

GEO - Geological Sciences

Geological Sciences: GEO

Lower-Division Courses

GEO 401 (TCCN: GEOL 1403). Physical Geology.

Registration priority given to environmental science and geological sciences majors. Nature, properties, and distribution of crustal materials; surficial processes; internal processes; origin of continents, oceans, and ocean basins; mineral and fuel resources. Three lecture hours and two hours of laboratory or fieldwork a week for one semester. Only one of the following may be counted: Geological Sciences 401, 303, 420H.

GEO 302C. Climate: Past, Present, and Future.

Designed for non-geological sciences majors. Principal factors that determine Earth's climate, evidence of climate change, causes of climate change, natural climatic variations and human-induced changes, prediction of climate in the next one hundred years, and uncertainties in climate prediction. Three lecture hours and one and one-half laboratory hours a week for one semester.

GEO 302D. Age of Dinosaurs.

An exploration of the general principles of natural history, focusing on the natural history of dinosaurs. An introduction to the basics of geology, anatomy, paleontology, and evolutionary theory, followed by the application of this knowledge, in tracing the evolutionary history of Dinosauria. Three lecture hours and one and one-half laboratory hours a week for one semester. May not be counted toward a degree in environmental or geological sciences.

GEO 302E. Earth, Wind, and Fire.

Designed for non-geological sciences majors. Geologic phenomena that affect everyday life, including global warming, earthquakes, volcanism, desertification, river and coastline flooding and erosion, groundwater, mineral resources, and plate tectonics. Three lecture hours and one and one-half laboratory hours a week for one semester. May not be counted toward a degree in environmental science or geological sciences.

GEO 302G. Earth Science and Sustainability.

Inquiry-based; explores grand challenges in earth science that affect sustainability and society, including climate change, energy production, soil erosion and agriculture, water availability, and natural hazards risk assessment and prediction. Activities include authentic data, simple models and maps used in geoscience gathering, and analysis and real-world application. The equivalent of three lecture hours a week for one semester. Geological Sciences 302K (Topic: Earth Science/Sustainability) and 302G may not both be counted.

GEO 302J. Crisis of Our Planet.

Designed for nonscience majors. Explores the interactions between humans and the Earth system by investigating the different time and spatial scales of the natural hazards that the planet presents, and exploring the societal and economic implications of civilizations co-existing with an evolving planet. Discussion of both long-term and punctuated catastrophic hazards, focusing on those from volcanoes, hurricanes, and earthquakes, using a combination of systems level exploration of the driving mechanisms as well as case histories. Discussion of issues related to risk, mitigation, and resilience for humans facing the vast array of natural hazards. Three lecture hours a week for one semester.

GEO 302K (TCCN: GEOL 1301, GEOL 1302). Selected Topics in Geological Sciences.

Designed for nonscience majors. The impact of geological processes on human activity; geologic topics of popular interest. Three lecture hours and one-and-one-half laboratory hours a week for one semester. May be repeated for credit when the topics vary.

GEO 302M. The Age of Mammals.

Introductory-level course on paleontology and natural history for nonscience majors. Basic geological processes, fossilization, and the fossil record. Overview of the "tree of life." Summary of the evolution and diversification of mammals, an introduction to interactions between physical and biological processes, and the impact of climate change and human activities on mammalian communities. Laboratory component focuses on the mammalian skeleton and common Texas mammals. Three lecture hours and one and one-half laboratory hours a week for one semester. May not be counted toward a degree in environmental or geological sciences.

GEO 302N. Geology of National Parks.

Explore the geology of the US National Park System through a detailed examination of its rocks, landscapes, climate, hydrology, natural resources, and environmental impacts. Examine particular national parks which exhibit specific Earth processes. Includes threats posed to the park system: environmental tourism, encroaching development, water and air quality, air pollution, and natural hazards. The equivalent of three lecture hours a week for one semester.

GEO 302P (TCCN: ENVR 1301, GEOL 1305). Sustaining a Planet.

Restricted to freshmen and sophomores. Explores the interactions between humans and the Earth system by investigating the different time and spatial scales of the natural hazards that the planet presents, and exploring the societal and economic implications of civilizations co-existing with an evolving planet. Discussion of both long-term and punctuated catastrophic hazards, focusing on those from volcanoes, hurricanes, and earthquakes, using a combination of systems level exploration of the driving mechanisms as well as case histories. Discussion of issues related to risk, mitigation, and resilience for humans facing the vast array of natural hazards. Three lecture hours and one and one-half laboratory hours a week for one semester. May not be counted toward a degree in geological sciences.

GEO 302Q. Gems and Gem Minerals.

Examine crystallography, occurrence, and identification of gem minerals and materials; artificial gems; simple cutting and polishing; and the history of gems and gemology. Three lecture hours and two laboratory hours a week for one semester. Only one of the following may be counted: Geological Sciences 302Q, 302K (Topic: Gems and Gem Minerals), 347K.

GEO 303. Introduction to Geology.

Registration priority given to environmental science, geological sciences, and petroleum and geosystems engineering majors. Mineral and rock composition of the earth; measurement of geologic time; origin and evolution of life; earth's interior; plate tectonics; depositional environments and processes; ancient climates; humans, earth resources, and the environment. Two lecture hours and two laboratory hours a week for one semester. Only one of the following may be counted: Geological Sciences 401, 303, 420H.

GEO 303C. Introduction to the Solar System.

Examines the origin and evolution of our solar system; how processes such as volcanism and impacts have shaped planet surfaces, as well as the workings of planetary interiors; the unique properties of Earth that

allowed life to arise and evolve; the prospects for seeking life on other planets in our own solar system and beyond; and the history of planetary exploration and the methods scientists use to explore fundamental questions regarding our place in the universe. Three lecture hours a week for one semester. Geological Sciences 303C and 310C (Topic: Introduction to the Solar System) may not both be counted. May not be counted towards a degree in environmental science, geological sciences, or geosystems engineering and hydrogeology.

GEO 303E. Earth in 2100.

Restricted to non-geological science majors. In a self-paced format, investigate Earth's physical climate system, how humans have contributed to climate change, what the Earth may look like in 2100, and how society can stop climate change. The equivalent of three lecture hours a week for one semester.

GEO 405 (TCCN: GEOL 1404). Life through Time.

The history and development of life, and the processes of change from the early Precambrian era to the present. Three lecture hours and two laboratory hours a week for one semester. Geological Sciences 404C and 405 may not both be counted. Prerequisite: Geological Sciences 401, 303, or 420H with a grade of at least C-.

GEO 305E. Energy and the Environment.

A survey of all forms of current and potential sources of energy, and how these might impact the earth's environment. Three lecture hours and one and one-half laboratory hours a week for one semester. May not be counted toward a degree in environmental science, geological sciences, or geosystems engineering and hydrogeology.

GEO 306P. Geology and Sustainability.

Restricted to environmental science entry-level majors. Examines sustainability and environmental science from an interdisciplinary perspective. Three lecture hours and one and one-half laboratory hours a week for one semester. Prerequisite: Written consent of instructor.

GEO 110C, 210C, 310C. Conference Course.

Supervised study of selected topics in geological sciences, by individual arrangement with the instructor. Conference course. May not be substituted for any required geological sciences course. May be repeated for credit when the topics vary. Prerequisite: Consent of instructor.

GEO 110T, 210T, 310T. Undergraduate Topics in Geological Sciences.

Selected undergraduate topics in geological sciences. For each semester hour of credit earned, one lecture hour a week for one semester. May be repeated for credit when the topics vary. Offered on the letter-grade basis only.

GEO 211. Emerging Scholars in Geological Sciences.

Introduction to research areas in the geological sciences, with emphasis on the skills needed for success in graduate school and the professional workplace. Four laboratory hours a week for one semester. May not be substituted for any required geological sciences course. Prerequisite: Consent of instructor.

GEO 012N. JSG Geosciences Mentors Program - First-year.

Restricted to first-year students in the Jackson School of Geosciences. Introduction to the various geosciences disciplines and corresponding degree programs and research areas. Emphasis on the skills needed for success in graduate school and the professional workplace, such as interactive sessions with the Jackson School of Geosciences Career Center to address internships, career planning, and job search skills. One lecture hour a week for one semester. May not be counted toward a

degree in geological sciences or environmental sciences. Offered on the pass/fail basis only. Prerequisite: Consent of instructor.

GEO 114G. Geophysics Colloquium.

Open to non-geological sciences majors, but registration priority is given to geological sciences majors. Introduction to geophysics to examine applications and discover career opportunities. Two lecture hours a week for one semester, and at least one weekend field trip. Geological Sciences 110C (Topic: Geophysics Colloquium) and 114G may not both be counted. May be repeated for credit. Offered on the pass/fail basis only.

GEO 315L. Earth From Lab to Planet.

Explore the physical laws that explain the dynamical changes observed on the surface and interior of our planet, from tectonic to generational timescales. Examine different earth behaviors using hands-on experiments, in the lab and on the computer, to illuminate particular geodynamical processes. Discuss abstractions from these experiments to understand how those processes can be scaled up to understand Earth dynamics, from sedimentation to regional groundwater transport to global mantle convection. Three lecture hours a week for one semester. Offered on the letter-grade basis only.

GEO 416E. Solid Earth Processes.

Study the physical and chemical processes governing Earth and planetary evolution from the deep interior to lithosphere and surface. Explore the societal relevance of geological processes such as natural hazards and resources. Address why solid Earth dynamics is critical to sustain life and civilization at the surface. Three lecture and two laboratory hours a week for one semester. Offered on the letter-grade basis only.

GEO 416K. Earth Materials.

Introduction to minerals, mineral study techniques, igneous and metamorphic rocks and ore deposits, and formation processes. Three lecture hours and four laboratory hours a week for one semester. Prerequisite: The following with a grade of at least C- in each: Chemistry 301, 302; and Geological Sciences 401, 303, or 420H.

GEO 416M. Sedimentary Rocks.

Description and interpretation of sedimentary rocks in hand specimen and thin section; characteristics of sedimentary rocks deposited in different environments. Three lecture hours and four laboratory hours a week for one semester, with two additional one-day field trips to be arranged. Prerequisite: Geological Sciences 401, 303, or 420H with a grade of at least C-.

GEO 316P. Sedimentary Rocks.

Registration priority given to petroleum and geosystems engineering majors and Energy and Management Certificate Program students. Examines the fundamentals of sedimentary rocks, including siliciclastic grain parameters and mineralogy, sediment transport and sedimentary structures; and carbonate mineralogy and geochemistry, grain and matrix constituents, modern facies, and classification. Reviews the principal siliciclastic and carbonate depositional systems, their process of formation and facies architecture and the role of process and architecture in petrophysical patterns, distribution of permeability and porosity, flow units, reservoir heterogeneities, and hydrocarbon recovery. Three lecture hours a week for one semester. May not be counted toward any degree in environmental science or geological sciences. Prerequisite: Geological Sciences 401, 303, or 420H with a grade of at least C-.

GEO 416S. Earth and Planetary Processes Through Time.

Explore modern physical, chemical, and biological processes through the prism of Texas's changing rivers and coastlines. Examine geologic times

since the last Ice Age, deep geological time by looking at the Permian age, and the interpretation of planetary systems with an emphasis on underlying tenets of the history of life, geologic time, and surface processes. Three lecture and two laboratory hours a week for one semester. Offered on the letter-grade basis only.

GEO 416W. Climate, Water, and the Environment.

Introduction to climate system science through quantitative exploration of the processes that control Earth's water and carbon cycles. Discuss how the geosphere, atmosphere, ocean, cryosphere, and biosphere interact to govern the movement of water and the evolution of climate and weather conditions throughout Earth's history and in the present day. Explore current issues in climate change, water resources, and environmental sustainability. Three lecture hours and two laboratory hours a week for one semester. Offered on the letter-grade basis only.

GEO 119S, 219S, 319S, 419S, 519S, 619S, 719S, 819S, 919S. Topics in Geological Sciences.

This course is used to record credit the student earns while enrolled at another institution in a program administered by the University's Study Abroad office. Credit is recorded as assigned by the study abroad adviser in the Department of Geological Sciences. University credit is awarded for work in an exchange program; it may be counted as coursework taken in residence. Transfer credit is awarded for work in an affiliated studies program. May be repeated for credit when the topics vary.

Upper-Division Courses

GEO 420F. Classic Geology in Scotland.

Introduction to the founding concepts of geology. Students use advanced field technologies while studying the geology of Scotland on all scales of size. The equivalent of four lecture hours a week for one semester, including field exercises in a variety of geological settings. Prerequisite: Geological Sciences 303, 401 or 420H with a grade of at least C-.

GEO 420H. Honors Introductory Geology.

An accelerated introductory course on the composition, structure, and history of the earth. Three lecture hours and two laboratory hours a week for one semester, and several all-day field trips. Only one of the following may be counted: Geological Sciences 401, 303, 420H. Prerequisite: Consent of instructor.

GEO 420K. Introduction to Field and Stratigraphic Methods.

Restricted to Jackson School of Geosciences majors. Field observation of geological processes and study of the mineralogy, petrology, stratigraphy, paleontology, and structural geology of central Texas. Two lecture hours and three laboratory hours a week for one semester, and six weekend field trips. Geological Sciences 420K and 320L may not both be counted. Prerequisite: For general geology majors: Geological Sciences 416K and 416M with a grade of at least C- in each, and credit or registration in Geological Sciences 426P with a grade of at least C-. For others: Geological Sciences 416K and 416M with a grade of at least C- in each.

GEO 320L. Introductory Field Geology.

Designed for non-geological sciences majors. Study of geologic features and processes in the field; emphasizes regional geology of central Texas and techniques of geologic mapping. The equivalent of three lecture hours a week for one semester. Geological Sciences 420K and 320L may not both be counted. May not be counted toward a degree in environmental science, geological sciences, or geosystems engineering and hydrogeology. Prerequisite: Geological Sciences 401 or 303 with a grade of at least C-.

GEO 322E. Scientific Research Design.

Examine principles of experimental design including formulation of target questions and method choice in an interdisciplinary, community context. Three lecture hours a week for one semester. Geosciences 322E and 371T (Topic: Scientific Research Design) may not both be counted.

