amount of vertical and offset associated with the most recent of these events about 700 years ago using 3-D excavation techniques. In addition to the trench study, a measurement of the amount of offset on terrace risers offset by many strike-slip rupture events on the fault was done. These values and radiocarbon dating of the terrace material provide good control on the longterm slip rate between the two plates.

# Joint Oceanographic Institutions, Inc.

### Safe Science Along the Mid-Atlantic Transect (MAT): Site-Specific Hazards Surveying on the Continental Terrace Offshore New Jersey in Support of Sealevel Objectives

*Principal Investigator: James A. Austin, Jr.*

A long-term, coordinated approach by the Ocean Drilling Program towards understanding the history of global sealevel change has been developed as a product of deliberations by the Sea Level Working Group (SL-WG). The report of the SL-WG has concluded that passive margin (i.e., marginal marine to slope/rise) transects are critical for estimating the magnitudes and rates of sealevel fluctuations. The SL-WG also identified Leg 150 on the New Jersey margin as the first step in estimating sealevel magnitude fluctuations in the "Neogene Icehouse" world. The original Leg 150 plan called for a number of sites to be drilled through Miocene prograding clinoforms on the mid- and outer shelf. However, safety review in the fall of 1992 denied permission for any designated sites in depths <200 m due to insufficient high-resolution site-survey data.

Since then the quality and quantity of geophysical data necessary (as a minimum) for "safe" drilling operations in water depths <200 m has been established and "hazards" geophysical surveys are required in the vicinity of proposed shelf drilling sites. As part of a regional, high-resolution MCS surveying effort to be carried out on the New Jersey continental shelf and upper slope UTIG and other investigators acquired "hazards" surveys at seven originally proposed MAT shelf sites. The shiptime was supported by ONR and JOI. JOI-USSAC funded supplemental analysis and interpretation support for the investigators involved.

### Huntec Surveying of Shelf Sites for the New Jersey/Mid-Atlantic Transect

*Principal Investigator: Craig S. Fulthorpe*

Relative sealevel exerts a fundamental influence on sedimentary deposition and other geological processes, but the role of eustasy in controlling relative sealevel remains unclear. The importance of understanding the history and effects of sealevel variation was recognized by the first Conference on Scientific Ocean Drilling (COSOD I, 1981) and was established as a "first order goal" for the Ocean Drilling Program (ODP) by COSOD II (1987). The Mid-Atlantic Transect (MAT) was designed to form a basis for study of Oligocene and Neogene sealevel variations. Recent events have dictated that additional geological and geophysical data will be required to document that shallow-water (<100 m) shelf sites can be safely drilled. In pursuit of that objective, researchers collected additional Huntec DTS® (deep-towed seismic) data and vibracores in the vicinity of MAT shelf sites.

### Barbados Ridge Accretionary Prism, ODP, Leg 156

*Principal Investigator: Thomas H. Shipley*

Leg 156 investigated temporal and spatial scales of fluid flow, the role of faults in fluid transport, and the relationship between mechanical state and seismicity in the northern Barbados Ridge accretionary prism. The strategy was to drill into areas of strikingly different polarity and amplitude of the décollement reflection, revealed by recently acquired, three-dimensional seismic data and interpreted as areas of varying fluid content and/or fluid migration paths within the décollement. Eight holes were drilled at Sites 947, 948, and 949,

located 6 km, 4 km, and 2 km west of the thrust front. The objective was to combine both in situ measurements of permeability and fluid pressures, long-term monitoring of temperature in and pressure, and fluid chemistry and structural fabric studies in an integrated program. This experiment is an important and necessary step in evaluating the role of faults in fluid transport, episodicity of fluid flow, and the relationship to seismicity. Understanding the fate of subducted and accreted fluids will also contribute to geochemical cycle definition. This program is a logical step in advancing the technological and drilling techniques needed in this environment.

# American Chemical Society

### Sequence Stratigraphy, Depositional Systems, Sediment Fairways, and Depositional History of Post Mid-Cretaceous Rocks, Gulf of Mexico Basin

*Principal Investigator: Richard T. Buffler*

The Gulf of Mexico basin is perhaps one of the best studied basins in the world, but there is still much to be learned about the deeper parts of the basin as well as how the depositional history of the basin fits together as a whole. One of the main objectives of the project is to understand continental slope processes and to identify the location of major sediment fairways across slope areas, which could enhance strategies for oil and gas exploration in deep-water settings. The longer-term goal is to understand the importance of and interplay between primary controls involved in the development of sequences and depositional systems (tectonics, eustacy, sediment supply, and climate).

# Various Sponsors (Industry)

### Post Mid-Cretaceous Sequence Stratigraphy, Depositional Systems, Sediment Transport Axes, and Depositional History, Gulf of Mexico Basin

*Principal Investigators: Richard T. Buffler/William E. Galloway*

The project involves a detailed, comprehensive and integrated synthesis of the Gulf of Mexico basin as a whole. The project will lead to major new contributions to the understanding of the geologic history of the Gulf of Mexico basin. The project will focus on such topics as refining sequence correlation between the shelf and basin, better understanding slope processes, identifying major sedimentary transport axes, explaining the role of submarine canyons, and better understanding the major controls on deposition. The three-year project will be conducted by a team of UT Austin graduate students. This project is supported by an international group of oil companies.

### Pre-Stack Plane Wave Kirchhoff Migration on Cray T3D

*Principal Investigator: Paul L. Stoffa*

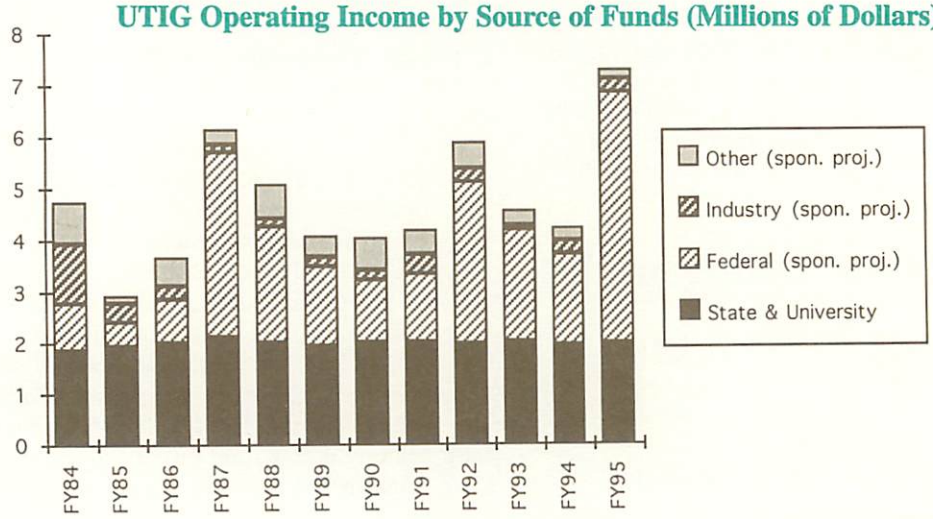
A new pre-stack depth migration scheme in laterally varying media has recently been developed. The method is based on a Kirchhoff-Helmholtz (KH) formulation of the wavefield. The source and receiver wave fields are expanded by ray theory and plane waves respectively, and are coupled at each interface using the KH integral. The migration is carried out on plane wave transformed shot gathers. The shot travel times and receiver plane wave travel times are calculated using a finite difference solution of the Eikonal equation. The imaging condition is calculated by a combination of the two times. Migration can be applied to all the plane wave traces for each shot or for common plane wave sections for several shot locations at a time. Both of these approaches can be implemented on parallel computer architecture. (Supported by Cray, Inc.)

### PLATES - the Global Plate Reconstruction Project

*Principal Investigators: Lawrence A. Lawver/Millard F. Coffin/ Ian W. D. Dalziel. Program Manager: Lisa M. Gahagan*

PLATES, a plate tectonic research project based at UTIG, models past plate motions, develops computer software to display and manipulate the reconstruction models, and compiles geoscientific data bases pertinent to plate motion modeling and resource evaluation. Plates is currently sponsored by seven industrial corporations.

**UTIG Operating Income by Source of Funds (Millions of Dollars)**

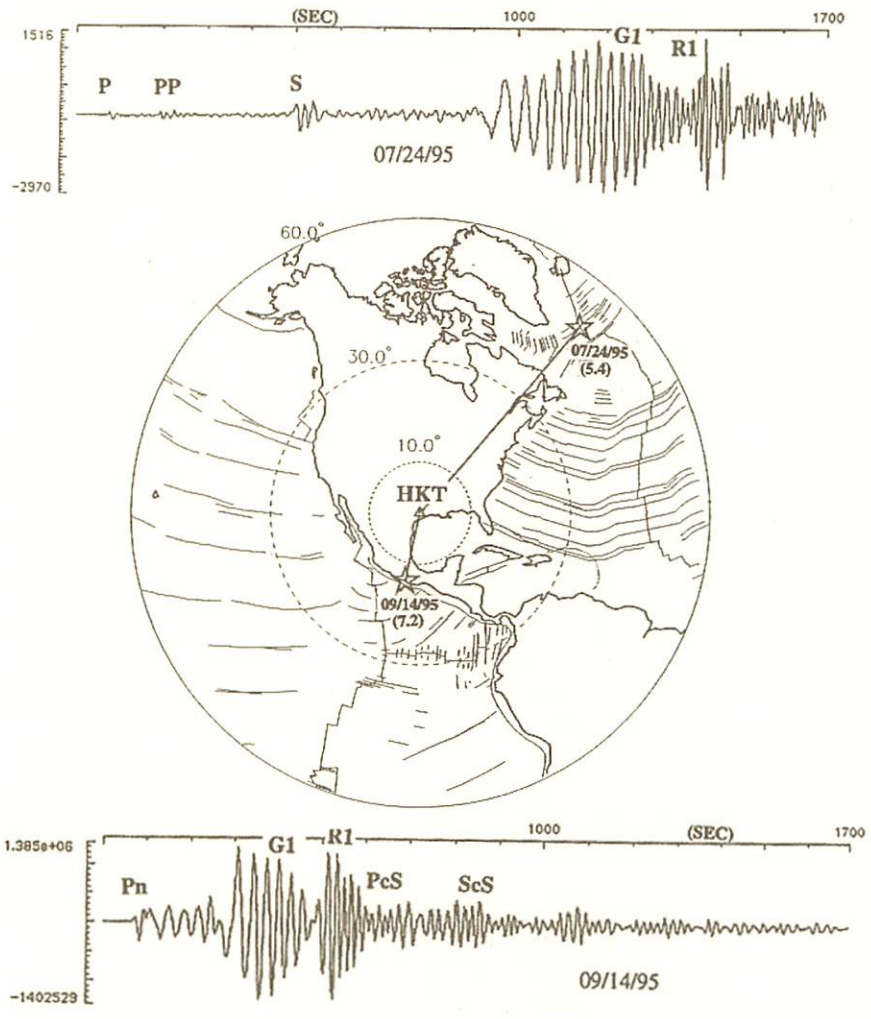


# Highlighted Areas of Research

## UT Recording Texas and Worldwide Quakes

The Institute has recently installed a modern broad-band digital seismic station containing a fully configured set of three-component Strekeisen STS-1 instruments for seismological research. This seismic station meets standards of both worldwide and national networks as part of the Incorporated Research Institutions for Seismology (IRIS)/Global Seismographic Network (GSN) and US National Seismographic Network (USNSN) of the US Geological Survey.

The seismic station is installed at a site in a salt mine in Hockley, Texas owned by United Salt Corp. The station consists of the data acquisition system (DA) installed on the ground of the salt mine (1500 ft below the surface), and the data processing system (DP) at UTIG. The seismic data is transmitted to the surface via a fiber optics cable, then the transmission from DA to DP is carried out via satellite link. Since last July this seismic station has been recording high quality broad-band waveform data generated by earthquakes worldwide or local events such as mine blasts and possibly induced earthquakes near oil fields and waste disposal sites. The data is being monitored at UTIG constantly and the waveforms can be displayed locally as significant events occur. Users worldwide can access our data base to obtain waveform data for current events through the Internet connection or request data at IRIS Data Management Center (DMC) at the University of Washington at Seattle. We send data on tape to the Data Collection Center at Albuquerque Seismological Laboratory on a regular basis.




The above figure shows the location of Hockley seismic station on an equal area map together with the epicenters of two recent earthquakes, a large event in Mexico (Ms=7.2 on 09/14/95) and a moderate event in North Atlantic (mb=5.4, 07/24/95). The vertical component seismograms recorded at Hockley station for these earthquakes are also shown with different phases identified.

Seismic station coverage in the mid-western United States has been sparse due to the few number of operational units in the network. This is the first IRIS/GSN station in Texas. The nearest regional broad-band stations are in Albuquerque, New Mexico, Tuscon, Arizona and in Mexico City. The geographical location of the Hockley station is ideal for studying the earth's crust and upper mantle structure beneath Texas and the Gulf of Mexico. Without this modern broad-band seismic station, this kind of research project would not have been possible. Fumiko Tajima, as Director of Hockley Seismic Station, coordinated efforts for the installation and maintenance of the seismic station. Now that the installation is complete, UTIG and Department of Geological Sciences researchers, with funding from NSF, will use the unique waveform data to study structures beneath Texas and the Gulf of Mexico. The installation and operation of this station will enrich the geophysical education and research programs at UT. Hockley Seismic Station is the eighth University Network site which was selected by the IRIS GSN program in 1993. The other seven University Network sites include Harvard University and California Institute of Technology. Support for this installation has been provided from IRIS, the U.S. Geological Survey, the University of Texas and industry and private foundation sources.

# Research Using UTIG Ocean-Bottom Seismographs

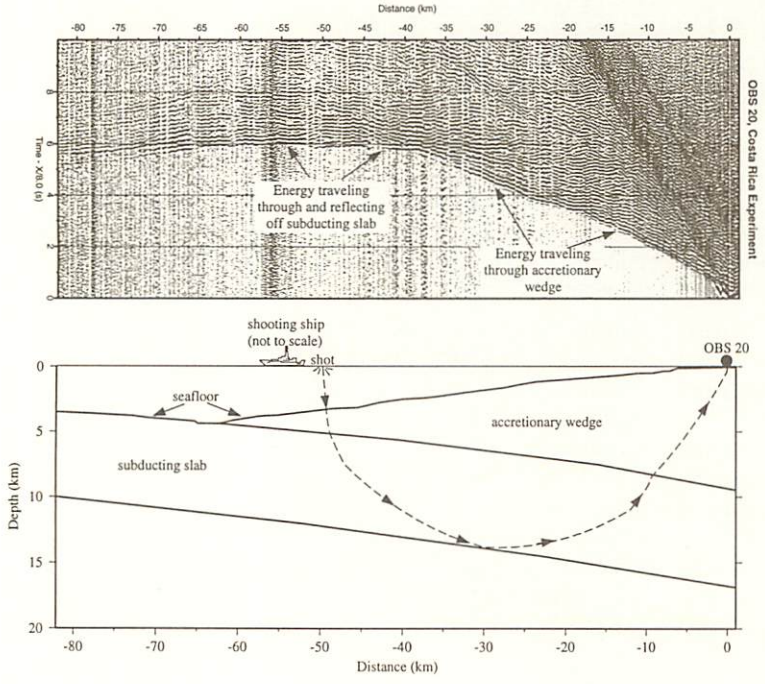
The Institute for Geophysics has developed a unique ocean-bottom seismograph (OBS) capability. The UTIG OBS is a microprocessor-controlled instrument to record seismic signals on the sea floor. It is deployed from a surface ship (see figure below), free-falls to the sea floor, and while on the sea floor detects and records seismic signals generated by natural or artificial seismic sources. After the data acquisition is completed, the OBS releases itself from the sea floor to be retrieved on the surface. A number of these instruments are being used in several offshore seismic investigations with diverse geological/geophysical targets in many parts of the world. Listed below are some of the recent and near-future studies using the instruments.

## MID-OCEAN RIDGES

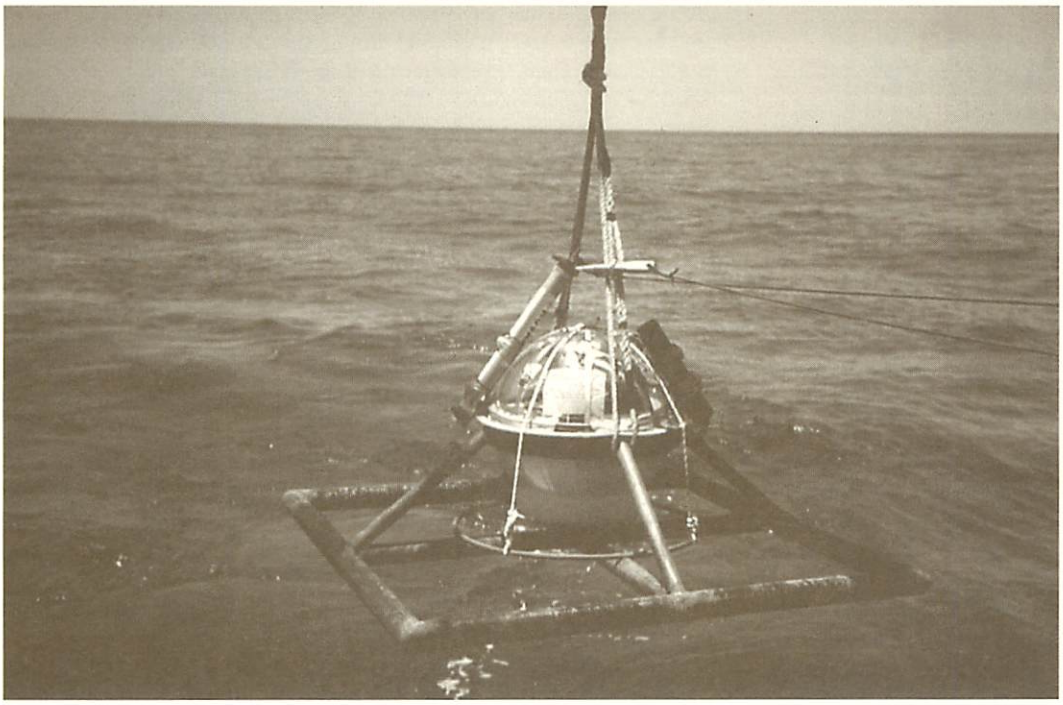
In April and May of 1993, we conducted an OBS field program to investigate the distribution of melt at the base of young oceanic crust near the fast-spreading East Pacific Rise. We focused our experimental design on the use of a rare horizontally polarized seismic phase that indicates the presence of melt. It was evident that OBSs were the ideal instrument for the detection of these phases because of their ability to distinguish the polarization of seismic waves. Using an unusual experimental geometry and the special capability of OBSs, we greatly improved our knowledge of the distribution of melt at the base of the crust in the course of analyzing these data. Without the ease of use of the UTIG instruments, this experiment would not have been possible, because the geometry of the experiment required a large number of OBS deployments. The results of this work have revolutionized our thinking about melt generation and delivery at mid-ocean ridges. We now know that melt generation in the mantle below the ridge is highly episodic, and that it is generated and delivered over a wide region (about 60 km wide) compared to the width of the axial high (about 4 km). We also have evidence that melt is extremely mobile, and that melt may simply be funneled to the more elevated ridge axis region along the sloping boundary at the base of the crust. We are developing new models of episodic melt generation and delivery that stem from these exciting results.

## SUBDUCTION ZONES

In the Spring of 1995, investigators from the Institute for Geophysics, together with scientists from Costa Rica and Germany, made a total of 84 deployments of UTIG and GEOMAR ocean bottom seismographs and hydrophones off the west coast of Costa Rica. In this region three distinct segments of the Cocos plate are subducting: 1) a smooth segment 2) a segment where a line of seamounts are subducting and 3) a segment where the Cocos Ridge is subducting. Experiments were carried out in each region. The data will be used to establish crustal structure and velocity models, to image the plate boundary zone, and to relocate earthquake hypocenters. In the seamount dominated segment, 30 instruments were laid out in a grid pattern above the focus of the recent (1990) Cobano earthquake in order to image the plate boundary zone and identify any features (i.e., a seamount) that might be related to the earthquake location. An example of the data recorded on the OBS instruments is shown in the figure below. OBS 20 was located in ~60 m of water, and recorded airgun shots out to 80 km range. Two types of arrivals are identified in the figure: energy traveling through the accretionary wedge, and energy traveling through and reflecting off of the subducting slab (the Cocos plate). The arrival times (from all OBS instruments) of each type of energy will be used to modify the simple structure of accretionary wedge/subducting slab shown in the lower portion. For instance, preliminary modeling suggests that there is several hundred meters of low-velocity sediment lying above the subducting slab; this may have implications for the mass balance between sediments added to the accretionary wedge and sediments recycled into the mantle.




(Top). Example of data collected by the UTIG OBS. The data shown was collected off the Nicoya Peninsula of Costa Rica. (Bottom). Simplified structure of the Costa Rica margin. OBS 20 was located at a depth of ~60 m; the seafloor deepens offshore to ~4 km at the Middle America Trench. In the example shown, energy from an airgun shot at 50 km distance travels to the base of the subducting slab and then to the OBS. The observed energy at a distance of 50 km in the top figure probably followed a similar path. For shots closer to the OBS, the first arriving energy travels through the accretionary wedge.



UTIG ocean-bottom seismograph ready to be deployed from a surface vessel.

## ARC-CONTINENT COLLISION

In August and September of 1995, investigators from the Institute for Geophysics joined those from San Jose State University, University of Hawaii, Florida State University, State University of New York at Binghamton in the U. S. and National Taiwan University, National Taiwan Ocean University, Academia Sinica, and Central Weather Bureau of Taiwan in a collaborative study to image the deep structure in and around Taiwan. In this region the Luzon volcanic arc is colliding with the Asian continent, creating one of the youngest mountain ranges in the world. Signals generated by a large air-gun array from the *R/V Maurice Ewing* for a standard multi-channel seismic (MCS) survey were recorded at sea as well as on land at large distances. This allowed us to obtain information from great depth within the collision zone. Our responsibility was to deploy a set of OBSs ahead of the MCS shooting, recover them afterwards, and process and analyze the data. During a month-long cruise, which was interrupted several times with threatening typhoons, we made a total of 39 OBS deployments along six seismic lines, four of which were combined onshore-offshore lines. Aside from a preliminary analysis on board *R/V Ocean Researcher I* at sea, the processing, analysis and interpretation of the acquired data are continuing.

## STRUCTURE OF CHICXULUB IMPACT CRATER

It is now widely believed that the impact responsible for the mass extinction at the Cretaceous-Tertiary boundary (including the demise of the dinosaurs) occurred on the Yucatan peninsula in the Gulf of Mexico near the present-day town of Chicxulub. The site of the impact has been identified on the basis of a circular feature on gravity and magnetic data, but its dimensions and structure are poorly known as it is buried beneath about a kilometer of carbonates. Scientists suggest that the transient crater following impact excavated the crust to depths of about 10-20 km, and produced a 3-km-thick, 100-km wide melt sheet. Size estimates for the entire Chicxulub structure range from 180-300 km, making it the largest impact structure on the planet.

Several scientists from the Institute for Geophysics are collaborating with colleagues from the U.K., Mexico, Canada, and the U.S. to collect seismic reflection, OBS, gravity, and magnetic data over the offshore portion of the Chicxulub impact crater in March of 1996. UTIG scientists will deploy and recover 33 OBSs from the *R/V Longhorn* (operated by University of Texas Marine Science Institute at Port Aransas) along two key reflection lines, which will be shot by a GECO seismic vessel. Objectives of the experiment include: the measurement of parameters such as the maximum radial extent of the crater, the size of the transient crater, the nature of slump blocks and faulting on the flanks of the impact structure, determination of the thickness and lateral extent of the melt sheet, determination of the amount, position, and lateral extent of deep basement uplift and basement fracturing, and constraining any impact related topography at the Moho. The Chicxulub structure is the only well-preserved, unaltered, and easily accessible example of a large impact structure, and thus these seismic measurements will be used to help understand the process of crater formation and to constrain the environmental effects of large impacts.

## OFFSHORE MICROEARTHQUAKES

The majority of small earthquakes associated with subduction zones occur offshore where no land seismic stations exist nearby. An array of OBSs deployed offshore for an extended time provides a very useful tool to augment this deficiency. In the spring of 1994, ORSTOM, an overseas scientific research organization of the French government, and National Taiwan Ocean University each separately conducted micro-earthquake observations offshore of the Philippines and Taiwan using duplicates of our instruments. Personnel from the Institute for Geophysics collaborated in each of these experiments. Preliminary results from the Taiwanese experiment show a systematic difference in hypocenter locations between those determined from the land stations alone and those determined from the OBS array, indicating that the addition of the OBS array helps to define the locations of the earthquake hypocenters more precisely.

# STRATAFORM: Stratal Formation on Margins

A number of UTIG investigators are involved in planning and executing this multi-year project, funded by the Office of Naval Research. STRATAFORM consists of three distinct but interrelated projects, whose objectives are to study: (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. The overall goal is to link short-term (i.e., acting over hours to weeks) biological and physical processes affecting sedimentation (so-called "event" stratigraphy) to the sequence stratigraphy and facies architecture of the preserved record (i.e., ~upper 100 m and occurring over the past $\sim 10^6$ years).

