GEOPHYSICS

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Chair: Jerry M. Harris
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Assistant Professor: Kevin Arrigo
Professors (Research): Antony Fraser-Smith,** Gerald M. Mavko
Associate Professor (Research): Biondo Biondi
Courtesy Professors: Stephan A. Graham, David D. Pollard
Lecturer: Phil Farrell
Consulting Professors: James Berryman, William Ellsworth, Stephen Kirby, Walter Mooney, David Scholl, Paul Spudich
Consulting Associate Professors: Stewart Levin, Zhijing Wang
Consulting Assistant Professor: David Lumley
Visiting Professors: Ze'ev Reches, William Symes
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Geophysics is the branch of earth science concerned with exploring and analyzing active processes of the earth through physical measurement. The undergraduate and graduate programs are designed to provide (1) a background of fundamentals in science, and (2) courses to coordinate these fundamentals with the principles of geophysics. The program leading to the Bachelor of Science (B.S.) in Geophysics permits many electives and a high degree of flexibility for each individual student. Graduate programs provide specialized training for professional work in resource exploration, research, and education and lead to the degrees of Master of Science and Doctor of Philosophy.

The Department of Geophysics is housed in the Ruth Wattis Mitchell Earth Sciences Building. It has numerous research facilities, among which are a state-of-the-art broadband seismic recording station, high pressure and temperature rock properties and rock deformation laboratories, computers, various instruments for field measurements including seismic recorders, nine dual frequency GPS receivers, and field equipment for measuring in-situ stress at great depth. Current research activities include biogeochemical cycling; crustal deformation; earthquake archaeology; earthquake seismology and earthquake mechanics; reflection, refraction, and tomographic seismology; rock mechanics, rock physics; seismic studies of the continental remote sensing. lithosphere, and environmental geophysics; and synthetic aperture radar studies.

UNDERGRADUATE PROGRAMS

BACHELOR OF SCIENCE

Objectives—To provide a solid background in the essentials of math, physics, and geology, while at the same time providing knowledge about the entire spectrum of geophysics ranging from exploration geophysics to earthquake seismology and plate tectonics. Students are prepared for either an immediate professional career in the resources and environmental sciences industries or future graduate study.

The following courses are required for the B.S. degree in Geophysics. A written report on original research or an honor's thesis is also required through participation in three quarters of Research Seminar (the Geophysics 185 series) during the senior year. Seniors in Geophysics who expect to do graduate work are urged to take the Graduate Record Examination as early as is convenient in their final undergraduate year.

CURRICULUM

Course No. and Subject
Chem. 31. Chemical Principles
Elect. Engr. 141 *or* Physics 120. Electromagnetic Fundamentals
Geolog. & Envir. Sci. 1. Fundamentals of Geology
Geophy. 185. Research Seminars
Math. 19, 20, 21 *or* 41, 42, *or* 51, 52
Math. 130. Ordinary Differential Equations
Physics 41. Mechanics
Physics 110. Intermediate Mechanics
9 units of Geophysics electives selected from Geophys. 40, 106, 111, 130, 135, 150, 160, 182, 183, 190, 196, 262
9 units of other earth science electives selected from Geolog. & Envir. Sci. 80, 90, 102, 110, 111, 112; *or* Pet. Engr. 120, 160

Recommended elective: Comp. Sci. 106A. Programming Methodology

MINORS

The Geophysics minor provides students with a general knowledge of geophysics in addition to a background in the related fields of physics, mathematics, and geology.