GEO 322J. Transitions in the History of Life.

Introduction to major perturbations in the history of life; specifically, mass extinctions and carbon-cycle perturbations (e.g. ocean anoxic events, hyperthermals, and acidification events). Addresses kill mechanisms (e.g. glaciations, impacts, large igneous provinces) and the subsequent environmental perturbations and ecological ramifications. Covers biotic crises in the past, with an eye to future ecosystem collapse, as well as the environmental and paleobiological responses to these events. Three lecture hours a week for one semester. Geological Sciences 322J and 371T (Topic: Transitions in the History of Life) may not both be counted. May be repeated for credit. Prerequisite: Upper-division standing; Geological Sciences 405 with a grade of at least C-, or consent of instructor.

GEO 422K. Paleobiology.

Registration priority given to environmental science and geological sciences majors. Systematics, biostratigraphy, paleoecology, and evolution of fossil organisms. Three lecture hours and four laboratory hours a week for one semester, with two additional one-day field trips to be arranged. Prerequisite: Biology 311D, Geological Sciences 404C or 405, and 416M with a grade of at least C- in each.

GEO 322S. Development and Evolution of the Vertebrate Skeleton.

Registration priority given to environmental science and geological sciences majors. Introduction to the organization and development of the vertebrate skeleton; survey of vertebrate history. Three lecture hours and two laboratory hours a week for one semester. Prerequisite: Consent of instructor.

GEO 022T. JSG Geosciences Mentors Program - Transfer.

Restricted to first semester transfer students in the Jackson School of Geosciences. Introduction to the various geosciences disciplines and corresponding degree programs and research areas. Emphasis on the skills needed for success in graduate school and the professional workplace, such as interactive sessions with the Jackson School of Geosciences Career Center to address internships, career planning, and job search skills. One lecture hour a week for one semester. May not be counted toward a degree in geological sciences or environmental sciences. Offered on the pass/fail basis only. Prerequisite: Consent of instructor.

GEO 322V. Morphology of the Vertebrate Skeleton.

Identification of skeletal elements from the major vertebrate taxa, and aspects of skeletal functional morphology, with emphasis on extant taxa. Subjects include the skeletal systems of fish, amphibians, reptiles, birds, and mammals. Three lecture hours and four laboratory hours a week for one semester. Prerequisite: Biology 311C and Geological Sciences 404C or 405 with a grade of at least C- in each, and consent of instructor.

GEO 325C. Continuum Mechanics.

Explore the foundation for the modeling of fluids and solids in geological and geophysical phenomena, such as mantle convection, glaciology, rock mechanics, and climate dynamics. Examine tensor analysis, the kinematics of motion, forces, and stresses. Discuss basic balance (conservation) laws for mass, momentum, and energy, and constitutive laws for fluids and solids. Develop governing equations to geodynamics, glaciology, seismology, and geophysical fluid dynamics. Three lecture hours a week for one semester. Geosciences 325C and 371T (Topic:

Continuum Mechanics) may not both be counted. Offered on the letter-grade basis only. Prerequisite: Upper-division standing, Mathematics 427J with a grade of at least C-, and credit or registration in Mathematics 427L.

GEO 325G. Computational Applications in the Geosciences.

An introduction to programming in MATLAB and applications to simulation of physical processes and data analysis in the geosciences. Two lecture hours and two laboratory hours a week for one semester. Geological Sciences 325J and 325G may not both be counted. Prerequisite: Geological Sciences 303 or 401, Mathematics 408D or 408M, and Physics 301 or 303K with a grade of at least C- in each.

GEO 325J. Programming in FORTRAN and MATLAB.

FORTRAN for students without knowledge of a computer programming language: survey of all variable types, loops, arrays, subroutines, and functions; overview of UNIX and MATLAB. Two lecture hours and two laboratory hours a week for one semester. Geological Sciences 325G and 325J may not both be counted. Prerequisite: Mathematics 427J or 427K with a grade of at least C-.

GEO 325K. Computational Methods.

Sampling and aliasing. Review of sinusoids and wave terminology, complex numbers and complex sinusoids, vectors and matrices, the discrete Fourier transform, convolution, the convolution theorem, linear digital filters and transfer functions, random variable concepts and statistics, and least squares estimation. MATLAB is used for homework problems and examples. Two lecture hours and two laboratory hours a week for one semester. Prerequisite: The following with a grade of at least C- in each: Geological Sciences 325J or 325G; Mathematics 427J or 427K; Physics 301 and 316 or Physics 303K and 303L.

GEO 325M. Numerical Modeling in the Geosciences.

Covers numerical solution of dynamical problems arising in the solid earth geosciences. Entails development of individual codes in Matlab and application of codes to understanding heat transfer, wave propagation, elastic, and viscous deformations. Requires familiarity with Matlab. Two lecture hours and two laboratory hours a week for one semester. Prerequisite: Upper-division standing; Geological Sciences 325G, and Mathematics 427J and 427L with a grade of at least C-; or consent of instructor.

GEO 425P. Modeling Flow and Transport in Porous Media.

Introduction to the modeling of flow and transport in porous media with focus on basic dynamic phenomena that occur during single-phase flow and solute transport in heterogeneous porous media. Discussion of the numerical solution of both the elliptic equations governing the flow of groundwater and the hyperbolic equations governing solute transport. Includes a programming project which requires writing a functional numerical simulator. Three lecture hours and one-and-one-half laboratory hours a week for one semester. Prerequisite: Upper-division standing and one of the following with a grade of at least C-: Civil Engineering 311K; Computational Engineering 301; Geological Sciences 325G or 325J; Mathematics 408D or 427L and Mathematics 427J or 427K; Mechanical Engineering 318M; Petroleum and Geosystems Engineering 310.

GEO 326D. Earth in Deep Time.

Examine the causes and consequences of significant changes in Earth's surface environment and tectonic processes over the past 4.5 billion years. Discuss the initial Earth accretion, the Faint Young Sun problem, the rise of oxygen in Earth's atmosphere and general requirements for planetary habitability and how interactions between Earth's interior, the surface, and biosphere have shaped planetary evolution. Three lecture hours a week for one semester. Offered on the letter-grade basis only.

GEO 426P. Igneous and Metamorphic Petrology.

Mineralogy, geochemistry, and processes of magmatism and metamorphism. Three lecture hours and four laboratory hours a week for one semester. Prerequisite: Geological Sciences 416K with a grade of at least C-; credit with a grade of at least C- or registration for Physics 301 and 101L, or 303K and 103M.

GEO 327G. Geographic Information System and Global Positioning System Applications in Earth Sciences.

Restricted to environmental science and geological sciences majors. Theory and practice of geographic information system (GIS) and Global Positioning System (GPS) technologies, and their applications to problems in earth sciences. Laboratories and field trips provide hands-on experience with the collection, mapping, and analysis of geologic and other field data using GPS equipment and GIS software. Topics include map projections; datums and reference frames; cartographic principles; remotely sensed data (satellite and aerial photos, image radar); vector- and raster-based image formats; geospatial data resources; GIS software applications; surveying principles; GPS constellation and data structure; differential GPS; data logging schemes; GPS postprocessing software; integration of GPS and GIS in mapmaking; extant GIS applications in geology and hydrogeology. Three lecture hours and two laboratory hours a week for one semester, and two weekend field trips. Geological Sciences 327G and 371C (Topic: Geographic Information System and Global Positioning System Applications in Earth Sciences) may not both be counted. Prerequisite: Geological Sciences 420K with a grade of at least C-.

GEO 428. Structural Geology.

Description, classification, and origin of Earth structures. Solution of problems by descriptive geometry, geologic maps, and contouring. Three lecture hours and three laboratory hours a week for one semester. Prerequisite: The following with a grade for at least C-: Geological Sciences 420K; Mathematics 408C or 408L; and Physics 301 and 101L, or Physics 303K and 103M.

GEO 328W. Vadose Zone Hydrology.

Introduction to hydrologic processes occurring in the vadose zone (unsaturated zone), the subsurface region between the ground surface and groundwater. Focus on the physical processes that govern the movement of water in variably saturated porous media, and the exchange of mass and energy at Earth's surface. Explore theoretical and applied aspects, measurement techniques and computational tools, and environmental challenges of the vadose zone. Three lecture hours a week for one semester. Geological Sciences 328W and 371T (Topic: Vadose Zone Hydrology) may not both be counted. Prerequisite: Geological Sciences 346C, 476K, or 376S with a grade of at least C-.

GEO 129S, 229S, 329S, 429S, 529S, 629S, 729S, 829S, 929S. Topics in Geological Sciences.

This course is used to record credit the student earns while enrolled at another institution in a program administered by the University's Study Abroad Office. Credit is recorded as assigned by the study abroad adviser in the Department of Geological Sciences. University credit is awarded for work in an exchange program; it may be counted as coursework taken in residence. Transfer credit is awarded for work in an affiliated studies program. May be repeated for credit when the topics vary.

GEO 329W. Hydrogeology Cooperative (Geological Sciences).

Restricted to environmental science and geological sciences majors. Covers the work period of geological sciences students in the Cooperative Education program, which provides supervised work experience by arrangement with the employer and the supervising instructor. Required submission of a final report to the supervising

instructor at the conclusion of the program. Forty laboratory hours a week for one semester. The student must repeat the course each work period and must take it twice to receive credit toward the degree; at least one of these registrations must be during a long-session semester. No more than three semester hours may be counted toward the major requirement; no more than six semester hours may be counted toward the degree. The student's first registration must be on the pass/fail basis. May be repeated for credit. Prerequisite: Application to become a member of the Hydrogeology Cooperative (Geological Sciences) Program, and consent of the Associate Dean for Academic Affairs.

GEO 330K. Energy Exploration.

Covers the fundamental elements of the petroleum system, including the origin of source rocks and reservoirs, rock properties, migration of hydrocarbons, and correlation methods for rock formations. During the final weeks of the course, students form exploration teams and work up real subsurface data from the Gulf of Mexico in order to participate in a simulated lease sale. Two lecture hours and two laboratory hours a week for one semester. Prerequisite: The following with a grade of at least C- in each: Geological Sciences 416M; and Physics 303L and 103N, or Physics 316 and 116L.

GEO 331K. Petrology and Plate Tectonics.

Registration priority given to environmental science and geological sciences majors. Sedimentation, metamorphism, igneous activity, and deformation patterns at rift zones, subduction zones, and transform margins. Three lecture hours a week for one semester. Offered irregularly, as shown in the Course Schedule. Prerequisite: Geological Sciences 428 with a grade of at least C-.

GEO 335. Geology and Mineral Resources of Texas.

Geologic history of the region; local rocks, fossils, and mineral resources; influence of physiography, surface and subsurface water supplies, and energy and mineral resource production on the state economy. Three lecture hours and two laboratory hours a week for one semester. May not be counted toward the Bachelor of Science in Geological Sciences: Option I (General Geology), Option II (Geophysics), or Option III (Hydrogeology). Prerequisite: The following with a grade of at least C-: Geological Sciences 401, 303, or 420H; and 405.

GEO 135J. Jackson Scholars Seminar.

Discuss professional development skills, scholarship, research, and outreach. One lecture hour a week for one semester. May be repeated for credit. Offered on the letter-grade basis only. Prerequisite: Consent of instructor.

GEO 338J. Marine Geology.

A survey of the field of marine geology by exploring the structure and evolution of the ocean basins, oceanic islands, and island arcs, the chemistry of the oceans, the sediments in the marine environments, the products and processes of the land-air-sea interface, and the history of the oceans over geologic time. Three lecture hours a week for one semester. Geological Sciences 338J and 371C (Topic: Marine Geology) may not both be counted. Prerequisite: Upper-division standing.

GEO 338T. Marine Tectonics.

Tectonic processes within the dynamic Earth, with a focus on oceanic structures. Subjects may include fundamentals of plate tectonics; plate motion, driving forces, and mantle convection; evolution of triple junction and plate margins; plate reconstructions; earthquakes and focal mechanisms; structure and geochemistry of the Earth's interior; mantle structure and tomography; rheology and deformation mechanisms in mantle and crust; heat flow, gravity, the geoid, and paleomagnetism; hotspots and mantle plumes; seafloor spreading and oceanic spreading ridges; oceanic transform faults and fracture zones; and subduction

zones, volcanic island arcs, and marginal seas. Three lecture hours a week for one semester. Geological Sciences 338T and 371C (Topic: Tectonics I) may not both be counted. Prerequisite: Geological Sciences 428 with a grade of at least C-.

GEO 338W. Paleoclimate.

Introduction to paleoclimatology, the study of Earth's past climate. Examine a broad spectrum of geological archives of climate change including those from the oceans, the land, and the cryosphere. Three lecture hours a week for one semester. Geological Sciences 338W and 371T (Topic: Paleoclimatology) may not both be counted. Prerequisite: Consent of instructor.

GEO 339T. Continental Tectonics.

Tectonic processes, with a focus on continental lithospheric structures. Subjects may include convergent margins, subduction zones, magmatic arcs, and foreland structures; collisional orogenesis, arc-continent collisions, continent-continent collision, and mountain building; formation of supercontinents; uplift and exhumation; orogenic collapse and extensional tectonics; continental rifting and passive margins; transform margins; and the effect of tectonics on climate and oceanic circulation. Three lecture hours a week for one semester. Geological Sciences 339T and 371C (Topic: Tectonics II) may not both be counted. Prerequisite: Geological Sciences 428 with a grade of at least C- or consent of instructor.

GEO 340T. Geoclimatology.

Examination of the climate records encoded in sedimentary archives through geologic time. Three lecture hours a week for one semester. Geological Sciences 340T and 371C (Topic: Geoclimatology) may not both be counted. May not be substituted for any required geological sciences course. Prerequisite: Chemistry 302, Geological Sciences 416K, and 416M with a grade of at least C- in each.

GEO 341. Mineral Resources, Society, and the Environment.

Registration priority given to majors in the Jackson School of Geosciences. Nature and origin of mineral resources; their discovery, extraction, and uses; and their relationship to global history, economics, and the environment. Three lecture hours and one laboratory hour a week for one semester. Prerequisite: Geological Sciences 416K with a grade of at least C-.

