# DEPARTMENT OF GEOLOGY AND GEOPHYSICS

http://geoweb.tamu.edu

**Head**: M. Pope

**Graduate Advisor**: R. Russell

## Geology

Graduate work in geology is offered at both the master's and doctoral levels. Programs are designed to provide the student with an understanding of the fundamentals of geology and of related disciplines. Research investigations comprise a significant part of each program. The Department of Geology and Geophysics can also serve as the "home" department for the Master of Geoscience degree. The MGsc is a non-thesis degree that provides a multidisciplinary background in the geosciences, appropriate for science teachers in public schools, or for individuals interested in environmental issues, for example.

Opportunities for research at both the MS and PhD levels are available in ground-water investigations, sedimentation, mineralogy, paleontology and paleoecology, stratigraphy, structural geology, tectonophysics, petrology, field geology, engineering and environmental geology and geochemistry.

Current research areas of members of the department include studies in the origin and spatial distribution of reservoir porosity in depositional, diagenetic and fracture systems; field, theoretical and experimental study of the formation of faults and fault networks; fluid flow and deformation within thrust sheets; the hydrostatic and hydrodynamic trapping of oil and gas; carbonate platform-to-basin transitions; sandstone provenance and diagenesis; integrated quantitative basin analysis; archaeological palynology; isotope stratigraphy and global change; paleobiogeography of plants; how fossil assemblages form from and reflect living communities; water/rock interactions in flow-through experimental systems; fate and transport of organic pollutants in the unsaturated and saturated zones; composition of movement of crustal fluids; crystal chemistry, phase relations and thermodynamics of mantle-derived amphiboles and micas; diagenesis of clastic sediments in relation to reservoir rock potential and quality; metal contaminants in alpine systems; groundwater impacts of surface mining; groundwater interference in civil construction and mining; landslide mechanics; fluid-flow properties of faults and dynamics of faulted reservoirs; and groundwater flow in strongly heterogeneous media.

The department has state-of-the-art laboratory facilities for radiogenic and stable isotope geochemistry, environmental geochemistry, evolutionary biology, paleobiology, rock mechanics, sedimentary geology, petrology and electron microprobe analysis. In addition, sample preparation labs, petrographic microscopes and an extensive network of computers and peripherals are available for student research. More detail can be found at http://geoweb.tamu.edu/ under Research Facilities.

The Texas A&M Microscopy and Imaging Center houses additional transmission and scanning electron microscopes. An inductively coupled Ar-plasma emission spectrometer (ICP) and other analytical equipment are available in the Department of Chemistry and the Center for Trace Characterization.

The department benefits from the close association with the Integrated Ocean Drilling Program (IODP). Located in the Texas A&M Research Park adjacent to campus, this $42 million-per-year basic research program is operated by the College of Geosciences, Texas A&M. The IODP facilities include a large core-storage station and physical-properties, petrography and sedimentary laboratories. Many scientific staff members of the IODP hold adjunct faculty positions in the Department of Geology and Geophysics. The facilities both in the department and elsewhere in the University provide students with an excellent opportunity to use state-of-the-art equipment in their research.

Although degree level is not a requirement for professional practice in geology, the BS should usually be considered as preparatory, the MS should be considered the professional degree and the PhD should be considered the teaching and research degree. The MS degree is granted thesis option only.

In addition to graduate studies requirements for the PhD, the student's committee chair, with advice from the other committee members, will determine, on an individual basis, the student's needs in either foreign language or other broadening areas of study.

## Geophysics

The degrees of Master of Science and Doctor of Philosophy are offered in geophysics. Geophysics includes all areas of scientific inquiry that deal with the physical state of the planets and with the dynamic physical processes that act on and within the planets. The deep interior, crust, atmosphere, oceans and space all lie within the province of the geophysicist. To work effectively in so broad an area requires considerable depth and breadth of understanding of physical principles and considerable proficiency in mathematics. Thorough undergraduate training in an earth or physical science is ordinarily regarded as a necessary prerequisite for advanced study.