Curriculum—
Earth Sys. 110. Geosphere *or* Geolog. & Envir. Sci. 1. Fundamentals of Geology
Geophys. 150. General Geophysics *or* 190. Environmental Geophysics
Math. 41. Single Variable Calculus
Physics 41. Mechanics
Two approved Geophysics courses of 3 units each

HONORS PROGRAM

The department offers a program leading to the B.S. degree in Geophysics with Honors. The guidelines are:

1. Select a research project, either theoretical, field, or experimental, that has the approval of an adviser.
2. Submit a proposal to the department, which will decide on its suitability as an honors project. Necessary forms are in the department office.
3. Course credit for the project is assigned by the adviser within the framework of Geophysics 205.
4. The decision as to whether a given independent study project does or does not merit an award of honors shall be made jointly by the department and the student's adviser. This decision shall be based on the quality of both the honors work and the student's other work in earth sciences.
5. The work done on the honors program should not be used as a substitute for regularly required courses.

COTERMINAL B.S. / M.S. PROGRAM

The department offers a coterminal program. Interested individuals should check with a member of the department faculty for the details.

GRADUATE PROGRAMS

University requirements for the M.S. and Ph.D. are described in the "Graduate Degrees" section of this bulletin.

MASTER OF SCIENCE

Objectives—To enhance the student's training for professional work in geophysics through the completion of fundamental courses, both in the major fields and in related sciences, and to begin independent work and specialization.

Requirements for the Degree—The candidate must complete 45 units from the following groups of courses:

1. Complete fifteen units of Geophysics lecture courses with at least nine units numbered 200 level or higher.
2. Complete six units numbered 100 level or higher and three units of 200 level, non-Geophysics lecture courses in earth sciences.
3. Complete one to four electives selected from courses numbered 100 or higher from mathematics, chemistry, engineering, physics, biology, computer science or earth science. At least one course must be numbered 200 level or higher.
4. At least 9, but not more than 18, of the 45 units must be independent work on a research problem resulting in a written report accepted and

archived by the candidate's faculty adviser. Normally, this research is undertaken as part of the candidate's participation in multiple quarters of research seminar (the Geophysics 385 series). A summer internship is encouraged as a venue for research, but no academic credit is given.
5. Submit a program proposal for approval by a faculty adviser in the first quarter of enrollment.
6. Each candidate must present and defend the results of his or her research at a public oral presentation attended by at least two faculty members.

DOCTOR OF PHILOSOPHY

Objectives—The Ph.D. degree is conferred upon evidence of high attainment in Geophysics, and ability to conduct an independent investigation and present the results of such research.

Requirements for the Degree—A minimum of 135 units of graduate study at Stanford must be satisfactorily completed. An acceptable program will normally consist of at least 45 lecture units of which 18 units may be satisfied by post-baccalaureate courses taken elsewhere. The following course and groups of courses must be completed:
1. Engineering 102W or 202W
2. Twelve (12) units of Geophysics lecture courses numbered 100 level or higher.
3. Twelve (12) units of Geophysics lecture courses numbered 200 level or higher, taken from at least four faculty members with a different research specialization.
4. One 3-unit course numbered 100 level or higher in math, science or engineering covering mathematical methods, continuum or fluid mechanics or Fourier/spectral analysis.
5. Nine (9) units of 200 level or higher courses in math, science or engineering covering the above topics.
6. Six (6) units of non-Geophysics lecture courses numbered 100 level or higher in earth or planetary sciences, ecology, hydrology, chemistry or relevant biology.
7. One 3-unit non-Geophysics lecture course numbered 200 level or higher in the above area.
8. Eighty-seven (87) units or more of independent work on a research problem. Twelve (12) units of this requirement must be met by participation in the Geophysics 385 series. Students are encouraged to participate in the Geophysics 385 series from more than one faculty member or group.

Waiving of any course requirements or substitution of other electives requires the written consent of the student's faculty adviser and the Geophysics Graduate Coordinator.