UTIG is most heavily involved in the stratigraphic sequences project, which is attempting to understand the creation of the stratigraphic record on continental shelves and slopes as the product of geologic processes acting with spatial and temporal heterogeneities. Ultimately, modern processes are to be linked to the seismically imaged and sampled (i.e., preserved) record through an evolution of increasingly sophisticated models. The key to this effort will be the collection of "nested" geophysical and geological data, through use of a variety of acquisition tools (multibeam seafloor mapping, multichannel seismic [MCS] reflection, Huntec™ deep-towed single-channel boomer, coring, ocean drilling[?]), whose individual temporal and spatial scales overlap to form a wide-ranging continuum of measurements.

Two "natural labs" have been chosen by STRATAFORM: offshore New Jersey and northern California. The former is characterized by a modern depositional regime which is quiescent, but where Neogene to Pleistocene sequence stratigraphic geometries are well-developed. The latter is a tectonically active environment, where modern sedimentation is overwhelming the shelf. Comparing and contrasting these environments is the modern key to the inherently complex depositional patterns of the past.

### High Resolution Seafloor Mapping (J. Goff)

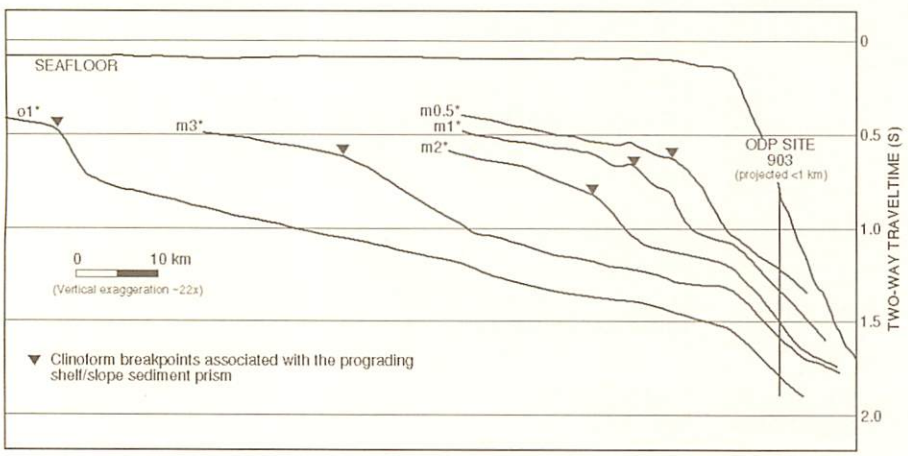
One of the major goals of STRATAFORM is to discover the preservation potential of currently-active depositional/erosional processes. Because all seismic strata are formed at the seafloor, and because the seafloor can be mapped in much greater detail and areal extent than any other stratum boundary, we hope to use seafloor characterizations as the modern analog for stratigraphic processes that occurred in the past. Seafloor mapping provides both bathymetric and sidescan backscatter information. Bathymetric data identify important structures related to modern sedimentary processes, including: erosional gullying, slumping, and bottom roughness. Side scan data distinguish sediment composition and/or texture, which are corroborated by gravity, piston, and vibra-cores. The structure and stratigraphic complexity of the seafloor can then be used as a basis for predicting the behavior of buried strata over gaps inherent in more sparsely sampled data, like multichannel seismic profiling and coring, or at scales smaller than can be observed by such methods.

In the summer of 1996, John Goff will participate as Co-Chief Scientist in a sea floor mapping field program on the New Jersey margin. Larry Mayer of the University of New Brunswick will act as Chief Scientist. This will be the second of two sea floor mapping cruises within ONR STRATAFORM natural labs. The first, which occurred in the summer of 1995, mapped the northern California margin off Eureka. A Simrad EM1000 swath sonar system is being used for both surveys; this 95 kHz system provides a swath width up to ~5 times water depth (up to ~1 km maximum swath width).

### Coring and Huntec™ High-Resolution 2D and 3D Seismic Profiling (M. Lagoe, T. A. Davies, J. A. Austin, Jr.)

Coring of the New Jersey shelf has been designed to constrain the lithology, paleoenvironment, and origin of high resolution seismic geometries, as revealed by 2D and 3D single-channel Huntec™ (deep-towed boomer) profiling. Analysis of sediments, physical properties and foraminiferal biofacies are being integrated with seismic interpretation and AMS C-14 dating to understand the late Quaternary deglacial history of the New Jersey margin and its sequence stratigraphic expression. Two sets of cores (and concurrent 2D and 3D Huntec™ profiles) are currently available. In 1989, 10 piston and vibra-cores were collected from an outer shelf sediment wedge (67-155 m water depth). In 1993, 21 vibra-cores penetrated surficial sediments of the outer to mid-shelf (60-90 m water depth). Core recovery has ranged from <1 to >6 meters.

Analysis of the 1989 cores indicates that seismic units in the outer shelf sediment wedge are




Interpretation of profile A157 which passes through the ODP Leg 150 drilling area. Sequence boundaries o1*, m3*, m2*, m1* and m0.5* are approximately correlative with sequence boundaries o1, m3, m2, m1 and m0.5 of Mountain, Miller, Blum, et al. (1994).

both sedimentologically and faunally distinctive. Modern environments are deeper than those represented by the underlying mid-shelf sediments. Ongoing studies of 1993 cores suggest a varied paleoenvironmental history, which is being compared with seismic images identifying several interesting stratigraphic geometries (e.g., sediment waves, channels) on the mid- and outer shelf. For example, mid-shelf channels, where cored, are filled with mud deposited in a marginal marine environment. This is in marked contrast to sand-filled channels seen within the outer shelf sediment wedge. Future plans include short coring and feasibility studies for taking continuous ~100 m samples in order to get complete coverage of the last ~1 million years of margin history.

### Oil Industry MCS: Sequence Stratigraphic Interpretation and Mapping, New Jersey (C. S. Fulthorpe)

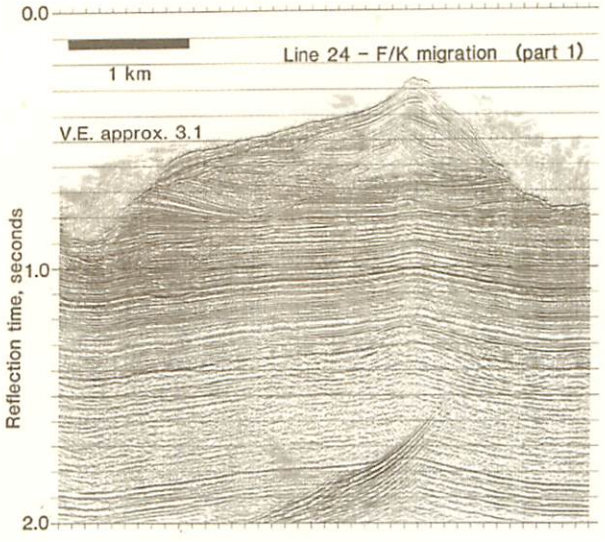
Low-frequency oil industry multichannel seismic (MCS) data form the largest-scale end member of a series of overlapping scales of observation offshore New Jersey, with higher-frequency Huntec™ seismic data, swath bathymetry/side-scan and observations on sediment cores, including those from Ocean Drilling Program (ODP) sites, at the other end of the spectrum. Use of large grids of existing oil industry data is the only way to achieve dense seismic coverage of large areas necessary to understand the inherently 3-D depositional processes that generate depositional sequences and create shelf/slope clinoform morphology. A great deal of oil industry MCS data were acquired on the New Jersey continental shelf and slope beginning in the mid-1970s; UTIG has obtained such a grid (112 seismic lines, total line length 9000 km).

Analysis of these profiles is documenting the 3-D geometries of Neogene sequences beneath the New Jersey continental shelf. Spatial variations in sequence architecture reflect large-scale drainage patterns, rates of sediment supply, geometries of sediment sources, subsidence rates, compaction, isostasy and gravity- and current-driven sediment transport. Temporal variations in sequence and systems tract geometries have a secular component resulting from changes in the above controls, as well as a cyclic component caused by global sealevel change (eustasy). Specific questions being addressed are: 1) Did Neogene shelf progradation occur predominantly in response to point sources of sediment or to distributed cross-shelf sediment transport?, and 2) How are Quaternary drainage patterns and shelf morphology, currently being investigated using existing Huntec™ data, related to those of the Neogene? Clinoform breakpoints on Neogene sequence boundaries (Figure) are morphologically analogous to the modern shelf edge, but their distances from corresponding paleo-shorelines and precise relationship to sealevel history are unknown. Sampling of the associated sedimentary facies by drilling is required to solve this problem, but mapping of seismic sequence geometries is also needed to provide a 3-D framework. Clinoform breakpoints are gently arcuate in plan view, suggesting that Neogene progradation was directly related to known major point sediment sources, e.g., Hudson River. This complements results of shallow-penetration (~30 m) 2D and 3D Huntec™ deep-towed seismic surveys on the shelf, which suggest that sediment supply from the Hudson was dominant during Quaternary glacial events.

### STRATAFORM and ODP (J. A. Austin, Jr.)

In the summer of 1995, UTIG and Lamont-Doherty Earth Observatory investigators conducted a high-resolution MCS survey of the New Jersey margin for two purposes: 1) to collect profiles in the frequency band (~30-500 Hz) intervening between existing oil industry MCS control (<100 Hz) and regional and 3D Huntec coverage (500-3,500 Hz), as envisioned by STRATAFORM, and 2) to complete detailed grid surveys and assess potential hydrocarbon hazards in the vicinity of proposed Ocean Drilling Program (ODP) sites on the New Jersey shelf. These sites comprise the most critical segment of the Mid-Atlantic Transect (MAT) that is designed to understand the history of Neogene sealevel on this margin.

The cruise was conducted on the Woods Hole Oceanographic *R/V Oceanus*, while the seismic acquisition and navigation systems were owned by John Chance & Associates, Inc. of Lafayette, LA. A single 90 cu. in. GI air gun fired at 2000 psi generated an extremely clean outgoing pulse. The 48-trace, 12.5 m group streamer was towed at 7 feet for most of the cruise, and a 12.5 m shot spacing (24-fold stacking) was maintained for most profiles. Approximately 950 nmi of regional MCS reflection profiles were collected over the shelf and slope; 8 drilling sites were surveyed at a 150 m/300 m profile spacing. The grid surveys are being processed to meet fall 1995 ODP deadlines. The goal is to pass these sites through safety review by ODP, and then assign New Jersey shelf drilling a position on the 1997 ODP schedule. Shelf drilling should provide the ultimate ground truth for the "nested" geophysical profiles and shorter samples collected in support of STRATAFORM.



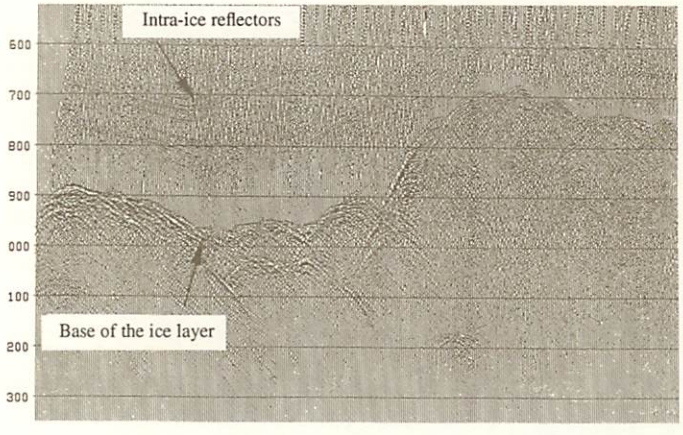

Portion of a high-resolution MCS profile collected over and approximately parallel to the New Jersey slope, in the vicinity of ODP Leg 150 sites. The profile is in two-way travel-time, and has been stacked and migrated using a simple velocity function. Note the previously unheralded complexity of slope stratigraphy, particularly in the vicinity of modern canyon topography.

# Seismic Survey in Antarctica

Glen Caglarcan, Steffen Saustrup and Vikramaditya Sen from UTIG participated in a seismic survey that was conducted in the Byrd Basin area in Central West Antarctica during the winter of 1994. One of the principal aims of this survey was to study different shooting techniques in ice-covered areas and identify the problems that may typically arise during the processing of seismic data acquired in similar situations. During these experiments, the group from UTIG was joined by researchers from the Pennsylvania State University and the British Antarctic Survey. The location of the survey area in the deep interior of Antarctica provided unique challenges in terms of logistics and technology and the field parties operated from a camp maintained by the United States Antarctic Program with financial support from the National Science Foundation. The field camp comprised over a dozen tents and was home to about forty personnel from various universities and research organizations.

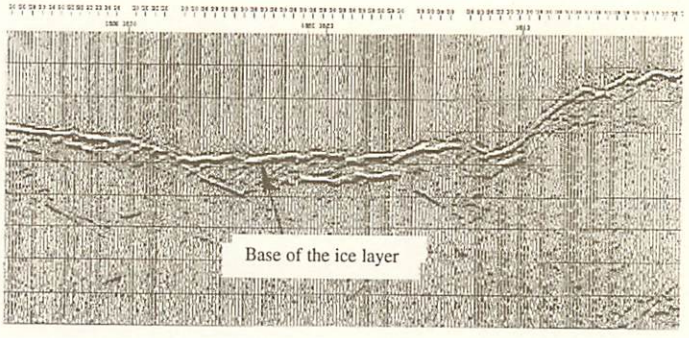
A 63 kilometer long multichannel seismic profile was acquired using a 60-channel snow-streamer and the data will be analyzed to create an image of the middle to lower crust. In addition to the main profile, two shorter wide angle surveys ( that overlapped with sections of the main line ) were also conducted along with a shallow refraction experiment aimed at determining velocities in the firn layer. Moreover, a 15 kilometer long profile was acquired in a direction perpendicular to that of the main line with the intention of studying the crossline dip. A wide range of charges were utilized to study the characteristics of different explosive sources and included conventional sausage-shaped charges, cone charges, detonating cord ( PETN ) and ANFO. The holes for the charges were drilled using a pressurized hot water drill.

The survey was conducted in three phases: a reconnaissance survey, the drilling of the shot holes and the actual shooting. The reconnaissance was carried out a week before the seismic shooting by a team of surveyors on snowmobiles who flagged the line and marked the shot locations. Drillers from the Polar Ice Coring Office of the National Science Foundation took over during the next stage to drill holes in the ice with a pressurized hot water drill




CDP Spacing : 50 m.

This is an efficient and fast method of drilling in the ice and the drillers were able to drill 30 - 35 holes per day with a three member team. A single 60-channel 1500 meter long streamer was used and the recording hut comprised a cabin built on metal skids that was towed along with the streamer by a Sno-Cat Tucker . In order



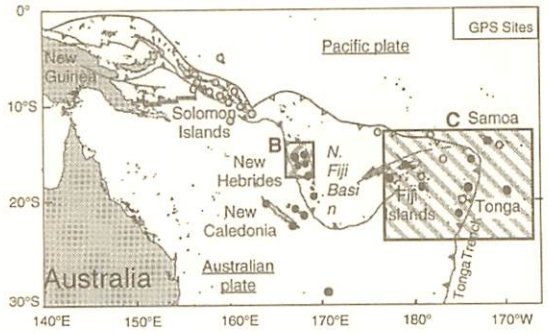

8km migrated section from det-cord survey.

to acquire high fold seismic data, offsets up to 9 kilometers were recorded and this required shooting several shots into the receiving array for each streamer position. Hence, for each location of the recording hut and the streamer, shots were fired at distances of 0 kilometer through 9 kilometers at intervals of 1.5 kilometers. Later the data were reorganized into pseudo-common shot gathers of 420 channels with a maximum offset of 10.5 kilometers. The shooters worked simultaneously in two groups shooting the near and the far offsets respectively. Their shooting schedule was synchronized so that the two groups moved together between consecutive shots, thereby minimizing the dead time lost during transit. After all the shots for a specific streamer location had been recorded, the recording hut along with the streamer was towed to the next hut location. The distance between consecutive hut locations was 300 meters which was also equal to the shot separation. The shot holes were drilled to depths between 16 to 20 meters and most of them were used several times for detonating charges of varying sizes. All shot holes were first 'sprung' with a 150 gm. charge. Springing is widely believed to enhance the signal to noise ratio for subsequent shots. The detonating cord, when used, was buried at a depth of about 30 cms. with a specially designed plow. This method of burying the detonating cord is very economical and fast compared to drilling holes in the ice.

During preliminary analysis of the data, it has been observed that energy from the detonating cord had poor penetration although the resolution was good for very shallow structure (above). The buried charges had better penetration and the snow-streamer was sensitive enough to record reflections from within the ice (left). The origin of these reflections is not clearly understood and can be attributed to either embedded moraines or to changes in the ice fabric. However, the shallow and middle crust are quite non-reflective in this area and very few reflections were recorded from these depths. In the wide-angle data generated by the 50-100 kg. granulated ANFO explosives, a deep reflection clearly appears proving that the penetration of seismic energy was good enough but it is the crust that is largely non-reflective.

# Active Tectonic Studies In the Southwest Pacific

The plate tectonic process of subduction was first recognized and described at the Tonga arc by Isacks et al. (1968). This region remains the world's greatest laboratory for studies of subduction tectonics and seismicity (Fig. 1). Our research in this region has evolved to include multi-disciplinary studies of "active tectonics" in addition to traditional seismology. Active tectonics is the study of ongoing or recent deformation of the earth of which seismology is an integral part. Extremely rapid rates of tectonic plate motion produce numerous earthquakes and volcanoes which, in turn, result in some of the most rapid crustal deformation rates to be found on the globe.




The Southwest Pacific: This natural laboratory for active tectonics has the most rapid plate motions on earth, with numerous earthquakes and volcanoes. Coral reefs record paleoseismic histories and the geographic distribution of extremely rapid vertical deformation. Measurements at each GPS site (filled black circles) determine distances to other GPS sites to within a few mm.

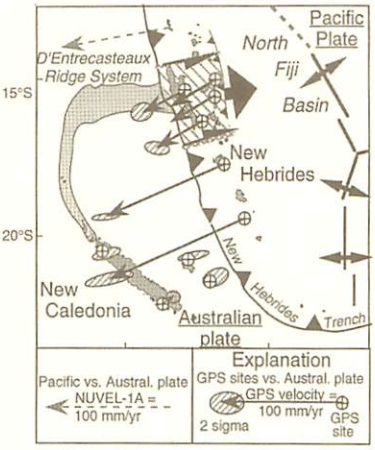
The first active tectonics studies in this region exploited the unique record of vertical tectonic motions represented in the morphology and age structure of living and uplifted coral reefs. This concept dates back to Charles Darwin's book "The Structure and Distribution of Coral Reefs" in which he recognized that barrier reefs and atolls form by subsidence as coral reefs grow upward to keep up with rising sea level. In contrast, tectonic uplift raises coral reefs above sea level and creates islands capped by a series of coral reef terraces. Because isotopic dating of fossil corals allows us to determine when the reefs were at sea level, we can determine uplift and subsidence rates and infer a detailed tectonic history. We can even use individual coral heads as natural tide gauges that record the increments of crustal motion that occur during large earthquakes. Thus, from emerged coral reefs we are able to obtain a record not only of the background vertical deformation history, but also a history of the times and amounts of individual earthquake uplifts. This approach is currently being applied in Indonesia under NSF funding in collaboration with American and Indonesian scientists.

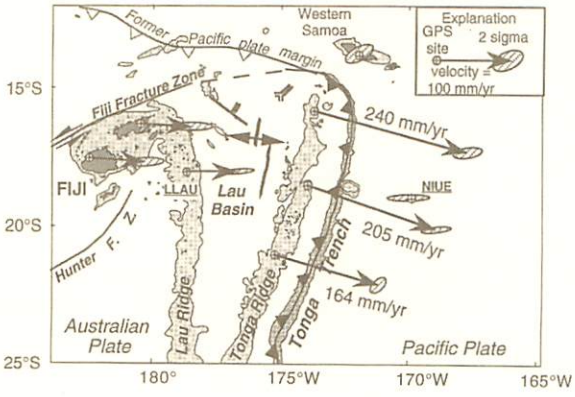
In 1988, we introduced a new Active Tectonics technology to the SW Pacific by beginning to measure crustal motions using the Global Positioning System (GPS). This method of satellite-based geodesy is so precise that we can determine the distance between sites on islands hundreds of km apart to within 1 cm. By repeating these measurements of distance we can calculate the horizontal motions of tectonic plates and the deformation within crustal blocks. This technique has tremendous potential for observing the relationships between earthquakes, plate motions, and the ongoing interseismic accumulation and release of elastic strain that causes earthquakes. By understanding these relationships, we not only gain insights into the processes of growth and modifications of island arcs but also better understand how earthquakes are generated and the factors that influence their size, distribution, and timing.

One of the rewarding aspects of the GPS work involved introducing a useful technology to local surveyors. We held annual training classes and collaborated with the local governments of seven island nations. On many occasions we performed service work such as precisely locating the international airport at Nandi, Fiji, by GPS.

GPS measurements show that the New Hebrides arc is breaking apart as the d'Entrecasteaux ridge impinges against the arc and thrusts beneath it. The Australian plate and most of the arc are coming together at rates of about 100 - 120 mm/yr. However, the central New Hebrides (shaded segment) is converging with the Australian plate at only 42 mm/yr, or about half the minimum rate that it should (minimum rates from plate tectonic models indicated by dashed arrows). This and other evidence shows that a large segment of the arc is being pushed backward into the North Fiji Basin at rates of 38 to 85 mm/yr.

The Tonga arc is moving rapidly toward the Pacific plate a little like a windshield wiper rotating clockwise. The Tonga arc occupies a microplate separated from the Australian plate by seafloor spreading centers in the Lau Basin. As the Lau basin opens, the Tonga arc moves eastward out ahead of the Australian plate adding to the convergence rate at the Tonga trench. As Tonga moves eastward, the Pacific plate sinks or thrusts beneath the Tonga arc generating numerous earthquakes within the sinking Pacific plate. (Below)




## James A. Austin, Jr.

Senior Research Scientist

Ph.D., Woods Hole Oceanographic Institution–Massachusetts Institute of Technology (1979), B.A., Amherst College (1973);
e-mail: jamie@utig.ig.utexas.edu


### Marine Geology and Geophysics

Structural and stratigraphic evolution of various types of continental margins, including carbonate platforms.

### Research Interests

Multichannel (both 2D and 3D) seismic reflection and refraction data are used to compare and contrast the structure and stratigraphy of passive margins in various parts of the world, including off the east coast of the United States, eastern Canada/Iberia and Morocco, as well as convergent margins like the southernmost Andes and off the northern part of the Antarctic Peninsula.

Of major interest is the application of seismic stratigraphic principles to geologic problems, in particular the significance of seismic unconformities in both shallow and deep-water environments and the uniformity of seismic facies in carbonate versus clastic depositional provinces. A second focus is the deep structure of continental lithosphere and the response of continental crust to deformation processes associated with plate fragmentation and convergence.

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Denny, W. M., III, J. A. Austin, Jr., and R. T. Buffler, Seismic stratigraphy and geologic history of mid-Cretaceous through Cenozoic rocks, southern Straits of Florida, *AAPG Bull.*, *78*, 461-487, 1994.

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Holik, J. S., P. D. Rabinowitz, and J. A. Austin, Jr., Effects of Canary hotspot volcanism on structure of oceanic crust off Morocco, *J. Geophys. Res.*, *96*, 12,039-12,067, 1991.

Austin, J. A., Jr., P. L. Stoffa, J. D. Phillips, J. Oh, D. S. Sawyer, G. M. Purdy, E. Reiter, and J. Makris, Crustal structure of the Southeast Georgia Embayment: A deep-penetration MCS/OBH image of a continental suture(?) and a volcanic passive margin, *Geology*, *18*, 1023-1027, 1990.

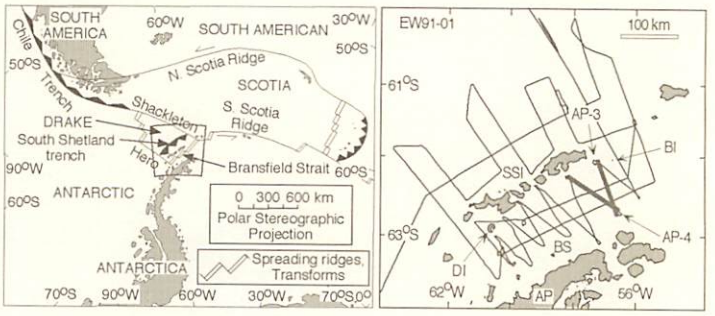
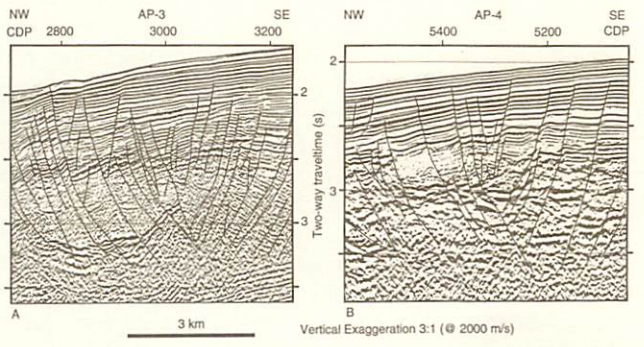




Plate tectonic setting of Bransfield Strait, Antarctica. The Drake plate is the last remnant of the Phoenix plate, subducted along the Antarctic Peninsula margin during the Tertiary. Sea-floor spreading at the Antarctic-Drake Ridge ceased approximately 4 million years ago, but slow subduction of the Drake plate apparently continues at the South Shetland Trench, contributing to Bransfield Strait extension. There is no active arc volcanism in the South Shetland Islands at present. Right: Close-up showing multichannel seismic profiles collected aboard the Lamont-Doherty Earth Observatory research vessel *Maurice Ewing* in 1991; highlighting pinpoints profiles shown in Figure 2. AP - Antarctic Peninsula, BI - Bridgeman Island, BS - Bransfield Strait, DI - Deception Island, SSI - South Shetland Islands.