An intensive two-year program of study at the master's level is available for students who wish to enter the petroleum industry. This MS curriculum pools the resources of the Departments of Geology and Geophysics and Petroleum Engineering in a manner designed to better prepare students for the petroleum industry than conventional offerings in the separate disciplines. The curriculum is intended for students with an undergraduate degree in geology or extensive exposure to geologic concepts through academic training and/or experience. The course sequencing and the subject sequence in each course is carefully designed to use previously acquired knowledge optimally, and to provide experience in applying fundamental concepts in different contexts and in integrating geological, physical, mathematical, computer and statistical skills in the solution of practical problems.

Current research areas of members of the department include studies in theoretical and model seismology focusing on the internal structure of the earth, earthquake mechanisms and seismic exploration; studies of the anisotropy and anelastic properties of sedimentary rocks and application to exploration; regional and global seismology; studies in experimental rock deformation focusing on the failure strength of rocks, friction in rocks; mechanics of fault development; fluid-flow properties of faults and dynamics of faulted reservoirs; marine studies of the structure of the oceanic crust and continental margins in the Gulf of Mexico, the Caribbean Sea and the Western Pacific; studies of the magnetic anomalies near mid-ocean-ridge systems and the magnetization of oceanic crust; the analysis of magnetic and gravity anomalies and application to exploration and global geophysics; gravity anomalies near

trenches, convection in the mantle and global tectonics; vertical seismic profiling; and attenuation of seismic waves.

Members of the department also are involved in geophysical investigations of the sea floor through the Integrated Ocean Drilling Program, which Texas A&M University manages on behalf of JOI, Inc. These investigations include rock magnetism, heat flow, borehole logging and other aspects of marine geophysics.

The department has an extensive computer network of workstations, computer servers and storage for data processing, imaging and modeling. The Immersive Visualization Center provides state-of-the-art 3D visualization of large data sets and models. The Texas A&M Supercomputing Facility is available to students and faculty for computer-intensive applications. The department has field exploration equipment for gravity, ground-penetrating radar, seismic reflection/refraction and electromagnetic surveys. More detail can be found http://geoweb.tamu.edu/ under Research Facilities.

## Faculty

Balta, Joseph B, Visiting Assistant Professor
Geology & Geophysics
PHD, California Institute of Technology, 2010

Bapst, David W, Lecturer
Geology & Geophysics
PHD, University of Chicago, 2013

Becker, Mauro R, Research Professor
Geology & Geophysics
PHD, University of Texas - Austin, 1996

Belanger, Christina L, Assistant Professor
Geology & Geophysics
PHD, University of Chicago, IL, 2011

Benavides Iglesias, Alfonso, Lecturer
Geology & Geophysics
PHD, Texas A&M University, 2007

Bhatia, Mukul R, Executive Professor
Geology & Geophysics
PHD, The Australian National University, 1982

Chester, Frederick M, Professor
Geology & Geophysics
PHD, Texas A&M University, 1988

Chester, Judith S, Professor
Geology & Geophysics
PHD, Texas A&M University, 1992

Clement, Brad M, Professor
Geology & Geophysics
PHD, Columbia University, 1985

Datta, Saugata, Visiting Professor
Geology & Geophysics
PHD, University of Western Ontario, Canada, 2001

Donovan, Arthur D, Professor of the Practice
Geology & Geophysics
PHD, Colorado School of Mines, 1985

Duan, Benchun, Associate Professor
Geology & Geophysics
PHD, University of California, Riverside, 2006

Everett, Mark E, Professor
Geology & Geophysics
PHD, University of Toronto, 1991

Ewing, Ryan C, Associate Professor
Geology & Geophysics
PHD, The University of Texas - Austin, 2009

Fulton, Patrick M, Assistant Professor
Geology & Geophysics
PHD, Pennsylvania State University, 2008

Giardino, John R, Professor
Geology & Geophysics
PHD, University of Nebraska, Lincoln, 1979