The student's record must indicate outstanding scholarship, and deficiencies in previous training must be removed. Experience, as a teaching assistant (quarter-time for at least two academic quarters) is required for the Ph.D. degree. The student must pass the departmental oral examination by presenting and defending a written research paper or proposal by the end of the second year; prepare under faculty supervision a dissertation that is a contribution to knowledge and the result of independent work expressed in satisfactory form; and pass the University oral examination. The Ph.D. dissertation must be submitted in its final form within five calendar years from the date of admission to candidacy. The Geophysics faculty monitor student progress by carrying out an annual performance appraisal (at a closed faculty meeting) of all students who have not yet passed their department oral examination. Following successful completion of the department oral examination, students are required to organize an annual meeting of their research committee to review their progress towards the Ph.D. degree.

COURSES

3. Earthquakes and Volcanoes—Introduction to the study of earthquakes and volcanoes: earthquake location, magnitude and intensity scales, seismic waves, styles of eruptions and volcanic hazards, tsunami waves, types and global distribution of volcanoes, volcano forecasting. Plate tectonics as a framework for understanding earthquake and volcanic processes. Forecasting; earthquake resistant design; building codes; and probabilistic hazard assessment. For non-majors and potential earth scientists. GER:2b

3 units, Aut (Beroza, Segall)

4. Natural Hazards and Human Survival—For non-majors and potential earth scientists. Introduction to understanding natural and other hazards, earthquakes, volcanic eruptions, tsunamis, toxic waste disposal, nuclear power plant siting, their risk assessment, possible mitigation, and protective measures. GER:2a

3 units, Win (Kovach)

5Q. Stanford Introductory Dialogue: Earthquakes of the Americas—Preference to sophomores. Earthquakes have had an impact on the development of cultures and societies. The early empires of the Maya and the Aztecs undoubtedly experienced earthquakes and volcanic eruptions and we rely on archaeological remains and glyphs from codices to ascertain past occurrences. Evidence from several Mexican and Central American archaeological sites uncovers the societal consequences and possible role of these natural events in the abandonment, migration, and settlement of cultural centers.

2 units, Aut (Kovach)

20Q. Stanford Introductory Dialogue: Predicting Volcanic Eruptions—Preference given to students with freshman math, physics, or earth science experience. Volcanoes represent spectacular manifestations of the Earth's internal energy, and a tremendous hazard to society. Earth scientists forecast eruptive activity by monitoring seismic activity, uplift of the ground surface, and the discharge of volcanic gases, and the deposits from past eruption. Topics: understanding the physics and chemistry of volcanic processes, methods for volcano monitoring, and the political and economic challenges of predicting future volcanic behavior. Field trip to Mt. St. Helens, site of the devastating 1980 eruption.

3 units, Spr (Segall)

30Q. Stanford Introductory Dialogue: The 1906 San Francisco Earthquake—Preference to sophomores. The impact of this event on the history of Northern California and on the scientific study of earthquakes. What happened in Northern California during the earthquake and the days that followed, and what experts think might happen the next time a large earthquake strikes the San Francisco Bay Area. Field trips to the San Andreas Fault and to San Francisco to view the source and effects of the earthquake first hand.

2 units, Spr (Beroza)

40. The Earth from Space: Introduction to Remote Sensing—Global change and remote sensing. Global warming, ozone depletion, the hydrologic and carbon cycles, topographic mapping, surface deformation. Physical concepts in remote sensing. EM waves and geophysical information. Sensors: optical, thermal IR, active and passive microwave. GER:2b

3 units, Spr (Zebker), alternate, given 2002-03

50Q. Stanford Introductory Seminar: Earthquakes and Archaeology in the Eastern Mediterranean—Lectures and Field Trip—Preference to sophomores. Why are there so many archaeological ruins in the eastern Mediterranean? Assumed by many to be the result of time and wars, many of these ruins are due to historic and prehistoric earthquakes. Modern science reveals that some of these earthquakes must have been so destructive, or happened at times of such political and military stress, that they changed history (e.g., the fall of Jericho before Joshua, the catastrophic collapse at the end of the Bronze Age). Lectures in Winter Quarter, followed during spring break by a 6-9-day field trip to the eastern Mediterranean or Central America. Students complete a term report on a site or event covered in the field trip.