Multichannel seismic examples of fan-shaped fault structures on the Antarctica Peninsula margin. Both profiles have been migrated, with frequency-wave number multiple suppression and weighted stacking applied to minimize water bottom reverberation. In each example, although the faulting pattern is clear, the inferred crustal diapir beneath is unreflective. Line AP-4 also shows short, high-amplitude, low-frequency events cut by faults at various depths, perhaps caused by disrupted intrusive bodies (sills?) related to melt associated with the crustal diapirism.


## Milo M. Backus

Senior Research Scientist and Shell Oil Companies Foundation Distinguished Chair in Geophysics, Dept. of Geological Sciences

Ph.D., B.S., Massachusetts Institute of Technology (1956,1952);
e-mail: backus@maestro.geo.utexas.edu


### Exploration Geophysics

Quantitative interpretation of geophysical data applied to petroleum exploration.

### Research Interests

Modern 3D seismic reflection data contains an incredible amount of information. Backus is interested in methods of characterization, extraction, and display of this information. The fluid anomaly signal (angle dependent reflection anomaly and tomographic anomalies) is of particular interest. Synthetic examples of the fluid anomaly signal are illustrated in a simple seismic section and in a more realistic synthetic stratal slice. In real data, Backus attacks the major issues of velocity estimation, estimation of the variable seismic wavelet, handling multiple reflections and converted shear waves, and the application of display, interpretation, and inversion methods. The focus extends from the detection problem in undrilled territory, to the combined use of well data and 3D seismic data for improved reservoir characterization and reservoir monitoring.

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Wang, D. L., and M. M. Backus, Resolution of P-Wave Velocity and Density in Linearized Inversion, SEG Expanded Abstracts, Sixty-first Annual Meeting, 879-882, 1991.

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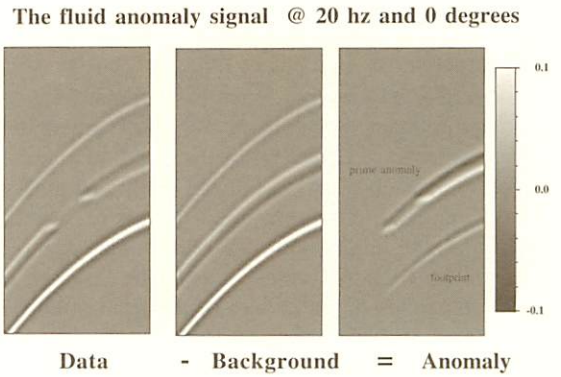
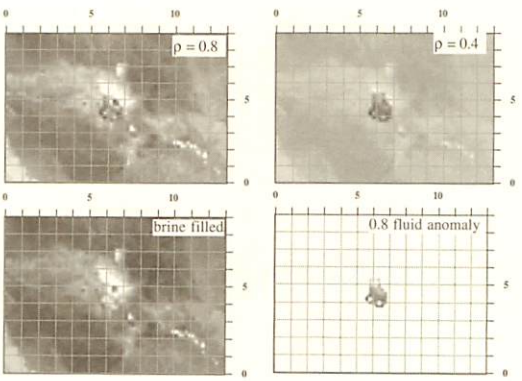



Illustrating the fluid anomaly signal. A synthetic stratal slice example.


## Nathan L. B. Bangs

Research Associate

Ph.D., M.Phil., M.A., Columbia University (1990, 1987, 1986); B.A., Williams College (1983); e-mail: nathan@utig.ig.utexas.edu


### Marine Geology and Geophysics

Structural development and tectonic processes along convergent margins, fluid migration in accretionary wedges, processing, inversion, and modeling of seismic reflection data.

### Research Interests

Collision zones are extremely dynamic regions with tectonic activities that range from growth by accretion of new materials to the overriding plate, to tectonic erosion and sediment subduction and assimilation into the asthenosphere. Multichannel seismic methods are being used to acquire good images of structure and stratigraphy within the subduction zone accretionary complexes of Barbados, Chile, and the Aleutians in order to examine the tectonic activity and deformational styles of the leading edge of collision zones. Styles of deformation are greatly influenced by pore fluids squeezed from accretionary complexes. Extensive research is being devoted to examining hydrogeology of subduction zones. Wedge consolidation and fluid migration patterns are also being examined in detail by measuring seismic velocities. Seismic modeling of reflection waveforms and amplitudes of anomalous reflections reveal patterns of fluid overpressures and fluid migration pathways through the accretionary complex.

### Selected Publications

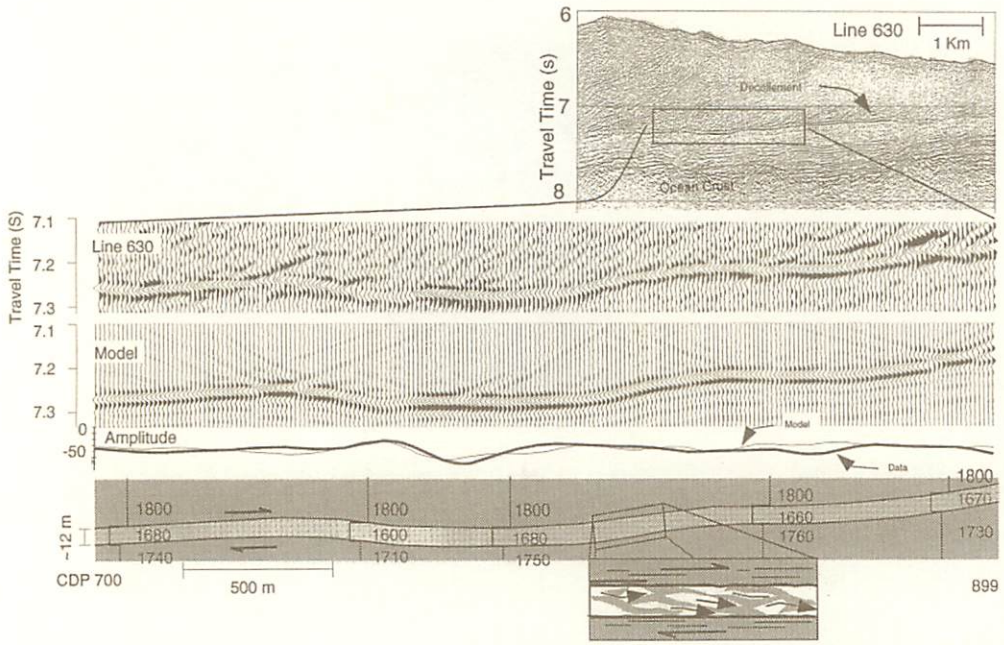

Bangs, N. L., T. H. Shipley, and G. F. Moore, Elevated fluid pressure and fault zone dilation inferred from seismic models of the northern Barbados ridge decollement, *J. Geophys. Res.*, in press, 1995.

Bangs, N. L. B., D. S. Sawyer, and X. Golovchenko, Free gas at the base of the gas hydrate zone in the vicinity of the Chile Triple Junction, *Geology*, *21*, 905-908, 1993.

Bangs, N. L. B., S. C. Cande, S. D. Lewis, and J. J. Miller, Structural framework of the Chile margin at the Chile Ridge collision zone: *In* Behrmann, J. H., S. D. Lewis, R. J. Musgrave et al., Proceedings Ocean Drilling Program Initial Reports, v. 141, College Station, Texas (Ocean Drilling Program), 11-21, 1992.

Bangs, N., and G. K. Westbrook, Seismic modeling of the décollement zone at the base of the Barbados Ridge accretionary complex, *J. Geophys. Res.*, *96*, 3853-3866, 1991.

Bangs, N., G. K. Westbrook, J. W. Ladd, P. Buhl, Seismic velocities from the Barbados Ridge Complex: Indicators of high pore-fluid pressure in an accretionary complex, *J. Geophys. Res.*, *95*, 8767-8782, 1990.


A portion of the 3-D seismic line 630 from the toe of the Barbados Ridge Complex showing a high-amplitude seismic reflection from the décollement plate-boundary detachment fault. An enlargement of the décollement (below) has been modeled to match the waveform and amplitude of the event. The model requires a drop in seismic velocity within a ~12 m thick layer. These anomalous properties are interpreted to be caused by pore fluid pressures elevated to near lithostatic within the thin fault zone layer.


## Donald D. Blankenship

Research Associate and Director, Support Office for Aerogeophysical Research

Ph.D., M.S., University of Wisconsin-Madison (1989, 1982); B.S., Eastern Illinois University (1978); e-mail: blank@utig.ig.utexas.edu


### Geophysics

Airborne geophysics, seismology, dynamics of large ice sheets, evolution of the Antarctic lithosphere.

### Research Interests

West Antarctica is characterized by two of the earth's most dynamic systems, the extending lithosphere of the West Antarctic rift system and the marine-based West Antarctic ice sheet. Active continental rift systems, caused by divergent plate motions, result in thinned crust. Associated with the thin crust are fault-bounded sedimentary basins, active volcanism and elevated heat flow. "Marine" ice sheets are characterized by rapidly moving streams of ice, penetrating and draining a slowly moving ice reservoir. Evidence left by past marine ice sheets indicates that they may have a strongly non-linear response to long-term climate change which results in massive and rapid discharges of ice and consequent increases in sea level. Understanding the evolution of the ice stream system and its interaction with the interior ice is the key to understanding this non-linear response.

Subglacial geology and ice dynamics are generally studied in isolation, but evidence is mounting that the behavior of the West Antarctic ice streams may be closely linked to the nature of the underlying West Antarctic rift system. The fast moving ice streams appear to glide on a lubricating layer of water-saturated till. This till requires easily eroded sediment and a source of water, both of which may be controlled by the geology of the rift system; the sediments from the fault-bounded basins and the water from the elevated heat flux associated with active lithospheric extension.

A current project involves coordinating an experiment to investigate the tectonic evolution of the West Antarctic rift system. This aerogeophysical experiment includes simultaneous acquisition of ice-penetrating radar, laser altimetry, airborne gravity and aeromagnetic measurements. The new airborne platform has completed its fourth successful season in Antarctica and has become the foundation for the Support Office for Aerogeophysical Research (SOAR) which is a national facility for airborne geophysics in Antarctica. Early results from this experiment give indications of active subglacial volcanism near the critical region where ice streams begin.

Additional investigations include the use of seismic anisotropy to determine the crystalline fabric of large ice masses and airborne radar surveys to study the hydrology of ice streams in the critical region where they go afloat. Knowledge of ice fabric is essential for the successful implementation of large-scale ice sheet models and understanding the basal hydrology of the ice streams is necessary for testing sedimentological models for the Antarctic continental shelf.

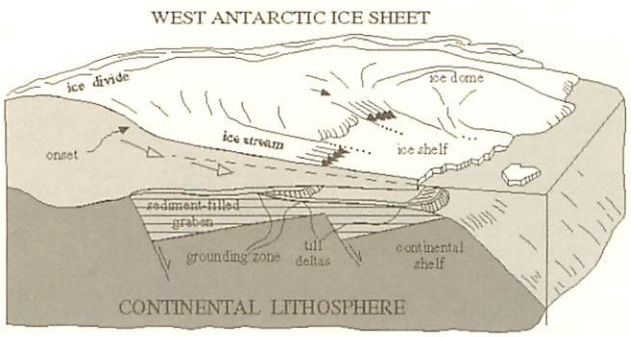
### Selected Publications


Behrendt, J. C., D. D. Blankenship, D. Damaske, and A. K. Cooper, Glacial removal of late Cenozoic subglacially emplaced volcanic edifices by the West Antarctic ice sheet, *Geology*, *23*, in press, 1995.

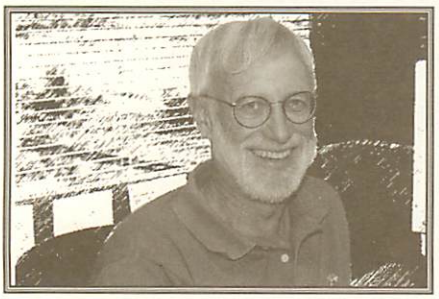
Behrendt, J. C. D. D. Blankenship, C. A. Finn, R. E. Bell, R. Sweeney, S. M. Hodge, and J. M. Brozena, Evidence of late Cenozoic volcanic activity in the West Antarctic rift system revealed by the CASERTZ aeromagnetic survey, *Geology*, *22*, 527-530, 1994.

Blankenship, D. D., R. E. Bell, S. M. Hodge, J. M. Brozena, J. C. Behrendt, and C. A. Finn, Active volcanism beneath the West Antarctic ice sheet and implications for ice-sheet stability, *Nature*, *361*, 526-529, 1993.

Bell, R.E., B. J. Coakley, D. D. Blankenship, S. M. Hodge, J. M. Brozena, and J. Jarvis, Airborne gravity from a light aircraft: CASERTZ 1990-91: *In* Yoshida Y., K. Kaminuma, S. Shiraishi, ed., Recent Progress in Antarctic Earth Science, TERRAPUB, Tokyo, 571-577, 1993.


Schematic of the West Antarctic ice sheet and its lithospheric setting. The interior ice reservoir is the portion of the ice sheet below the ice divide where the ice sheet is attached to its bed. This interior ice is penetrated and drained by the fast moving ice streams which flow between regions of relatively stagnant ice. The open arrows indicate the gliding of ice over its bed from the onset region toward the ice shelf. Beneath the ice streams the lubricating till is illustrated. The extensional nature of the underlying lithosphere is indicated by the sediment filled grabens beneath the ice streams.




## Richard T. Buffler

Senior Research Scientist; also Professor, Dept. of Geological Sciences

Ph.D., University of California, Berkeley (1967); B.S., The University of Texas at Austin (1959); e-mail: dick@utig.ig.utexas.edu


### Marine Geology and Geophysics

Seismic sequence stratigraphy, depositional systems, structural and stratigraphic evolution of ocean basins and adjacent margins.

### Research Interests

Main research interests involve the study of ocean basins and their margins using marine geological and geophysical tools, mainly seismic reflection data. Principles of seismic sequence stratigraphy are applied to interpret the depositional and structural history of a region. The principle focus continues to be the geologic history of the Gulf of Mexico basin. Two recently completed Ph.D. dissertations include "Post Mid-Cretaceous Seismic Stratigraphy and Depositional History, Deep Gulf of Mexico" by Jianhua Feng, and "Jurassic Evolution of the Southeastern Gulf of Mexico" by György Marton. The latter project proposed a new, better constrained model for the early evolution of the Gulf basin. Current research projects include: 1) Sequence stratigraphy of the northeastern Gulf of Mexico: An integrated seismic, well-log, and biostratigraphic approach, 2) Sequence stratigraphy, depositional systems, sediment fairways and depositional history, post mid-Cretaceous rocks, Gulf of Mexico basin, 3) Structure of the Chicxulub KT impact crater, Yucatan, Gulf of Mexico, and 4) Distribution, age and origin of Late Maastrichtian catastrophic units in Cuba; tectonic or impact event. All of these projects involve students. Besides the students working on Gulf of Mexico research projects, many are working on seismic related projects all over the world, including Australia, Brazil, Trinidad, Venezuela, and Columbia. In addition, several students have just completed or are working on field-oriented sequence stratigraphic studies in West Texas, the central valley of California, the Black Hills, and central Texas. New field projects are being planned for the western US, northern Mexico, and Eritrea.

### Selected Publications


Marton, G., and R. T. Buffler, Application of Simple Shear Model to the Evolution of the Gulf of Mexico Basin Passive Continental Margins, *Geology*, *21*, 495-498, 1993.

Buffler, R. T., L. M. Dobson, and D. A. DeBalko, Middle Jurassic through Early Cretaceous evolution of the northeastern Gulf of Mexico basin, *In* Pindell, J. L. and Perkins, B. F. (eds.), Mesozoic and Early Cenozoic developments of the Gulf of Mexico and Caribbean region: Gulf Coast Section-SEPM, 33-50, 1993.

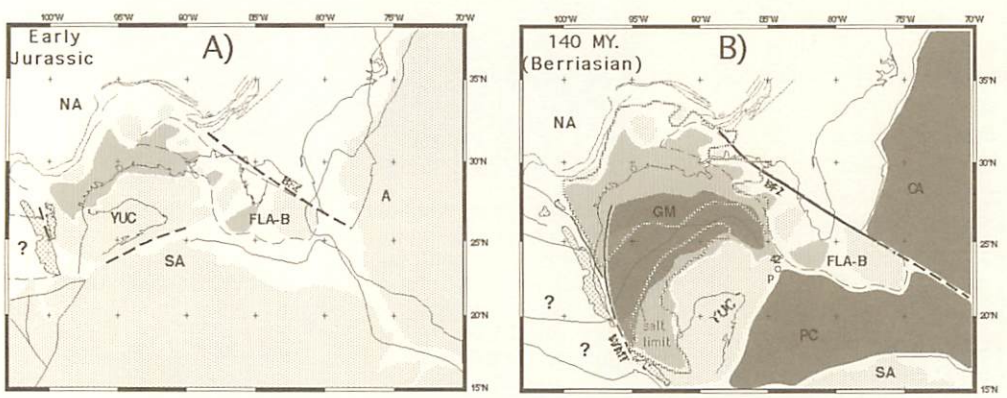
Denny, W. M., J. A. Austin, and R. T . Buffler, Seismic stratigraphy and geologic history of Mid-Cretaceous through Cenozoic rocks, southern Straits of Florida: *AAPG Bull. 78*, 461-487, 1994.

Buffler, R. T., Geological history of the eastern Argo Abyssal Plain based on ODP drilling and seismic data, *AGSO J. Australian Geol. and Geophys., 15*, 157-164, 1994.

Feng, J., R. T. Buffler, and M. A. Kominz, Laramide orogenic influence on late Mesozoic-Cenozoic subsidence history, western deep Gulf of Mexico basin, *Geology*, *22*, 359-362, 1994.

Buffler, R. T., and W. Thomas, Crustal structure and evolution of the southeastern margin of North America and the Gulf of Mexico basin, *In* Speed, R. C. (ed.), Phanerozoic Evolution of North American Continent-Ocean Transitions: Boulder, Colorado, Geological Society of America, The Geology of North America, v. CTV-1, 219-264, 1994.

Marton, G. and R. T. Buffler, Jurassic reconstruction of the Gulf of Mexico basin, *Intl. Geol. Rev.*, *36*, 545-586, 1994.


Early evolution of the Gulf of Mexico basin and surrounding region: A) Early rift reconstruction showing the paleo-position of the large continental plates and smaller continental blocks in the gulf region. B) Post-spreading reconstruction showing paleo-position of continental blocks, distribution of salt, as well as the distribution of oceanic crust in Gulf of Mexico (GM), Proto-Caribbean (PC), and Central Atlantic (CA) (from Marton and Buffler, 1994).


## Gail L. Christeson

Research Associate

Ph.D., Massachusetts Institute of Technology/Woods Hole Oceanographic Institution (1994); B.S., Texas A&M University (1988);
e-mail: gail@utig.ig.utexas.edu


### Marine Geophysics

Ocean bottom seismology, mid-ocean ridge structure and emplacement processes, physical properties of young oceanic crust.

### Research Interests

Primary research is concerned with increasing our understanding of how oceanic crust is emplaced at mid-ocean ridges, with an emphasis upon fast-spreading ridges and the use of seismic techniques to image the uppermost several hundred meters of the crust. Prior work has focused on a series of on-bottom seismic refraction experiments located on young crust at the East Pacific Rise (EPR). By placing both the shots and receivers within a few meters of the seafloor, high-resolution determinations of shallow crustal structure are obtained. This work, combined with results from other studies in the EPR region (submersible, near-bottom imaging, seismic tomography, multi-channel seismic studies, expanding spread profiles, and attenuation tomography) have allowed a picture of lava and dike emplacement processes at the mid-ocean ridge to be built. The seismic data suggest that the shallow crustal architecture is in place within 1-2 km of the rise axis. Dikes penetrate within 100 m of the surface at the rise axis, and then rapidly subside. The mechanism controlling the magnitude and rate of the dike subsidence (believed to be the robustness of the magma chamber) is the primary mechanism that determines the final thickness of the extrusive section.

Current work involves using the University of Texas Institute for Geophysics ocean bottom seismographs (OBSs) in a variety of settings: the East Pacific Rise, offshore Costa Rica, and offshore the Yucatan Peninsula. The East Pacific Rise project is concerned with the onset of faulting in oceanic crust. The Costa Rica program entails building an accurate velocity model for offshore Costa Rica and imaging the subducting Cocos plate. The Yucatan project will image the crustal structure of the Chicxulub impact crater and quantify its dimensions. This crater is believed to be formed by the impact that resulted in mass extinctions (including the dinosaurs) at the Cretaceous-Tertiary boundary.

### Selected Publications

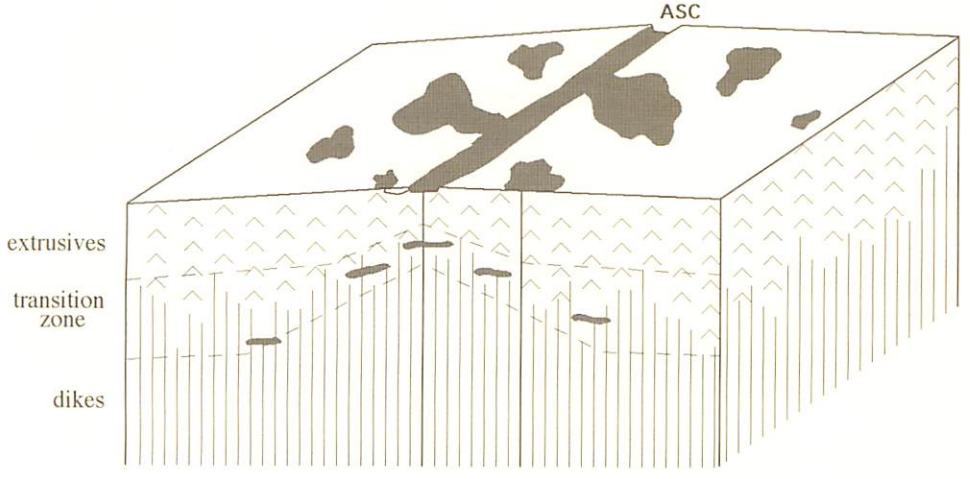

Christeson, G. L., G. M. Purdy, and G. J. Fryer, Seismic constraints on shallow crustal emplacement processes at the fast-spreading East Pacific Rise, *J. Geophys. Res., 99,* 17957-17973, 1994.

Christeson, G. L., W. S. D. Wilcock, and G. M. Purdy, The shallow attenuation structure of the fast-spreading East Pacific Rise near 9°30'N, *Geophys. Res. Lett., 21,* 321-324, 1994.

Christeson, G. L., G. M. Purdy, and K. M. M. Rohr, Structure of the Northern Symmetrical Segment of the Juan de Fuca Ridge, *Mar. Geophys. Res., 15,* 219-240, 1993.

Christeson, G. L., G. M. Purdy, and G. J. Fryer, Structure of young upper crust at the East Pacific Rise near 9°30'N, *Geophys. Res. Lett., 19,* 1045-1048, 1992.

Christeson, G. L., and M. K. McNutt, Geophysical constraints on the shear stress along the Marquesas Fracture Zone, *J. Geophys. Res., 97,* 4425-4437, 1992.


Cartoon depicting the emplacement process for lavas and dikes at the fast-spreading EPR. The cartoon shows a snapshot in time, with the shaded areas showing the most recent lava flows and sills. The extrusive layer doubles in thickness within 1 km of the rise axis due to lava that overflows the walls of the axial summit caldera (ASC), lava flows which are emplaced outside of the ASC, and lava that travels laterally from the ASC through conduits. The transition zone also doubles in thickness within 1 km of the rise axis, due to off-axis sill emplacement. The shallow crustal architecture is in place within 1-2 km of the rise axis.


## Mark Cloos

Senior Research Scientist; also Professor, Dept. of Geological Sciences

Ph.D., University of California, Los Angeles (1981); B.S., University of Illinois at Urbana-Champaign (1976);
e-mail:cloos@maestro.geo.utexas.edu


### Structural Geology and Tectonics

Tectonic evolution of convergent plate margins, field studies in California and Irian Jaya, Indonesia.

### Research Interests

1) Field, laboratory and theoretical studies of the structure, metamorphism, geochronology, sedimentation and seismicity at convergent plate margins. Active field projects in the central and northern Coast Ranges of California. 2) Application of the method of apatite fission track thermochronology to tectonic problems and basin thermal evolution. 3) Tectonics of forearc-continent collision zones. Active field projects in the vicinity of the Gunung Bijih (Ertsberg) Mining district in Irian Jaya, Indonesia (west New Guinea). 4) Structural controls on the origin of porphyry copper-type ore deposits.