Gibson Jr, Richard L, Professor
Geology & Geophysics
PHD, Massachusetts Institute of Technology, 1991

Grossman, Ethan L, Professor
Geology & Geophysics
PHD, University of Southern California, 1982

Kabir, Mian M, Lecturer
Geology & Geophysics
PHD, Delft University Of Technology, 1997

Kitajima, Hiroko, Assistant Professor
Geology & Geophysics
PHD, Texas A&M University, 2010

Knappett, Peter S, Assistant Professor
Geology & Geophysics
PHD, University of Tennessee at Knoxville, 2010

Kronenberg, Andreas K, Professor
Geology & Geophysics
PHD, Brown University, 1983

Lamb, William M, Associate Professor
Geology & Geophysics
PHD, University of Wisconsin - Madison, 1987

Laya Pereira, Juan Carlos, Assistant Professor
Geology & Geophysics
PHD, Durham University, United Kingdom, 2012

Marcantonio, Franco, Professor
Geology & Geophysics
PHD, Columbia University, 1994

Miceli Romero, Andrea A, Research Professor
Geology & Geophysics
PHD, The University of Oklahoma, 2014

Miller, Brent V, Associate Professor
Geology & Geophysics
PHD, Dalhousie University, Canada, 1997

Newman, Julie, Professor
Geology & Geophysics
PHD, University of Rochester, 1993

Perez, Nicholas D, Assistant Professor
Geology & Geophysics
PHD, University of Texas at Austin, 2015

Pope, Michael, Professor
Geology & Geophysics
PHD, Virginia Tech, 1995

Raymond, Anne L, Professor
Geology & Geophysics
PHD, University of Chicago, 1983

Reece, Julia S, Assistant Professor
Geology & Geophysics
PHD, University of Texas, 2011

Reece, Robert S, Assistant Professor
Geology & Geophysics
PHD, The University of Texas - Austin, 2012

Riggs, Eric A, Associate Professor
Geology & Geophysics
PHD, University of California-Riverside, 2000

Shebl, Mamdouh A, Research Professor
Geology & Geophysics
PHD, University of Wyoming, 1996

Sparks, David W, Professor
Geology & Geophysics
PHD, Brown University, 1992

Sun, Yuefeng, Professor
Geology & Geophysics
PHD, Columbia University, 1994

Tice, Michael M, Associate Research Scientist
Geology & Geophysics
PHD, Stanford University, 2006

Torrez, Betsy D, Lecturer
Geology & Geophysics
PHD, University of Alabama, 1994

Yancey, Thomas E, Professor
Geology & Geophysics
DOC, University of California, Berkeley, 1971

Zhan, Hongbin, Professor
Geology & Geophysics
PHD, University of Nevada, Reno, 1996

## Masters

- Master of Science in Geology (http://catalog.tamu.edu/graduate/colleges-schools-interdisciplinary/geosciences/geology-geophysics/geology-ms)
- Master of Science in Geophysics (http://catalog.tamu.edu/graduate/colleges-schools-interdisciplinary/geosciences/geology-geophysics/geophysics-ms)

## Doctoral

- Doctor of Philosophy in Geology (http://catalog.tamu.edu/graduate/colleges-schools-interdisciplinary/geosciences/geology-geophysics/geology-phd)
- Doctor of Philosophy in Geophysics (http://catalog.tamu.edu/graduate/colleges-schools-interdisciplinary/geosciences/geology-geophysics/geophysics-phd)

## Certificates

- Petroleum Geoscience Certificate (http://catalog.tamu.edu/graduate/colleges-schools-interdisciplinary/geosciences/geology-geophysics/petroleum-geoscience-certificate)

## Courses

**GEOL 609 Field Geology**
**Credits 1 to 6. 1 to 6 Other Hours.**
Individual instruction in advanced and specialized field methods, geologic interpretation and field evaluation procedures. Choice of topics and locations of field studies will vary depending upon individual and specific needs.
**Prerequisite:** GEOL 300 or approval of instructor.

