GEOPHYSICS

Emeritus: George A. Thompson (on active duty)
Chair: Jerry M. Harris
Professors: Jon F. Claerbout, Steven Gorelick, Jerry M. Harris, Rosemary J. Knight, Robert L. Kovach, Marcia McNutt††, Amos M. Nur, Joan Roughgarden*, Paul Segall, Norman H. Sleep, Mark D. Zoback
Associate Professors: Gregory C. Beroza, Simon L. Klemperer, Howard Zebker**
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: Steven R. Pride, William Symes
Visiting Associate Professor: Goetz Bokelmann
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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, in addition to the University requirements in general studies. A written report on original research or an honor's thesis is also required. Normally, this is undertaken as part of the student's 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, 170, 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 objective of the Geophysics minor is to provide 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.

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:

1. Be registered as a graduate student for at least three quarters at full tuition.
2. Complete 45 units with a grade point average (GPA) of at least 'B.' Geophysics 110, 111, 112, 120, 150, 190, and Engineering 102W are required. If appropriate, requirements may be waived and additional electives substituted with consent of the candidate's faculty adviser and of the Geophysics Graduate Coordinator. Recommended electives are Geophysics 160, 170, 174, 180; Mechanical Engineering 200A; and Electrical Engineering 261. At least 6, but not more than 18, of these units must be independent work on a research problem, resulting in a written report accepted 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).

3. Make up deficiencies in previous training. Not more than 10 units of such work may be counted as part of the minimum total of 45 units.
4. Submit a Program Proposal for the Master's Degree in the first quarter of enrollment.
5. Each student must present and defend the results of his or her research at a public oral presentation attended by at least two faculty members. Students who do not meet the standard course requirements (see the undergraduate curriculum), but who have unusual competence in other areas such as earth systems, science, or space physics may petition the Geophysics faculty to arrange individual programs.

M.S. IN EXPLORATION AND DEVELOPMENT

Objectives—To provide the theoretical and practical background needed for a career in petroleum exploration and development geophysics. The program takes a minimum of four quarters (beginning and ending in the Autumn Quarter), but more typically six quarters. A summer internship working in industry, or a research or experimental laboratory, is an integral part of the program. A written report based on the summer internship is publicly presented and defended. Some MSED students also accomplish independent research during their degree program through their participation in one or multiple quarters of Research Seminar (the Geophysics 385 series).

Prerequisites—B.S. degree in engineering, geology, geophysics, mathematics, or physics; a sequence of courses in mathematics at least through ordinary differential equations; and at least one course in introductory geology. The following additional undergraduate courses are recommended: computer science, complex variables, linear algebra, petrography, and structural geology.

Requirements for the Degree—Geophysics 111, 112, 120, 150, 174, 182, 183, 190, 210, 262, 380A, 380B; Geological and Environmental Sciences 110 or 111, 240, 247 or 248, 251, 253; Petroleum Engineering 120, 130; Electrical Engineering 104 or 261; and elective courses in earth sciences, mathematics, physics, and engineering. If appropriate, requirements may be waived and additional electives substituted with consent of the candidate's faculty adviser and of the Geophysics faculty Graduate Coordinator. Recommended electives include Geophysics 160, 170, 180, 202, 230, 285, 397; Geological and Environmental Sciences 151, 249; and Mechanical Engineering 200A. At least 45 units with a grade point average (GPA) of at least 'B' are required for the completion of this degree.

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 three years and the completion of 108 units of graduate study at Stanford must be satisfactorily completed. During their first two years, candidates must complete a core sequence of classes: Geophysics 111, 112, 120, 150, 160; Mechanical Engineering 200A, 238A; Electrical Engineering 261 or Mechanical Engineering 308; and one data analysis course such as Geophysics 180 or 211, Petroleum Engineering 284, Civil and Environmental Engineering 267, Geological and Environmental Sciences 160 or 240, Statistics 110, or equivalent. Candidates must also participate in Research Seminars (the Geophysics 385 series) from their first quarter.