### Selected Publications


Cloos, M., T. P. McMahon, A. Quarles van Ufford, B. Sapiie, P. Q. Warren, and R. J. Weiland, Collisional delamination in New Guinea, *Geol. Soc. Amer. Abstracts with Programs*, *26*, 7, A-502, 1994.

Sapiie, B., and M. Cloos, Strike-slip fault control on emplacement of the Grasberg intrusive complex, Gunung Bijih (Ertsberg) Cu-Au District, Irian Jaya, Indonesia (west New Guinea), *Geol. Soc. Amer. Abstracts with Programs*, *26*, 7 A-186, 1994.

Cloos, M., and R. L. Shreve, Subduction channel model for accretion, sediment subduction, and tectonic erosion at convergent plate margins: Seamount asperities and thrust-type subduction zone seismicity: SUBCON: An Interdisciplinary Conference on the Subduction Process, June 12-17, 1994, Catalina Island, California, Sponsored by U.S. Geological Survey, JOI/USSAC and NSF, Extended Abstract, 109-111, 1994.

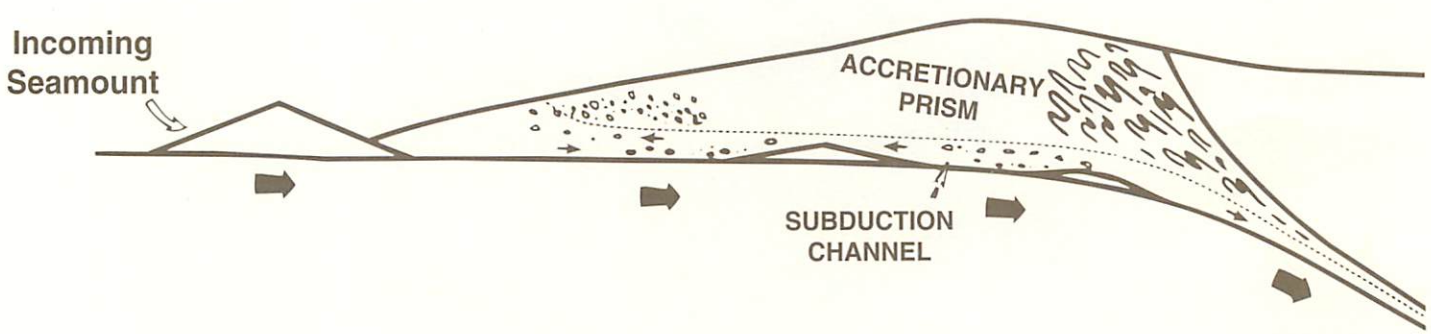
Cloos, M., Lithospheric buoyancy and collisional orogenesis: Subduction of oceanic plateaus, continental margins, island arcs, spreading ridges, and seamounts, *Geol. Soc. Amer. Bull.*, *105*, 715-737, 1993.

Cloos, M., Thrust-type subduction zone earthquakes and seamount asperities: A physical model for seismic rupture, *Geology*, *20*, 601-604, 1992.

Cloos, M., Plate Tectonics, The World Book Encyclopedia, 565-569, 1992.

Cloos, M., Nicasio Dam Pillow Basalts: Marin County, California: A Fragment from a Seamount Accreted During Franciscan Subduction, *In:* B. J. Bilodeau and S. O. Davies, (eds.), *Geologic Guidebook to the Point Reyes Area, Northern California,* American Association of Petroleum Geologists 1990 National Meeting, San Francisco, CA, 9–16, 1990.

Cloos, M., Blueschists, *In:* F.N. Magill, (ed.), *Magill's Survey of Science, Earth Science Series,* Salem Press, Inc., 1561–1569, 1990.


Seamount subduction, dismemberment, and incorporation into offscraped melange.


## Millard F. Coffin

Research Scientist

Ph.D., M.Phil., M.A., Columbia University (1985, 1982, 1981); A.B., Dartmouth College (1978); e-mail: mikec@utig.ig.utexas.edu


### Marine Geology and Geophysics

Structure, stratigraphy, and tectonics of large igneous provinces, plate boundaries, and continental margins using multichannel seismic reflection, refraction, gravity, satellite altimeter, magnetic, and rock sample data.

### Research Interests

Massive magmatic events created oceanic plateaus, volcanic passive margins, and continental flood basalts. Of these large igneous provinces (LIPs), oceanic plateaus are the least understood, despite their being the dominant residual depth anomalies of the sea floor. Studies of plateaus have the potential to reveal spatial and temporal patterns of mantle dynamics, to elucidate the effects of emplacement on the Earth's hydrosphere and atmosphere, and to help understand continental growth. Research focuses on the seismic structure, gravity field, and stratigraphy of oceanic plateaus, especially the Ontong Java Plateau in the western Pacific and the Kerguelen Plateau in the southern Indian Ocean.

Plate boundaries and passive continental margins are the Earth's major crustal discontinuities. Compressional and transform boundaries are associated with the most vivid demonstrations of Earth-altering forces active on a human time scale, thrusting lithosphere over lithosphere or sliding plate past plate, resulting in earthquakes, volcanism, and complex stratigraphy. Passive margins contain sediment which records with infinite variation the interaction of subsidence with sea level, and with marine and terrestrial sedimentary processes. At deeper levels oceanic and continental basement is juxtaposed, and the record of rifting and transform kinematics is preserved. Interest in the stratigraphic, structural, and kinematic evolution of plate boundaries and passive margins has inspired work on the Macquarie Ridge and on the conjugate SE Australia-Lord Howe Rise margins.

### Selected Publications


Coffin, M.F., and L. Gahagan, Ontong Java and Kerguelen Plateaux: Cretaceous Icelands?, *J. Geol. Soc., London*, 152, 1047-1052, 1995.

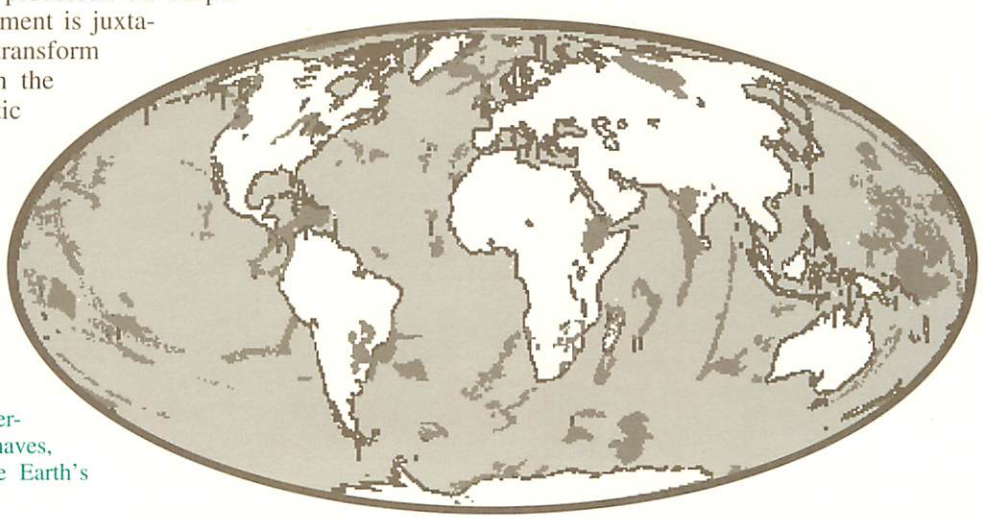
Coffin, M.F., and O. Eldholm, Large igneous provinces: crustal structure, dimensions, and external consequences, *Revs. Geophys., 32*, 1-36, 1994.

Coffin, M.F., and O. Eldholm, Large igneous provinces, *Sci. Am., 269*, 42-49, 1993.

Coffin, M.F., and O. Eldholm, Scratching the surface: estimating dimensions of large igneous provinces, *Geology, 21*, 515-518, 1993.

Coffin, M.F., Emplacement and subsidence of Indian Ocean plateaus and submarine ridges, in Duncan, R.A., D.K. Rea, R.B. Kidd, U. von Rad, and J.K. Weissel, (eds.), Synthesis of Results from Scientific Drilling in the Indian Ocean, *Geophysical Monograph 70, American Geophysical Union*, (Washington, D.C.), 115-125, 1992.

Coffin, M.F., and O. Eldholm, Volcanism and continental break-up: a global compilation of large igneous provinces, in Storey, B.C., T. Alabaster, and R.J. Pankhurst, (eds.), Magmatism and the Causes of Continental Break-up, *Geol. Soc. London Spec. Pub., 68*, 21-34, 1992.

Large igneous provinces, shown in black, appear in many geologic setting worldwide. Studies of the huge magmatic emplacements are adding to our understanding of how the Earth's interior behaves, and how these features may affect the Earth's surface environment.

## Ian W. D. Dalziel

Associate Director and Senior Research Scientist; also Professor, Dept. of Geological Sciences

Ph.D., University of Edinburgh (1963); B.Sc., University of Edinburgh (1959); e-mail: ian@utig.ig.utexas.edu

### Tectonics

Earth history and tectonic processes.

### Research Interests

Development of the hypothesis that the Pacific margins of North America and East Antarctica-Australia were juxtaposed prior to the opening of the Pacific Ocean basin, put forward in 1991 with Eldridge Moores of the University of California at Davis, has led to an entirely new scenario for the tectonic history of the Earth before the amalgamation of Pangea. New research projects are designed to test the ideas that the Precambrian geology of Texas, New Mexico, and Arizona can be traced into Antarctica, and that the Taconic Appalachians once continued into southern South America; possible implications with regard to global environmental changes are also being pursed. Work on processes of orogenesis and continental fragmentation around the southern rim of the Pacific Ocean continues. New seismic studies of the lithospheric "cradle" of the West Antarctic ice sheet were initiated in 1994-95.

### Selected Publications

Dalziel, I. W. D., L. H. Dalla Salda, and L. M. Gahagan, Paleozoic Laurentia-Gondwana Interaction and the Origin of the Appalachian-Andean Mountain System, *Geol. Soc. Am. Bull.*, *106*, 243-52, 1994.

Dalziel, I. W. D., Precambrian Scotland as a Laurentia-Gondwana link: Origin and Significance of Cratonic Promontories, *Geology*, *22*, 589-592, 1994.

Dalziel, I. W. D., Earth Before Pangea, *Sci. Amer.*, *272*, 58-63, 1995.

Kohn, M. J., F. S. Spear, and I. W. D. Dalziel, Ar/ Ar geochronology and *P-T-t* paths from the Cordillera Darwin metamorphic complex, Tierra del Fuego, Chile, *J. Metamorphic Geol.*, *12*, 251-270, 1995.

Cunningham, W. D., I. W. D. Dalziel, T.-Y. Lee, L. A. and Lawver, Southernmost South America-Antarctic Peninsula relative plate motions since Gondwana break-up: Implications for the tectonic evolution of the Scotia Arc region, *J. Geophys. Res.*, *100*, 8257-8266, 1995.

Joint UTIG/UT Department of Geological Sciences field party working in the Shackleton Range, Antarctica on possible Texas-Antarctic connection. The party is supported by a ski-equipped "Twin Otter" aircraft.


## Thomas A. Davies

Associate Director and Senior Research Scientist

Ph.D., B.A., University of Cambridge (1967, 1964);
e-mail: tomd@utig.ig.utexas.edu


### Marine Sedimentation

Processes of marine sediment formation and distribution, deep sea stratigraphy, sedimentary mass balances, paleoceanography.

### Research Interests

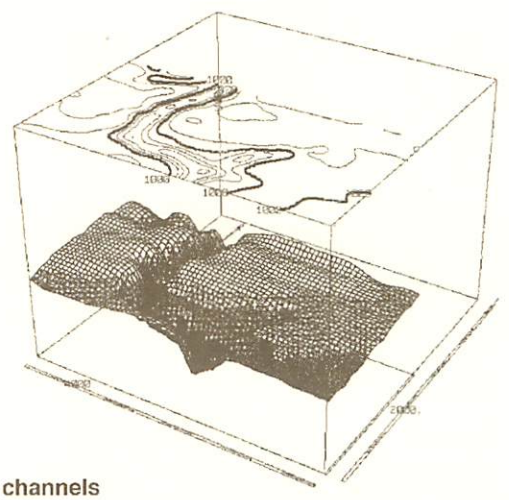
Current research covers the extremes of scale from detailed studies of a small area of the continental shelf off New Jersey to oceanwide patterns of sediment distribution in the Indian and Southern oceans. The common thread linking these studies is that in both cases the results can be interpreted in terms of past environmental changes. The New Jersey study involves the use of high resolution seismic reflection methods, in conjunction with piston and vibracoring, to examine the nature and distribution of detrital sediments of late Pleistocene and Holocene age. The deposition of these sediments can be related to stages in the deglaciation of eastern North America following the last glacial maximum. The Indian and Southern ocean studies are based on the results of scientific ocean drilling over the past two decades. The objective is to map oceanwide patterns of sedimentation as these have changed through the past 65 m.y., and to relate these to paleoclimatic and tectonic events which affect the size, shape and location of the ocean basins, ocean circulation, and erosion from the surrounding land areas.

### Selected Publications

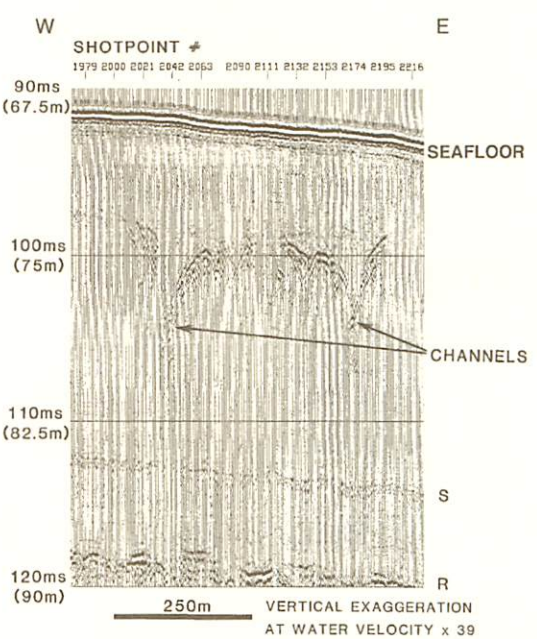

T. A. Davies, J. G. Baldauf, and R. B. Kidd, A simple spreadsheet routine for calculating depth/age relations, *Computers & Geosciences, 18*, 579-585, 1991.

T. A. Davies, J. A. Austin, Jr., M. B. Lagoe, and J. D. Milliman, Late Quaternary Sedimentation off New Jersey: new results using 3-D seismic profiles and cores, *Mar. Geol., 108*, 323-343, 1992.

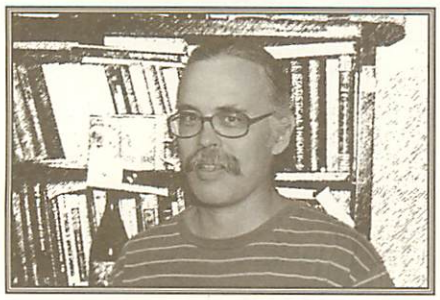
T. A. Davies, R. B. Kidd, and A.T.S. Ramsay, A time-slice approach to the history of Cenozoic sedimentation in the Indian Ocean, *Sed. Geol., 96*, 157-179, 1995.


A 3-D representation of a meandering, channeled surface within the sediment wedge on the New Jersey outer shelf. The box is 1.0 km on a side horizontally. The vertical dimension is about 22.5 m. Thus the channel is about 100 m across and 3 m deep. The channel is thought to be part of the distributary system of the post glacial Hudson River drainage.




Close-up of a seismic section across one of the channels, showing high amplitude reflections from the channel bottom, possibly indicative of lag deposits. Depths below sea surface given in milleseconds 2-way travel time and meters, assuming a sound velocity of 1.5 km/s (from Davies et al., 1992).




## Cliff Frohlich

Senior Research Scientist

Ph.D., M.S., Cornell University (1976, 1973); B.A., Grinnell College (1969); e-mail: cliff@utig.ig.utexas.edu


### Solid Earth Geophysics

Earthquake seismology, tectonics, synthetic stratigraphy, statistics, classical physics.

### Research Interests

The observed seismic waves from some earthquakes cannot be explained as being caused by slip along a planar fault surface. So, what process might cause these "non-double-couple" events? More than one physical mechanism is required to explain the various observed varieties, however, the simplest explanation is that some earthquakes are complex, with stress released on two or more suitably oriented, non-parallel fault surfaces. One current research program focuses on two questions: 1) What proportion of the reported non-double-couple mechanisms can be attributed to fault complexity?; and 2) How much of the reported non-double-couple component can be attributed to systematic errors in the process of determining the mechanism?

Not all of Frohlich's research concerns earthquakes, he also has an active program devising forward modeling methods to study stratigraphy. In these programs, one must specify sealevel history, initial topography, and various parameters controlling sediment supply and the geometry of deposition, then a computer determines the stratigraphic sections that ensue after millions of years of deposition. Comparison of the synthetic cross sections with actual observations provides a means to test whether the various assumptions are appropriate, and sometimes permits the prediction of properties of stratigraphic sections that have not been adequately sampled.

Other current research interests concern the statistical properties of earthquake catalogs, the characteristics and physical causes of deep-focus earthquakes, and the analysis of earthquakes induced by fluid injection.

### Selected Publications


Frohlich, C., Characteristics of well-determined deviatoric non-double-couple earthquakes in the Harvard CMT catalog, *Phys. Earth Planet. Interiors, 91*, 213-228, 1995.

Davis, S. D., P. Nyffenegger, and C. Frohlich, The April 9, 1993 earthquake in south-central Texas: was it induced by fluid withdrawal?, *Bull. Seis. Soc. Amer.*, 85, 6, 1888-1895, 1995.

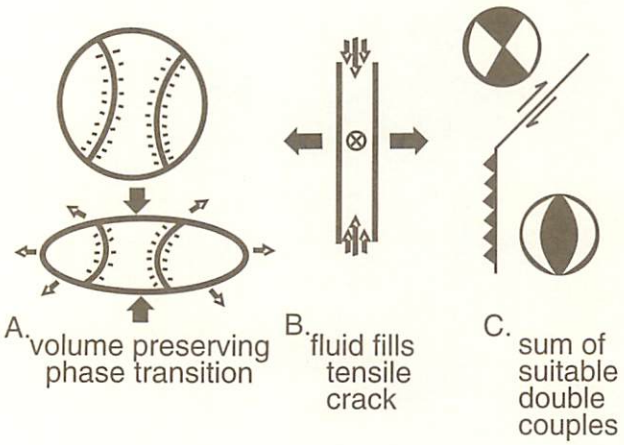
Frohlich, C., Earthquakes with non-double-couple mechanisms, *Science, 264*, 804-809, 1994.

Davis, S. D., and C. Frohlich, Did (or will) fluid injection cause earthquakes?- Criteria for a rational assessment, *Seis. Res. Lett., 64*, 207-224, 1993.

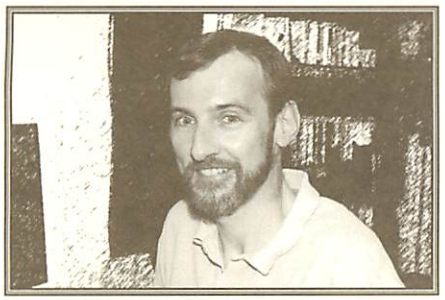
Frohlich, C., and S. D. Davis, Teleseismic b values; Or, much ado about 1.0, *J. Geophys. Res., 98*, 61-644, 1993.

Frohlich, C., and K. D. Apperson, Earthquake focal mechanisms, moment tensors, and the consistency of seismic activity near plate boundaries, *Tectonics, 11*, 279-296, 1992.

Frohlich, C., and R. K. Matthews, STRATA-various: A flexible Fortran program for dynamic forward modeling of stratigraphy, in *Sedimentary Modeling: Computer Simulations and Methods for Improving Parameter Definition*, edited by William Ross and Chris Kendall, Kansas Geological Survey Publication, 1991.


Possible models for an earthquake source that is caused neither by slip on a fault nor by an explosion. For one such source, particle motion is inward along one axis and outward along the two normal axes, with no net volume change. This might occur (a) if a phase change caused a spherical volume to become disk-shaped, with no net change in volume, (b) when fluid suddenly fills a tensile crack, or (c) if two double-couple (ordinary) earthquakes occur simultaneously and are suitably oriented as shown. Some deep earthquakes appear to have near-source motions of this type.




## Craig S. Fulthorpe

Research Associate

Ph.D., M.S., Northwestern University (1988, 1979); B.S., University of Leeds (1975); e-mail: craig@utig.ig.utexas.edu


### Marine Geology

Sedimentary geology, seismic stratigraphy and sedimentary architecture, sequence stratigraphy and sealevel variation.

### Research Interests

The technique of sequence stratigraphy is based on the recognition (on seismic profiles, well logs and in outcrop) of unconformities which bound genetically related packages of sediment known as sequences. Sequence stratigraphy has gained general acceptance as an interpretive tool. The global synchroneity and eustatic origin of depositional sequences has proved difficult to demonstrate, however, largely because both sequence architecture and the timing of sequence-bounding unconformities are influenced by local geological controls (e.g., rates of subsidence and sediment supply, isostasy, compaction, current activity) in addition to eustasy.

Current research will evaluate the roles of such local processes in controlling the depositional geometries of passive continental margins offshore New Jersey and northwest Florida. Dense industry seismic coverage provides a three-dimensional framework at both locations. This work will complement ongoing research on the sequence stratigraphy of the Canterbury Basin, New Zealand. Sequences identified on all three margins are approximately coeval and are potentially correlative. The New Jersey project is one component of a broad sealevel and stratigraphic initiative focused on that margin and involving the Ocean Drilling Program (ODP) and the STRATAFORM (STRATA FORmation on Margins) program of the Office of Naval Research.

### Selected Publications

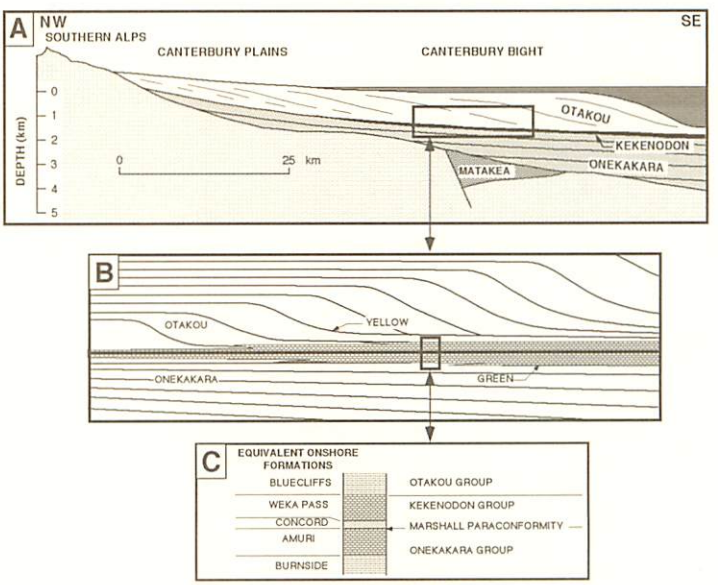

Fulthorpe, C. S., G. S. Mountain, and K. G. Miller, Mapping of Neogene depositional geometries, New Jersey continental slope ODP Leg 150 drilling area, *Proc. ODP, Sci. Results*, 150: College Station, TX (Ocean Drilling Program), in press, 1996.

Fulthorpe, C. S., R. M. Carter, K. G. Miller, and J. Wilson, Marshall Paraconformity: a mid-Oligocene record of inception of the Antarctic Circumpolar Current and coeval glacio-eustatic lowstand?, *Mar. Petr. Geol.*, 13, 61-77, 1996.

Fulthorpe, C. S., and R. M. Carter, Continental shelf progradation by sediment drift accretion, *Geol. Soc. Amer. Bull.*, *103*, 300-309, 1991.

Fulthorpe, C. S., Geological controls on seismic sequence resolution, *Geology*, *19*, 61-65, 1991.

Carter, R. M., S. T. Abbott, C. S. Fulthorpe, D. W. Haywick, R. A. and Henderson, Application of global sealevel and sequence stratigraphic models in southern hemisphere Neogene strata from New Zealand, *in* MacDonald, D., (ed.), *Sealevel and Active Plate Margins*, International Association of Sedimentologists Special Publication No. 12, 41-65, 1991.


Schematic stratigraphy of the Canterbury Basin, New Zealand, at various scales. A. Large-scale (first-order), post-rift stratigraphy. Onekakara, Kekenodon and Otakou groups were deposited during regional, tectonically driven transgressive, highstand and regressive phases, respectively. B. Seismic-scale stratigraphy. Successive clinoforms, some of which represent third- and fourth-order sequence boundaries, generally prograde over older, toe-of-clinoform sediment, but current reworking produces downlap onto seismic reflection Yellow in places. Limestones are, in part, distal facies of upper transgressive Onekakara Group and lower regressive Otakou Group and lie within the condensed section of the first-order sequence. Prominent seismic reflection Green is associated with the base of the limestones. C. Outcrop-scale stratigraphy across the Marshall Paraconformity, a regional omission surface within the limestone interval.