**GEOL 610 Field Methods in Hydrogeology**
**Credits 3. 1 Lecture Hour. 6 Lab Hours.**
Field methods in hydrogeology; including ground water drilling technology and law; investigation and planning of well sites; installation of ground water wells; field testing of aquifer properties and analysis of field data. Field trips may be required for which departmental fees may be assessed to cover costs.
**Prerequisite:** GEOL 410 or approval of instructor.

**GEOL 612 Structural Geology**
**Credits 3. 3 Lecture Hours.**
Mechanical principles important to structural geology and experimental results relating to rock deformation followed by applications to natural deformation; mechanisms, rather than geometries. Primarily for students not concentrating in structural geology but who desire an advanced general course.
**Prerequisite:** Approval of instructor.

**GEOL 614 Advanced Hydrogeology**
**Credits 3. 2 Lecture Hours. 2 Lab Hours.**
Geologic conditions determining the distribution and movement of ground water and their effect on the hydrologic properties of aquifers.
**Prerequisites:** MATH 151 and MATH 152, or equivalent.

**GEOL 617 Introduction to the Petroleum Industry**
**Credits 3. 3 Lecture Hours.**
Introduction to the petroleum industry and geoscience issues associated with the full petroleum cycle from resource discovery to marketing of refined petroleum products; focuses on the role of geoscientists in all facets of the business.
**Prerequisite:** Graduate classification or approval of instructor.

**GEOL 619 Petroleum Geology**
**Credits 3. 3 Lecture Hours.**
Properties of reservoir rocks; origin, migration and accumulation of petroleum; geologic interpretation of borehole logs and fluid-pressure measurements and the role of hydrostatic and hydrodynamic pressures in oil accumulation.
**Prerequisite:** Approval of instructor.

**GEOL 621 Contaminant Hydrogeology**
**Credits 3. 3 Lecture Hours.**
Physical concepts of mass transport; dispersion; diffusion; advection; geochemical processes including surface reaction; hydrolysis; biodegradation; aspects of modeling; process and parameter; and remediation.
**Prerequisite:** GEOL 410 or approval of instructor.

**GEOL 622 Stratigraphy**
**Credits 3. 3 Lecture Hours.**
Principles for correlating and naming stratigraphic units; controls on stratigraphic development (sediment supply, base-level change, subsidence, climate, and compaction); principles and application of sequence stratigraphy; subsurface stratigraphy; facies analysis and stratigraphic architecture.
**Prerequisite:** Graduate classification or approval of instructor.

**GEOL 623 Carbonate Rocks**
**Credits 3. 3 Lecture Hours.**
Principles of carbonate sedimentology; carbonate depositional sequences defined in modern environments and utilized to interpret the rock record; introduction to depositional and diagenetic microfacies; shelves, ramps and isolated platforms and their tectonosedimentary significance; suggested for geoscience majors.
**Prerequisites:** A basic understanding of sedimentology and the associated terminology; graduate classification.

**GEOL 624 Carbonate Reservoirs**
**Credits 3. 3 Lecture Hours.**
Recognition and description of hydrocarbon reservoirs in carbonate rocks; classification of carbonate porosity; capillary pressure curves and pore types; pore characteristics as proxies for permeability in reservoir modeling; techniques for mapping flow units.
**Prerequisites:** Graduate classification and approval of instructor.

**GEOL 625 Applied Ground Water Modeling**
**Credits 3. 3 Lecture Hours.**
Concept of groundwater flow and contaminant transport; numerical simulations of solving flow and transport equations; finite difference and finite element methods; software structures of groundwater flow, contaminant transport, density-dependent fluid flow and hydrocarbon remediations; real case applications of software including geological, physical, chemical, biological and hydrological information.
**Prerequisite:** GEOL 410 or approval of instructor.

**GEOL 629 Regional Geology of North America**
**Credits 3. 3 Lecture Hours.**
Regional geology of North America, examining the accumulation and deformation of the rock units involved; structural form and style emphasized; entire geologic history investigated.
**Prerequisite:** Graduate classification or approval of instructor.