5 units, Win (Nur)

60Q. Stanford Introductory Seminar: Man vs. Nature—Coping with Disasters using Space Technology—(Same as Electrical Engineering 60Q.) Preference to sophomores. Natural hazards (earthquakes, volcanoes, floods, hurricanes, and fires) affect thousands of people everyday. Twenty years of developments in spaceborne imaging technology monitor and respond to such disasters more rapidly than in the past, saving lives and money. Understanding the physical processes involved allows us to anticipate and plan for mitigation of the consequences. Students consider how these new tools are applied to natural disasters, and how remotely sensed data are manipulated and analyzed.
3 units, Aut (Zebker)

100. Directed Reading—Intensive study of the literature of any special topic. Preparation and presentation of reports. Individual assignments with any faculty member on any topic in Geophysics.
1-2 units, any quarter (Staff)

102. Earth, Oceans and Atmospheres—(Same as Earth Systems 102.) For non-majors and potential earth scientists. The changing planet presents society with a myriad of problems. How do global climate systems work and how do natural and anthropogenic sources of climate change affect us? Are we running out of energy? What are the consequences of energy use? What are our options? How does plate tectonics affect our daily lies and what is the nature of earthquake hazards in both California and the Bay Area? A large scale "system" approach to the solid earth, oceans; and atmospheres to address the questions is taken of current and future generations of Stanford students. GER:2a
3 units, Aut (Zoback, Arrigo)

104. The Water Course—(Same as Earth Systems 104.) Issues associated with the use and abuse of our surface and ground water supplies. The ways the geological environment controls the quantity and quality of our water; illustrated with a "taste test" of water from around the world. An understanding of current concerns regarding water supplies is used as a basis for considering the past and future impact of the availability of water on natural ecosystems and human settlement. Lab. Prerequisite: Math 51.
3 units, Win (Knight)

106. Planetary Exploration—(Enroll in Electrical Engineering 106.)
3 units, Spr (Fraser-Smith)

111. Introduction to Computing in Earth Sciences—Computing tools for research in earth sciences at Stanford. Focuses on: UNIX operating system, including file system, editors, process control, and X windows; computer networking services, and management of programming projects.
1 unit, Aut (Farrell)

112. Exploring Geosciences with MATLAB—Introduction to efficient use of Matlab as a tool for research in Engineering and Earth Sciences. Hands-on, computer-based exercises explore the 2-D and 3-D visualization features, numerical capabilities, and various Matlab toolboxes, addressing simple problems in widely applicable areas, e.g., data analysis, statistics, regressions, least-squares, Fourier transforms and filtering in 1- and 2-D, simple spectral analysis, differential equations, and simulations. Emphasis is from a scientific and engineering application perspective.
1-3 units, Aut (Mukerji)

120. Frontiers of Geophysical Research at Stanford—Required of new students entering the department. Second year and other graduate students may attend either for credit or as auditors. Department and senior research staff lectures introduce the frontiers of research problems and the methods being employed or developed in the department and unique to department faculty and students (what the current research is, why the research is important, what methodologies and technologies are being used, and what the potential impact of the results might be).
2 units, Aut (Harris)

130. Biological Oceanography—(Same as Earth Systems 130.) Required for Earth Systems students in the Oceans track. Interdisciplinary look at how oceanic environments control the form and function of marine life. Topics: distributions of planktonic production and abundance, nutrient cycling, the role of ocean biology in the climate system, expected effects of climate changes on ocean biology. Possible local field trips weekends. Prerequisites: Biology 43. and Geological and Environmental Sciences 8 or equivalent.
3-4 units, Spr (Arrigo)

135. Remote Sensing of the Oceans—(Same as Earth Systems 135.) How to observe and interpret physical and biological changes in the oceans using satellite technologies. Topics: principles of satellite remote sensing, classes of satellite remote sensors, converting radiometric data into biological and physical quantities, sensor calibration and validation, interpreting large-scale oceanographic features.
3 units, Win (Arrigo) alternate years, not given 2002-03