## Jan D. Garmany

Senior Research Scientist

Ph.D., University of California, San Diego, Scripps Institution of Oceanography (1978); B.S., California Institute of Technology (1972); e-mail: jan@utig.ig.utexas.edu


## Solid Earth Geophysics

Seismology, inverse theory, formation of the oceanic lithosphere, modeling and inference of the structure and dynamics of the earth.

### Research Interests

All knowledge of the earth's structure deeper than a few miles is indirect, and the sharpest tool available for these investigations is seismology. The application of seismology to the inference of oceanic crustal and upper mantle structure can lead to a better understanding of the workings of seafloor spreading. Associated with the generation of new crust are forces which leave a birthmark on the material just below the crust in the form of anisotropy. This property delineates the direction in which the material has been strained over great spans of time. Anisotropy is a key to defining ancient and current deformations of certain regions of the earth and is an important subject of recent investigations. The shallow machinery of the mid-ocean rises and the deep variability of the earth's mantle are dynamic processes that seismology can disclose. Recent work shows that melt may frequently arrive away from mid-ocean ridges, giving rise to melt sills at or near the base of young oceanic crust.

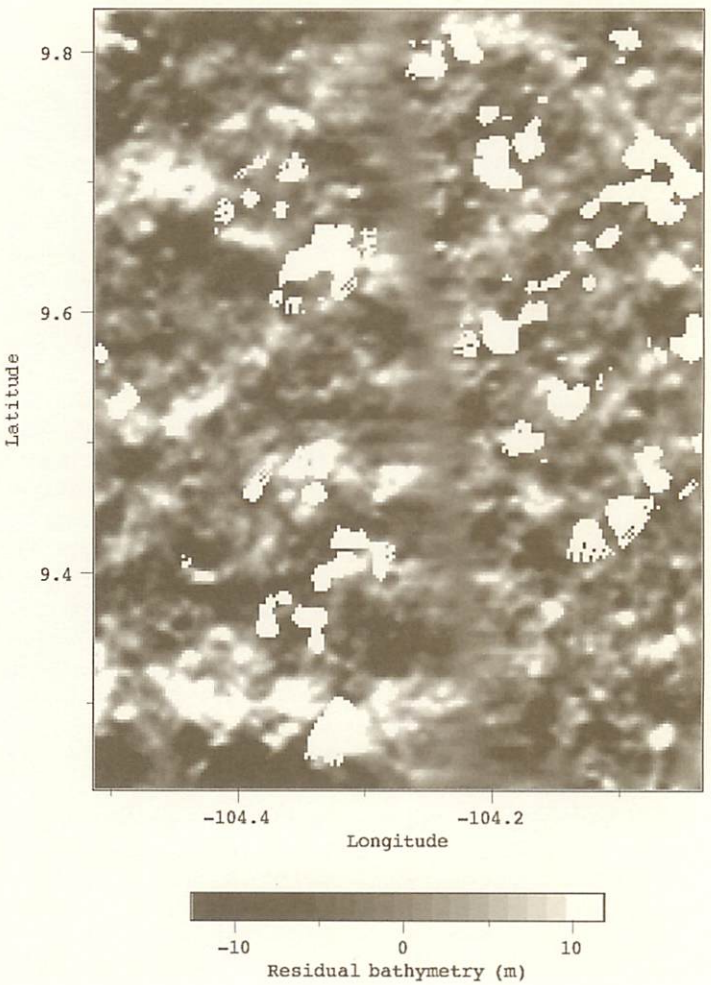
Since the methods of inference are indirect, it must also be determined to what extent the data are adequate to tell us something definite about the earth. This problem occurs in all branches of geophysics and in other sciences and is treated by inverse theory. This broad subject is a significant component of this research with applications to data analysis and experimental design.

### Selected Publications


Garmany, J., Accumulations of Melt at the Base of Young Oceanic Crust, *Nature, 340,* 628–632, 1989.

Garmany, J., Seismograms in Stratified Anisotropic Media: II. Uniformly Asymptotic Approximations, *Geophys. Jour., 92,* 379–389, 1988.

Garmany, J., Seismograms in Stratified Anisotropic Media: I. WKBJ Theory, *Geophys. Jour., 92,* 365–377, 1988.


Our 1993 seismological expedition to the East Pacific Rise has permitted us to map the abundance of melt at the base of the young oceanic crust there. Detection of this melt has important consequences for models of melt production and movement. The figure shows the correlation of melt location and the topography of the seafloor. We filtered bathymetric data to remove the strongly defined abyssal hill topography. The residual bathymetry is shown above, where deeper regions are darker. The white regions show where melt was observed. The association of melt is with deeper seafloor levels is statistically highly significant. Because the crust is supported buoyantly by the mantle (isostatically compensated), lows in seafloor elevation have corresponding highs in the Moho boundary that separates the crust and mantle. These high Moho spots serve to collect the low density melt. This strong association of topography and melt suggests that melt is quite mobile at the base of the crust.


## John A. Goff
Research Associate

Ph.D., Massachusetts Institute of Technology/Woods Hole Oceanographic Institution (1990); B.S., Brown University (1985)
e-mail: goff@utig.ig.utexas.edu


### Marine Geophysics and Statistical Morphology

Structural analysis of seafloor morphology based on sonar data; statistical characterization of geophysical fields, including abyssal hills, shelf bathymetry, sea ice draft, and crustal heterogeneity.

### Research Interests

Seafloor mapping techniques can be used to investigate the large- and fine-scale tectonic structure associated with plate boundaries and other submarine features. One research focus involves deep-water surveys of the mid-ocean ridge environment, exploring the process of abyssal hill formation, and the complex tectonic history of ridge reorganization and microplate formation. Another focus is on shallow-water surveys of active and passive continental margins (see figure below).

Statistical characterization provides quantitative tools necessary for relating complex morphology to the geological processes which form or interact with them. Active areas of abyssal hill research involve use of deep-towed swath bathymetry and side-scan sonar imagery to extend quantitative modeling to finer scales and to determine the contribution of surface volcanism, normal faulting, mass wasting and sedimentation to the total makeup of seafloor morphology. Statistical analysis of sea ice topography is aimed at unraveling the sequence of geologic events that modify any one patch of sea ice through time. Research in crustal heterogeneity is focused on developing appropriate statistical models of lithologic heterogeneity based on crustal exposures, and exploring through finite difference algorithms the relationship between such fields and the observed seismic wavefield.

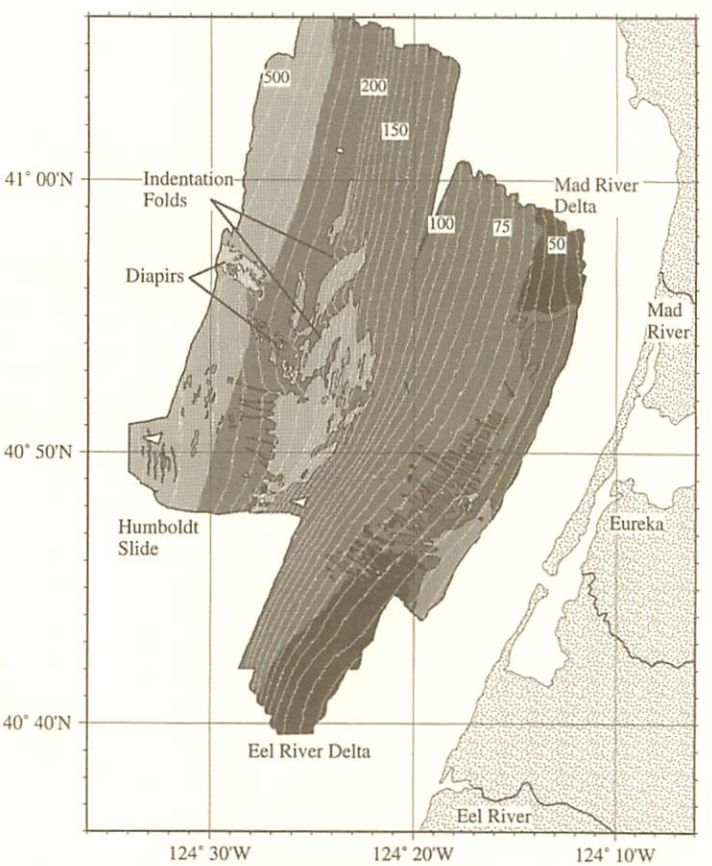
### Selected Publications


Goff, J. A., B. E. Tucholke, J. Lin, G. E. Jaroslow, and M. C. Kleinrock, Quantitative analysis of abyssal hills in the Atlantic ocean: A correlation between inferred crustal thickness and extensional faulting, *J. Geophys. Res.*,100, 22509-22522, 1995.

Goff, J. A., W. K. Stewart, H. Singh, and X. Tang, Quantitative analysis of sea ice draft: 2. Application of stochastic modeling to intersecting topographic profiles, *J. Geophys. Res.*, *100*, 7005-7017, 1995.

Goff, J. A., K. Holliger, and A. R. Levander, Modal fields: A new method for characterization of random velocity heterogeneity, *Geophys. Res. Lett.*, *21*, 493-496, 1994.

Goff, J, A., D. J. Fornari, J. R. Cochran, C. Keeley, and A. Malinverno, Wilkes transform system and "nannoplate", *Geology*, *21*, 623-626, 1993.


Structural interpretation of the northern California margin survey based on EM1000 side scan data. EM1000 bathymetric contours (meters) are overlain. Data were separated into 5 brightness classifications. While this procedure represents an oversimplification for many observations (for example, the Mad River delta is not as dark as the Eel River delta), it enables the viewer to easily identify the regional pattern of acoustic brightness variations through greatly enhanced contrast.


## Stephen P. Grand

Research Associate; also Associate Professor, Dept. of Geological Sciences

Ph.D., California Institute of Technology (1986); B.Sc., McGill University (1978); e-mail: steveg@maestro.geo.utexas.edu


### Seismology

Seismic structure of the upper mantle, inversion for lateral seismic variations in the Earth, attenuation structure of the mantle.

### Research Interests

Research interests involve determining the seismic structure of the Earth's mantle. This process includes seismic waveform modeling to determine detailed profiles of the upper mantle elastic velocities in various regions. Large scale tomographic inversions applied to travel time data determine the lateral variations throughout the mantle. Recently an inversion for mantle heterogeneity has been completed for the mantle beneath North and South America and the north Atlantic ocean. Seismic wave amplitude studies help determine the Q structure of the shallow mantle and show how it varies laterally. The ultimate goal of this work is to help determine the mineralogy and chemical composition of the mantle, the depth of tectonic plates, and the convection patterns in the mantle.

### Selected Publications

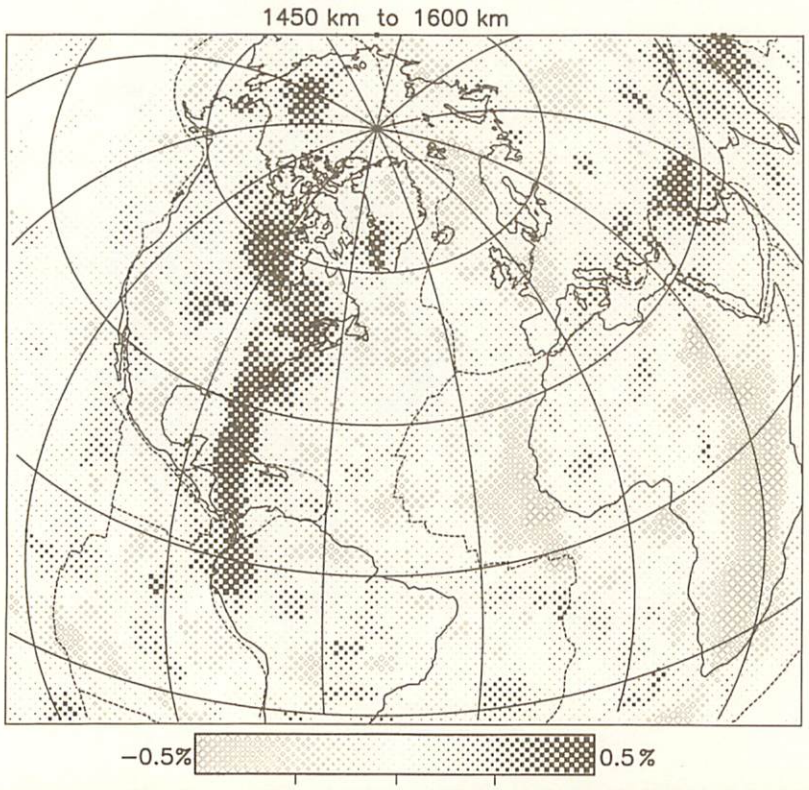

Garnero, E. J., S. P. Grand, and D. V. Helmberger, Low P-velocity at the base of the mantle, *Geophys. Res. Lett., 20*, 1843-1846, 1993.

Ding, X. Y., and S. P. Grand, Mantle Q Structure Beneath the East Pacific Rise, *J. Geophys. Res., 98*, 1973-1985, 1993.

Ding, X. Y., and S. P. Grand, Seismic structure of the deep Kurile subduction zone, *J. Geophys. Res., 99*, 23,767-23,786, 1994.

Nolet, G., S. P. Grand, and B.L.N. Kennett, Seismic heterogeneity in the upper mantle, *J. Geophys. Res., 99* 23,753-23,766, 1994.

Grand, S. P., Mantle shear structure beneath the Americas and surrounding oceans, *J. Geophys. Res., 99*, 11,591-11,621, 1994.


A map of seismic velocity variations from 1450 to 1600 km depth. The dark structure stretching from the Caribbean to northern Canada may be the remnants of the Farrallon plate that subducted 50 to 100 Ma.


## Kenneth H. Griffiths

Research Engineer

B.S.E.E., Duke University (1968); e-mail: ken@utig.ig.utexas.edu


UTIG multi-outrigger-bow heat flow instrument

### Instrumentation

Measurement and processing techniques for geophysical research. Shipboard/Aircraft systems and sensors.

### Research Interests

Research activities concentrate on applying modern technology to the solution of geophysical problems. Many of today's problems require measurements that are orders of magnitude more accurate than in the past, so scientists are turning to modern instruments, sensors, and computers to help solve these problems.

A basic example would be in the navigation of a ship at sea. Less than 20 years ago the uncertainty of ship's position was measured in miles. Today those errors are measured in meters, and we are working to reduce that even further. With this improvement in position information, many more sophisticated experiments become possible. In our airborne geophysics program in Antarctica, position accuracies of less than a meter are routinely achieved in order to process the gravity measurements.

The use of computers has had an equally strong impact on the ability to collect and process vast amounts of data. Without these tools we would be unable to analyze the data collected. Now, by taking the computer to sea, we have substantially improved the acquisition phase. The use of microprocessors has made instruments smaller and more reliable. The improvement in real time information available to the scientists on board ship has aided the decision-making necessary for a successful experiment.

The UTIG Ocean Bottom Seismometer (OBS) is an example of an instrument developed using this new technology. Each generation instrument is smaller, lighter and has a larger data capacity.

The Institute facilities are well equipped to continue this advance in state-of-the-art measurement and processing. These include capabilities in design, engineering, programming, and construction. Projects have ranged from small, portable instruments such as the UTIG multi-outrigger-bow heat flow instrument to complete shipboard and aircraft systems. The current SOAR Antarctic aircraft includes an ice-penetrating radar, gravimeter, magnetometer, laser altimeter and a full INS/GPS navigation system.

### Selected Publications


Nagihara, S., L. A. Lawver, B. Della Vedova, J. G. Sclater, K. H. Griffiths, and M. Wiederspahn, Multi-outrigger-bow Marine Heat Flow Instrument: Measurement Technique, *UTIG Technical Report No. 103*, March 1990.

Latham, G., P. Donoho, K. Griffiths, A. Roberts, and A. K. Ibrahim, The Texas Ocean-Bottom Seismograph, *Proc. Offshore Tech. Conf., OTC 3223*, 1467–1476, 1978.

Griffiths, K., and D. Hayes, ELTANIN Shipboard Data Processing, Antarctic Journal, December, 1969.


## Lawrence A. Lawver
Senior Research Scientist

Ph.D., University of California at San Diego, Scripps Institution of Oceanography (1976); B.S., Stanford (1970);
e-mail: lawver@utig.ig.utexas.edu

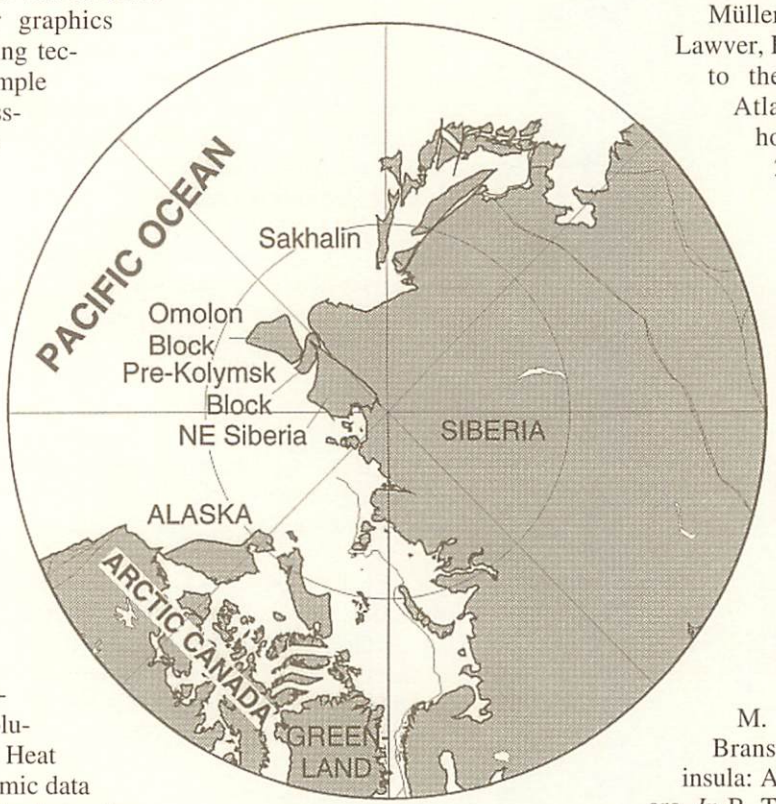

### Marine Geophysics

Plate tectonics; magnetics, gravity, heat flow, and seismic studies of marginal basins, paleogeographic reconstructions of polar regions, East Asia, and the Western Pacific. Development of paleoseaways and their impact on climate.

### Research Interests

As knowledge of the Earth increases, the need to develop new ways of looking at vast amounts of data increases. Computer graphics enable us to look at time-varying tectonic scenarios rather than simple snapshots. Evolutionary processes can be analyzed through the use of animation techniques.

Global databases that cover most of the major plate motions for the last 600 million years are used to define the problem areas of plate tectonics. The break-up of West Antarctica/New Zealand/Australia/East Antarctica and the agglomeration and extension of East Asia are two of the fundamental remaining problems. Paleomagnetic data, heat flow, over-the-ice geophysics, and computer graphics aid in understanding the break-up and evolution of the Antarctic region. Heat flow, marine magnetic, and seismic data are acquired during cruises to the Antarctic Peninsula and in the Ross Sea region. The tectonics of Southeast Asia, satellite gravity interpretation involving the margins of Antarctica, and the neotectonics of the Antarctic Peninsula/Southwest Scotia Sea are also studied. Future plans include mapping of Bransfield Strait looking for evidence of hydrothermal venting to the seafloor and seismic reflection and sidescan sonar work in the Southwest Scotia sea to look at the neotectonic evolution of the plate boundary between the Antarctic and Scotia plates.




Reconstruction of the Arctic Ocean at 130 Ma (Early Cretaceous). The Canada Basin begins to open as the North Slope Alaska-Chukotka block rotates counter-clockwise about a pole of rotation located near the present-day Mackenzie Delta.

### Selected Publications

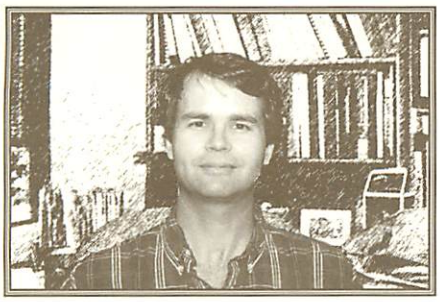

Lawver, L.A., L. M. Gahagan,, and M. F. Coffin, The development of paleoseaways around Antarctica, *In* Kennett, J. P. and D. A. Warnke, (eds.), The Antarctic Paleoenvironment: A Perspective on Global Change, *AGU Antarctic Research Series*, v. 56, 7-30, 1992.

Müller, R.D., J.-Y. Royer, and L. A. Lawver, Revised plate motions relative to the hotspots from combined Atlantic and Indian Ocean hotspot tracks, *Geology*, *21*, 275-278, 1993.

Lawver, L. A. and L. M. Gahagan, Subduction zones and the breakup of Pangea, *In* Stone, D. and K. Runcorn, (eds.), Flow and Creep in the Solar System: Observations, Modeling, and Theory, Kluwer Academic Publishers, Amsterdam, NATO ASI Series Vol. 139, 225-247, 1993.

Lawver, L. A., and R. D. Müller, The Iceland Hotspot Track, *Geology*, *22*, 311-314, 1994.

Lawver, L. A., R. A. Keller, M. R. Fisk, and J. A. Strelin, Bransfield Strait, Antarctic Peninsula: Active extension behind a dead arc, *In* B. Taylor (ed.), Back Arc Basins: Tectonics and Magmatism Volume, Plenum Press, Holland, 315-342, 1995.




## Paul Mann

Research Scientist

Ph.D., State University of New York at Albany (1983); B.A. Oberlin College (1978); e-mail: paulm@utig.ig.utexas.edu


### Tectonics

Geophysical studies of strike-slip and convergent margins; integration of offshore multichannel and sidescan data with onshore field observations; application of GPS and satellite remote sensing data to tectonic problems.

### Research Interests

Recent projects have focussed on:

- Collisions of island arcs with continents, seamounts, and oceanic plateaus in Cuba, Hispaniola, Puerto Rico trench, Kamchatka, Venezuela, Panama, Costa Rica and the Solomon Islands.
- Strike-slip faulting and basin formation in the circum-Caribbean and southwest Pacific.
- Paleoseismology and seismic potential of interplate strike-slip faults in the circum-Caribbean and southwest Pacific.

The overall goal of these geographically diverse studies is to relate plate margin structure and sedimentation to controlling relative plate motions. Methods of offshore study include sidescan sonar, multichannel seismic reflection, refraction, gravity, and magnetics. 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.

### Selected Publications


Mann, P., F. Taylor,, R. Edwards,, and T. Ku,, Actively evolving microplate formation by oblique collision and sideways motion along strike-slip faults: An example from the northeastern Caribbean plate margin, *Tectonophysics*, *246* 1-69, 1995.

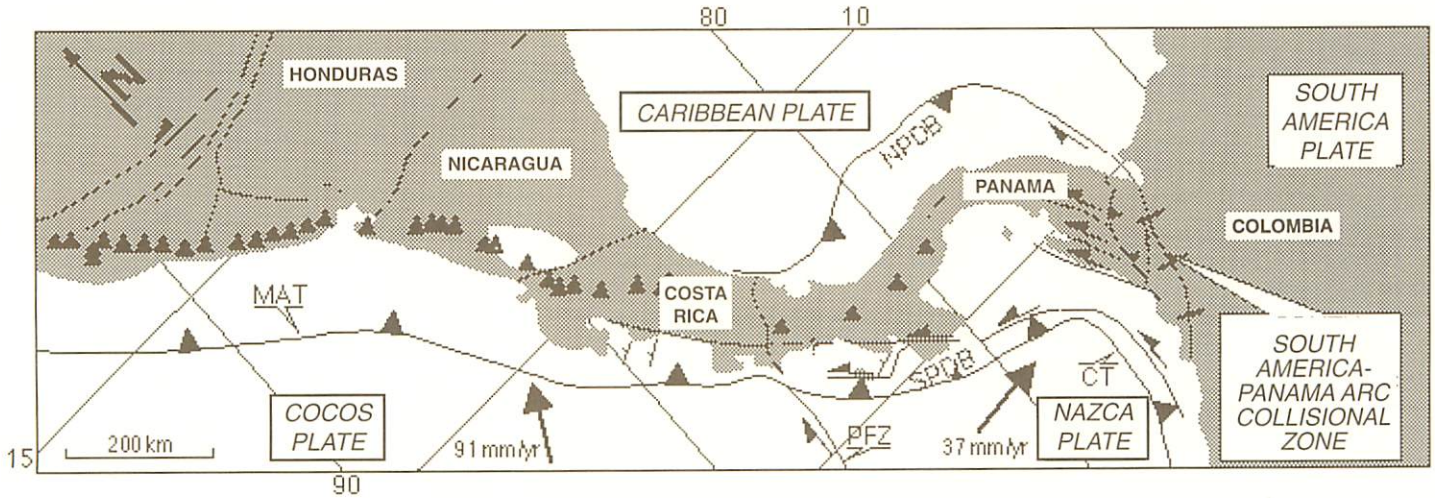
Lugo, J., P. and Mann,, Jurassic-Tertiary history of the Maracaibo basin, Venezuela, in *AAPG Memoir, Petroleum Basins of South America*, edited by A. Tankard, R. Suárez S., and J. J. Welsink, editors, pp. 699-725, 1995.