**GEOL 631 Engineering Geomorphology**
**Credits 3. 3 Lecture Hours.**
Active surface processes as they influence engineering construction; erosion, rivers and floods, slope processes, subsidence, coastal processes, ice, weathering and ground water.
**Prerequisites:** Graduate classification in engineering or geosciences; GEOG 331 or approval of instructor.

**GEOL 633 River Restoration**
**Credits 3. 3 Lecture Hours.**
Geologic, geomorphic and geomechanical principles applied to the investigation, design, construction, and maintenance of river restoration projects.
**Prerequisite:** GEOL 631 or GEOG 626 or approval of instructor.

**GEOL 635 Engineering Geology**
**Credits 3. 3 Lecture Hours.**
Geological principles applied to the investigation design, construction and maintenance of engineering projects; history, development and role of engineering geologic practice as applied to dams, waste disposal, surface and ground water, tunneling, quarrying and construction materials.

**GEOL 640/WMHS 640 Geochemistry of Natural Fresh Waters**
**Credits 3. 3 Lecture Hours.**
Chemistry of aqueous solutions; weathering/redox reactions and controls on fresh waters; natural and anthropogenic factors affecting major, minor, and trace elements in fresh waters; evaluation of fresh water composition; application of water-quality measurements to quantitative hydrology.
**Cross Listing:** WMHS 640/GEOL 640.

**GEOL 641 Environmental Geochemistry**
**Credits 3. 3 Lecture Hours.**
Geochemical processes affecting the fate and transport of inorganic and organic pollutants in terrestrial systems; equilibrium and kinetic modeling.
**Prerequisite:** GEOL 451 or approval of instructor.

**GEOL 643 Introduction to Electron Microprobe Analysis**
**Credits 2. 1 Lecture Hour. 3 Lab Hours.**
Digital imaging and qualitative and quantitative chemical analysis of geological and material science samples using the electron microprobe; emphasis on quantitative chemical analysis using WDS (wavelength-dispersive spectrometry) methods; use the electron microprobe and correctly interpret analytical results.
**Prerequisite:** Approval of instructor.

**GEOL 645 Geochronology**
**Credits 3. 3 Lecture Hours.**
Earth's 4.5 billion-year history is divided into units of geologic time based on the observed changes in the rock record: the timing of those changes is quantified by numerical dating methods: this course examines both dating methods and physical and biological changes observed in the rock record.
**Prerequisite:** Graduate classification or approval of instructor.

**GEOL 647 Radiogenic Isotope Geology**
**Credits 3. 3 Lecture Hours.**
Use of radiogenic isotopes in addressing problems in high- and low-temperature geochemistry; their use as tracers for past and present-day processes at the surface and interior of the Earth.
**Prerequisite:** Approval of instructor.

**GEOL 648 Stable Isotope Geology**
**Credits 3. 2 Lecture Hours. 3 Lab Hours.**
Stable isotopes of oxygen, carbon, sulfur and hydrogen applied to problems in paleontology and paleoecology, carbonate diagenesis, petroleum exploration, and igneous and metamorphic petrology; isotopic paleotemperatures; analytical methods; theory of isotopic fractionation.
**Prerequisite:** GEOL 451 or approval of instructor.

**GEOL 650 Paleoecology**
**Credits 3. 2 Lecture Hours. 3 Lab Hours.**
Interrelationships of organisms and environment in the fossil record; methods and criteria available for interpreting ancient environments; critical review of classical studies and current research in paleoecology.
**Prerequisite:** Approval of instructor.

**GEOL 651 Paleoecological Community Analysis**
**Credits 3. 3 Lecture Hours.**
Quantitative analysis of multivariate paleoecological community data; measurement of diversity; cluster analysis; gradient analysis by standard and canonical ordination techniques.
**Prerequisite:** A basic course in statistics or approval of instructor.