150. General Geophysics and Physics of the Earth—Elementary study of gravitational, magnetic, seismic, and thermal properties of the earth. Earth's crust, mantle, core. Plate tectonics and mantle convection. Probing earth structure with seismic waves. Measurements, interpretation, and applications to earth structure and exploration. Prerequisites: calculus, first-year college physics.
3 units, Aut (Sleep, Klemperer)

160. Waves—Topics: derivations of wave equations and their solutions in 1-D, 2-D, and 3-D; amplitude, polarization, phase and group velocities, attenuation, and dispersion; reflection and transmission at single and multiple interfaces; ray theory. Applications from acoustics, elastodynamics, and electromagnetics. Prerequisites: differential/integral calculus and complex functions.
3 units, Win (Harris, Claerbout, Beroza)

180. Geophysical Inverse Problems—Fundamental concepts of inverse theory, with application to geophysics. Inverses with discrete and continuous models, generalized matrix inverses, resolving kernels, regularization, use of prior information, singular value decomposition, nonlinear inverse problems, back-projection techniques, and linear programming. Application to seismic tomography, earthquake location, migration, and fault-slip estimation. Prerequisite: Mathematics 103.
3 units, Spr (Beroza, Segall)

182. Reflection Seismology—The principles of seismic reflection profiling, focusing on methods of seismic data acquisition and seismic data processing for hydrocarbon exploration.
3 units (Klemperer) alternate years, given 2002-03

183. Interpretation of Seismic Reflection Profiles—Lectures and workshops on the structural and stratigraphic interpretation of seismic reflection data, emphasizing hydrocarbon traps in two and three dimensions on industry data, including workstation-based interpretation. Lectures only, 1 unit. Prerequisite: 182, or consent of instructor.
1-4 units (Klemperer, Graham) alternate years, given 2002-03

184. Seismic Data Processing—Workshop experience in computer processing of seismic reflection data. Students individually process a commercial seismic reflection profile from field tapes to migrated stack, using interactive software on a workstation. Prerequisite: consent of instructor.
3 units (Klemperer) alternate years, given 2002-03

185. Research Seminar Series—Limited to Geophysics undergraduates and coterminal master's candidates. Undergraduates participate directly in an ongoing research project: experimental and computational work, joining in reading and study groups, giving seminar papers, and doing original research for the undergraduate thesis. Prerequisite: consent of instructor.
1-2 units, Aut, Win, Spr

185A. Reflection Seismology—Department research in reflection seismology and petroleum prospecting.
(Biondi, Claerbout)

185B. Environmental Geophysics—Research on the use of geophysical methods for near-surface environmental problems.
(Knight)

185D. Topics in Crustal Fluids—Research in interdisciplinary problems involving the state and movement of fluids in the earth's crust. Content varies each quarter.
(Nur)

185E. Tectonics—Research on the origin, major structures, and tectonic processes of the earth's crust. Emphasis is on use of deep seismic reflection and refraction data.
(Klemperer, Sleep, Thompson)

185K. Borehole Geophysics—Research in areas of petrophysics, seismology, in situ stress, and subjects related to characterization of the physical properties of rock in situ.
(Zoback)

185L. Earthquake Seismology, Deformation, and Stress—Current research on seismic source processes, crustal stress, and deformation associated with faulting and volcanism.
(Segall, Zoback, Beroza)

185S. Seismic Tomography—Current research in transmission and reflection tomography, including topics on forward modeling, inversion, and data acquisition.
(Harris)

185V. Poroelasticity—Current research topics on the mechanical properties of porous rocks: dynamic problems of seismic velocity, dispersion, and attentuation; and quasi-static problems of faulting, fluid transport, crustal deformation, and loss of porosity. Participants define, investigate, and present an original problem of their own.
(Mavko)