Mann, P., (Ed.), *Geologic and tectonic development of the Caribbean plate boundary in southern Central America*, GSA Special Paper 295, 349 pp., 1995.

Mann, P., G. Draper, and J. Lewis, (Eds.), *Geologic and tectonic development of the North America-Caribbean plate boundary in Hispaniola,* GSA Special Paper 262, 401 pp, 1991.

Prentice, C., P. Mann,, F. Taylor,, G. Burr,, and S. Valastro, Paleoseismicity of the North American-Caribbean plate boundary (Septentrional fault), Dominican Republic, *Geology*, *21*, 49-52, 1993.

Mann, P., S. Tyburski, and E. Rosencrantz, Neogene Development of the Swan Islands restraining-bend complex, Caribbean Sea, *Geology*, *19*, 823-826, 1991.


Tectonic setting of Central America, the Middle America trench (MAT), North Panama deformed belt (NPDB), South Panama deformed belt (SPDB), and Panama fracture zone (PFZ) from Kolarsky and Mann (GSA Special Paper 295, 1995). Black triangles represent active calc-alkaline volcanoes; arrows represent plate convergence directions with numbers indicating rates of relative plate motion in mm/yr from DeMets et al. (1990). Note oblique convergence predicted along the Nazca-Caribbean plate boundary along the southern margin of Panama.


## Kirk D. McIntosh

Research Associate

Ph.D., University of California, Santa Cruz (1992); B.Sc., Colorado School of Mines (1980); e-mail: kirk@utig.ig.utexas.edu


### Marine Geology and Geophysics

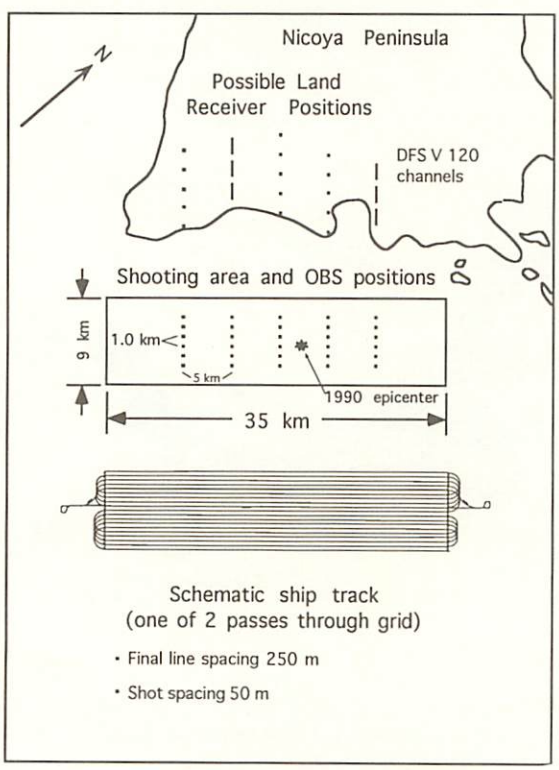
Structural geology and processes of convergent margins, seismic methods, marine geology.

### Research Interests

Structure and development of continental margins along convergent and transpressive plate boundaries are the primary research interests with structures and processes ranging from crustal scale to (large) outcrop scale that can be investigated using seismic reflection and refraction data, side scan 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, the role of fluids in accretionary prisms, and the nature of shallow subduction earthquakes. The primary study areas for this research are currently Costa Rica and Taiwan.

Costa Rica poses challenges with its variety of tectonic processes: seamount subduction, Cocos Ridge subduction, backarc thrusting, forearc extension, and a migrating triple junction. Researchers have 2-D and 3-D seismic reflection data available to study these processes and in 1995 acquired a large wide-angle seismic data set. The new data include detailed seismic refraction transects to determine the crustal geometry and velocity structure of Costa Rica and a 3-D OBS data set designed to image structures in the plate boundary zone that may be sites of repeated earthquake nucleation.

Taiwan is one of the few locations in the world with an ongoing continent-island arc collision. Seismic reflection data (six channel) and side scan sonar data have documented much of the shallow structure and processes of the developing collision south of Taiwan, but because these data do not provide information about the deep structure, new deep penetration seismic reflection and refraction data have been acquired in 1995. The new data will be used to identify the crustal thickening processes that precede and accompany the collision and also examine the complicated plate boundary zone east and northeast of Taiwan.




Detailed view showing approximate shot and receiver configurations for 3-D ocean bottom seismometer experiment off central Costa Rica. This experiment was conducted off the SE coast of the Nicoya Peninsula above the 1990 Cobano epicenter and may link subducting seamounts with earthquake activity.

### Selected Publications


McIntosh, K. D. and E. A. Silver, Using 3D seismic reflection data to find fluid seeps from the Costa Rica accretionary prism, *Geophys. Res. Lett.*, in press 1995.

McIntosh, K. D., E. A. Silver, T. H. Shipley, Evidence and mechanisms for forearc extension at the accretionary Costa Rica convergent margin, *Tectonics*, *12*, 1,380-1,392, 1993.

Shipley, T. H., K. D. McIntosh, E. A. Silver, D. Dean, and P. L. Stoffa, Three dimensional seismic imaging of the Costa Rica Accretionary Prism: Structural diversity in a small volume of the lower slope, *J. Geophys. Res.*, *97*, 4439-4459, 1992.

McIntosh, K. D., D. L. Reed, E. A. Silver, and A. Meltzer, Deep structure and basin inversion along the central California continental margin from the EDGE seismic profile RU-3, *J. Geophys. Res.*, *96*, 6459-6473, 1991.

Reed, D. L., N. Lundberg, C.-S. Liu,, and K. D. McIntosh, Evidence of frontal thrust propagation and fluid migration in an offscraped sedimentary basin sequence: Offshore Taiwan, *Proc. TAICRUST Workshop*, Taipei, Taiwan R.O.C., 103-106, 1991.


## Yosio Nakamura

Senior Research Scientist; also Professor, Dept. of Geological Sciences

Ph.D., Pennsylvania State University (1963); M.S., B.S., Tohoku University (1958, 1956); e-mail: yosio@utig.ig.utexas.edu


### Geophysics

Terrestrial and extraterrestrial seismology; properties of inner solar system bodies; marine seismic instrumentation and observation.

### Research Interests

The Earth is but a planetary body at a specific stage of its evolution. Observations we make of the Earth face the inescapable limitation of the particular environment and conditions in which we find our Earth today. It would not be possible to conduct a controlled experiment to test various hypotheses by subjecting the whole Earth to a different environment or placing it in a different evolutionary stage. Fortunately, however, there are several other planetary objects nearby in vastly different environments from ours, and they provide us with some quite valuable information.

One such object close to us is the Moon. The extensive data collected during and following the Apollo lunar landing project by a network of seismic stations on the Moon gave us the first direct seismic observation of an extraterrestrial object. Contrary to most earlier expectations, the Moon was found to be not so dead after all. Over 12,000 moonquakes were observed during the eight years of the network operation. Many of them were very deep, about halfway to the center of the Moon, but a small number of rather strong quakes occurring at shallow depths were also detected, suggesting continuing tectonic activity. From the recording of these seismic events, a detailed internal structure of the Moon could be inferred.

The Earth remains an interesting planetary body. The vast floor of the ocean, which was not easily accessible until recently, is now readily available to direct observation with ocean-bottom seismic stations. The ocean-bottom seismometers have now been developed sufficiently so that extensive collections of high quality seismic data can be acquired both in seismic exploration of the sub-ocean structures and in earthquake studies.

### Selected Publications

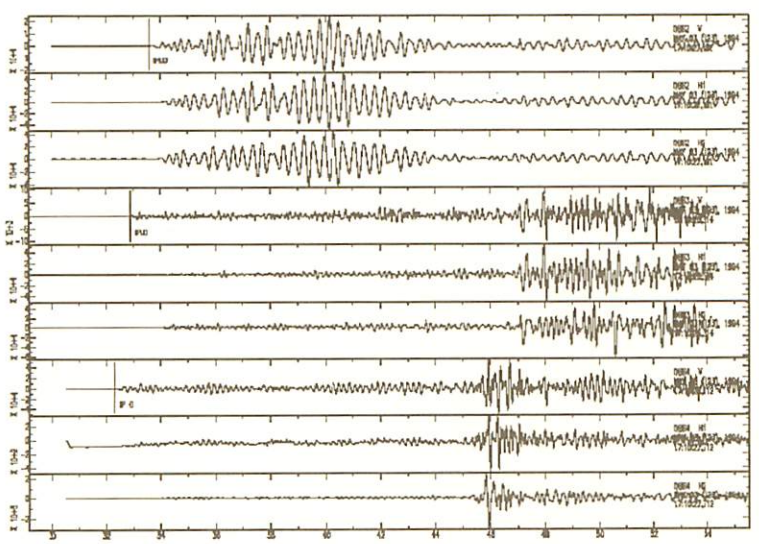

Oberst, J., and Y. Nakamura, Search for clustering among the meteoroid impacts detected by the Apollo lunar seismic network, *Icarus*, *91*, 315-325, 1991.

Frohlich, C., R. Louat, and Y. Nakamura, Earthquake Activity in the Southern Vanuatu Arc Recorded by the Texas Digital OBS, *Mar. Geophys. Res.*, *12*, 253-267, 1990.

Nakamura, Y., D. S. Sawyer, F. J. Shaub, K. MacKenzie, and J. Oberst, Deep Crustal Structure of the Northwestern Gulf of Mexico, *Trans., Gulf Coast Assoc. Geol. Soc.*, *38*, 207-215, 1988.

Ebeniro, J. O., Y. Nakamura, D. S. Sawyer, and W. P. O'Brien, Jr., Sedimentary and Crustal Structure of the Northwestern Gulf of Mexico, *J. Geophys. Res.*, *93*, 9075–9092, 1988.

Nakamura, Y., P. L. Donoho, P. H. Roper, and P. M. McPherson, Large-Offset Seismic Surveying Using Ocean-Bottom Seismographs and Air Guns: Instrumentation and Field Technique, *Geophysics*, *52*, 1601–1611, 1987.

Micro-earthquake signals recorded by a network of UTIG-designed ocean-bottom seismographs (OBS) set up on the sea floor of the Okinawa Trough in 1994. Shown on this figure, from top to bottom, are three traces representing vertical and two horizontal components of ground motion for each of three stations, 2, 3, and 4. The arrival times of seismic phases measured on this and similar OBS seismograms were significantly different from those predicted from earthquake locations determined from land station networks in Taiwan to the west and the Ryukyu Islands to the east alone, leading to a better characterization of the subducting Philippine plate deep underneath the trough.


## Mrinal K. Sen

Research Scientist

Ph.D., University of Hawaii at Manoa, Hawaii Institute of Geophysics (1987); M.Sc., B.Sc., Indian School of Mines (1979,1977)
e-mail: mrinal@utig.ig.utexas.edu


### Seismology & Exploration Geophysics

Wave propagation in heterogeneous media; seismic data processing and analysis; nonlinear geophysical inversion; parallel computing; seismic anisotropy.

### Research Interests

Current interests include development of new techniques for prestack migration of seismic data in laterally varying media in three dimensions and nonlinear inversion techniques for application to geophysical data.

Two prestack migration methods are currently being developed. One is applicable in the plane wave domain and is based on the principle of plane wave Kirchhoff formulation. The method is valid for general laterally varying media and is ideally suited for parallel computer architecture. Separate plane wave sections can be migrated independently and the images can be compared to obtain velocity estimates. The second method is a conventional Kirchhoff 3-d migration method and relies on the rapid calculation of travel time. Here constant offset sections can be migrated independently and the images can be compared to obtain migration velocities.

Development of nonlinear inversion methods based on simulated annealing (SA), genetic algorithms (GA) and mean field annealing has been the major area of interest. Several new concepts have been introduced in the development of the algorithms and they have been applied to a wide variety of geophysical problems such as seismic waveform inversion, AVO analysis, velocity estimation in 2-D, reservoir characterization, seismic deconvolution, inversion of resistivity data in 1-D and 2-D and magnetotelluric data inversion.

### Selected Publications


Sen, M. K., and Stoffa, P. L., *Global Optimization Methods in Geophysical Inversion*, Elsevier Science Publishing Co., The Netherlands, 1995.

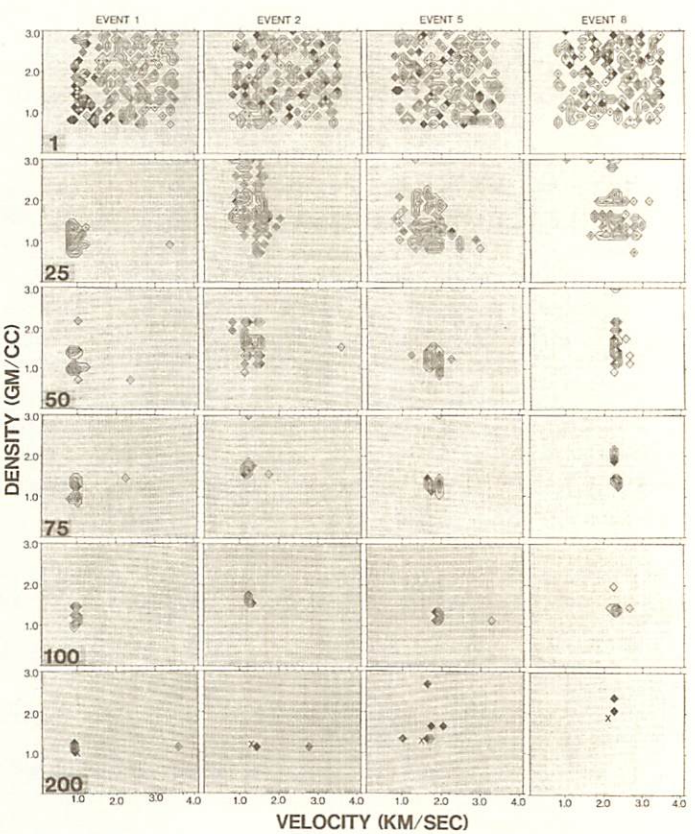
Sen, M. K., A. Duttagupta, P. L. Stoffa, L. Lake, and G. Pope, Stochastic reservoir modeling by simulated annealing and genetic algorithms, *SPE Formation Evaluation*, March, 49-55, 1995.

Sen, M. K., and P. L. Stoffa, Rapid sampling of model space using genetic algorithms: examples from seismic waveform inversion, *Geophys. J. Int.*, *108*, 281-292, 1992.

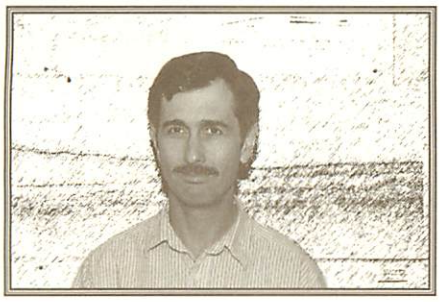
Stoffa, P. L., and M. K. Sen, Nonlinear multiparameter optimization using genetic algorithms: Inversion of plane wave seismograms, *Geophysics*, 56, 1794-1810, 1991.

Sen, M. K., and P. L. Stoffa, Nonlinear one-dimensional seismic waveform inversion using simulated annealing, *Geophysics*, *56*, 1624-1638, 1991.

Sen, M. K., and L. N. Frazer, Multifold Phase Space Path Integral Synthetic Seismograms, *Geophys. J. Int.*, *104*, 479-487, 1991.


Example from genetic inversion of seismic waveform data. The figure shows how the genetic algorithm searches the model space; in this case it consists of velocity and density of a 10 layer earth model. In the initial generations, models are picked at random from the entire model space. In the later generations, the processes of crossover and mutation enable the algorithm find the true solution (shown by a cross in the lowest panel).




## Thomas H. Shipley

Senior Research Scientist

Ph.D., Rice University (1975); B.S. California State University at Hayward (1971); e-mail: tom@utig.ig.utexas.edu


### Marine Geology and Geophysics

Convergent margin processes, seismic reflection methods, marine geology.

### Research Interests:

Investigations of fluids in accretionary prisms are becoming more focused with the appreciation of the crucial role of fluids in controlling structural evolution. It has been known for a long time that super-hydrostatic fluid pressure greatly reduces rock strength and therefore influences fault mechanics. The location of fluids and how they propagate in accretionary prisms controls the distribution of low shear strength fault zones. From rock outcrops and drilling in modern accretionary prisms there is evidence for multiple episodes of fracturing and vein filling, attesting to episodic fluid flow and suggesting that low-strength fault zones may be transient. In accretionary prisms the dynamics of fluid flow are complicated by both spatial and temporal effects but dimensions of possible pathways and permeability are barely known. Acquisition of a 3-D seismic reflection data volume of the accretionary prism off Barbados was designed to seismically examine some of these issues. The seismic reflections image the low-angle detachment fault between the Caribbean and Atlantic and characterize spatial variations of fault zone properties. There is good seismic evidence for a heterogeneous fault plane of very high porosity (and thus probably low-strength) punctuated with areas of low porosity (and thus higher strength). The JOIDES Ocean Drilling Program (Leg 156) confirmed and calibrated the seismic images by drilling through the fault zone to measure *in situ* fluid pressures and permeability as well as sample pore-fluids to help determine migration paths. The combination of the drilling experiments and seismic reflection data will provide a significant improvement in understanding the relationship between hydrologic and tectonic processes at accretionary margins. Other investigations are underway in the Middle America Trench, South Shetland Trench, the Solomons and Costa Rica.

### Selected Publications

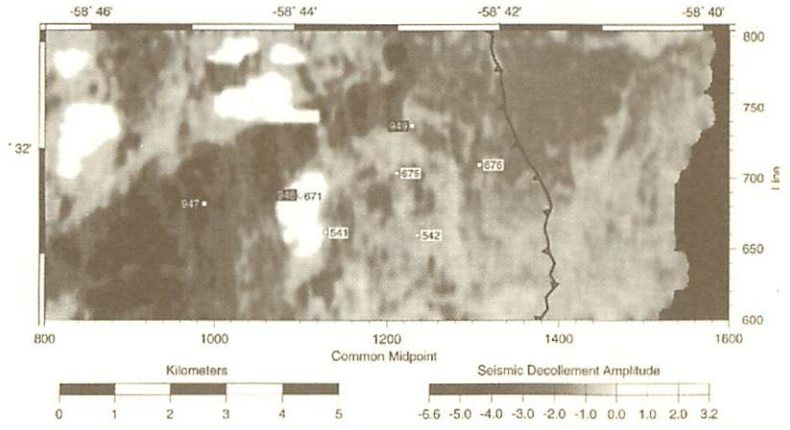

Shipley, T. H., G. F. Moore, N. L. Bangs, J. C. Moore, and P. L. Stoffa, Seismically inferred dilatancy distribution, northern Barbados Ridge décollement: Implications for fluid migration and fault strength, *Geology*, *22*, 411-414, 1994.

Wood, W., P. Stoffa, and T. Shipley, Quantitative detection of methane hydrate through high-resolution seismic velocity analysis, *J. Geophys. Res., 99*, 9681-9695, 1994.

McIntosh, K, E. Silver, and T. Shipley, Evidence and mechanisms for forearc extension at the accretionary Costa Rica convergent margins, *Tectonics*, *12*, 1380-1392, 1993.

Shipley, T.H., L. Abrams, Y. Lancelot, and R. Larson, Late Jurassic-Early Cretaceous oceanic crust, Mid-Cretaceous volcanic sequences of the Nauru Basin, Western Pacific, *In* Pringle, M., W. Sager, B. Sliter and S. Stein, (eds.), The Mesozoic Pacific: Geology, Tectonics, and Volcanism, Geoph. Mono. 77, 103-119, 1993.

Shipley, T.H., K. McIntosh, E. Silver, and P. Stoffa, Three dimensional seismic imaging of the Costa Rica Accretionary Prism: Structural diversity in a small volume of the lower slope, *J. Geophys. Res.*, *97*, 4,439-4,459, 1992.


A three-dimensional seismic data set imaged a portion of the plate-boundary detachment fault (décollement) between the Caribbean and North America plates. The figure portrays the spatial pattern of variations in the peak amplitude associated with the fault reflection and thus fault zone properties. Positive values represent normal velocity-density increase with depth while negative values indicate a reversal in velocity-density. The normal polarity patches are normally pressured, higher-strength regions on the fault surface, while the reversed polarity patches are high-pressured, low-strength areas undergoing dilation.


## Paul L. Stoffa

Director, Institute for Geophysics and Carlton Centennial Professorship in Geophysics, Department of Geological Sciences

Ph.D., Columbia University (1974); B.S., Rensselaer Polytechnic Institute (1970); e-mail: pauls@utig.ig.utexas.edu


### Marine Seismology

One- and two-dimensional signal processing, acoustic and elastic wave propagation, multichannel seismic acquisition and processing system, modeling and inversion of geophysical data, parallel computers for use in seismic processing.

### Research Interests

Answers to many complex geological problems often can be obtained from seismic measurements. Understanding tectonic processes at both active and passive rifted continental margins requires knowledge of their deep geological structure. Overall research has been focused on developing new seismic data acquisition and processing methods that can be used to address these and other specific geologic problems; for example, mapping the transition from continental to oceanic crust requires the ability to probe beneath large accumulations of sediment to depths often in excess of 15 to 20 km. 2D and 3D seismic acquisition combined with pre- and post-stack migration methods of the original or plane wave decomposed data have been developed that account for vertical and lateral velocity variations. Both surface and ocean bottom seismic data can be used for these migration algorithms to form images of the subsurface. To define the subsurface velocity structure, nonlinear optimization procedures such as genetic algorithms and very fast simulated annealing have been developed 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 making them within reach of solving practical problems.

### Selected Publications

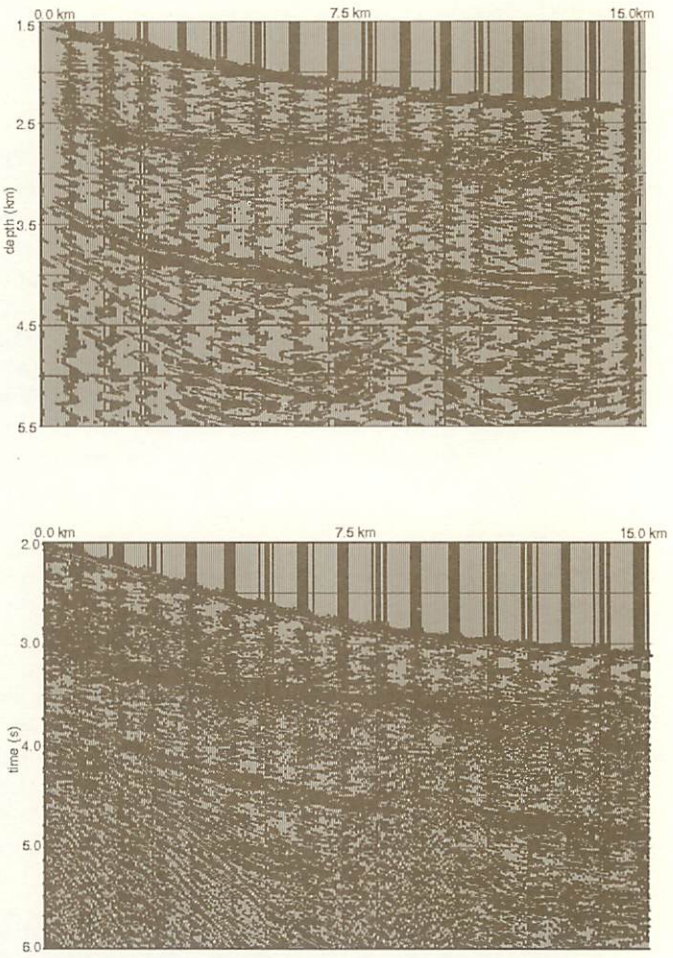

Sen, M. K., and P. L. Stoffa, *Global Optimization Methods in Geophysical Inversion*, as part of Advances in Exploration Geophysics Series, Elsevier Publishing Co., The Netherlands, 1995.

Stoffa, P. L., J. T. Fokkema, R. de Luna Freire, and W. Kessinger, Split-step Fourier Migration, *Geophysics*, *55*, 410-421, 1990.

Faria, E., and P. L. Stoffa, Traveltime Computation in Transversely Isotropic Media, *Geophysics*, *59*, 272-281, 1994.

Sen, M. K., and P. L. Stoffa, Rapid sampling of model space using genetic algorithms: Examples from seismic waveform inversion, *Geophys. J. Int.*, *108*, 281-292, 1992.

Stoffa, P. L., and M. K. Sen, Nonlinear multiparameter optimization using genetic algorithms: Inversion of plane wave seismograms, *Geophysics*, *56*, 1794-1810, 1991.


Pre-stack depth migration images correspond to the stacked data in the upper figure. The velocities used for the pre-stack migration were obtained using a nonlinear optimization method known as very fast simulated annealing (from the Ph.D. dissertation of Carlos L. Varela).


## Fumiko Tajima

Research Scientist

Ph.D., M.S., B.S., University of Tokyo (1982, 1972, 1970)
e-mail: fumiko@utig.ig.utexas.edu


### Seismology and Geophysics

Earthquake sources; seismicity; upper-mantle and transition zone structure; seismological data base.