GEO 341F. Microstructures and Rock Rheology.

Focuses on processes of deformation operative in the crust and upper mantle, with an emphasis on distinguishing these processes using microstructural analysis and describing them using basic constitutive relationships from rock mechanics. Three lecture hours a week for one semester. Prerequisite: Geological Sciences 428 with a grade of B or higher.

GEO 341G. Geomicrobiology.

Registration priority given to majors in the Jackson School of Geosciences. Geologic and hydrologic controls on subsurface microbial growth, metabolism, and community structure; the geochemical consequences of microbial processes in subsurface settings; and the influence of geology on microbial ecology. Three lecture hours a week for one semester. Geological Sciences 341G and 381G may not both be counted. May not be substituted for any required geological sciences course. Prerequisite: Upper-division standing and consent of instructor.

GEO 343Q. Fundamentals and Applications of Inductively Coupled Plasma Mass Spectrometry.

Explores inductively coupled plasma mass spectrometry (ICP-MS) for trace, minor and major element measurement, and applications in analytical fields. Discussion of fundamentals of technique, applications,

and capabilities of ICP-MS through hands-on lab experience. Two lecture hours and one-and-one-half laboratory hours a week for one semester. Geological Sciences 343Q and 371C (Topic: Fundamentals and Applications of ICP-MS) may not both be counted. Prerequisite: Upper-division standing.

GEO 344K. Marine Mining and Minerals.

Same as Marine Science 344K. Overview of seafloor mineral deposits, their exploration, and mining. Three lecture hours a week for one semester. May not be counted toward the Bachelor of Science in Geological Sciences or the Bachelor of Science in Environmental Sciences degrees. Prerequisite: Geological Sciences 401 or 303, 416K, and 416M.

GEO 344U. Quantitative Seismic Interpretation.

Seismic inversion, a tool for reservoir characterization, post- and pre-stack modeling, rock physics and fluid replacement modeling, wavelet estimation and post-stack inversion, AVO and pre-stack inversion, multiattribute regression and neural network, and net pay estimation. Extensive hands-on training with three-dimensional seismic and well-log data. Three lecture hours a week for one semester. Prerequisite: Upper-division standing.

GEO 145E. Professional Ethics in Geosciences.

Registration priority is given to majors in the Jackson School of Geosciences. Supervised study devoted to the subject of professional ethics and personal integrity in the sciences, with specific subject matter designed to evolve with the science and our society. One lecture hour a week for one semester. Geological Sciences 145E and 171C (Topic: Professional Ethics in Geosciences) may not both be counted. Offered on the letter-grade basis only. Prerequisite: For non-Jackson School of Geosciences majors, consent of instructor.

GEO 346C. Introduction to Physical and Chemical Hydrogeology.

Basic concepts of fluid flow, surface and subsurface hydrology, aqueous geochemistry, and fluid-rock interaction. Additional subjects include isotope hydrogeology, evolution of seawater, and mineral-solution equilibrium. Three lecture hours a week for one semester. Prerequisite: Chemistry 302 with a grade of at least C- or consent of instructor.

GEO 347D. Global Warming.

Discussion of the fundamental sciences of global warming, including an active investigation of contemporary climate change issues. Three lecture hours a week for one semester. Geological Sciences 347D and 371C (Topic: Global Warming) may not both be counted. Offered on the letter-grade basis only. Prerequisite: Upper-division standing.

GEO 347G. Climate System Modeling.

Studies the basic theory of weather/climate system modeling using state-of-the-art regional climate models in a variety of applications. Includes instruction on how to run models on the TACC supercomputers for scientific applications. Subjects may include paleoclimate, contemporary, and/or future climate prediction based on changes in greenhouse gas concentrations. Three lecture hours a week for one semester. Only one of the following may be counted: Geological Sciences 347G, 371C (Topic: Climate System Modeling), 387G, 391 (Topic: Climate System Modeling). May not be substituted for any required geological sciences course. Prerequisite: Upper-division standing.

GEO 347K. Gems and Gem Minerals.

Crystallography, occurrence, and identification of gem minerals and materials; artificial gems; simple cutting and polishing; history of gems and gemology. Three lecture hours and two laboratory hours a week for

one semester. May not be counted toward a degree in environmental science or geological sciences.

GEO 347P. Climate System Physics.

Discussion of first-order principles and processes that govern the thermodynamical structure and energy distribution of the atmosphere, ocean, land, and cryosphere and their interaction with the dynamic aspect of the climate system. Three lecture hours a week for one semester. Only one of the following may be counted: Geological Sciences 347P, 371C (Topic: Climate System Physics). May not be substituted for any required geological sciences course. Prerequisite: Upper-division standing; Mathematics 408D or 408M, and Physics 303K with a grade of at least C- in each.

GEO 348K. Marine Geology and Geophysics Field Course.

Hands-on, team-based instruction in the collection and processing of marine geological and geophysical data along the Gulf of Mexico coast. For Marine Science 148, one lecture hour and one laboratory hour a week for one semester. For Geological Sciences 348K and Marine Science 348, one lecture hour and four laboratory hours a week for one semester with additional hours to be arranged. Only one of the following may be counted: Geological Sciences 348K, 397F, Marine Science 348 (Topic 2). Fulfills the field experience requirement for some geological sciences degree programs. Students should contact the Department of Geological Sciences before registering. Prerequisite: For geological sciences majors, Geological Sciences 420K or 320L with a grade of at least C-, and consent of instructor; Geological Sciences 416M and 465K are recommended; for others, Marine Science 307 and 354F with a grade of at least C- in each, and consent of instructor.

GEO 348P. Field Methods in Planetary Geology.

Restricted to geological sciences majors. Field studies combined with remote sensing to support studies of remote imagery from planetary missions. Two lecture hours and two laboratory hours a week for one semester. Three week field trip to the Southwestern United States also required. Geological Sciences 348P and 371C (Topic: Field Methods Planetary Geology) may not both be counted. May not be substituted for any required geological sciences course. Prerequisite: Upper-division standing and consent of instructor.

GEO 349C. Introduction to the Cryosphere.

Restricted to students in a geosciences major and students pursuing a minor in geosciences. A survey of the cryospheric sciences. Three lecture hours a week for one semester. Geological Sciences 349C and 371T (Topic: Introduction to the Cryosphere) may not both be counted. Prerequisite: Upper-division standing; and the following with a grade of at least C- in each: Chemistry 204, Geological Sciences 401 or 303, Mathematics 408D or 408M; and Physics 303L and 103N or Physics 316 and 116L.

GEO 350D. Ice Dynamics.

Physics of ice motion, basal processes, glacial hydrology, and unstable flow. Three lecture hours a week for one semester. Geological Sciences 350D and 371C (Topic: Glaciology) may not both be counted. Prerequisite: Upper-division standing; and the following with a grade of at least C-: Chemistry 204, Geological Sciences 401 or 303, and 349C; Mathematics 408D or 408M; and Physics 303L and 103N, or 316 and 116L.

GEO 350L. Topics in Lithosphere and Deep Earth.

Three lecture hours a week for one semester. May be repeated for credit when the topics vary. Prerequisite: Upper-division standing.

Topic 1: Tectonic Geodynamics. Examine dynamic processes that govern plate tectonics and lithospheric deformation, combining

tectonics, structural geology, and geodynamics from the ground up. Geological Sciences 350L (Topic 1) and 371T (Topic: Tectonic Geodynamics) may not both be counted.

Topic 2: Geophysics Seminar I.

Topic 3: Geophysics Seminar II. Three lecture hours a week for one semester.

GEO 350S. Topics in Subsurface, Surface, and Life.

Three lecture hours a week for one semester. May be repeated for credit when the topics vary. Prerequisite: Upper-division standing.

GEO 350W. Topics in Water, Climate, and Environment.

Three lecture hours a week for one semester. May be repeated for credit when the topics vary. Prerequisite: Upper-division standing.

Topic 1: Dynamics of Polar Systems. Examine the fundamental physics that govern dynamics of ice sheets, oceans, and sea ice from a theoretical viewpoint that is supported with as many observations as possible. Geological Sciences 350W (Topic 1) and 371T (Topic: Dynamics of Polar Systems) may not both be counted.

Topic 4: Statistical Data Analysis. Examine the statistical, scientific, and computational approaches used to test hypotheses concerning the physics governing observed changes in the Earth System. Explore concepts in linear algebra and statistics such as regression, least-squares inversion, singular spectral analysis, Bayesian inference, Markov Chain Monte Carlo sampling, and test statistics to survey the existence of a discernable influence of humanity on the observational record of climate.

GEO 352P. Python for Geoscience Research.

Explore the Python 3 programming language and its application to scientific research. Examine basic Python and common scientific Python libraries such as numpy, pandas, matplotlib, datetime. Three lecture hours a week for one semester. Geological Sciences 352P and 371T (Topic: Python in Geoscience Resrch) may not both be counted.

GEO 354. Physics of Earth.

Examines the kinematics and dynamics of the solid Earth as well as its evolution through time. Observations from multiple geophysical techniques are reviewed and applied towards understanding the planet. Three lecture hours a week for one semester. Prerequisite: The following with a grade of at least C- in each: Mathematics 427J or 427K, and Physics 315 and 115L.

GEO 355G. Geodynamics of the Lithosphere and Mantle.

Explores continuum dynamics problems that can serve to form a physical understanding of the tectonic and convective processes that shape our planet. Geared toward all undergraduate majors and graduate students from the Earth sciences and related fields in the natural sciences including physics, computer science, and engineering. The equivalent of two lecture hours and one-and-one-half laboratory hours a week for one semester. Geological Sciences 355G and 371T (Topic: Geodynamics) may not both be counted. Offered on the letter-grade basis only. Prerequisite: Upper-division standing; Geological Sciences 401 or 303 with a grade of at least C-; or consent of instructor.

GEO 455S. Introduction to Remote Sensing for Geoscientists.

Examine the fundamentals of acquiring, processing, and interpreting remote sensing data. Explore the development of skills in the use and analysis of remote sensing data. Survey the physics of electromagnetic radiation and its interaction with geologic materials; common techniques for remote sensing; science goals and instruments onboard ongoing and planned remote sensing missions; and techniques for analysis of remote sensing data. Three lecture hours and two laboratory hours a week for

one semester. Geological Sciences 455S and 471T (Topic: Intro Remote Sensing Geosci) may not both be counted. Prerequisite: Upper-division standing.

GEO 356S. Ins and Outs of Subduction Zones.

Explore an overview of subduction zones, including sites of lithospheric scale recycling, critical to understanding the chemical evolution of the Earth's crust and mantle, volcanism, earthquakes, and orogenesis. Includes the thermal and seismic structure of subduction zones, volatile and geochemical cycling, seismicity, mantle wedge dynamics, and volcanism. Three lecture hours a week for one semester. Geological Sciences 356S and 371T (Topic: Ins & Outs of Subduction Zones) may not both be counted. Prerequisite: Upper-division standing and consent of instructor.

GEO 358K. Volcanology.

Registration priority given to majors in the Jackson School of Geosciences. Ash deposits, lava flows, eruption processes; prediction and mitigation of volcanic hazards. Three lecture hours and one laboratory hour a week for one semester. Prerequisite: Geological Sciences 416K with a grade of at least C-, or consent of instructor.

GEO 660. Field Geology.

Restricted to geological sciences majors. Methods of geologic mapping with topographic maps and aerial photographs. Field studies include measuring sections, interpretation of stratigraphy, structure, environments of deposition of various sedimentary rocks, and the origin and petrology of igneous and metamorphic rocks. Students must register for this course during the first summer registration period. Given for six weeks each summer in Colorado, New Mexico, and other western states. Prerequisite: Geological Sciences 420K and 428 with a grade of at least C- in each.

GEO 360G. Construction and Interpretations of 3-D Stratigraphy.

From Earth surface to subsurface, examines three-dimensional volumes of basin-filling stratigraphy to explore how depositional landscapes are preserved in the sedimentary record and how sedimentary deposits can be analyzed to produce quantitative reconstructions of past environmental states. Data includes both laboratory and industry-grade volumes of stratigraphy. Intended for Earth scientists requiring a quantitative understanding of how the structure of depositional landscapes is translated into subsurface stratigraphy. Three lecture hours and one laboratory hour a week for one semester. Geological Sciences 360G and 371C (Topic: Construction and Interpretation of 3-D Stratigraphy) may not both be counted. May not be substituted for any required geological sciences or environmental sciences course. Prerequisite: Upper-division standing; Geological Sciences 416M or 354 with a grade of at least C-.

GEO 661. Geophysics Field Camp.

Restricted to geophysics majors. Field studies for geophysics majors, including seismic, magnetic, electrical, gravity, and other techniques; related data processing and interpretation. Each half requires three consecutive weeks of fieldwork. Geological Sciences 661A is offered either between the spring semester and the summer session or in the summer session; Geological Sciences 661B is offered in the summer session. Students may take Geological Sciences 661 for University credit while enrolled in the Los Alamos National Laboratory SAGE program. May be used in place of Geological Sciences 660 to fulfill the requirements for the Bachelor of Science in Geological Sciences (Option II: Geophysics). Prerequisite: Geological Sciences 420K, 465K, and 365P with a grade of at least C- in each.

GEO 363S. Sedimentary Basin Analysis.

Quantitative and applied analysis of basin subsidence and sediment accumulation. Consider theoretical basin evolution due to flexural, thermal, dynamic, and fault-related subsidence. Analyze selected basin systems. Three lecture hours a week for one semester. Geological Sciences 363S and 371T (Topic: Sedimentary Basin Analysis) may not both be counted. Offered on the letter-grade basis only. Prerequisite: Upper-division standing.

GEO 364P. Physical Oceanography.

Basic concepts for understanding and describing the large-scale circulation of the ocean. Covers measurement methods, properties of seawater, description of the global ocean's mean state and variability, introductory dynamics including balanced motions, wind-driven and abyssal circulation, wave motions, air-sea interactions, sea level science, and the ocean's role in climate. Three lecture hours a week for one semester. Geological Sciences 364P and 371T (Topic: Physical Oceanography) may not both be counted. May not be substituted for any required geological sciences course. Offered on the letter-grade basis only. Prerequisite: Upper-division standing and consent of instructor.