**GEOL 652 Biogeology**
**Credits 3. 2 Lecture Hours. 3 Lab Hours.**
Major trends and processes in the evolution of life through geologic time. Interrelationships of biological and physical processes in earth history; application of paleontology to current problems in geology; critical review of modern developments in biogeology.
**Prerequisite:** GEOL 305 or approval of instructor.

**GEOL 653 Geobiological Research**
**Credits 3. 1 Lecture Hour. 6 Lab Hours.**
Team-based research in modern or historical geobiology; definition of questions and hypothesis testing; analytical techniques; project lifecycle; reporting of results. May be taken two times for credit.
**Prerequisite:** Approval of instructor.

**GEOL 654 Evolutionary Patterns and Theory**
**Credits 3. 3 Lecture Hours.**
Evolutionary patterns in the fossil record and application of evolutionary theory to understanding these patterns; comparisons of neo-Darwinian and punctuational hypotheses; events and processes pertaining to microevolutionary and macroevolutionary change; and methods of determine phylogenies of organisms.
**Prerequisite:** Graduate classification in geological or biological sciences.

**GEOL 658 Earth Systems Through Deep Time: Global Change, Paleoclimate and Life**
**Credits 3. 3 Lecture Hours.**
History and cause of global change in the earth system, Archean to Holocene; Impact of biotic change on the earth system; influence of tectonics on paleochemistry and climate change; influence of climate on tectonics; methods and models for evaluating global change.
**Prerequisite:** Graduate classification.

**GEOL 663 Fracture and Faulting of Rocks**
**Credits 3. 3 Lecture Hours.**
The structure of fractures and faults in the Earth's crust at the macroscopic and microscopic scale; formation and evolution of faults, faults networks and fault zones; fault-related rocks and faulting mechanisms; influence of faults on fluid flow properties; seismic faulting and creep; current problems and research opportunities.
**Prerequisite:** Graduate classification.

**GEOL 664 Mechanical Analysis in Geology**
**Credits 3. 3 Lecture Hours.**
Mechanical analysis of geological problems based on concepts of stress, strain, strength, elasticity, viscosity and plasticity; folding, faulting, dike formation, hydraulic fracturing, magma and glacial flow, and cooling of magmatic bodies.
**Prerequisites:** MATH 253; approval of instructor.

**GEOL 665 Structural Petrology**
**Credits 4. 3 Lecture Hours. 3 Lab Hours.**
Mechanisms of rock deformation from single crystal to mountain range; techniques for mapping stresses and strains and for inferring physical conditions and mechanical behavior at time of deformation; laboratory assignments on descriptive techniques include petrographic microscope-universal stage methods, field procedures and data analysis.
**Prerequisite:** Approval of instructor.

**GEOL 668 Clastic Sedimentology and Sedimentary Petrology**
**Credits 4. 3 Lecture Hours. 3 Lab Hours.**
Detailed analyses of clastic sedimentary rocks: relationships of facies and depositional environments with emphasis on continental, coastal and shallow shelf clastic sediments; petrography and diagenesis of modern and ancient clastic sediments.
**Prerequisites:** Optical mineralogy course and sedimentology (undergraduate); graduate classification.

**GEOL 678 Earth Science Modeling**
**Credits 4. 3 Lecture Hours. 3 Lab Hours.**
Techniques for building, solving and analyzing numerical models applied to a wide variety of problems in geology, geochemistry, geobiology and geophysics; derivation and scaling of conservation laws; finite difference and finite element techniques and error analysis; programming in MATLAB or a high-level language.

**GEOL 681 Seminar**
**Credit 1. 1 Lecture Hour.**
Reports and discussions of current research and selected topics from geologic literature.
**Prerequisite:** Graduate classification.

**GEOL 685 Directed Studies**
**Credits 1 to 12. 1 to 12 Other Hours.**
Enables graduate students to undertake limited investigations not within their thesis or dissertation research and not covered in established curricula.
**Prerequisites:** Graduate classification and approval of instructor.