### Research Interests

Most research projects have involved the study of earthquake source characteristics in major subduction zones as well as in continental tectonic regions worldwide. Recently research interests are focusing more on the upper mantle transition zone structure which is fundamentally important for understanding the mode of mantle convection as well as the chemical composition of the Earth. This project is being carried out using triplicate regional broad-band waveform data in collaboration with Steve Grand. A co-authored paper on this subject presents a narrower high velocity anomaly for the transition zone associated with the southern Kurile subduction zone than had been implied with more ambiguities by the recent ISC P-wave travel-time tomography models.

The past decade was a very special era for earthquake seismology, characterized by rapid globalization. Close contact has been kept with the Incorporated Research Institutions for Seismology (IRIS), an initiative by the U.S. scientists for global seismology since its inception. A major commitment and effort resulted in the selection of UTIG to host the Data Management Center (DMC) of IRIS during the interim system development (1988-1991). Recent efforts have culminated in the purchase and installation of the new UTIG IRIS station at Hockley as part of the Global Seismographic Network (GSN) in collaboration with the National Seismographic Network (NSN) of the U. S. Geological Survey. This is the first GSN station in Texas and provides unique high quality broad-band digital data to users worldwide. Waveform data recorded by this station and some other regional broad-band stations will be used to image the upper mantle structure in the Gulf of Mexico and Texas.

### Selected Publications


Tajima, F., and M. Kikuchi, Tectonic Implications of the Seismic Ruptures Associated with the 1983 and 1991 Costa Rica Earthquakes, Geologic and Tectonic Development of the Caribbean Plate Boundary in Southern Central America: Boulder, CO., Geol. Soc. Am., Special Paper 295, 327-340, 1995.

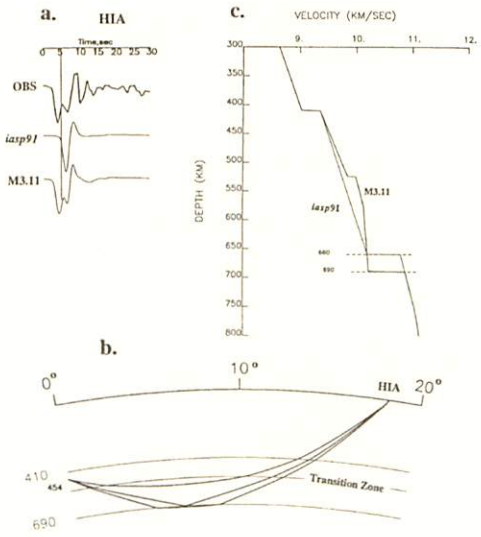
Tajima, F., and E. A. Okal, The 1977 Three Kings Ridge Earthquake (Ms=6.7): Broad-Band Aspect of the Source Rupture, Phys. Earth Planet. Int., 89, 109-125, 1995.

Zhou, R., F. Tajima and P. L. Stoffa, Application of Genetic Algorithms to Constrain Near-Source Velocity Structure for the 1989 Sichuan Earthquakes, Bull. Seismo. Soc. Am., 85, 590-605, 1995.

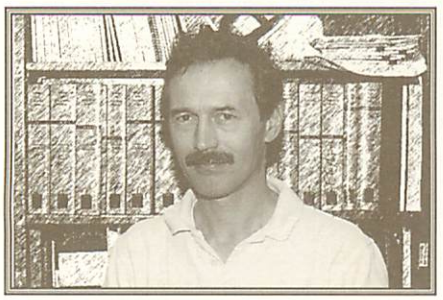
Zhou, R., F. Tajima and P. L. Stoffa, Earthquake Source Parameter Determination Using Genetic Algorithms, Geophys. Res. Lett., 22, 517-520, 1995.

Tajima, F., and S. P. Grand, Evidence of High Velocity Anomalies in the Transition Zone Associated with Southern Kurile Subduction Zone, Geophys. Res. Lett., 22, 3139-3142, 1995.

Zhou, R., S. P. Grand, F. Tajima and X. Y. Ding, High velocity zone beneath the southern Tibetan plateau from P-wave differential travel-time data, Geophys. Res. Lett., 23, 25-28, 1996.


Seismic studies of the upper mantle transition zone have played an important role in trying to determine the fate of subducted slabs at depths near 660 km. Broad-band waveforms observed at regional stations contain excellent information concerning upper mantle transition zone structure associated with subducted zones. (a) (top trace) P waveform observed at station HIA, one of the Chinese Digital Seismographic Network stations, which is located at about 18° from a deep focus event (~454 km) in the southern Kurile subduction zone. The vertical line indicates the theoretical arrival time based on *iasp91* model. Note the fast arrival anomaly and triplication of the waveform. Synthetic waveforms calculated using a reflectivity code with *iasp91* model (middle trace) and with our new model (bottom trace). (b) Ray paths of triplication to station HIA using M3.11 which is characterized with high velocity anomaly in the transition zone and depression of the "660" discontinuity to 690 km as is shown in (c) (from Tajima and Grand, 1995)




## Frederick W. Taylor

Senior Research Scientist.

Ph.D., Cornell University (1978); M.S., Brown University (1974); B.S., University of North Carolina (1971); e-mail: fred@utig.ig.utexas.edu


### Neotectonics, Paleoseismology, Paleoclimatology

Studies of Quaternary and contemporary crustal motions and paleoclimatology in the Southwest Pacific and Indonesian Regions.

### Research Interests

Current research interests are quite multi-disciplinary, but a common theme is the use of corals and reefs as recorders of earth history.

Neotectonics deals with crustal deformation, earthquakes, and their underlying causes. Even in the 19th century, Charles Darwin recognized that coral reefs indicate vertical crustal movements with barrier reefs forming on subsiding coasts and marine terraces on uplifting coasts. On time scales of thousands of years and longer, rates of vertical deformation are determined by isotopic dating of coral samples from measured heights above sealevel. For the past few decades, the timing and amounts of vertical tectonism are determined by counting annual density growth bands in coral skeletons that were affected by vertical movements relative to sealevel. By using both approaches, we can document the long-term accumulation as well as the increments of vertical deformation that integrate to produce the longer-term tectonic deformation.

In complementary studies, the Global Positioning System (GPS) is used to measure the horizontal plate motions that drive earthquakes and deformation at the edges of SW Pacific tectonic plates. Some of the results are startling: 24 cm/yr convergence rates of the Pacific plate at the northern Tonga arc and fragmentation of the New Hebrides arc where a large segment of the arc is being shoved eastward at rates of 4 - 8 cm/yr due to impingement of the subducting d'Entrecasteaux ridge against the forearc.

Fortunately for paleoclimate studies, chemical variations in the annual density bands in corals (similar to tree rings) precisely record sea surface temperatures. The ratios of $^{18}O/^{16}O$, Sr/Ca, and U/Ca are analyzed in a series of tiny samples taken along the growth direction in a coral skeleton. Variations in these ratios reflect temperatures so precisely that the seasonal cycle is clear even where the seasonal variation is only $2^{o}$ C. This method is most often applied to living corals, but by drilling deep into coral reefs, we obtain coral samples that grew during the last glacial period about 20,000 years ago. Plans are to obtain cores and climate records from living and fossil corals at sites from New Caledonia northward across the heart of the equatorial Western Pacific Warm Pool. The resulting records of tropical ocean temperatures will improve the basis for predicting how climate may change in the future.

Photograph: Drilling into a live *Porites lutea* coral head on the barrier reef near Noumea, New Caledonia, Southwest Pacific; September, 1992. Cores from this coral colony provide a record of sea surface temperatures from A.D. 1658 to 1992. This record extends well back into the Little Ice Age, a period of cooler global climate.

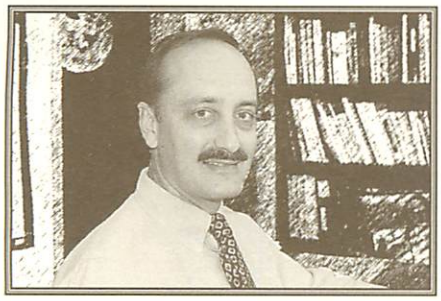
### Selected Publications


Min, G.R., Edwards, R.L., Taylor, F.W., Recy, J., Gallup, C.D., and Beck, J.W., 1995, Annual cycles of U/Ca in coral skeletons and U/Ca thermometry: Geochim. *Cosmochim. Acta.*,59, 2025-2042.

Taylor, F. W., Quinn, T. M., Gallup, C. G., and Edwards, R. L., 1994, Quaternary plate convergence rates at the New Hebrides arc from the chronostratigraphy of Bougainville Guyot (Site 831), *Proc. ODP, Sci. Results*, 134, College Station, TX (Ocean Drilling Program) 47-57.

Bevis, M., Taylor, F.W., Schutz, B.E., Recy, J., Isacks, B.L., Helu, S., Singh, R., Kendrick, E., Stowell, J., Taylor, B., and Calmant, S., 1995, Geodetic observations of convergence and back-arc spreading at the Tonga island arc, *Nature,* 374, 249-251.

Taylor, F. W., R. L. Edwards, G. J. Wasserburg, and C. Frohlich, 1990, Seismic Recurrence Intervals and timing of aseismic subduction inferred from emerged corals and reefs of the central New Hebrides (Vanuatu) Island Arc, *J. Geophys. Res.*, 95, 393-408.




## Clark R. Wilson

Senior Research Scientist and Wallace E. Pratt Professor of Geophysics, Dept. of Geological Sciences

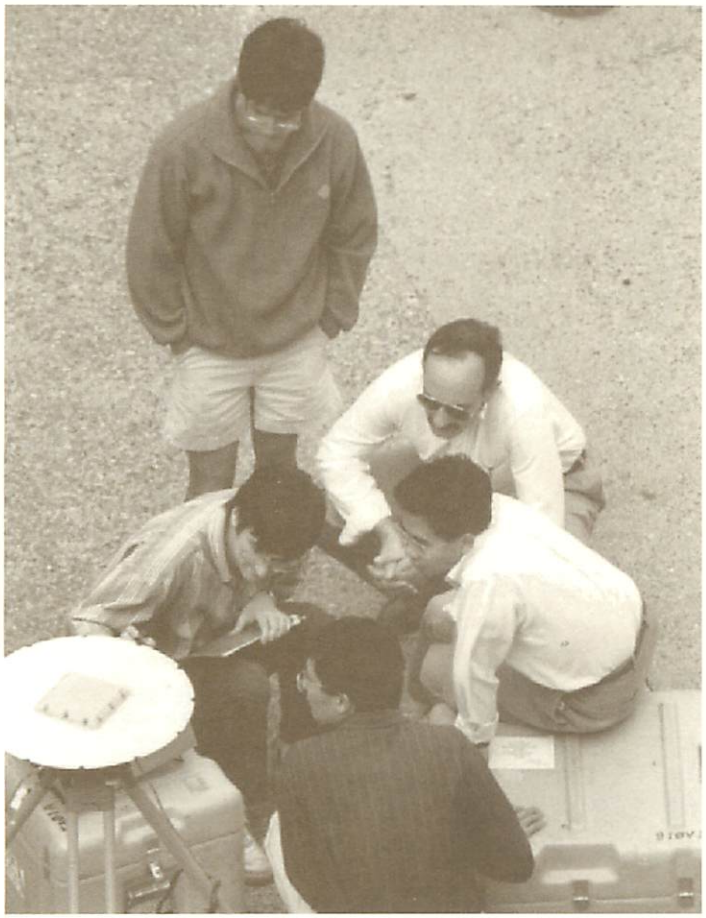
Ph.D., MS, (Earth Sciences) Scripps Institution of Oceanography, University of California (1975, 1973); B.A. (Physics); Revelle College, University of California, San Diego (1970); e-mail: clarkw@maestro.geo.utexas.edu


### Geophysics

Geodesy, seismology, and exploration geophysics

### Research Interests

Clark Wilson's research activities are centered around the use of space geodesy to observe variations in the Earth system. As part of a NASA Earth Observing System interdisciplinary investigation, he is examining long term variability in the oceans and atmosphere using changes in the Earth's rotation and gravity field. Other projects included investigation of causes of short period (sub-annual) polar motion and Earth rotation changes and the establishment of a permanent Global Positioning System observatory in West Texas.



Clark Wilson oversees the graduate geodesy class learning the use of the UTIG Trimble GPS receivers.

### Selected Publications


Hoar, T., C. and Wilson, Geosat Observations of sealevel Response to Barometric Pressure Forcing, *Geophys. Res. Lett.*, *21*, 2515-2518, 1994.

Kuehne, J., S. Johnson, and C. Wilson, Atmospheric Excitation of non-seasonal Polar Motion, *J. Geophys. Res.*, *98*, 19973-19978, 1993.

Wilson, C., Contributions of Water Mass Redistribution to Polar Motion Excitation, Contributions of Space Geodesy to Geodynamics, *AGU Geophys. Monograph Series*, *24*, 77-82, 1993.

Kuehne, J., C. and Wilson, Terrestrial Water Storage and Polar Motion, *J. Geophys. Res.*, *96*, 5337-4345, 1991.

Wilson, C., "Polar Motion and Earth Rotation", in Encyclopedia of Earth System Science, W. Nierenberg, editor, Academic Press, 1991.


## Lian-She Zhao

Research Associate

Ph.D., California Institute of Technology (1992); M.Sc., Institute of Geophysics, Chinese Academy of Sciences (1985); B.Sc., China University of Science and Technology (1982); e-mail: lianshe@utig.ig.utexas.edu


### Geophysics

Seismology, theoretical and observational. Earth structure, physics of earthquakes, and tectonics.

### Research Interests

Any part of a recorded seismogram is influenced by Earth structure and the seismic source, thus providing important information about tectonics, geodynamics, and the Earth's composition. Characteristics of Earth structure and the seismic source can be obtained from analyzing seismograms using various techniques. One of the most efficient techniques is the synthetic seismogram method, in which synthetically generated seismograms are compared directly with recorded seismograms in the time domain.

The advent of the modern very broadband seismographs requires more advanced techniques to decipher their recordings. All techniques for generating synthetic seismograms are based on solutions of the wave propagation equation. Unfortunately, the wave equation has no analytical solutions, except in a few cases where the Earth's structure is homogeneous, isotropic, flat or perfectly spherical. Some approximate solutions are available in the literature, but they are not useful in practice. Knowledge of how the more realistic Earth structures affect waveforms becomes increasingly important, because the Earth's overall structure is fairly well known from the past few decades of research. Every effort on this line, theoretical and numerical, would be useful as long as its result can help to understand the real Earth.

Current research focuses on: 1) developing synthetic seismogram techniques and techniques for travel time inversion and waveform inversion; 2) understanding the seismic velocity structure of the Earth, including crust, mantle and core, using synthetic seismogram methods, travel time tomography, and waveform inversion; 3) understanding the characteristics of seismic sources; 4) understanding tectonics and geodynamics of the Tibetan Plateau from the studies of the seismic velocity structures and source characteristics of Tibetan earthquakes; 5) searching for anisotropy from travel times and waveforms.

### Selected Publications


Zhao, L.-S., and D. V. Helmberger, Source estimation from broadband regional seismograms, *Bull. Seism. Soc. Am. 84,* 91-104, 1994.

Zhao, L.-S., Lateral variations and azimuthal isotropy of Pn velocities beneath Basin and Range Province, *J. Geophys. Res., 98,* 22,109-22,122, 1993.

Zhao, L.-S., and J. Xie, Lateral variations of the compressional velocity structure beneath the Tibetan Plateau from Pn travel time inversion, *Geophys. J. Int., 115,* 1,070-1,084, 1993.

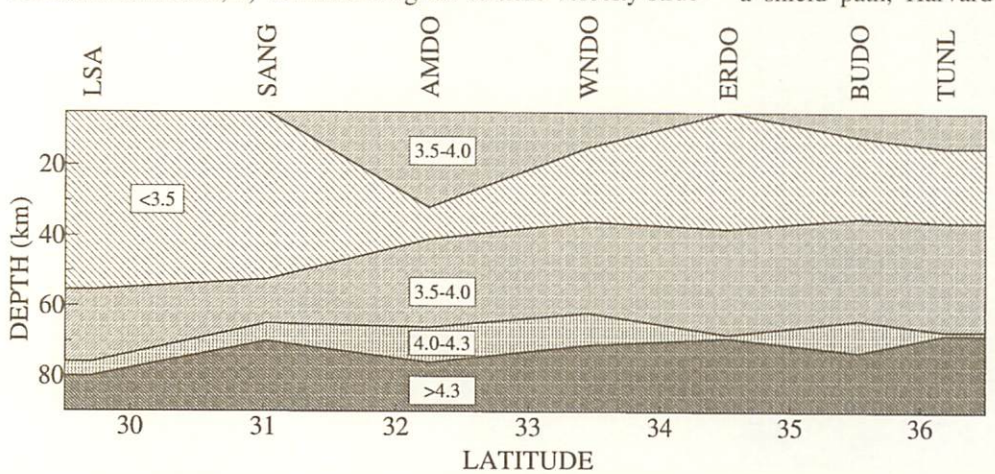
Zhao, L.-S., and D. V. Helmberger, Upper mantle compressional velocity structure beneath the Northwest Atlantic Ocean, *J. Geophys. Res., 98,* 14,185-14,196, 1993.

Zhao, L.-S., and D. V. Helmberger, Source retrieval from broadband regional seismograms; Hindu Kush region, *Phys. Earth Planet.* Int,, *78,* 69-95, 1993.

Zhao, L.-S., and D. G. Harkrider, Wavefields from an off-center explosion in an embedded solid sphere, *Bull. Seism. Soc. Am., 82,* 1927-1955, 1992.

Zhao, L.-S., and D. V. Helmberger, Broadband modeling along a shield path, Harvard recording of the Saguenay earthquake, *Geophys. J. Int., 105,* 301-312, 1991.

Zhao, L.-S., D.V. Helmberger, and D. G. Harkrider, Shear-velocity of the crust and upper mantle beneath Tibetan Plateau and southern China, *Geophys. J. Int., 105,* 713-730, 1991.


The shear velocity structure beneath the Tibetan Plateau from inversion of teleseismic bodywave waveforms. The numbers in boxes are velocities in km/sec.

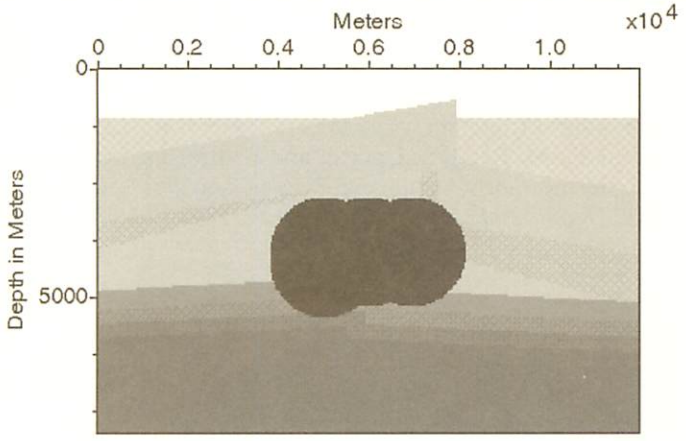

## R. Phillip Bording

Postdoctoral Fellow

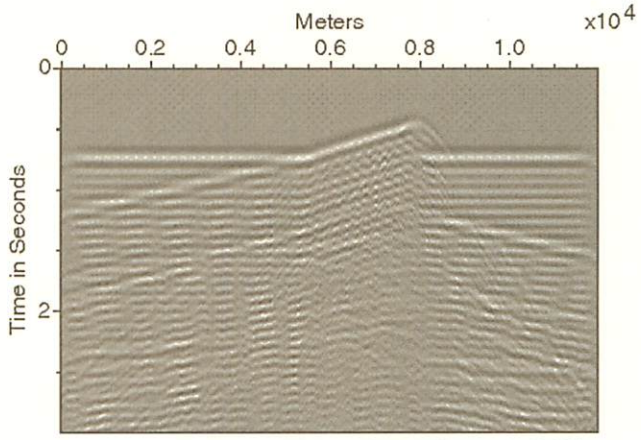
Ph.D., University of Tulsa (1995); M.S., University of Alabama in Huntsville (1984); B.S. Missouri School of Mines and Metallurgy (1967); e-mail: bording@utig.ig.utexas.edu


### Computational Geophysics

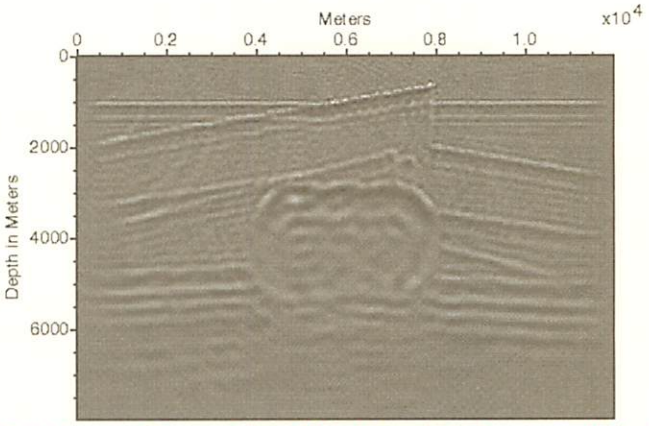
Model based inversion of geophysical data; computational aspects of wave propagation, seismic modeling of complex structure.




**Salt Intrusion Model, 200 by 300 grid**




**Salt Intrusion Exploding Reflector Data, dt=0.002**




**Salt Intrusion Reverse Time Migration, Grid Spacing = 40 Meters**

### Research Interests

Geophysics offers a number of challenging computational science problems. Areas of current interest include the spatial representation of geological models and inversion algorithms, which use these unstructured model descriptions. Model based seismic inversion methods in multiple dimensions require intense computational resources and the development of wave machines is an area of active research. This compliments the prototype of the two dimensional machine. Visualization of the numerical processes of these complex algorithms is an ongoing research project. Interests also include the development of application specific compute engines, and the theory for design, language and for programming of such machines. Wave equation algorithms for migration of three dimensional seismic data have been verified and are being expanded for real data. These reverse time methods use a variable grid and higher order difference operators to conserve memory and operations count.

### Selected Publications


Nickerson, W. A., and R. P. Bording, Process Visualization: The Migration Movie, *The Leading Edge*, January 1996.

Bording, R. P., Seismic Modeling and Earth Imaging, Computational Science Education Project, case study, chapter in the CSEP HTML electronic book, released December 1994, http://csep1.phy.ornl.gov/csep.html, 50 pages.

Dong, W., J. Emanuel, R. P. Bording, and N. Bleistein, A computer implementation of the 2.5D common shot inversion, *Geophysics*, *56*, 1384-1394, 1991.

Myron, J. R., L. R. Lines, and R. P. Bording, Computers in Seismic Tomography, *Computers in Physics Journal*, March/April issue, invited paper, p. 26-32 and cover page, 1989.

Bording, R. P., A. Gersztenkorn, L. R. Lines, J. A. Scales, and S. Treitel, Applications of seismic travel-time tomography, *Geophys. J. Royal Astr. Soc.*, *90*, 285-303, 1987.


## Stéphane O. Operto

Postdoctoral Fellow

Ph.D., University of Paris 6 (1995); Ecole Nationale Supérieure des Arts & Métiers, Paris (1990); e-mail: operto@utig.ig.utexas.edu


### Marine Seismology

Seismic data analysis, deep structure of oceanic crust, oceanic plateaus and continental margins.

### Research Interests

Current research involves determining the deep seismic structure of oceanic crust, submarine plateaus and continental margins.

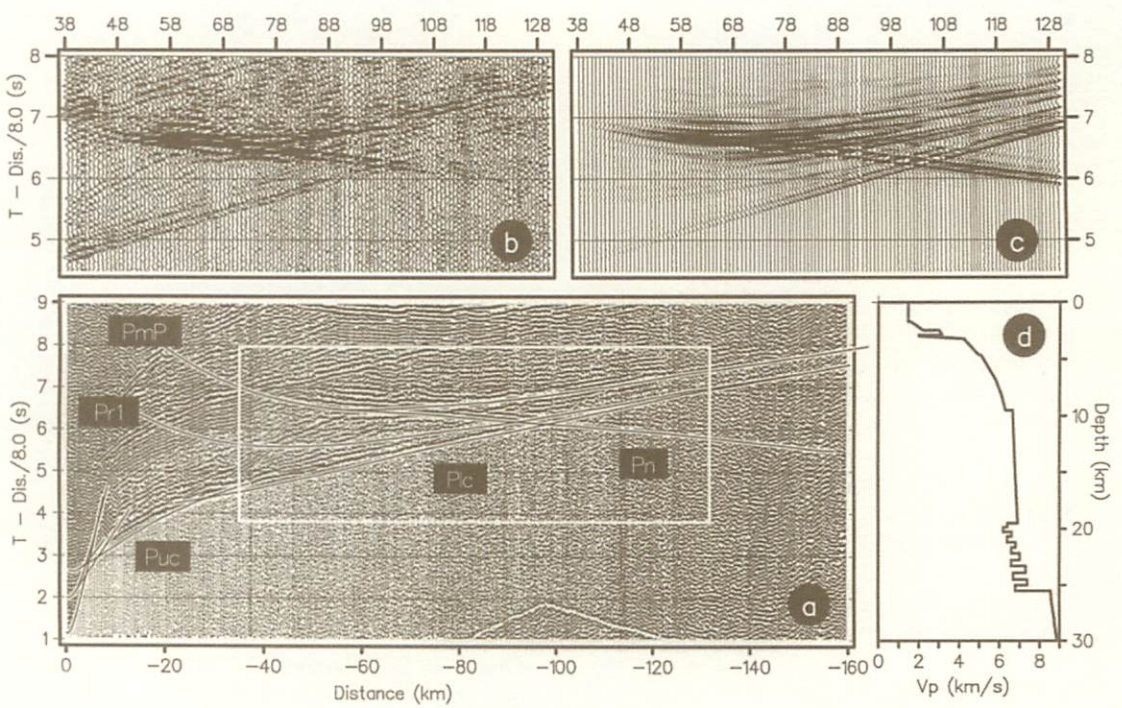
Doctoral research focused on the study of the deep structure of the submarine Kerguelen plateau (Indian Ocean) from OBS wide angle seismic profiles. Travel time inversion and synthetic seismogram computation provided velocity models of the Kerguelen Plateau and adjacent oceanic basins.