GEO 465K. Seismic Exploration.

Seismic theory, including body and surface waves, attenuation, rays, reflection and transmission coefficients, principles of synthetic seismogram calculations, seismic imaging principles, reflection data processing methods, rock physics overview, seismic attributes overview, and seismic exploration field methods. Three lecture hours and two laboratory hours a week for one semester. Prerequisite: Mathematics 427L; and Physics 315 and 115L with a grade of at least C- in each.

GEO 365N. Seismic Data Processing.

Reduction of seismic data from field records to final geologic images, using real data sets and open-source data analysis software. Two lecture hours and two laboratory hours a week for one semester. Prerequisite: Upper-division standing; and Geological Sciences 325K and 465K with a grade of at least C- in each.

GEO 365P. Potential Field Applications in Geophysics.

Introduction to the theory, measurement, and application of gravity and magnetic and electric fields to exploration and global-scale problems. Three lecture hours a week for one semester. Prerequisite: The following with a grade of at least C- in each: Mathematics 427J or 427K, 427L, and Physics 315 and 115L.

GEO 365Q. Geomorphology Process and Form.

Explores how Earth surface processes combine to shape landscapes through erosion and deposition. Includes discussion of open channel flow, sediment transport, fluvial and hillslope processes, and tectonic controls on landscape evolution. Three lecture hours a week for one semester, with several field trips to be arranged. Geological Sciences 365Q and 371C (Topic: Geomorphology: Landscape Process, Form, and Evolution) may not both be counted. May not be substituted for any required geological sciences course. Prerequisite: Upper-division standing, and Mathematics 408C or 408L with a grade of at least C-.

GEO 366M. Mathematical Methods in Geophysics.

A survey of mathematics for geoscientists that includes infinite series, complex variables, linear algebra, integral transforms, ordinary and partial differential equations, tensor analysis, and probability and statistics. Three lecture hours a week for one semester. Prerequisite: Mathematics 427L with a grade of at least C-.

GEO 366P. Planetary Geology and Geophysics.

Introduction to planetary geology, with an emphasis on geophysical observations of terrestrial planets in our solar system. Discussion of

missions, instruments, and techniques, and incorporation of mission data in student projects. Includes field trip to study planetary analog sites. The equivalent of three lecture hours a week for one semester. Geological Sciences 366P and 371C (Topic: Planetary Geology & Geophysics) may not both be counted. Offered on the letter-grade basis only. Prerequisite: Upper-division standing and consent of instructor.

GEO 367M. Morphodynamics and Quantitative Stratigraphy.

Explores development of numerical tools to quantitatively understand sediment transport and stratigraphic development in sedimentary basins. Focus on applications of principles in fluid mechanics, sediment transport, and depositional mechanics to one-dimensional and quasi-two dimensional numerical modeling of sediment morphodynamics in depositional settings such as river deltas, carbonate platforms, and submarine fans. Requires development of geometrical and morphodynamic models as research tools to understand gathered data. Three lecture hours per week for one semester. Geological Sciences 367M and 371T (Topic: Morphodynamics and Quantitative Stratigraphy) may not both be counted. Prerequisite: Geological Sciences 416M with a grade of at least C-.

GEO 468K. Geophysics for Geological Sciences Majors.

Registration priority given to majors in the Jackson School of Geosciences. A survey of seismic, magnetic, gravitational, and other geophysical tools and their application to exploration and global-scale problems. Three lecture hours and two laboratory hours a week for one semester. May not be counted toward the Bachelor of Science in Geological Sciences, Option II: Geophysics. Prerequisite: Mathematics 408D; and Physics 303L and 103N, or 316 and 116L with a grade of at least C- in each.

GEO 369E. Evolution of Reef Ecosystems.

Introduction to the paleobiology, sedimentology, and oceanography of reef ecosystems throughout the geological record as well as the environmental and evolutionary factors that controlled the expansion and collapse of the carbonate ecosystems (and others). Explore ocean chemistry, how organisms biomineralize a skeleton, symbiosis, ecology, mass extinctions, and both current and future threats to reef health. Three lecture hours a week for one semester. Geological Sciences 369E and 371T (Topic: Evolution of Reef Ecosystems) may not both be counted. Prerequisite: Upper-division standing; Geology 405 with a grade of at least C-, or consent of instructor.

GEO 370E. Ecohydrology and Biometeorology.

Study the terrestrial biosphere and the ways ecosystems influence the water cycle. Investigate water, carbon, and energy fluxes within the Earth system from a hands-on experimental approach and through exposure to land-surface and climate models. Includes hydrology, Earth science, environmental engineering, ecology, biology, and climatology. Three lecture hours a week for one semester. Geological Sciences 370E and 371T (Topic: Ecohydrology/Biometeorology) may not both be counted. Prerequisite: Upper-division standing.

GEO 370K. Sedimentology.

Registration priority given to majors in the Jackson School of Geosciences. Processes of sediment formation, transportation, and deposition; textures, structures, and facies of sedimentary rocks. Three lecture hours a week for one semester, and two one-day field trips. Offered irregularly. Prerequisite: Geological Sciences 420K with a grade of at least C-.

GEO 370Q. Morphodynamics and Quantitative Stratigraphy.

Explore numerical tools useful for quantitatively assessing sediment transport and stratigraphic development in sedimentary basins. Apply principles in fluid mechanics, sediment transport, and depositional

mechanics to one-dimensional and quasi-two-dimensional numerical modeling of sediment morphodynamics in various depositional settings such as river deltas, carbonate platforms, and submarine fans. Develop geometrical and morphodynamic models as research tools to understand data collected from laboratory experiments and in the field. Three lecture hours a week for one semester. Geological Sciences 370Q and 371C (Topic: Morphodynamics) may not both be counted. Offered on the letter-grade basis only. Prerequisite: Upper-division standing.

GEO 171C, 271C, 371C. Conference Course.

Restricted to majors in the Jackson School of Geosciences. Supervised study of selected topics in geological sciences, by individual arrangement with the department and instructor. Conference course. May not be substituted for any required geological sciences course. May be repeated for credit when the topics vary. Prerequisite: Consent of instructor.

GEO 171H. Honors Research Methods I.

Restricted to students in the Geological Sciences Honors Program. Preparation for independent research projects through exposure to current research programs, facilities, personnel, and projects in the Jackson School of Geosciences. Includes selecting research topics, mentors, and supervisors; preparing research proposals; conducting research activities; and presenting research results. One lecture hour a week for one semester.

GEO 371S. Geological Sciences Research Methods.

Restricted to geological sciences majors. Supervised research project completed in collaboration with faculty supervisor and related research group members either as a one-semester research activity in preparation for a senior thesis project. Three lecture hours a week for one semester, with additional hours to be arranged. Offered on the letter-grade basis only. Prerequisite: Upper-division standing; Geological Sciences 416K, 416M, and 420K with a grade of at least C-.

GEO 171T, 271T, 371T, 471T, 571T, 671T. Undergraduate Seminar in Geological Sciences.

For each semester hour of credit earned, the equivalent of one lecture hour a week for one semester; additional hours may be required for some topics. May not be substituted for any required geological sciences courses. May be repeated for credit when the topics vary. Prerequisite: Upper-division standing and consent of instructor; additional prerequisites may vary with the topic.

GEO 172H. Honors Research Methods II.

Restricted to students in the Geological Sciences Honors Program. Preparation for independent research projects through exposure to current research programs, facilities, personnel, and projects in the Jackson School of Geosciences. Includes selecting research topics, mentors, and supervisors; preparing research proposals; conducting research activities; and presenting research results. One lecture hour a week for one semester. Prerequisite: Geological Sciences 171H with a grade of at least B-.

GEO 372S. Geochemical Problem Solving with Atoms and Ions.

Discussion of mass spectrometers, which are analytical balances that operate at molecular and atomic levels, used for gathering compositional data (both isotopic and elemental). Explores conversion of sample molecules into charged particles (ions), and measurement according to mass-to-charge ratio to assess chemical identity and abundance. Introduction to inorganic mass spectrometry methods and applications to the Earth sciences, surveying key modalities: TIMS, ICP-MS, LA-ICP-MS, MC-ICP-MS, and IRMS. Examines techniques in generating and critically evaluating high-quality data, and research. Two lecture hours

and three lab hours per week for one semester. Geological Sciences 372S and 371T (Topic: Geochemical Problem Solving with Atoms and Ions) may not both be counted. Prerequisite: Upper-division standing and consent of instructor.

GEO 173H. Honors Research Methods III.

Restricted to students in the Geological Sciences Honors Program. Preparation for independent research projects through exposure to current research programs, facilities, personnel, and projects in the Jackson School of Geosciences. Includes selecting research topics, mentors, and supervisors; preparing research proposals; conducting research activities; and presenting research results. One lecture hour a week for one semester. Prerequisite: Geological Sciences 171H and 172H with a grade of at least B- in each.

GEO 376C. Isotope Geology.

Overview of the principles of stable and radiogenic isotope geochemistry. Subjects include mass spectrometry, geochronology and thermochronology, cosmogenic nuclides, radiogenic geochemistry, isotopic fractionation, traditional and non-traditional stable isotope geochemistry and its applications to the hydrologic cycle, low-temperature geochemistry, magmatic and metamorphic processes, thermometry, fluid-rock interactions, tectonics, crust-mantle evolution, and extraterrestrial materials. Three lecture hours a week for one semester. Only one of the following may be counted: Geological Sciences 371C (Topic: Isotope and Environmental Geology Research), 376C, 388L. Prerequisite: Chemistry 302, and Mathematics 408D or 408M with a grade of at least C- in each, and consent of instructor.

GEO 376E. Environmental Isotope Geochemistry.

Restricted to students in the Jackson School of Geosciences. The application of the isotope and trace element geochemistry of natural waters and sediments to studies of the hydrologic cycle. Stable, radiogenic, and cosmogenic isotopes are used as tracers of the evolution of groundwater, surface water, and ocean water. Three lecture hours a week for one semester, with additional laboratory hours to be arranged. Prerequisite: Chemistry 302, 204, Geological Sciences 416K, 416M, 346C; Mathematics 408D or 408M; and Physics 303L and 103N with at least a C- in each.

GEO 476K. Groundwater Hydrology.

Registration priority given to majors and minors in the Jackson School of Geosciences. Introduction to subsurface hydrology, emphasizing geological controls on groundwater flow; quantitative methods of analyzing aquifer systems; regional hydrology; water quality and pollution. Three lecture hours and one and one-half laboratory hours a week for one semester, with several local field trips to be arranged. Prerequisite: Geological Sciences 346C, Mathematics 408D, or Mathematics 408M with a grade of at least C-.

GEO 376L. Field Methods in Groundwater Hydrology.

Registration priority given to hydrogeology majors. Introduction to field methods, including geophysics, pump tests, stream gauging, well-logging, water sampling, and mapping. Students must register for this course during the first summer registration period. An intensive three-week course meeting eight hours a day, Monday through Friday, and four hours on Saturday: lectures, laboratory exercises, and field exercises; nightly homework involving map exercises, reduction of field data, report preparation; Saturdays devoted to report presentation, review sessions, and local field trips. Offered between the spring semester and the summer session. Prerequisite: Geological Sciences 476K with a grade of at least C-.

GEO 476M. Aqueous Geochemistry.

An introduction to aqueous geochemistry and contaminant hydrogeochemistry; topics include basic thermodynamics, kinetics, rock-water interactions, and solute transport. Three lecture hours and two laboratory hours a week for one semester. Prerequisite: Geological Sciences 346C, 476K, or 376S with a grade of at least C- in each.

GEO 376S. Physical Hydrology.

Modern conceptual and methodological approaches to hydrological science: qualitative assessment of hydrological processes, quantitative representation, approaches to measurement, and treatment of uncertainty. Major components of the hydrological cycle: precipitation, snow and snowmelt, infiltration, soil moisture, evapotranspiration, and runoff and their link to the coupled-earth system. Three lecture hours a week for one semester. Prerequisite: Geological Sciences 346C; or Mathematics 408D or 408M with a grade of at least C-.

GEO 376T. High-Temperature Geochemistry.

Study of the composition, origin, and chemical and physical evolution of the earth and its interior. Examines the links between the fields of geochemistry and tectonics, igneous petrology, geophysics, and other areas of inquiry. Three lecture hours a week for one semester. Prerequisite: Upper-division standing; Geological Sciences 416K or 426P with a grade of at least C-; or consent of instructor.

GEO 476W. Hydrogeophysics.

Application of geophysical methods in hydrogeology. Modules include method theory and hydrogeological applications; using instruments in the field; and analysis of data, interpretation, and hydrogeological insights. Class discussions; field exercises and written field exercise summaries; individual and group reports. Previous coursework and/or experience in hydrogeology and geophysics is recommended. Four lecture hours a week for one semester, with field work hours to be arranged. Geological Sciences 371C (Topic: Hydrogeophysics) and 476W may not both be counted. May not be substituted for any required geological sciences course. Prerequisite: Consent of instructor.

GEO 377K. Applied Karst Hydrogeology.

The study of karst landforms, processes, flow systems, and water resources. Geologic controls, natural resources, aquifer recharge and discharge, system evolution, geochemistry/water quality, tracing methodologies, geophysical methods, and modeling are covered with an emphasis on collecting and interpreting field data. Three lecture hours a week for one semester, with additional fieldwork hours to be arranged. Course fulfills three hours of field course requirement for Bachelor of Science in Geological Sciences (Option III: Hydrogeology) degree program. Geological Sciences 371C (Topic: Applied Karst Hydrogeology) and 377K may not both be counted.

GEO 377P. Physical Climatology.

Investigates the nature of earth's climate and examines the physical processes that maintain the climate system. Three lecture hours and two laboratory hours a week for one semester. Prerequisite: Upper-division standing, Computer Science 303E, Geography 301K, Mathematics 408D or 408M, and Physics 303K with a grade of at least C- in each.

GEO 378D. Introduction to Machine Learning and Geosciences.