185Y. Theoretical Ecology—Discussions of recent and classical research papers in ecology, and presentation of work in progress by seminar participants. Prerequisite: consent of instructor.
(Roughgarden)

185X. Applied Geophysics
(Staff)

185Z. Seminar in Radio Remote Sensing—Radar remote sensing techniques and applications. Emphasis is on current research applications, especially crustal deformation measurements. Recent instrumentation and system advancements.
(Zebker)

190. Applied Geophysical Methods—Principles and applications of geophysical methods, seismic reflection and refraction, gravity, magnetics, electromagnetics, resitivity and ground penetrating radar. Hands-on field exercises and demos, run at the Stanford geophysical test site and other locations on campus, familiarize students with the instrumentation and the application of each method.
3 units (Harris, Fraser-Smith) alternate years, given 2002-03

196. Introduction to Geographic Information Systems (GIS): using ARC/View—(Graduate students enroll in 296; same as Geological and Environmental Sciences 196.) Hands-on experience with ESRI's ArcView GIS packages. Topics: setting up geographic databases and manipulating spatial data, including database query and analysis. Hands-on computer-based exercises using sample datasets on workstations. Guest lectures on GIS applications in the environmental, geological, and biological sciences; and in town planning. Students unable to register for 196 may sign up, with consent of instructor, for a self-paced computer tutorial version in 197, any quarter.
2 units, Win (Klemperer)

197. Problems in Geographic Information Systems (GIS)—Supervised research and/or reading with written reports.
1-5 units, Aut, Win, Spr (Klemperer)

200. Fluids and Tectonics—Interdisciplinary problems involving the state and movement of fluids in the earth's crust: basics of the coupling in porous and cracked rocks between chemical transport, fluid flow, deformation and stress, and waves; applications to gas hydrates under the oceans; pore pressure in faulting and aftershocks and in the earth's crust; dilatancy; permeability from seismic; aseismic plate deformation; viscoelastic earthquake rebound; pore fluids and subduction; sediment transport and seismic reflection; deformation by pressure solution and stylolites; the opening of backarc basins, and time/space patterns of large earthquakes. Prerequisite: consent of instructor.
3 units, Win (Nur) alternate years, not given 2002-03

202. Reservoir Geomechanics—Basic principles of rock mechanics and the state of stress and pore pressure in sedimentary basins related to exploitation of hydrocarbon and geothermal reservoirs. Mechanisms of hydrocarbon migration, exploitation of fractured reservoirs, reservoir compaction and subsidence, hydraulic fracturing, utilization of directional and horizontal drilling to optimize well stability.
3 units, Win (Zoback)

205. Honors Program—Experimental, observational, or theoretical honors project and thesis in geophysics under supervision of a faculty member. Students who elect to do an honors thesis should begin planning it no later than Winter Quarter of the junior year. Prerequisites: superior work in the earth sciences and approval of the department.
1-3 units, Aut, Win, Spr, Sum (Staff)

210. Basic Earth Imaging—Echo seismogram recording geometry, head waves, moveout, velocity estimation, making images of complex shaped reflectors, migration by Fourier and integral methods. Anti-aliasing. Dip moveout. Computer labs. See http://sepwww.stanford.edu/sep/prof/.
3-4 units, Aut (Claerbout)

211. Environmental Soundings Image Construction—Basic ideas of geophysical data mapping and imaging as exemplified by a variety of elementary examples: interpolate, extrapolate, regrid, depth sounding, sea-beam bathymetry, satellite altimetry, imaging, seismic velocity, and reflectivity. Adjoints, back projection, and images. Applied inverse theory using least-squares conjugate gradients. Weights and filters in data space and model space. Decompose data into signal and noise. See http://sepwww.stanford.edu/sep/prof/.
3 units, Win (Claerbout)