Future plans include processing and analysis of 3D OBS data recorded on the Costa Rica convergent margin.

### Selected Publications


Operto S., and P. Charvis, Kerguelen Plateau: a volcanic passive margin fragment?, *Geology, 23*, 137-140, 1995.

Charvis P., M. Recq, S. Operto, and D. Bréfort, Deep structure of the northern Kerguelen-Plateau and hot spot-related activity, *Geophys. J. Intl.*, 122, 899-924, 1995.


(a) OBS Record section (southern Kerguelen Plateau) with superimposed travel time curves predicted by velocity model shown in (d); (b) enlargement of the section shown in (a) delineated by the frame; (c) reflectivity synthetic section predicted by model in (d); (d) velocity-depth function of the crust and upper mantle.


## Jay Pulliam

Postdoctoral Fellow

Ph.D., University of California, Berkeley (1991); A.B., Cornell University (1983); e-mail: jay@utig.ig.utexas.edu


### Seismology

Seismic tomography, global seismology, inverse problems, ray theory, waveform modeling by global optimization methods.

### Research Interests

Energy generated by earthquakes propagates through the Earth and may be recorded, for large earthquakes, on seismograms at stations around the world. These seismograms can be used to construct an image of the most remote parts of the Earth—the mantle and core. These images can be helpful in suggesting hypotheses about Earth structure, chemical composition, evolution and dynamic processes. This imaging is a complicated procedure, however, and the final results should not be assumed to reflect the real Earth exactly. The assessment of a model's reliability is usually the most difficult aspect of the modeling process.

Interests lie in evaluating the effects of errors in seismic data on models of Earth structure and exploring the bias introduced by the model parameterization, model smoothing, and the bending of seismic rays. Ray bending occurs because the Earth is both laterally and radially heterogeneous, although the lateral variations are generally far smaller than the radial. Methods of computing ray bending and the associated change in travel time tend to be computationally too demanding to be useful with the many data needed to produce reliable models. The ray perturbation method makes use of the fact that lateral variations are small and finds a ray close to a given ray that represents the minimum time path in a slightly different medium. This method can also be used to compute first Fresnel zones, a zone of sensitivity, for a given source-receiver pair. This may be helpful in constructing a model parameterization for imaging that has a physical, rather than purely mathematical, justification.

Future work entails applications of the ray perturbation method to data and the fast computation of Fresnel zones for realistic Earth models, migration strategies and methods for 3D exploration data sets, waveform modeling by global optimization and the experimental investigation of hypotheses suggested by global modeling.

### Selected Publications

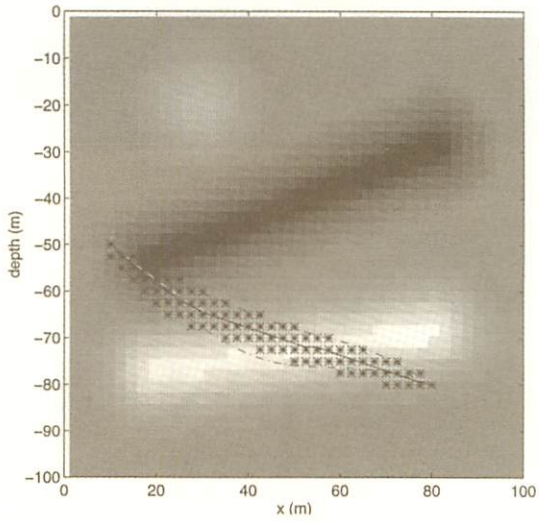

Pulliam, J., and R. Snieder, Fast, efficient calculation of rays and travel times with ray perturbation theory, *J. Acoust. Soc. Am.*, in press, 1995.

Pulliam, R. J., and P. B. Stark, Confidence regions for mantle travel time tomography, *J. Geophys. Res.*, *98*, 6931-6943, 1994.

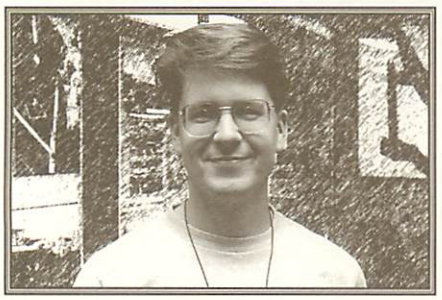
Pulliam, R. J., and P. B. Stark, Bumps on the Core-Mantle Boundary: Are they facts or artifacts?, *J. Geophys. Res.*, *98*, 1943-1955, 1993.

Pulliam, R. J., D. W. Vasco, and L. R. Johnson, Tomographic inversions for mantle P wave velocity structure based on the minimization of l and l norms of International Seismological Centre travel time residuals, *J. Geophys. Res.*, *98*, 699-734, 1993.

Pulliam, R. J. and L. R. Johnson, What patterns of heterogeneity in the Earth's mantle can be revealed by seismic tomography?, *Phys. of the Earth and Planet. Inter.*, *73*, 109-151, 1992.


The energy emanating from a source (at left) and arriving at a receiver (right) is assumed by ray theory to have traveled a single, infinitely thin path between the two points (solid line). In reality, the energy we record at a receiver has finite frequency and has traveled paths that cover a finite area (or volume). For a monochromatic wave, all the paths that arrive within a quarter period of the minimum time path will interfere constructively and will contribute to the signal we read from the seismogram. Finding this exact envelope of paths from ray theory means computing the travel times to all points in a model and evaluating each one individually (represented by asterisks). This is a time-consuming process, particularly in 3D. Alternatively we can compute the envelope approximately from ray perturbation theory (dashed-dot lines) by considering only two additional rays in the vicinity of the minimum time ray.




## Benjamin J. Sloan

Postdoctoral Fellow

Ph.D., University of Texas at Austin (1995); B.A., Northwestern University (1987); e-mail: ben@utig.ig.utexas.edu


### Marine Geology and Geophysics

Seismic stratigraphy, foraminiferal micropaleontology, glacial-marine sedimentation.

### Research Interests

Primary interest is geology of marine clastic rocks. Research focuses on description of sedimentary deposits from basins and continental margins and interpretation of their genesis using seismic data to define stratal surfaces and geometries, core and well log information to evaluate lithologic relationships, and foraminifera for paleoenvironmental interpretations. Recent work has been in the North Sea basin and Antarctic Peninsula continental shelf.

Doctoral research concerned the Eocene sequence stratigraphy of the North Sea basin, combining seismic, well log, and foraminiferal data. Five Eocene sequences within the clastic basin fill were described and interpreted. Well logs, were used to construct maps of the lithofacies and interpreted depositional systems and paleogeographies. Each of the sequences was characterized by a distinct foraminiferal biofacies representative of a particular marine paleoenvironment.

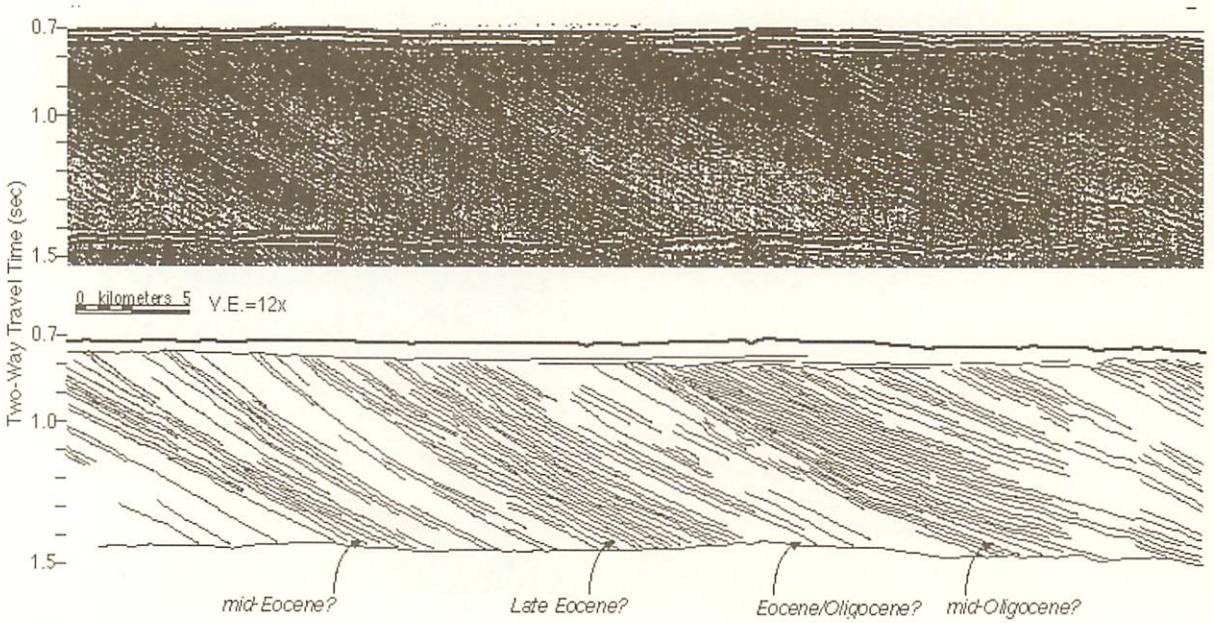
Post-doctoral work, in conjunction with Martin Lagoe, utilizes seismic data and foraminifera in samples from a set of shallow cores acquired in the Larsen Basin along the continental margin of the eastern Antarctic Peninsula. Sloan and Lagoe are collaborating with scientists who are studying the stable isotopes and palynology of the cores. The group intends to produce a Quaternary history of the continental shelf within the study area which resolves glacial activity and its influence on the benthic and planktic environment, oceanography, palynomorph production, reworking, and preservation, and stable isotopic ratios.

### Selected Publications


Sloan, B. J., L. A. Lawver, and J. B. Anderson, Seismic stratigraphy of the Larsen Basin, Eastern Antarctic Peninsula, *AGU Antarctic Research Series*, 68, 59-74 1995.

Sloan, B. J., Eocene sequence stratigraphy of the North Sea Basin, Ph.D. dissertation, 214 pp., University of Texas at Austin, Austin, Texas, 1995.

Galloway, W. E., J. L. Garber, X. Liu, and B. J. Sloan, Sequence stratigraphy and depositional framework of the Cenozoic fill, central and northern North Sea Basin, *In* Petroleum Geology of Northwest Europe: Proceedings of the 4th Conference, edited by J. R. Parker, Geological Society of London, London, pp. 33-43, 1993.


Single-channel seismic data from the Larsen Basin, Antarctic Peninsula, showing strata dipping east about four degrees and inferred ages of unconformities.

# Graduate Student Opportunities

Graduate student training is an important component of the research activities of UTIG. The Institute itself does not award degrees or offer formal classes for academic credit. Rather, the Institute maintains a close relationships with the Department of Geological Sciences. The Institute maintains its affiliation with the department through cooperative programs and joint faculty appointments. Approximately one third of the research staff hold joint appointments in the Institute and the Department of Geological Sciences. Many geophysics graduate students at UT and other universities take advantage of the opportunity to work with the staff and the facilities of the Institute. Since 1974, 145 students have received higher degrees based on research conducted by UTIG staff. UTIG supports students by providing fellowships, research assistantships and student training opportunities. Fellowships supported by NSF, The University of Texas, and several industries are awarded each year.

The Palisades Geophysical Institute has established the Maurice Ewing and J. Lamar Worzel Graduate Student Fellowship Program in Geophysics at UTIG. The fellowships are named after the late Maurice Ewing, renowned oceanographer and founder of the Institute for Geophysics and J. Lamar Worzel, long-time colleague of Ewing and Director of the Marine Science Institute Geophysical Laboratory at Galveston from 1975 through 1979. Four or five students receive full fellowships under this program each semester.

Research assistantships are awarded each semester by University departments and the Institute for Geophysics. Applicants having special interests or qualifications for a research assistantship should contact an appropriate member of the faculty directly or notify the Graduate Advisor when applying for financial aid. Research assistantships carry a stipend equivalent to a teaching assistantship. In general, each year an average of 30 students, including undergraduates, receive some sort of research assistantship support from funds included in research grants awarded to Institute scientists.

UTIG sponsors a student cruise program, aimed explicitly at exposing graduate and undergraduate students to at-sea marine geophysical methods. This program was initiated in May 1982, using the UT research vessel R/V *Fred H. Moore*. Since the *Moore* was retired, UTIG has used TAMU's R/V *Gyre* and/or other ships of opportunity. As part of the student cruise program, UTIG provides support for students to join research cruises funded by other agencies. Typically, the student is funded for the semester during which the cruise takes place. The program provides specialized training for graduate students in geophysical data acquisition and this past year the concept was extended to include other geophysical field activities. Training in geophysical data acquisition methods is critical to a student's ability to comprehend the methods employed and their practical limitations. UTIG is unique among academic institutions in its ability to provide student training support during scheduled training cruises and as Institute funded participants in research projects. Consequently, virtually every research cruise lead by UTIG scientists involves undergraduate and/or graduate student participation.

**How to Apply**—Inquiries about fellowships, scholarships, and assistantships should be addressed to:

Chairman, Fellowship Committee
Institute for Geophysics
The University of Texas at Austin
8701 North Mopac Expressway
Austin, Texas 78759-8397
or:
Graduate Office
Department of Geological Sciences
The University of Texas at Austin
Austin, Texas 78712

## The University of Texas at Austin Students in the Department of Geological Sciences Doing Research at the Institute for Geophysics, Fall 1995

### M.A. Candidates:

Bartelmann, Monika
*A Hydrogeological study of Barton Springs*
UTIG Supervisor: Phillips

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Buck, Keith
*2D/3D Seismic and core data analysis, New Jersey Shelf project*
UTIG Supervisor: Austin

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Carpenter, Danielle
*Tectonic history of the metamorphic basement of the Sierra del Carmen, Coahuila, Mexico*
UTIG Supervisor: Dalziel

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Cowley, Shane
*2-D modeling of gravity and uplift data from the North Solomon trench and Malaita anticlinorium, Southwest Pacific*
UTIG Supervisor: Mann

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Luhurbudi, Eddy
*Ray tracing by solving the eikonal solution*
UTIG Supervisor: Stoffa/Sen

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Lundy, Jim
*Analysis and modeling of interseismic strain accumulation and coseismic release at convergent plate boundaries in the SW Pacific*
UTIG Supervisor: Taylor

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Massell, Chris
*Neotectonics of the Macquarie Ridge Complex*
UTIG Supervisor: Coffin

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Phinney, Eric
*Processing and interpretation of MCS data from the Solomon Islands-Ontong Java Plateau collision zone*
UTIG Supervisor: Mann

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Schuur, Laurie
*Interplay of tectonic processes, current flow, and the distribution of sediment along the Macquarie plate boundary, Southern Ocean*
UTIG Supervisor: Coffin

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Setiyono, Kriyanti
*A comparison of multiple suppression methods*
UTIG Supervisor: Stoffa/Sen

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Teagan, Alison
*Migration velocity analysis using 3D seismic reflection data*
UTIG Supervisor: Shipley

### Ph.D. Candidates:

Akbar, Faruq
*2D and 3D plane wave Kirchhoff depth migration*
UTIG Supervisor: Stoffa

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Babb, Stephen
*Tectonic controls on sedimentation in Trinidad*
UTIG Supervisor: Buffler

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Barker, Dan
*Geophysical investigation of an extending marginal basin in a convergent plate margin setting - Bransfield Strait, Antarctica*
UTIG Supervisor: Dalziel/Austin

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Calderon-Macias, Carlos
*Artificial neural systems for interpretation and inversion of seismic data*
UTIG Supervisor: Stoffa/Sen

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Chunduru, Raghu
*Global and hybrid optimization in geophysical inversion*
UTIG Supervisor: Stoffa/Sen

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Fitchen, William
*Sequence stratigraphy of Lower Permian carbonate platform margins, Sierra Diablo, West Texas*
UTIG Supervisor: Buffler

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He, Leipin
*Sequence Stratigraphy of the Neogene section, Northeastern Gulf of Mexico*
UTIG Supervisor: Buffler

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Hutson, Frederick
*Geologic investigation of the Shackleton Range & Coats Land Nunataks, Antarctica*
UTIG Supervisor: Dalziel

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Kong, Fanchen
*Sedimentary basin evolution and tectonic reconstruction in East Asia*
UTIG Supervisor: Dalziel

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Konnecke, Lis
*The early development of the Kerguelen Plateau, southern Indian Ocean*
UTIG Supervisor: Coffin

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Liu, Julia
*Ocean Bottom Seismic data processing, analysis, and modeling for major tectonic subduction zones in Taiwan region*
UTIG Supervisor: Nakamura

Liu, Qunling
*Testing the sequence stratigraphic and global sealevel models. Main Pass area, NE Gulf of Mexico*
UTIG Supervisor: Buffler

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McKenna, Tom
*Fluid and heat flow near a thermal anomaly in South Texas, Gulf of Mexico Basin*
UTIG Supervisor: Buffler

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Nyffenegger, Paul
*Systematic analysis of non-double couple earthquake sources*
UTIG Supervisor: Frohlich

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Schlottmann, Brian
*A path integral formulation of elastic wave propagation*
UTIG Supervisor: Garmany

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Sen, Vikramaditya
*3D Velocity estimation using pre-stack migration*
UTIG Supervisor: Stoffa/Shipley

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Sudomo, Widodo
*Tertiary tectonic evolution of Salawati Basin, Irian Jaya, Indonesia*
UTIG Supervisor: Lawver

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Tanis, Mehmet
*Pre-stack depth migration and velocity analysis of constant angle seismic sections*
UTIG Supervisor: Stoffa

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Tsoflias, Georgios
*Geophysical characterization of fractures in aquifers*
UTIG Supervisor: Phillips

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Varela, Carlos
*Automated background velocity estimation in 2D laterally varying media*
UTIG Supervisor: Stoffa

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Xia, Ganyuan
*Prestack migration and AVO inversion*
UTIG Supervisor: Stoffa/Sen

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Ye, Qiucheng (Mike)
*Detailed sequence stratigraphy and modeling of Miocene rocks in the N.W.Gulf of Mexico.*
UTIG Supervisor: Frohlich

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Zhou, Ran
*Earthquake source rupture processes and regional tectonics in the southeastern Eurasian Continent*
UTIG Supervisor: Tajima

# The University of Texas at Austin

In its 110 years, The University of Texas at Austin has grown from a small campus of 40 acres near the State Capitol to become a major institution known nationally for the quality of its academic programs, research and public service. UT Austin places a premium on outstanding instruction; about 100 faculty members each year receive teaching excellence awards.

In research, a faculty member in human ecology is developing dietary strategies that could slow tumor growth so that established treatment procedures such as chemotherapy would have a better chance to work. An atomic and molecular physicist is conducting an experiment that may answer the question of where the universe is headed. A zoology professor is conducting research that could lead to drugs or treatment processes to cure balance problems or certain types of hearing loss. As a state-supported institution, UT Austin is engaged in many forms of public service. These range from studies conducted for state agencies to legal services offered by students in the law school to various disadvantaged populations.

As the academic flagship of the UT System's 15 component institutions, UT Austin has come far from its beginning in 1883, when it had only one building, eight teachers, two departments and 221 students. Today it has a main campus of 357 acres and 120 buildings that are home to more than 49,000 students, 2,388 faculty and almost 15,000 staff members. Since its opening, UT Austin has awarded more than 345,000 degrees.

Several national publications, citing its low tuition and high academic standing, have ranked the University among the country's best values in higher education. UT Austin is one of only three Southwestern members of the Association of American Universities, which is composed of the 58 leading universities in the United States and Canada.

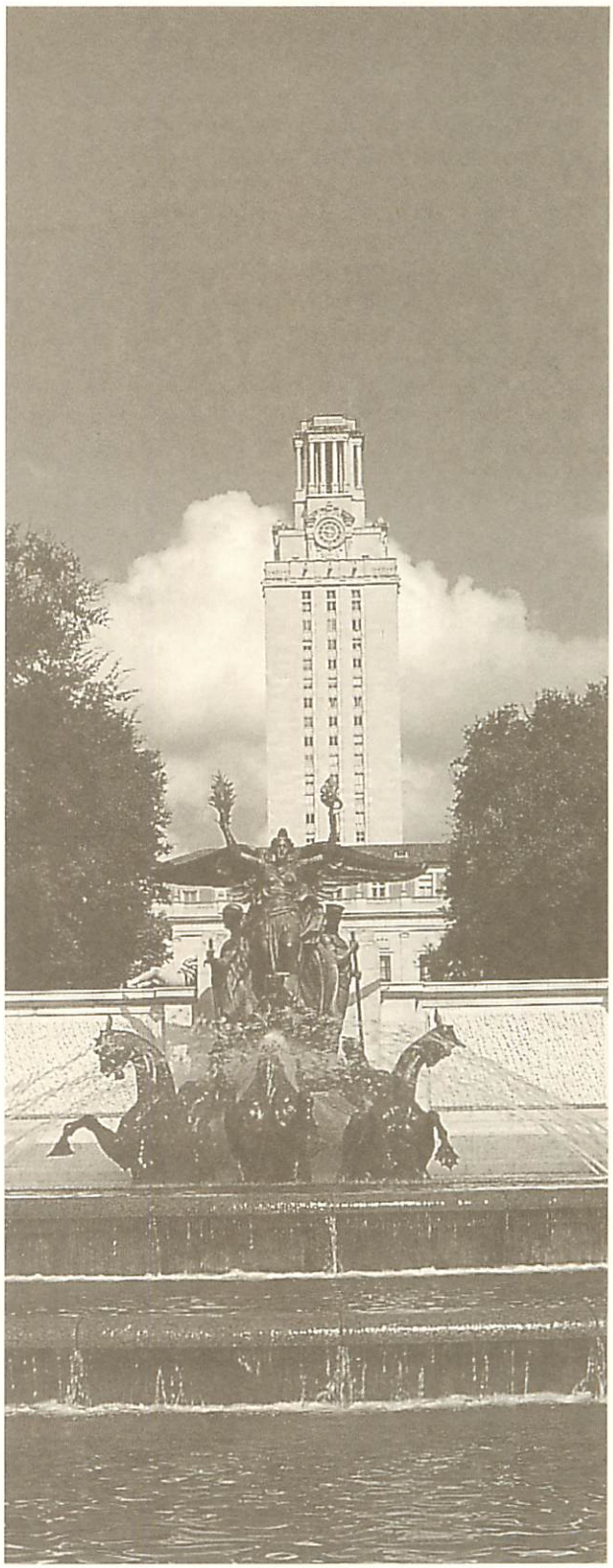
The University also leads all institutions in the South in the quality of its graduate programs, as well as in the number of doctoral degrees awarded. Assessments of selected doctoral programs in the United States have ranked three UT Austin programs (botany, linguistics and Spanish) among the nation's top five, while five other programs (Germanic languages, civil engineering, classics, zoology and computer sciences) are in the top 10. Ranked among the top 20 are doctoral programs in chemistry, geosciences, French, music, chemical engineering, electrical engineering, mechanical engineering, anthropology and sociology. Assessments of professional programs have found UT Austin graduate offerings in law, education, pharmacy, business, engineering and public affairs to be among the top 10 of all U.S. public institutions.

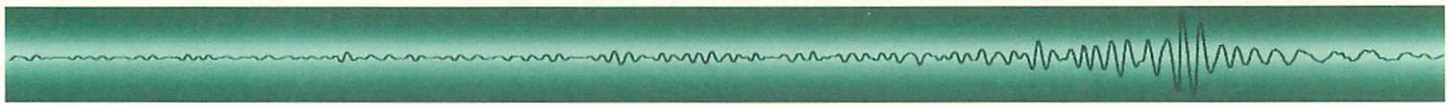
The Office of Admissions can provide further information.
Call (512) 471-7601 or write:

Admissions Center
John Hargis Hall
The University of Texas at Austin
Austin, Texas 78712

Electronic admissions forms are available at:

http://www.utexas.edu/student/giac/online.html
The University of Texas at Austin general admissions site is:
http://www.utexas.edu/student/admissions





Further information regarding the Institute for Geophysics and its programs can be obtained from:


Information Office

Institute for Geophysics

The University of Texas at Austin

8701 N. MoPac Expressway

Austin, Texas 78759-8397

Phone: (512) 471-6156

Fax: (512) 471-8844

E-mail: utig@utig.ig.utexas.edu

World Wide Web URL address:

http://www.ig.utexas.edu