Explore an overview of commonly used machine learning algorithms for Geosciences applications. Three lecture hours a week for one semester. Prerequisite: Knowledge of basic calculus, linear algebra and statistics, and python programming; or consent of instructor.

GEO 679G. Special Studies in Geophysics Research, Fieldwork, or Internship.

Restricted to geophysics majors. Special research projects, field studies, or geophysical/industrial internship. Assigned reading with written and oral report. Three lecture hours a week for two semesters. May be used instead of Geological Sciences 660 in fulfilling the requirements for the Bachelor of Science in Geological Sciences (Option II: Geophysics). Prerequisite: Consent of instructor.

GEO 379H. Honors Thesis in Geological Sciences.

Restricted to students in the Geological Sciences Honors Program. Supervised research project resulting in an honors thesis with an oral defense. For each semester hour of credit earned, the equivalent of one lecture hour a week for one semester. May be counted as three of the six geological sciences senior elective hours. Prerequisite: Geological Sciences 171H, 172H, and 173H with a grade of at least B- in each.

GEO 679J. Internship in Hydrogeology.

Restricted to hydrogeology majors. Special hydrogeological studies under the joint supervision of industry professionals and faculty members. Students present a written report. Forty hours a week for one semester. May be used in place of Geological Sciences 660 in fulfilling the requirements for the Bachelor of Science in Geological Sciences (Option III: Hydrogeology). Prerequisite: Geological Sciences 476K with a grade of at least C-, and consent of instructor.

GEO 279K, 379K. Special Studies in Advanced Geological Sciences.

Special emphasis on recent developments in geosciences. Conference course. May be repeated for credit when the topics vary. Prerequisite: Consent of instructor.

GEO 479M. Mammalogy.

Restricted to biology, geological sciences, and anthropology majors. Surveys the biology and evolutionary history of mammals. Introduction to the diversity of living mammals through the study of mammalian ecology, behavior, morphology, and taxonomy. Laboratory work focuses on the characters diagnosing the major mammalian clades and identifying the common recent mammals of Texas using skins and recent osteological specimens. Fossils and the fossil record of mammals. Three lecture hours and three laboratory hours a week for one semester. Prerequisite: Upper-division standing.

GEO 379N, 679N. Geosciences Internship.

Restricted to geological sciences and environmental science majors. Work experience in geological sciences under the joint supervision of industry professionals (the employer) and a supervising faculty member. Requires submission of a final report to the supervising faculty member at the end of the semester. Internship position must be on file with JSG Career Services. For 379N, twenty laboratory hours a week for one semester. For 679N, forty laboratory hours a week for one semester. Prerequisite: Consent of instructor.

GEO 379S. Geological Sciences Senior Thesis.

Restricted to geological sciences majors. Second course in a two-course sequence focused on supervised student research and preparation of a final report on research activities. Three lecture hours a week for one semester, with additional hours to be arranged. Offered on the letter-grade basis only. Prerequisite: Upper-division standing, and Geological Sciences 371S with a grade of at least C-.

Graduate Courses

GEO 380C. Advanced Structural Geology.

Origin of earth structures, solution of advanced structural problems, newest techniques, field techniques, and field problems. Three lecture hours a week for one semester. Prerequisite: Graduate standing and consent of instructor.

GEO 380F. Seismology II.

Basic seismology theory and its application to the study of the interior of the Earth (crust, mantle, and core), earthquakes, and plate tectonics. Three lecture hours a week for one semester. Prerequisite: Graduate standing, and Mathematics 408C or the equivalent.

GEO 380G. Construction and Interpretation of 3-D Stratigraphy.

Uses three-dimensional volumes of basin-filling stratigraphy to explore how depositional landscapes are preserved in the sedimentary record and how sedimentary deposits can be analyzed to produce quantitative reconstructions of past environmental states. Four lecture hours a week for one semester. Prerequisite: Graduate standing.

GEO 380J. Mathematical Methods in Geophysics.

A survey of mathematics for geoscientists that includes infinite series, complex variables, linear algebra, integral transforms, ordinary and partial differential equations, tensor analysis, and probability and statistics. Three lecture hours a week for one semester. Geological Sciences 366M and 380J may not both be counted. Prerequisite: Graduate standing.

GEO 380N. Sequence Stratigraphy.

Organization and interpretation of stratigraphic successions in time-bounded units of genetically related strata. Sequence stratigraphy, as a predictive branch of stratigraphic analysis, provides insight into the origin of the entire spectrum of siliciclastic, carbonate, and evaporite sediments from shallow to deep settings. Laboratory component involves the interpretation of sequences using outcrop measured sections, core data, wireline log sections, field trips, and 2D and 3D seismic data from modern and ancient settings. Three lecture hours and one and one-half laboratory hours a week for one semester. Prerequisite: Graduate standing, and Geological Sciences 416M and 465K or their equivalents.

GEO 380P. Advanced Reservoir Characterization: Carbonates.

Advanced instruction in the integration of geologic and engineering methods for building 3-D reservoir models of carbonate reservoirs. Four lecture hours a week for one semester. Offered in alternate years. Geological Sciences 380P and 391 (Topic: Advanced Reservoir Characteristics: Carbonates) may not both be counted. Prerequisite: Graduate standing.

GEO 380R. Dynamics of Sedimentary Systems I.

Explores the fundamental concepts of transport systems at the Earth's surface, focusing on principles and quantitative aspects of fluid flow, sediment transport, and bedforms, as well as atmospheric and oceanic circulation, complex systems, and the integration of small-scale processes in developing quantitative stratigraphic models. Four lecture hours a week for one semester. Prerequisite: Graduate standing.

GEO 380S. Dynamics of Sedimentary Systems II.

Explores the fundamental concepts of transport systems at the Earth's surface, focusing on principles and quantitative aspects of fluid flow, sediment transport, and bedforms, as well as atmospheric and oceanic circulation, complex systems, and the integration of small-scale

processes in developing quantitative stratigraphic models. Four lecture hours a week for one semester. Prerequisite: Graduate standing and Geological Sciences 380R.

GEO 380T. Geoclimatology.

Examines climate records encoded in sedimentary archives through geologic time. Three lecture hours a week for one semester. Prerequisite: Graduate standing or consent of instructor.

GEO 381C. Structural Petrology.

Deformation processes from atomic to macroscopic level, resultant textures and fabrics, and conditions required to produce such deformation. Three lecture hours and three laboratory hours a week for one semester. Prerequisite: Graduate standing and an undergraduate course in structural geology and petrology.

GEO 381E. Brittle Structure.

Quantitative analysis of folding, faulting, and fracturing at all scales in the upper crust, with emphasis on cross-section construction, subsurface mapping, and fracture analysis. Three lecture hours a week for one semester, and several field trips. Prerequisite: Graduate standing and a course in structural geology.

GEO 381F. Microstructures and Rock Rheology.

Focuses on processes of deformation operative in the crust and upper mantle, with an emphasis on distinguishing these processes using microstructural analysis and describing them using basic constitutive relationships from rock mechanics. Three lecture hours a week for one semester. Geological Sciences 381F and 391 (Topic: Microstructures and Rock Rheology) may not both be counted. Prerequisite: Graduate standing.

GEO 381G. Geomicrobiology.

Geologic and hydrologic controls on subsurface microbial growth, metabolism, and community structure; the geochemical consequences of microbial processes in subsurface settings; and the influence of geology on microbial ecology. Three lecture hours a week for one semester. Prerequisite: Graduate standing in geological sciences, or graduate standing and consent of instructor.

GEO 381J. Marine Geology.

Survey of the field of marine geology by exploring the structure and evolution of the ocean basins, oceanic islands, and island arcs, the chemistry of the oceans, the sediments in the marine environments, the products and processes of the land-air-sea interface, and the history of the oceans over geologic time. Three lecture hours a week for one semester. Geological Sciences 381J and Geological Sciences 391 (Topic: Marine Geology) may not both be counted. Prerequisite: Graduate standing.

GEO 381P. Plate Margins.

Study of the tectonics of the earth. Topics include history of early concepts, ocean spreading ridges and ophiolites, rifting, core complexes, passive margins, subduction zones, trenches, volcanic arcs, collisional orogenesis, and transform margins. Three lecture hours a week for one semester. Geological Sciences 381P and 391 (Topic: Plate Margins) may not both be counted. Prerequisite: Graduate standing in geological sciences.

GEO 381R. Regional Studies in Mineral Resources Geology.

Geologic evolution of a region, with emphasis on factors that control the origin of selected mineral resources. Study area varies according to the interests of participants and other factors. Three lecture hours a week

for one semester. May be repeated for credit. Prerequisite: Graduate standing and consent of instructor.

GEO 381S. Tectonic Problems.

Explore the origin of regional structural features, complex and controversial structures, and the tectonic control of ore deposits. Three lecture hours a week for one semester. Prerequisite: Graduate standing in geological sciences and consent of instructor.

GEO 381T. Marine Tectonics.

Tectonic processes within the dynamic Earth, with a focus on oceanic structures. Subjects may include fundamentals of plate tectonics; plate motion, driving forces, and mantle convection; evolution of triple junction and plate margins; plate reconstructions; earthquakes and focal mechanisms; structure and geochemistry of the Earth's interior; mantle structure and tomography; rheology and deformation mechanisms in mantle and crust; heat flow, gravity, the geoid, and paleomagnetism; hotspots and mantle plumes; seafloor spreading and oceanic spreading ridges; oceanic transform faults and fracture zones; and subduction zones, volcanic island arcs, and marginal seas. Three lecture hours a week for one semester. Geological Sciences 338T and 371C (Topic: Tectonics I) may not both be counted. May not be substituted for any required geological sciences course. Prerequisite: Graduate standing in geological sciences, or graduate standing and consent of instructor.

GEO 382C. Groundwater Field Methods.

Basic field methods used in evaluation of groundwater conditions, with emphasis on field interpretation and on hands-on experience with geophysical, geochemical, stream-gauging, and pump test methods. Forty-five hours of field and laboratory work in a three-week period. Prerequisite: Graduate standing, and Geological Sciences 391C or consent of instructor.

GEO 382D. Crustal Geofluids.

Designed to provide a technical foundation for exploring how fluids drive fundamental geologic processes in sedimentary basins. Includes characterizing pressure and stress in sedimentary basins, exploring the origin of overpressure through theory and characterization, and examining how pressure and stress couple. Problems include how sedimentation generates overpressure, how hydrocarbons are trapped in the subsurface, how mud volcanoes form, how submarine landslides are generated, and the origin of methane hydrates. Three lecture hours per week for one semester, with a four-day field trip to be arranged. Geological Sciences 382D and 391 (Topic: Crustal Fluids) may not both be counted. Prerequisite: Graduate standing.

GEO 382E. Scientific Research Design.

Explore the principles of experimental design including formulation of target questions and method choice in an interdisciplinary, community context. Three lecture hours a week for one semester. Geological Sciences 382E and 391 (Topic: Scientific Research Design) may not both be counted. Prerequisite: Graduate Standing.

GEO 382F. Fractured Rock Hydrology and Mechanics.

Introduction to the physics of flow in fractured rocks and soils, fracture mechanics, fracture skins, analysis of solute transport, and methods of characterizing and modeling fractured systems. Class field trips are an integral part of the class. Three lecture hours a week for one semester, with additional hours to be arranged. Prerequisite: Graduate standing and consent of instructor; previous coursework in advanced calculus (differential equations, vector spaces and Fourier series), and hydrogeology.

GEO 382G. Fluid Physics for Geologists.

Restricted to students in the Department of Geological Sciences. Flow and transport phenomena within an earth science context. Includes extensive use of Maple, MATLAB, and COMSOL Multiphysics. Three lecture hours a week for one semester. Prerequisite: Graduate standing, previous coursework in advanced calculus (differential equations, vector spaces and Fourier series), and Geological Sciences 391C, 383D or 383E; non-majors also require consent of instructor.

GEO 382M. Programming in FORTRAN and MATLAB.

FORTRAN for students without knowledge of a computer programming language: survey of all variable types, loops, arrays, subroutines, and functions; overview of UNIX and MATLAB. Two lecture hours and two laboratory hours a week for one semester. Geological Sciences 382M and 391 (Topic: Programming in FORTRAN and MATLAB) may not both be counted. Prerequisite: Graduate standing, and Mathematics 408D or the equivalent.

GEO 382P. Physical Oceanography.

Basic concepts for understanding and describing the large-scale circulation of the ocean. Covers measurement methods, properties of seawater, description of the global ocean's mean state and variability, introductory dynamics including balanced motions, wind-driven and abyssal circulation, wave motions, air-sea interactions, sea level science, and the ocean's role in climate. Three lecture hours a week for one semester. Geological Sciences 382P and 391 (Topic: Physical Oceanography) may not both be counted. Prerequisite: Graduate standing.

GEO 382S. Physical Hydrology.

Comprehensive treatment of modern conceptual and methodological approaches to hydrological science. Combines qualitative understanding of hydrological processes with quantitative representation, approaches to measurement, and treatment of uncertainty. Major components of the hydrological cycle. Three lecture hours and two laboratory hours a week for one semester. Prerequisite: Graduate standing in geological sciences, or graduate standing and consent of instructor.

GEO 382T. Continental Tectonics.

Tectonic processes, with a focus on continental lithospheric structures. Subjects may include convergent margins, subduction zones, magmatic arcs, and foreland structures; collisional orogenesis, arc-continent collisions, continent-continent collision, and mountain building; formation of supercontinents; uplift and exhumation; orogenic collapse and extensional tectonics; continental rifting and passive margins; transform margins; and the effect of tectonics on climate and oceanic circulation. Three lecture hours a week for one semester. Geological Sciences 382T and 391 (Topic: Tectonics II) may not both be counted. May not be substituted for any required geological sciences course. Prerequisite: Graduate standing in geological sciences, or graduate standing and consent of instructor.

GEO 382W. Hydrogeophysics.

Application of geophysical methods in hydrogeology. Modules include method theory and hydrogeological applications; using instruments in the field; and analysis of data, interpretation, and hydrogeological insights. Class discussions; field exercises and written field exercise summaries; individual and group reports. Three lecture hours a week for one semester, with fieldwork hours to be arranged. Geological Sciences 382W and 391 (Topic: Hydrogeophysics) may not both be counted. Prerequisite: Graduate standing and consent of instructor; previous coursework and/or experience in hydrogeology and geophysics is recommended.