During the course of their studies, Ph.D. candidates are additionally required to complete Geophysics 170, 190; Engineering 102W; Physics 210 or Mathematics 220A or Mechanical Engineering 200B. Students are also encouraged to complete Physics 211 or Mathematics 220B or Mechanical Engineering 200C. Candidates are required to complete lecture classes outside the core sequence from at least two different Geophysics faculty members; and at least two non-Geophysics lecture classes in Earth Sciences (that is, the Department of Geological and Environmental Sciences and/or the Department of Petroleum Engineering). A minimum equivalent knowledge at the level of Geological and Environmental sciences 1 is required. Highly recommended non-Geophysics Earth Science courses are Geological and Environmental Sciences 111, 120, 140, 231, and 251; and Petroleum Engineering 120, 130, 221, 224, and 240. Additional advanced courses should be selected from other science and engineering departments. A typical sequence for entering graduate students in their first year is: Autumn—Geophysics 111, 112, 120, 150, and Mechanical Engineering 200A or 238A; Winter—Geophysics 160, 385, and one elective; Spring—Geophysics 180, 385, and Electrical Engineering 261 or other elective. All students prepare a proposed study list for each year by the end of the first quarter of that year.

If appropriate, any class requirement may be waived, or electives substituted, with written consent of both the candidate's faculty adviser and the Geophysics Graduate Coordinator.

The candidate'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, which is essentially a defense of the dissertation. 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, candidates are required to organize an annual meeting of their research committee to review their progress towards the Ph.D. degree.

COURSES

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 (DR:5)

3 units, Aut (Beroza, Segall)
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)

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 (DR:6)

3 units, Spr (Zebker)

50Q. Stanford Introductory Dialogue: 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 10-day field trip to Israel and a neighboring country (Jordan, Egypt, or Greece). Students complete a term report on a site or event covered in the field trip.

2 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)

106. Planetary Exploration—(Enroll in Electrical Engineering 106.)

3 units, Spr (Fraser-Smith)

111. Introduction to Computing in Earth Science—Computing tools for research in earth sciences. How to use existing hardware and software tools. Focuses on: UNIX operating system, computer networking, graphics software, text processing software, 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 unit, 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. Deparment 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 (Nur, 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 plantonic production and abundance, nutrient cycling, the role of ocean biology in the climate system, expected effects of climate changes on ocean biology. Local field trips on weekends. Prerequisites: Biological Sciences core, Geological and Environmental Sciences 8 or equivalent.

4 units, Spr (Arrigo)

135. Remote Sensing of the Oceans—(Same as Earth Systems 135.) How to observe and interpret physical and biological changes using remote technologies such as satellites and instrumented moorings. Topics: principals of satellite remote sensing, classes of satellite sensors and mooring platforms, converting radiometric data into biological quantities, sensor calibration and validation, interpreting large-scale oceanographic features. Prerequisites: Geophysics 130, Earth Systems 130, or Hopkins Marine 163H/263H.

4 units (Arrigo) alternate years, given 2001-02

142. Principles of Ecology—(Same as Biological Sciences 142.) Introduction to ecology, emphasizing ecological theory and the population and community scales of organization, using primarily zoological examples. Evolutionary processes in ecology. Prerequisites: first-year calculus (Mathematics 19-21 or higher). Recommended: Biological Sciences 43 or 51.

4 units, Aut (Roughgarden)

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. Recommended: Geological and Environmental Sciences 110.

3 units, Aut (Sleep, Klemperer)

160. Waves-Wave Propagation in Homogenous, Layered, and Smoothly Varying Heterogenous Media—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)

170. Fluids in the Earth's Crust—Interdisciplinary problems involving the state and movement of fluids in the earth's crust: basics of the coupling in porous rocks between chemical transport, fluid flow, deformation and stress, and waves; applications to gas hydrates under the oceans; reservoir geophysics; geophysical recovery monitoring; aquifer geophysics; pore pressure in faulting and aftershocks and in the earth's crust; permeability from seismic; viscoelastic rebound; pore fluids and subduction; sediment transport to seismic reflection; pressure solution and stylolites. Prerequisite: consent of instructors.

3 units, Win (Nur, Dvorkin)

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, not given 2001-02

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. Lec-

tures only=1 unit. Prerequisite: 182, or consent of instructor.

1-4 units, Spr (Klemperer, Graham) alternate years, not given 2001-02

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, not given 2001-02

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)

185C. Computational Geophysics Seminar—Topics on computational methods in rock physics.

(Bosl)

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—(Same as Biological Sciences 384.) Discussions of recent and classical research papers in ecology, and presentation of work in progress by seminar participants. Prerequisite: consent of instructor.

Spr (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. Environmental and Applied Geophysics—Utilization of geophysical techniques, seismic reflection and refraction, gravity, magnetics, electromagnetics, resistivity and ground penetrating radar for problems related to environmental clean-up, civil engineering, and site characterization.