215. Advanced Structural Geology and Rock Mechanics—(Same as Geological and Environmental Sciences 215.) The observational techniques, analysis methods, and theoretical foundations of structural geology, engineering geology, and rock mechanics. Computer exercises are integrated with field data to understand the role of geologic structures in the evolution of the earth's crust (folding, faulting, flow, and fracturing of rock) and geologic hazards (earthquakes and volcanoes). Topics: structural quantities and dimensional analysis; use of stress, strain, displacement, and velocity fields in structural analysis; concept and measurement of deformation; mechanical properties of rock (elasticity, viscosity, strength, friction, fracture toughness); case studies of typical geologic structures using continuum mechanics. Computer labs.
5 units, Aut (Pollard)

216. Rock Fracture Mechanics—(Same as Geological and Environmental Sciences 216.) Theoretical and experimental principles of continuum and fracture mechanics are applied to the origin and physical behavior of faults, dikes, joints, veins, solution surfaces, and other natural structures in rock. Field observations, engineering rock fracture mechanics, and the elastic theory of cracks. The role of natural fractures in brittle rock deformation, fluid flow, and heat transport in the earth's crust with applications to crustal deformation and tectonophysics, structural geology, petroleum geology and engineering, and hydrogeology. Prerequisite: 215 or equivalent.
5 units, Spr (Pollard) alternate years, not given 2002-03

230. Advanced Topics in Well Logging—(Same as Petroleum Engineering 230.) Designed to follow a course in basic well logging, and assumes knowledge of standard practice and application of electric well logs. State-of-the-art tools and analyses; the technology, rock physical basis, and applications of each measurement. Hands-on computer-based analyses illustrate instructional material. Guest speakers on specific formation evaluation topics. Prerequisite: Petroleum Engineering 130 or equivalent.

3 units, Spr (Lindblom)

240. Borehole Seismology—The study and application of seismic-acoustic waves in and around boreholes for application to sonic well logging, crosswell seismic profiling, and vertical seismic profiling. Topics: forward modeling, seismogram interpretation, data processing, imaging, and inversion. Applications from reservoir and site characterization studies and reservoir monitoring. Prerequisite: consent of instructor.

3 units (Harris) alternate years, not given 2002-03

241. Practice of Geostatistics and Seismic Data Integration—(Same as Geological and Environmental Sciences 241, Petroleum Engineering 241.) Students build a synthetic 3D fluvial channel reservoir model with layer depths, channel geometry, and facies-specific petrophysic and seismic properties, stressing the physical significance of geophysical data. Reference data set is sparsely sampled, providing the sample data typically available for an actual reservoir assessment. Geostatistical reservoir modeling uses well and seismic data, with results checked against the reference database. All software provided (Gslib and SRB-tools). Recommended: basic prior experience with Unix, Matlab/Fortran programming. Prerequisite: Petroleum Engineering 240.

3-4 units, Spr (Caers, Mukerji)

260. Rock Physics for Reservoir Characterization—Topics: learn to integrate well log and laboratory data to determine and theoretically generalize rock physics transforms between sediment wave properties (acoustic and elastic impendance), bulk properties (porosity, lithology, texture, permeability) and pore fluid conditions (pore fluid and pore pressure); these transforms will be used in seismic interpretation for reservoir properties, and seismic forward modeling in what-if scenarios.

3 units (Dvorkin) alternate years, given 2002-03

262. Rock Physics—Properties of and processes in rocks as related to geophysical exploration, crustal studies, and tectonic processes. Emphasis is on wave velocities and attenuation, hydraulic permeability, and electrical resistivity in rocks. Application to in situ problems, using lab data and theoretical results.

3 units, Spr (Mavko)

265. Radar Remote Sensing: Fundamentals and Geophysical Applications of Imaging Radar Systems—Topics include radar system elements, the radar equation and signal to noise ratio, signal and image processing, range/Doppler algorithms, interferometric measurements. Applications to crustal deformation, topographic mapping, velocities of ice sheets and glaciers, polarimetry and terrain analysis. Computational labs give hands-on-experience with real data.