GEO 383. Clastic Depositional Systems.

River-, wave-, tide-, and gravity-driven processes are examined in modern depositional systems and considered in relation to sediment-flux, base-level, and autogenic changes. Application to the development of dynamic facies models and alluvial-shoreline-shelf-deepwater transitions in stratigraphic data. The equivalent of four lecture hours a week for one semester, including a four to five day field seminar. Prerequisite: Graduate standing in geological sciences.

GEO 383C. Geology and Hydrology.

Study of the interaction of fluids with the rock matrix, with emphasis on the role of hydrology in geologic processes and the role of geology in affecting hydrologic processes. Three lecture hours a week for one semester, and several field trips. Offered irregularly. May be repeated for credit when the topics vary. Prerequisite: Graduate standing and a course in hydrogeology or hydrology.

GEO 383D. Numerical Methods I: Computational Methods in Geological Sciences.

A survey of geophysical data analysis methods, with a focus on time series, including sampling and aliasing, convolution and correlation, statistics, linear digital filters, properties and applications of the discrete Fourier transform, and least squares. Instruction in MATLAB and Fortran and solution of data analysis problems using these two languages. Two lecture hours and two laboratory hours a week for one semester. Prerequisite: Graduate standing.

GEO 383E. Digital Methods in Hydrogeology.

Applications of mathematical software to earth science problems, with emphasis on hydrogeologic problems. Includes a brief introduction to numerical methods. Three lecture hours a week for one semester. Prerequisite: Graduate standing, previous coursework in advanced calculus (differential equations, vector spaces and Fourier series), and Geological Sciences 391C.

GEO 383F. Holocene-Pleistocene Sedimentology and Stratigraphic-Structural Evolution of the Caicos Platform.

Investigation of the broad range of depositional environments of the Caicos Platform through mapping exercises using state of the art digital imagery and lidar datasets, lab exercises, core workshops and a week-long field trip. Study of the evolution of the Caicos Platform carbonate system from modern sediments to complex stratigraphic records including grain types, sedimentary structures, and facies successions from the tidal flats, salinas, high-energy shoreline, and grainy back reef environments. Two lecture hours and two laboratory hours a week for one semester; field trip to Caicos Platform also required. Geological Sciences 383F and 291 (Topic: Sedimentol of Caicos Platform) may not both be counted. Prerequisite: Graduate standing, and Geological Sciences 383M or 383N.

GEO 383G. Geochemistry of Sedimentary Rocks.

The hydrologic cycle, the early diagenesis, carbonate sediments, chemical sediments, and burial processes. Three lecture hours a week for one semester, with laboratory hours to be arranged. Offered irregularly. May be repeated for credit. Prerequisite: Graduate standing.

GEO 383K. Paleoecology.

Relationships of fossil animals and plants to their environments and to the sedimentary deposits in which they occur. Three lecture hours a week for one semester, with one optional field trip. Prerequisite: Graduate standing.

GEO 383L. Petrography of Sandstones.

Interpretation of microscale features of sandstones to decipher the paleogeographic, tectonic, and postdepositional controls on sandstone

composition and texture. Examines the effects of chemical and mechanical processes in the subsurface on sandstone properties, including porosity. Two lecture hours and three laboratory hours a week for one semester. Offered irregularly. Prerequisite: Graduate standing in geological sciences.

GEO 383M. Petrology of Carbonates and Evaporites.

Description and interpretation of carbonate and evaporite rock deposition and paragenesis. Essentials of petrology; petrography, including identification of grain types, cement types, recrystallization, and dolomitization; and porosity evolution. Global geochemical signals in carbonate sediments, and geochemical processes of early and late diagenesis. Three lecture hours and two laboratory hours a week for one semester. Offered irregularly. Prerequisite: Graduate standing.

GEO 383N. Depositional Systems: Carbonates and Evaporites.

Analysis of carbonate and evaporite depositional systems from sedimentary structures, faunal and ichnofaunal associations, grain types, vertical and lateral facies successions within time-significant packages, and sediment body geometries. Three lecture hours and three laboratory hours a week for one semester. Offered irregularly. Prerequisite: Graduate standing and consent of instructor.

GEO 383P. Potential Field Applications in Geophysics.

Introduction to the theory, measurement, and application of gravity and magnetic and electric fields to exploration and global-scale problems. Three lecture hours a week for one semester. Prerequisite: Graduate standing.

GEO 383R. Reservoir Geology and Advanced Recovery.

Analysis of geologic controls on composition and architecture of oil and gas reservoirs, with emphasis on reservoir heterogeneity resulting from depositional and diagenetic processes. Geological and petrophysical determinants of fluid flows and behavior. Three lecture hours a week for one semester. May be repeated for credit. Prerequisite: Graduate standing; and credit or registration for Geological Sciences 380N, 383, and 383N, or consent of instructor.

GEO 383S. Sedimentary Basin Analysis.

Quantitative and applied study of basin subsidence and sediment accumulation. The first half of the course considers theoretical basin evolution due to flexural, thermal, dynamic, and fault-related subsidence. The second half of the course involves analysis of selected basin systems and includes student research projects and presentations on assigned topics. Three lecture hours a week for one semester. Prerequisite: Graduate standing.

GEO 383T. Tectonic and Climatic Interactions in Foreland Basins.

Integration of recent advances in foreland basins and adjacent orogenic belts, with emphasis on sedimentation, quantitative basin models, regional and global climate change, and the geometry and kinematics of fold-thrust belts. Three lecture hours a week for one semester. Prerequisite: Graduate standing and consent of instructor.

GEO 383U. Dynamic Field Stratigraphy.

Field-based evaluation of the dynamics of the stratigraphic record, with implications for sedimentary, tectonic, and climatic processes. Three lecture hours per week for one semester. Geological Sciences 383U and 391 (Topic: Dynamic Field Stratig: Andes) may not both be counted. Prerequisite: Graduate standing and consent of instructor.

GEO 384C. Seismology I.

Seismic, gravity, magnetic, electrical, and electromagnetic methods of exploration for petroleum and minerals. Three lecture hours and two laboratory hours a week for one semester. Prerequisite: Graduate standing.

GEO 384D. Physics of Earth.

Geophysics of the whole Earth: seismic methods of inferring Earth structure, chemical makeup of Earth, tides and rotational variations, geomagnetism, heat flow, earthquakes, and seismicity. Three lecture hours a week for one semester. Prerequisite: Graduate standing.

GEO 384E. Seismic Migration and Inversion.

Use of the acoustic or elastic wave equation to construct subsurface images in seismic processing. Different methods of solution and data domains employed in routine applications. Investigates integral, implicit, and explicit finite differences and Fourier methods for the imaging and inversion of seismic reflection data. Three lecture hours a week for one semester. Offered irregularly. Prerequisite: Graduate standing in geological sciences.

GEO 384F. Finite Element Methods in Geophysics.

Numerical methods for solution of partial differential equations arising in continuum geophysics and geodynamics. Focuses on finite element methods and their application to heat conduction, viscous flow, wave propagation, and transport problems in geophysics. Four lecture hours a week for one semester. Geological Sciences 384F and 391 (Topic: Computational Methods for Geophysics) may not both be counted. Prerequisite: Graduate standing and consent of instructor.

GEO 384G. Subsurface Mapping and Petroleum Workstations.

Introduction to basin analysis, subsurface mapping, and petroleum exploration using a workstation. Subjects may include common tectonic settings of petroleum basins, seismic stratigraphy, structural styles, and petroleum systems. Workstation techniques include well log editing, lithology interpretation, correlation of tectonic events, integration of seismic and subsurface well data, interpretation of two- and three-dimensional seismic reflection data and structure, and isopach and seismic attribute mapping. Four lecture hours a week for one semester. Geological Sciences 384G and 391 (Topic: Introduction to Petroleum Workstations) may not both be counted. Prerequisite: Graduate standing and consent of instructor.

GEO 384H. Multidimensional Data Analysis in Geosciences.

Extracting multidimensional patterns from data, data reconstruction and registration, signal and noise separation. Elements of geostatistics, linear estimation, image analysis, and multidimensional sparsity-promoting transforms with applications to large-scale geoscientific data. Three lecture hours a week for one semester. Geological Sciences 384H and 391 (Topic: Multidimensional Data Analysis) may not both be counted. Prerequisite: Graduate standing.

GEO 384M. Inverse Theory.

Vector spaces; model parameter estimation methods from inaccurate, insufficient, and inadequate measurements; linear, quasi-linear, and highly non-linear problems; local and global optimization methods. Emphasis on practical problem solving. Three lecture hours and two laboratory hours a week for one semester. Prerequisite: Graduate standing and knowledge of linear algebra, basic calculus, and statistics.

GEO 384N. Rock Physics.

Focuses on how rocks, pore fluids, and physical conditions of temperature, stress, diagenesis, and geological processes impact wave propagation, with an emphasis on how laboratory and theoretical

results can be applied to field data. Presentation of case studies that outline strategies for seismic interpretation, site characterization, and recovery monitoring. Upscaling seismic and rock properties from the laboratory scale to borehole and reservoir scales. Multidisciplinary approaches to combination of geostatistical and stochastic methods, seismic-to-rock property transforms, and geologic information for reservoir characterization. Three lecture hours a week for one semester. Geological Sciences 384N and 391 (Topic: Rock Physics) may not both be counted. Prerequisite: Graduate standing.

GEO 384R. Geophysical Time Series Analysis.

Surveys the following topics in time series analysis with geophysical applications: Fourier transforms, linear digital filters and their design, frequency domain analysis methods (power and coherence spectrum estimation), least squares and related methods with time series applications. MATLAB is used extensively. Three lecture hours a week for one semester. Prerequisite: Graduate standing, and Geological Sciences 325K or 383D or the equivalent.

GEO 384S. Seismic Data Processing.

Reduction of seismic data from field records to final geologic images, using real data sets and open-source data analysis software. Three lecture hours and two laboratory hours a week for one semester. Prerequisite: Graduate standing, and Geological Sciences 384R.

GEO 384T. Seismic Lithology.

How seismic waves propagating through earth materials respond to relevant rock, reservoir, and fluid properties in the subsurface, and how seismic data recorded on the surface are used to describe, discriminate, and estimate these rock, reservoir, and fluid properties in the subsurface. Three lecture hours and one and one-half laboratory hours a week for one semester. Geological Sciences 384T and 391 (Topic: Seismic Lithology and Exploration Geophysics) may not both be counted. Prerequisite: Graduate standing.

GEO 384U. Quantitative Seismic Interpretation.

Seismic inversion, a tool for reservoir characterization, post- and pre-stack modeling, rock physics and fluid replacement modeling, wavelet estimation and post-stack inversion, AVO and pre-stack inversion, multiattribute regression and neural network, and net pay estimation. Extensive hands-on training with three-dimensional seismic and well-log data. Three lecture hours a week for one semester. Prerequisite: Graduate standing.

GEO 384W. Seismic Imaging.

Seismic reflection imaging for visualizing the interior of Earth's upper crust. Study of fundamental imaging concepts from a unified geometrical point of view. Hands-on practical experience with imaging seismic data in an open-source software environment. Three lecture hours and one laboratory hour a week for one semester. Geological Sciences 384W and 391 (Topic: Wavefield Imaging) may not both be counted. Prerequisite: Graduate standing; programming experience and familiarity with seismology are helpful.

GEO 185G. Geophysics Colloquium.

Open to non-geological sciences majors, but registration priority is given to geological sciences majors. Exploration of a variety of problems in modern geophysics. Two lecture hours a week for one semester, and at least one weekend field trip. Geological Sciences 185G and 194 (Topic: Geophysics Colloquium) may not both be counted. May be repeated for credit. Offered on the credit/no credit basis only. Prerequisite: Graduate standing.

GEO 385Q. Geomorphology Process and Form.

Explores how Earth surface processes combine to shape landscapes through erosion and deposition. Emphasis on open channel flow, sediment transport, fluvial and hillslope processes, and tectonic controls on landscape evolution. Three lecture hours a week for one semester, with several field trips to be arranged. Geological Sciences 385Q and 391 (Topic: Geomorphology: Landscape Process, Form, and Evolution) may not both be counted. May not be substituted for any required geological sciences course. Prerequisite: Graduate standing in geological sciences.

GEO 485S. Introduction to Remote Sensing for Geoscientists.

Examine the fundamentals of acquiring, processing, and interpreting remote sensing data. Explore the development of skills in the use and analysis of remote sensing data. Survey the physics of electromagnetic radiation and its interaction with geologic materials; common techniques for remote sensing; science goals and instruments onboard ongoing and planned remote sensing missions; and techniques for analysis of remote sensing data. Three lecture hours and two laboratory hours a week for one semester. Geological Sciences 485S and 491 (Topic: Intro Remote Sensing Geosci) may not both be counted. Prerequisite: Graduate standing.

GEO 386. Metamorphic Petrology.

Metamorphism as a record of processes in the Earth's deep crust; phase equilibria among minerals and fluids at elevated temperatures and pressures; tectonometamorphic regimes; petrographic interpretation of metamorphic mineral assemblages and textures; and secular evolution of metamorphic patterns during Earth's history. Three lecture hours and three laboratory hours a week for one semester. Prerequisite: Graduate standing and consent of instructor.

GEO 386D. Earth in Deep Time.

Examine the causes and consequences of significant changes in Earth's surface environment and tectonic processes over the past 4.5 billion years. Discuss the initial Earth accretion, the Faint Young Sun problem, the rise of oxygen in Earth's atmosphere and general requirements for planetary habitability and how interactions between Earth's interior, the surface, and biosphere have shaped planetary evolution. Three lecture hours a week for one semester. Offered on the letter-grade basis only.

GEO 386E. Economic Geology.

Origin of economic mineral concentrations within the context of their overall geologic settings; geologic aspects of economic evaluation, mining, and mineral processing; and mineral exploration. Three lecture hours and two laboratory hours a week for one semester. May be repeated for credit. Prerequisite: Graduate standing and consent of instructor.