3 units, Spr (Harris, Knight) alternate years, not given 2001-02

196. Introduction to GIS: ARC/Info and Arc-View—(Graduate students enroll in 296; same as Geological and Environmental Sciences 196.) Hands-on experience with ESRI's ARC/INFO or Arc-View commercial GIS packages. Topics: setting up geographic databases and manipulating spatial data, including database query and analysis. Hands-on computer-based exercises using sample ARC 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. Research in the Application of Geographic Information Systems (GIS)—(Enroll in Geological and Environmental Sciences 197.)

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

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 borehole stability, minimization of sand production.

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/sep/prof .

3-4 units, Aut (Claerbout)

211. Environmental Soundings Image Enhancement—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/sep/prof .

3 units, Win (Claerbout)

215. Advanced Structural Geology and Rock Mechanics—(Same as Geological and Environmental Sciences 215.)

5 units, Aut (Pollard)

216. Rock Fracture Mechanics—(Same as Geological and Environmental Sciences 216.)

5 units (Pollard) alternate years, given 2001-02

230. Advanced Topics in Well Logging—(Same as Petroleum Engineering 230.) Designed to follow a course in standard well logging, and assumes knowledge of standard practice and application of electric well logs. Guest lectures on state-of-the-art tools and analyses; and the technology, rock physical basis, and applications of each measurement. Hands-on computer-based analyses illustrate instructional material. 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, given 2001-02

241. Practice of Geostatistics and Seismic Data Integration—(Same as 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 SRBtools). Recommended: basic prior experience with Unix, Matlab/Fortran programming. Prerequisite: 240.

3-4 units, Spr (Caers, Mukerji)

242. Principles of Ecology—(Enroll in Biological Sciences 242.)

4 units, Aut (Roughgarden)

255. Report on Energy Industry Training—Provides on-the-job training for master's and doctoral degree students under the guidance of experienced, on-site supervisors. Students must submit a concise report detailing work activities, problems, assignments, and key results. Prerequisite: written consent of adviser.

1-3 units, any quarter (Staff)

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)

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)

285. Earth Soundings Analysis—Convolution, spectra, discrete Fourier transform, Z-plane, feedback, adjoint operators, model fitting by least squares, time series analysis, missing data restoration, phase, resolution and random signals, signal entropy.

3 units (Claerbout) alternate years, given 2001-02

286. Electromagnetic Techniques in Geophysics—The general principles behind the electromagnetic techniques used to study the interior of the earth and to detect ore bodies, oil reservoirs, and underground man-made structures. Topics: the earth's magnetic and electric fields, electromagnetic wave propagation through the earth (and through earth materials), electric and magnetic properties of earth materials, earth resistivity methods, magnetotellurics, magnetometers and magnetic-field gradiometers, electromagnetic induction, and ground-penetrating radar. Recommended: undergraduate electromagnetism.

4 units (Fraser-Smith) alternate years, not given 2001-02

287. Earthquake Seismology—Topics: basic theorems in elastodynamics, Green's functions, attentuation, 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, not given 2001-02

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, given 2001-02

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, Win (Segall) alternate years, not given 2001-02

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. Recommended: Geological and Environmental Sciences 215.

3 units (Zoback) alternate years, not given 2001-02

296. Introduction to GIS: ARC/INFO and Arc-View—(Same as Geological and Environmental Sciences 296.) For graduate students; see 196.

2 units, Win (Klemperer)

297. Research in the Application of Geographic Information Systems (GIS)—(Enroll in Geological and Environmental Sciences 297.)

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

355. Report on Energy Industry Training—Provides on-the-job training for advanced doctoral students under the guidance of experienced, on-site supervisors. Students must submit a concise report detailing work activities, problems, assignments, and key results. Prerequisite: written consent of adviser.

1 unit, any quarter (Staff)

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

3 units, alternate years, given 2001-02

380A,B. Seminar: Exploration and Development Geophysics—Visiting speakers discuss aspects of the hydrocarbon exploration industry. Opportunity for M.S. candidates to frame and pursue their thesis research. Second-year students in the Exploration Program report on summer jobs and develop independent research projects, culminating in a written report and oral presentation to the department. First-year students register in 380A. Second year in 380B.

380A. *1 unit, Aut (Mavko)*

380B. *3 units, Aut (Mavko)*

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)

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.)
Spr (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)