3 units, Spr (Zebker) alternate years, not given 2002-03

280. 3-D Reflection Seismology—The principles of imaging complex structures in the Earth subsurface using 3-D reflection seismology. Emphasis is on processing methodologies and algorithms, with examples of applications to field data. Topics: acquisition geometrics of land and marine 3-D seismic surveys, time vs. depth imaging, migration by Kirchhoff methods and by wave-equation methods, migration velocity analysis, velocity model building, imaging irregularly sampled and aliased data. Computational labs involve some programming. Lab for 3 units.

2-3 units, Spr (Biondi)

287. Earthquake Seismology—Topics: basic theorems in elastodynamics, Green's functions, attenuation, wave propagation in layered media, ray theory, seismic moment tensors, finite-source effects, kinematics and dynamics of earthquakes, engineering aspects of seismology.

3 units (Beroza) alternate years, given 2002-03

288. Crustal Deformation—Collection, reduction, and analysis of crustal deformation measurements for the study of relative plate motions, plate boundary deformation, earthquake and volcanic processes, post-glacial rebound, and land subsidence. Mechanical models of faulting and magmatic deformation, coupled fluid flow and deformation, and inverse methods for analyzing data.

3 units (Segall) alternate years, not given 2002-03

289. Global Positioning System in Earth Sciences—The basics of GPS, emphasizing monitoring crustal deformation with a precision of millimeters over baselines tens to thousands of kilometers long. Applications: mapping with GIS systems, airborne gravity and magnetic surveys, marine seismic and geophysical studies, mapping atmospheric temperature and water content, measuring contemporary plate motions, and deformation associated with active faulting and volcanism.

3 units (Segall) alternate years, given 2002-03

290. Tectonophysics—The physics of faulting and plate tectonics. Topics: plate driving forces, lithospheric rheology, crustal faulting, and the state of stress in the lithosphere.

3 units (Zoback) alternate years, given 2002-03

296. Introduction to Geographic Information Systems (GIS): using Arc-View—(Same as Geological and Environmental Sciences 296.) For graduate students; see 196.

2 units, Win (Klemperer)

297. Problems in Geographic Information Systems (GIS)—Supervised research and/or reading with written reports.

1-5 units, Aut, Win, Spr (Klemperer)

355A. Imaging Radar and Applications—(Enroll in Electrical Engineering 355.)

3 units, alternate years, given 2002-03

385. Research Seminar Series—Opportunity for advanced graduate students to frame and pursue research or thesis research within the context of one of the ongoing research projects in the department, and present thesis research progress reports before a critical audience on a regular basis. See 185 series for descriptions. Prerequisite: consent of the instructor.

1-3 units, Aut, Win, Spr

385A. Reflection Seismology
(Biondi, Claerbout)

385B. Environmental Geophysics
(Knight)

385D. Topics in Crustal Fluids
(Nur)

385E. Tectonics
(Klemperer, Sleep, Thompson)

385K. Borehole Geophysics
(Zoback)

385L. Earthquake Seismology, Deformation, and Stress
(Segall, Zoback, Beroza)

385S. Seismic Tomography
(Harris)

385V. Poroelasticity
(Mavko)

385Y. Theoretical Ecology—(Same as Biological Sciences 384.)
(Roughgarden)

385X. Applied Geophysics
(Staff)
385Z. Radar Remote Sensing
(Zebker)

399. Teaching Experience in Geophysics—On-the-job training in the teaching of geophysics. An opportunity to develop problem sets and lab exercises, grade papers, and give occasional lectures under the supervision of the regular instructor of a geophysics course. Regular conferences with instructor and with students in the class provide the student teacher with feedback about effectiveness in teaching.
2-4 units, any quarter (Staff)

400. Research in Geophysics
any quarter (Staff)

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