GEO 386G. Geographic Information System and Global Positioning System Applications in Earth Sciences.

Theory and practice of geographic information system (GIS) and Global Positioning System (GPS) technologies, and their applications to problems in earth sciences. Laboratories and field trips provide hands-on experience with the collection, mapping, and analysis of geologic and other field data using GPS equipment and GIS software. Subjects include map projections; datums and reference frames; cartographic principles; remotely sensed data (satellite and aerial photos, image radar); vector- and raster-based image formats; geospatial data resources; GIS software applications; surveying principles; GPS constellation and data structure; differential GPS; data logging schemes; GPS postprocessing software; integration of GPS and GIS in mapmaking; extant GIS applications in geology and hydrogeology. Three lecture hours and two laboratory hours a week for one semester, and two weekend field trips. Offered in the fall semester only. Geological Sciences 386G and 391 (Topic: Geographic

Information System and Global Positioning System Applications in Earth Sciences) may not both be counted. Prerequisite: Graduate standing.

GEO 386K. Igneous Petrology.

Origin, differentiation, and crystallization of igneous rocks. Three lecture hours and three laboratory hours a week for one semester. Offered in alternate years. May be repeated for credit. Prerequisite: Graduate standing, and Geological Sciences 390M or the equivalent.

GEO 386R. Geology of Earth Resources.

Same as Energy and Earth Resources 396 (Topic 5). Study of geologic, economic, societal, and environmental issues related to the production and consumption of energy, metal, industrial mineral, and water resources. Emphasizes the descriptive geology and origin of earth resources within the context of their overall geologic settings. Three lecture hours and one laboratory hour a week for one semester. Only one of the following may be counted: Energy and Earth Resources 396 (Topic: Geology of Earth Resources), 396 (Topic 5), Geological Sciences 386R, 391 (Topic: Geology of Earth Resources). May not be counted toward a graduate degree in geological sciences or petroleum engineering. Prerequisite: Graduate standing.

GEO 386S. Ins and Outs of Subduction Zones.

Explore an overview of subduction zones, including sites of lithospheric scale recycling, critical to understanding the chemical evolution of the Earth's crust and mantle, volcanism, earthquakes, and orogenesis. Includes the thermal and seismic structure of subduction zones, volatile and geochemical cycling, seismicity, mantle wedge dynamics, and volcanism. Three lecture hours per week for one semester. Geological Sciences 386S and 391 (Topic: Ins & Outs of Subduction Zones) may not both be counted. Prerequisite: Graduate-standing.

GEO 386T. Topics in Volcanology.

Explores the physical and chemical processes involved in the eruption, transport, and deposition of volcanic material through the use and study of field measurements, fluid dynamics, petrology, and geophysical observations. Three lecture hours a week for one semester. Geological Sciences 386T and 391 (Topic: Volcanology) may not both be counted. Prerequisite: Graduate standing.

GEO 387C. Aqueous Geochemistry.

Introduction to the chemistry of water in the subsurface. Topics include basic thermodynamics and kinetics of rock-water interaction, acid-base theory, redox, and coordination chemistry. Three lecture hours and two laboratory hours a week for one semester. May be repeated for credit. Prerequisite: Graduate standing and consent of instructor; previous graduate-level coursework in hydrogeology and at least two semesters of college chemistry.

GEO 387D. Climate Dynamics.

Studies features of the climate system and the basics of climate system dynamics. Subjects may include climate variability, radiation and heat budgets, atmospheric and ocean circulation systems, and the physics of climate change. Three lecture hours a week for one semester. Geological Sciences 387D and 391 (Topic: Climate System Science) may not both be counted. May not be substituted for any required geological sciences course. Prerequisite: Graduate standing and two semesters of calculus and one semester of physics.

GEO 387E. Environmental Organic Geochemistry.

Environmental and organic chemistry of organic contaminants in groundwater and soils. Three lecture hours and one laboratory hour a week for one semester. Offered irregularly. May be repeated for credit. Prerequisite: Graduate standing and consent of instructor.

GEO 387G. Climate System Modeling.

Studies the basic theory of weather/climate system modeling using state-of-the-art regional climate models in a variety of applications. Includes instruction on how to run models on the TACC supercomputers for scientific applications. Subjects may include paleoclimate, contemporary, and/or future climate prediction based on changes in greenhouse gas concentrations. Three lecture hours a week for one semester. Only one of the following may be counted: Geological Sciences 347G, 371C (Topic: Climate System Modeling), 387G, 391 (Topic: Climate System Modeling). May not be substituted for any required geological sciences course. Prerequisite: Graduate standing, basic knowledge of Unix, and programming experience in Fortran.

GEO 387H. Physical Climatology.

Investigates the nature of Earth's climate and examines the physical processes that maintain the climate system. Topics include the energy balance, the hydrological cycle, general atmosphere circulation, and how they all interact and vary at various spatial and temporal scales. Discusses human-induced modifications to the climate system, such as urbanization, anthropogenic global warming, desertification, and tropical deforestation. Focuses on descriptive, analytical, programming, and modeling skills. Three lecture hours a week for one semester. Prerequisite: Graduate standing and Computer Science 303E, Geography 301K, Mathematics 408D, and Physics 303K.

GEO 387P. Climate System Physics.

Discussion of first-order principles and processes that govern the thermodynamical structure and energy distribution of the atmosphere, ocean, land, and cryosphere and their interaction with the dynamic aspect of the climate system. Three lecture hours a week for one semester. Geological Sciences 387P and 391 (Topic: Climate System Physics) may not both be counted. May not be substituted for any required geological sciences course. Prerequisite: Graduate standing.

GEO 388G. Global Biogeochemical Cycles.

Examination of the major reservoirs, fluxes, and processes controlling the distribution of biologically active chemical constituents of the earth. The importance of these biogeochemical cycles in the geologic past and the effects of human perturbation of these cycles. Three lecture hours a week for one semester. Geological Sciences 388G and 391 (Topic: Global Biogeochemical Cycles) may not both be counted. Prerequisite: Graduate standing in geological sciences, or graduate standing and consent of instructor.

GEO 388H. Environmental Isotope Geochemistry.

The application of the isotope and trace element geochemistry of natural waters and sediments to studies of the hydrologic cycle. Stable, radiogenic, and cosmogenic isotopes are used as tracers of the evolution of groundwater, surface water, and ocean water. Three lecture hours a week for one semester, with laboratory hours to be arranged. May be repeated for credit. Prerequisite: Graduate standing.

GEO 388L. Isotope Geology.

Overview of the principles of stable and radiogenic isotope geochemistry. Covers mass spectrometry, geochronology and thermochronology, cosmogenic nuclides, radiogenic geochemistry, isotopic fractionation, traditional and non-traditional stable isotope geochemistry and its applications to the hydrologic cycle, low-temperature geochemistry, magmatic and metamorphic processes, thermometry, fluid-rock interactions, tectonics, crust-mantle evolution, and extraterrestrial materials. Three lecture hours a week for one semester. Prerequisite: Graduate standing.

GEO 388P. Paleontological Laboratory Techniques.

Overview and application of laboratory techniques used for in-depth investigation of the systematics of vertebrates. Three lecture hours a week for one semester. Geological Sciences 388P and 391 (Topic: Paleontological Laboratory Techniques) may not both be counted. Prerequisite: Graduate standing in geological sciences.

GEO 388R. Radiogenic Isotopes and Tectonic Processes.

Application of radiogenic isotopes to tectonic problems. Particular attention is given to methods and tools in thermochronology and geochronology for understanding thermal histories, uplift rates, slip rates, timing relationships, landform development, and provenance. Three lecture hours a week for one semester. Offered in alternate years. Prerequisite: Graduate standing.

GEO 388T. High-Temperature Geochemistry.

An introduction to the application of isotope and trace element geochemistry in the modern geological sciences, with emphasis on problems related to the origin and evolution of the Earth's interior. Three lecture hours a week for one semester. Prerequisite: Graduate standing.

GEO 389E. Evolution of Reef Ecosystems.

Introduction to the paleobiology, sedimentology, and oceanography of reef ecosystems throughout the geological record as well as the environmental and evolutionary factors that controlled the expansion and collapse of the carbonate ecosystems (and others). Explore ocean chemistry, how organisms biomineralize a skeleton, symbiosis, ecology, mass extinctions, and both current and future threats to reef health. Three lecture hours a week for one semester; required field trip date(s) to be arranged. Geological Sciences 389E and 391 (Topic: Evolution of Reef Ecosystems) may not both be counted. Prerequisite: Graduate standing.

GEO 389J. Transitions in the History of Life.

Exploration of the transitions in the history of life, including mass extinctions, climactic perturbations, and environmental changes and their impact on the Earth's biota. Three lecture hours a week for one semester. May be repeated for credit. Prerequisite: Graduate standing.

GEO 389K. Paleontologic Nomenclature and Techniques.

Rules of nomenclature: preparation, illustration, and description of Paleozoic invertebrate fossils. Three lecture hours a week for one semester. Prerequisite: Graduate standing in geological sciences and consent of instructor.

GEO 389M. Vertebrate Paleontology: Mammals.

Comparative osteology and phylogenetic history of the living and extinct mammals. Two lecture hours and four laboratory hours a week for one semester. Offered in alternate years. Prerequisite: Graduate standing in geological sciences and Geological Sciences 389V.

GEO 389P. Digital Methods in Morphology.

The use of digital multimedia for analysis of paleontological problems, with emphasis on three-dimensional high-resolution CT data. One lecture hour and three laboratory hours a week for one semester. Prerequisite: Graduate standing in geological sciences.

GEO 389R. Morphology of the Vertebrate Skeleton.

Identification of skeletal elements from the major vertebrate taxa, and aspects of skeletal functional morphology, with emphasis on extant taxa. Topics include the skeletal systems of fishes, amphibians, reptiles, birds, and mammals. Three lecture hours and four laboratory hours a week for one semester. Prerequisite: Graduate standing in geological sciences, and Geological Sciences 405 or the equivalent; or consent of instructor.

GEO 389S. Systematics and Paleontology.

Seminar course focusing on current issues in digital/instructional technologies. Provides students with an opportunity to explore, discuss, and demonstrate issues designing, acquiring, manipulating, authoring, and publishing digital content. Students work toward completing a specific project. Three lecture hours a week for one semester. Offered in alternate years. Geological Sciences 389S and 391 (Topic: Systematics and Paleontology) may not both be counted. Prerequisite: Graduate standing in geological sciences and consent of instructor.

GEO 389V. Vertebrate Paleontology.

Comparative osteology and phylogenetic history of the living and extinct fishes, amphibians, and reptiles. Two lecture hours and four laboratory hours a week for one semester. Prerequisite: Graduate standing in geological sciences, and Biology 349 or the equivalent.

GEO 390D. Seismology III.

Advanced treatment of elastic wave propagation in heterogeneous anisotropic media, vectors and tensors, Christoffel equation, group and phase velocities, invariant embedding (reflectivity), finite difference, finite elements, and spectral elements. Three lecture hours a week for one semester. Prerequisite: Graduate standing, and Geological Sciences 380F or the equivalent.

GEO 390E. Ecohydrology and Biometeorology.

Study the terrestrial biosphere and the ways ecosystems influence the water cycle. Investigate water, carbon, and energy fluxes within the Earth system from a hands-on experimental approach and through exposure to land-surface and climate models. Includes hydrology, Earth science, environmental engineering, ecology, biology, and climatology. Three lecture hours a week for one semester. Geological Sciences 390E and 391 (Topic: Ecohydrology/Biometeorology) may not both be counted. Prerequisite: Graduate standing.

GEO 390M. Thermodynamics of Geologic Processes.

Applications of physical chemistry to natural systems; interactions of minerals, solutions, and the atmosphere. Three lecture hours a week for one semester. Offered in alternate years. Prerequisite: Graduate standing and consent of instructor.

GEO 390Q. Morphodynamics and Quantitative Stratigraphy.

Explore numerical tools useful for quantitatively assessing sediment transport and stratigraphic development in sedimentary basins. Apply principles in fluid mechanics, sediment transport, and depositional mechanics to one-dimensional and quasi-two-dimensional numerical modeling of sediment morphodynamics in various depositional settings such as river deltas, carbonate platforms, and submarine fans. Develop geometrical and morphodynamic models as research tools to understand data collected from laboratory experiments and in the field. Three lecture hours a week for one semester. Geological Sciences 390Q and 391 (Topic: Morphodynamics) may not both be counted. Offered on the credit/no credit basis only. Prerequisite: Graduate standing.

GEO 390R. Analytical Methods: Electron-Microbeam Techniques.

An introduction to electron-microbeam instruments and their applications in the earth sciences. Lectures on relevant theory and concepts are supplemented by hands-on experience. Two lecture hours and three laboratory hours a week for one semester. Prerequisite: Graduate standing in geological sciences or graduate standing and consent of instructor.

GEO 390T. Tectonic Problems.

Restricted to students in the Jackson School of Geosciences. Explore cutting-edge and debated concepts and processes governing plate

tectonics, the unifying concept of solid Earth Sciences, in both the marine and continental realms. Investigate and test the validity of processes-oriented concepts in subduction, rift, and collision tectonics settings. Study regional and global tectonic problems through an interdisciplinary structural, petrological, geochemical, sedimentological, and geophysical approach. Three lecture hours a week for one semester. May be repeated for credit. Prerequisite: Graduate standing and consent of instructor.

GEO 191, 291, 391, 491, 591, 791, 891, 991. Seminar in Geological Sciences.

For each semester hour of credit earned, the equivalent of one class hour a week for one semester; additional hours may be required for some topics. Offered irregularly. May be repeated for credit when the topics vary. Prerequisite: Graduate standing in geological sciences; additional prerequisites vary with the topic.

GEO 391C. Physical Hydrogeology.

Geological controls on groundwater resources; evaluation of aquifers, geothermal systems, and contamination problems; natural hazards caused by human use of groundwater. Three lecture hours a week for one semester, with discussion hours to be arranged. Prerequisite: Graduate standing and concurrent enrollment in Geological Sciences 191W.