**GEOL 689 Special Topics in...**
**Credits 1 to 4. 1 to 4 Lecture Hours. 1 to 7 Lab Hours.**
Selected topics in an identified area of geology. May be repeated for credit.
**Prerequisite:** Approval of instructor.

**GEOL 691 Research**
**Credits 1 to 23. 1 to 23 Other Hours.**
Original research on problems in various phases of geology. Research for thesis or dissertation.

**GEOP 611 Geomechanics**
**Credits 3. 3 Lecture Hours.**
Development of continuum mechanics and its application to rock deformation; stress, strain, stress equilibrium, constitutive relations; governing equations for elastic solids and viscous fluids formulated and used to solve elementary boundary-value problems which have application to structural geology and solid-state geophysics.
**Prerequisite:** MATH 221 or equivalent.

**GEOP 615 Experimental Rock Deformation**
**Credits 4. 3 Lecture Hours. 3 Lab Hours.**
Results of laboratory testing of mechanical properties of rocks at high pressure and temperature; interaction of theoretical, experimental, petrofabric and field studies of rock deformations as applied to problems in structural geology, seismology and engineering; philosophy of experimentation, apparatus design, data interpretation and extrapolation.
**Prerequisite:** GEOP 611 or GEOL 665 or approval of instructor.

**GEOP 618 Numerical Methods for the Geosciences**
**Credits 3. 3 Lecture Hours.**
Mathematical theory and numerical techniques for modeling physical systems and processes in the Geosciences; discretization of continuum equations for solids and fluids; finite difference methods, convergence, consistency, and stability; finite element and spectral methods in fluid dynamics and seismology; iterative solvers; implicit and explicit methods for diffusion and advection.
**Prerequisite:** Graduate classification or approval of instructor.
**Cross Listing:** ATMO 618 and OCNG 618.

**GEOP 620 Geophysical Inverse Theory**
**Credits 3. 3 Lecture Hours.**
Inferences about Earth structure from geophysical data; explicit treatment of sparse and noisy observations; construction of smooth Earth models; linear inversion of marine magnetic anomalies from seafloor magnetization; smooth inversion of DC sounding data from electrical structure; seismic tomography and geodetic fault-plane reconstructions; advanced methods for nonlinear deterministic inversion.
**Prerequisite:** Graduate classification.

**GEOP 622 Petroleum Seismology II**
**Credits 4. 3 Lecture Hours. 2 Lab Hours.**
Sampling (wavefield sampling); F-K analysis (applications to dip filtering and migration); deconvolution (deterministic and predicative); velocity estimation and tomography (travel time inversion); imaging in time and depth (migration); Zoeppritz equations and AVO analysis.
**Prerequisite:** GEOP 421 or approval of instructor.

**GEOP 628 Basin Architecture**
**Credits 3. 3 Lecture Hours.**
Tectonic classification of basins; tectonic mechanisms responsible for basin formation: mechanical behavior of the lithosphere; subsidence; geophysical signatures of sedimentary basins; tectonic controls on sedimentation and basin filling; petroleum systems and basin-scale hydrologic systems.
**Prerequisite:** Approval of instructor.

**GEOP 629 Seismic Interpretation**
**Credits 4. 3 Lecture Hours. 3 Lab Hours.**
Introduces the problem of converting seismic properties of reflection time, velocity, impedance, amplitude and phase to geologic parameters of lithology, structures and stratigraphy using both models and real data.
**Prerequisite:** Approval of instructor.

**GEOP 631 Seismic Data Processing**
**Credits 4. 3 Lecture Hours. 3 Lab Hours.**
Methods used to image the Earth using seismic reflection data, including deconvolution, f-k filtering, velocity analysis and migration; processing software; emphasis on field data.
**Prerequisite:** Graduate classification or approval of instructor.

**GEOP 651 Theoretical Seismology**
**Credits 3. 3 Lecture Hours.**
Wave propagation in unbounded and bounded elastic media; seismic reciprocity and the elastodynamic representation theorem; radiation patterns from earthquake sources; body waves, Rayleigh waves, Stoneley waves, Love waves and Lamb waves; characteristic equation for surface waves in a layered half-space; dispersion and phase and group velocities; methods of stationary phase and steepest descents; Cagnaird-deHoop technique; ray theory in an inhomogeneous earth; inversion of travel times; viscoelastic wave propagation; normal modes of vibration of the earth.
**Prerequisite:** GEOP 652 or approval of the instructor. (Offered in alternate years.)

**GEOP 652 Earthquake Seismology**
**Credits 3. 3 Lecture Hours.**
Seismometry and earthquake precursors; mathematical theory of elasticity and its application to earthquake studies; dissipation of elastic energy; seismic sources; earthquake risk; free modes of the earth; discrimination between underground nuclear explosions and earthquakes.
**Prerequisite:** GEOP 421 or approval of instructor.

**GEOP 655 Borehole Acoustic**
**Credits 3. 3 Lecture Hours.**
Introduces propagation of acoustic waves in boreholes, with applications to petroleum exploration and comparisons to other waveguide phenomena in the earth sciences; survey of full waveform acoustic logging and influence of borehole modes for crosswell and vertical seismic profile experiments; exercised in data analysis with industry software.
**Prerequisite:** GEOP 421 or GEOP 652 or approval of instructor.

**GEOP 660 Physics of the Earth's Interior**
**Credits 3. 2 Lecture Hours. 3 Lab Hours.**
Physics of the Earth's Interior. Structure, composition and physical state of the Earth's interior; constraints on models of the Earth imposed by seismic, gravity, heat flow, and electrical conductivity; thermodynamics and high pressure mineral physics; Earth's motion and deformation; rheology.
**Prerequisite:** Graduate classification.

**GEOP 661 Reservoir Rock Physics**
**Credits 4. 3 Lecture Hours. 2 Lab Hours.**
Poroelasticity and electrodynamics of porous media; Biot Theory, Gassman fluid substitution and advanced rock physics models; relationships between seismic/electromagnetic properties and multiphase reservoir properties such as porosity, saturation, permeability, wettability, connectivity and other pore-structure parameters; computer-based rock physics modeling; application to reservoir characterization; time-lapse reservoir monitoring.
**Prerequisite:** Approval of instructor. (Spring, alternate years.)

**GEOP 662 Advanced Reservoir Rock Physics**
**Credits 3. 3 Lecture Hours.**
Continuation of GEOP 661; topological characterization of fractured porous media and Reimannian manifold, balance laws of an effective medium, balance laws of interacting fields, compatibility equations and structural evolution, equations of relative motion, thermodynamics and constitutive relations, wave phenomena and fluid flow in fractured porous media.
**Prerequisites:** GEOP 661 and approval of instructor.

**GEOP 666 Principles of Geodynamics**
**Credits 4. 4 Lecture Hours.**
Geological and geophysical methods and phenomena pertinent to geodynamics; plate tectonics; seismicity and seismology; magnetics; gravity; heat flow; igneous, metamorphic and sedimentary petrology; paleontology; and rock mechanics.
**Prerequisite:** Approval of instructor.

**GEOP 681 Seminar**
**Credit 1. 1 Lecture Hour.**
Discussion of subjects of current importance.
**Prerequisite:** Graduate classification.

**GEOP 685 Directed Studies**
**Credits 1 to 6. 1 to 6 Other Hours.**
For graduate students to undertake limited investigations not within their thesis or dissertation research and not covered in established curricula.
**Prerequisites:** Graduate classification and approval of department head.

**GEOP 689 Special Topics in...**
**Credits 1 to 4. 1 to 4 Lecture Hours.**
Selected topics in an identified area of geophysics. May be repeated for credit.
**Prerequisites:** Graduate classification and approval of instructor.

**GEOP 691 Research**
**Credits 1 to 23. 1 to 23 Other Hours.**
Research toward thesis or dissertation.