GEO 391D. Regional Tectonics.

Development of tectonic theory culminating in the new global tectonics, and application of theory to selected orogenic areas. Three lecture hours a week for one semester. Offered irregularly. Prerequisite: Graduate standing in geological sciences.

GEO 391K. Applied Karst Hydrogeology.

The study of karst landforms, processes, flow systems, and water resources. Geologic controls, natural resources, aquifer recharge and discharge, system evolution, geochemistry/water quality, tracing methodologies, geophysical methods, and modeling are covered with an emphasis on collecting and interpreting field data. Three lecture hours a week for one semester, with additional fieldwork hours to be arranged. Geological Sciences 391 (Topic: Applied Karst Hydrogeology) and 391K may not both be counted. Prerequisite: Graduate standing, and Geological Sciences 391C or consent of instructor.

GEO 391Q. Topics in Quaternary Geology.

Interdisciplinary analysis of Quaternary chronology, environments, climatic changes, and erosional-depositional processes. Three lecture hours a week for one semester. Offered irregularly. May be repeated for credit when the topics vary. Prerequisite: Graduate standing.

GEO 391S. Current Topics in Paleobiology.

Seminar reviewing recent publications on evolutionary and ecologic theories applied to the fossil record. Three lecture hours a week for one semester. Prerequisite: Graduate standing.

GEO 191W. Aquifer Testing.

Techniques of aquifer evaluation, including pumping tests, laboratory techniques, field mapping, and numerical analysis. Two laboratory hours a week for one semester. Geological Sciences 191 (Topic: Aquifer Testing) and 191W may not both be counted. Prerequisite: Graduate standing, and concurrent enrollment in Geological Sciences 391C or consent of instructor.

GEO 392F. Fundamentals and Applications of ICP-MS.

Explores inductively coupled plasma mass spectrometry (ICP-MS) for trace, minor and major element measurement, and applications in analytical fields. Covers fundamentals of technique, applications, and capabilities of ICP-MS through hands-on lab experience. Two lecture

hours and one-and-one-half laboratory hours a week for one semester. Geological Sciences 391 (Topic: Fundamentals/Applic of ICP-MS) and 392F may not both be counted. Prerequisite: Graduate standing; and working knowledge of MS Excel, including manipulation of rows and columns of data, application of basic algebraic functions to derive statistics, sorting and filtering of data.

GEO 392M. Modern Geological Sciences.

General discussion of the entire spectrum of geological sciences. Three lecture hours a week for one semester. Offered in the fall semester only. Geological Sciences 391 (Topic: Modern Geological Sciences) and 392M may not both be counted. Offered on the credit/no credit basis only. Prerequisite: Graduate standing in geological sciences, or graduate standing and consent of instructor.

GEO 392P. Python for Geoscience Research.

Explore Python 3 programming language for application to scientific research. Examine basic Python and common scientific Python libraries such as numpy, pandas, matplotlib, datetime. Three lecture hours a week for one semester. Geological Sciences 391 (Topic: Python in Geosci Resrch) and 392P may not both be counted. Prerequisite: Graduate standing.

GEO 392S. Geochemical Problem Solving with Ions Atoms.

Overview of mass spectrometers, which are analytical balances that operate at molecular and atomic levels, used for gathering compositional data (both isotopic and elemental). Explores conversion of sample molecules into charged particles (ions), and measurement according to mass-to-charge ratio to assess chemical identity and abundance. Introduction to inorganic mass spectrometry methods and applications to the Earth sciences, surveying key modalities: TIMS, ICP-MS, LA-ICP-MS, MC-ICP-MS, and IRMS. Examines techniques in generating and critically evaluating high-quality data, and research. Two lecture hours and three laboratory hours a week for one semester. Prerequisite: Graduate standing; and for non-geological sciences majors, consent of instructor.

GEO 193. Technical Lecture Series.

Attendance required of all graduate students in geological sciences. Two lecture hours a week for one semester. Additional hours may be required. May be repeated for credit. Offered on the credit/no credit basis only. Prerequisite: Graduate standing.

GEO 393D. 3D Analysis of Volumetric Data.

Explore the theory and practice of acquiring and utilizing volume image data, predominantly from X-ray computed tomography (CT). Examine CT data instrumentation and acquisition, as well as 3D data processing, visualization, and quantification using a range of methods, including machine learning approaches. Geosciences 391 (Topic: 3D Analysis of Volumetric Data) and 393D may not both be counted. Prerequisite: Graduate standing and consent of instructor.

GEO 194, 294, 394, 494, 594, 694, 794, 894, 994. Research in Geological Sciences.

Restricted to graduate students in geological sciences. For each semester hour of credit earned, the equivalent of one class hour a week for one semester. Offered every semester. May be repeated for credit when the topics vary. Offered on the credit/no credit basis only. Prerequisite: Graduate standing in geological sciences.

GEO 494P. Modeling Flow and Transport in Porous Media.

Introduction to the modeling of flow and transport in porous media with focus on basic dynamic phenomena that occur during single-phase flow and solute transport in heterogeneous porous media. Discuss the numerical solution of both the elliptic equations governing the flow of

groundwater and the hyperbolic equations governing solute transport. Includes a programming project which requires writing a functional numerical simulator. Three lecture hours and one and one-half laboratory hours per week for one semester. Prerequisite: Mathematics 408D or 427L; Mathematics 427J or 427K; one of the following with a grade of at least C-: Petroleum and Geosystems Engineering 310, Civil Engineering 311K, Mechanical Engineering 318M, Computational Engineering 301, or Geological Sciences 325G or 325J.

GEO 395D. Ice Dynamics.

Physics of ice motion, basal processes, glacial hydrology, and unstable flow. Three lecture hours a week for one semester. Geological Sciences 391 (Topic: Ice Dynamics) and 395D may not both be counted. Prerequisite: Graduate standing.

GEO 395S. Seismic Structural Analysis.

Addresses interpretation of 2D and 3D seismic reflection data for unraveling the geometry and kinematic evolution of crustal structures, principally in sedimentary rocks. Foundational subjects include understanding how structures manifest themselves in seismic data, and approaches to effective interpretation and kinematic analysis. Covers structural systems including extensional, fold and thrust belts, salt tectonics, and inversion. Applied subjects include computer workstation interpretation and analysis approaches, determination of geologic and basin history, fault system analysis, fault permeability structure, and geomechanical evaluations such as in situ stress determination and application to induced seismicity risking. Three lecture hours per week for one semester. Only one of the following may be counted: Geological Sciences 191, 391 (Topic: Seismic Structural Analysis), 395S Seismic Structural Analysis. Prerequisite: Graduate standing.

GEO 397F. Marine Geology and Geophysics Field Course.

Hands-on, team-based instruction in the collection and processing of marine geological and geophysical data along the Gulf of Mexico coast. Includes classroom, laboratory, and field components in Austin and at sea. Offered between the spring semester and the summer session; limited class meetings may begin in the spring semester. Only one of the following may be counted: Geological Sciences 348K, 397F, Marine Science 348 (Topic 2: Marine Geology and Geophysics Field Course). Prerequisite: Graduate standing.

GEO 397L. Transitions in the History of Life.

Introduction to major perturbations in the history of life; specifically, mass extinctions and carbon-cycle perturbations (e.g. ocean anoxic events, hyperthermals, and acidification events). Examine kill mechanisms (e.g. glaciations, impacts, large igneous provinces) and the subsequent environmental perturbations and ecological ramifications. Explore biotic crises in the past, with an eye to future ecosystem collapse, as well as the environmental and paleobiological responses to these events. Three lecture hours a week for one semester. Geological Sciences 391 (Topic: Transitions in the History of Life) and 397L may not both be counted. Prerequisite: Graduate standing.

GEO 397M. Morphodynamics and Quantitative Stratigraphy.

Covers development of numerical tools to quantitatively understand sediment transport and stratigraphic development in sedimentary basins. Focus on applications of the principles in fluid mechanics, sediment transport, and depositional mechanics to one-dimensional and quasi-two dimensional numerical modeling of sediment morphodynamics in various depositional settings such as river deltas, carbonate platforms, and submarine fans. Requires development of geometrical and morphodynamic models as research tools to understand gathered data. Three lecture hours per week for one semester. Geological Sciences 397M and 391 (Topic: Morphodynam/

Quant Stratigraphy) may not both be counted. Prerequisite: Graduate standing.

GEO 397P. Field Methods in Planetary Geology.

Field studies combined with remote sensing to support studies of remote imagery from planetary missions. Two lecture hours and two laboratory hours a week for one semester; three week field trip to the Southwestern United States also required; offered in summer session only. Geological Sciences 391 (Topic: Field Methods Planetary Geology) and 397P may not both be counted. Prerequisite: Graduate standing.

GEO 297Q. Preparing Future Faculty.

Examine the academic and research career track, including a number of different career paths. Participate in a workshop covering all application materials for these kinds of jobs. Two lecture hours a week for one semester. Geological Sciences 297Q and 291 (Topic: Preparing Future Faculty) may not both be counted. Prerequisite: Graduate standing.

GEO 698. Thesis.

The equivalent of three lecture hours a week for two semesters. Offered on the credit/no credit basis only. Prerequisite: For 698A, graduate standing in geological sciences and consent of the graduate adviser; for 698B, Geological Sciences 698A.

GEO 398C. Continuum Mechanics.

Explore the foundation for the modeling of fluids and solids in geological and geophysical phenomena, such as mantle convection, glaciology, rock mechanics, and climate dynamics. Examine tensor analysis, the kinematics of motion, forces, and stresses. Discuss basic balance (conservation) laws for mass, momentum, and energy, and constitutive laws for fluids and solids. Develop governing equations to geodynamics, glaciology, seismology, and geophysical fluid dynamics. Three lecture hours a week for one semester. May be repeated for credit. Offered on the letter-grade basis only. Prerequisite: Graduate standing and consent of instructor.

GEO 398D. Topics in Machine Learning Data Analytics.

Restricted to geological sciences students. Three lecture hours a week for one semester. May be repeated for credit when the topics vary. Prerequisite: Graduate standing; additional prerequisites vary with the topic.

Topic 1: Introduction to Machine Learning and Geosciences. Explore an overview of commonly used machine learning algorithms for Geosciences applications. Additional prerequisite: Knowledge of basic calculus, linear algebra and statistics, and python programming; or consent of instructor.

Topic 2: Applications of Data Analysis, Visualization, and Machine Learning. Examine computational approaches to take advantage of complex data. Explore addressing real-world geoscience challenges using the Python programming language and Jupyter computational notebooks. Discuss techniques in data analysis, modeling, and machine learning for subsurface characterization applicable to resource assessment and geomorphology and stratigraphy applicable to hazard assessment.

Topic 3: Data Analytics and Geostatistics. Explore data analytics and geostatistics for geosciences applications. Additional prerequisite: Knowledge of basic calculus, linear algebra and statistics, and python programming; or consent of instructor.

Topic 4: Subsurface Machine Learning. Explore problem formulation, feature engineering, and inferential and predictive machine learning algorithms for geosciences applications. Additional prerequisite: Knowledge of basic calculus, linear algebra and statistics, and python programming; or consent of instructor.

Topic 5: Machine Learning Research. Examine machine learning and its application to the geosciences. Study and discuss current literature and complete a capstone project applying machine learning to a research area of choice. Additional prerequisite: Geosciences 398D (Topic 1) and 392P.

GEO 398G. Geodynamics of the Lithosphere and Mantle.

Explores continuum dynamics problems that can serve to form a physical understanding of the tectonic and convective processes that shape our planet. Geared toward graduate students from the Earth sciences and related fields in the natural sciences including physics, computer science, and engineering. The equivalent of two lecture hours and one-and-one-half laboratory hours a week for one semester. Prerequisite: Graduate standing.

GEO 398L. Topics in Lithosphere and Deep Earth.

Three lecture hours a week for one semester. May be repeated for credit when the topics vary. Prerequisite: Graduate standing.

Topic 1: Tectonic Geodynamics. Examine dynamic processes that govern plate tectonics and lithospheric deformation, combining tectonics, structural geology, and geodynamics from the ground up. Geological Sciences 391 (Topic: Tectonic Geodynamics) and 398L (Topic 1) may not both be counted.

GEO 398M. Numerical Modeling in the Geosciences.

Covers numerical solution of dynamical problems arising in the solid earth geosciences. Entails development of individual codes in Matlab and application of codes to understanding heat transfer, wave propagation, elastic, and viscous deformations. Requires familiarity with Matlab. Two lecture hours and two laboratory hours a week for one semester. Prerequisite: Graduate standing and knowledge of programming in Matlab, vector calculus, and ordinary differential equations.

GEO 398P. Planetary Geology and Geophysics.

Introduction to planetary geology, with an emphasis on geophysical observations of terrestrial planets in our solar system. Discussion of missions, instruments, and techniques, and incorporation of mission data in student projects. Includes field trip to study planetary analog sites. The equivalent of three lecture hours a week for one semester. Geological Sciences 391 (Topic: PLANETARY GEOLOGY/GEOPHYSICS) and 398P may not both be counted. Prerequisite: Graduate standing.

GEO 398R. Master's Report.

Preparation of a report to fulfill the requirement for the master's degree under the report option. The equivalent of three lecture hours a week for one semester. Offered on the credit/no credit basis only. Prerequisite: Graduate standing in geological sciences and consent of the graduate adviser.

GEO 398S. Topics in Subsurface, Surface, and Life.

Three lecture hours a week for one semester. May be repeated for credit when the topics vary. Prerequisite: Graduate standing.

GEO 298T, 398T. Supervised Teaching in Geological Sciences.

Open to graduate students engaged in laboratory instruction under close supervision of the course instructors. For each semester hour of credit earned, the equivalent of one lecture hour a week for one semester. Offered on the credit/no credit basis only. Prerequisite: Graduate standing.

GEO 398W. Topics in Water, Climate, and Environment.

Three lecture hours a week for one semester. May be repeated for credit when the topics vary. Prerequisite: Graduate standing.

Topic 1: Vadose Zone Hydrology. Introduction to hydrologic processes occurring in the vadose zone (unsaturated zone), the subsurface region between the ground surface and groundwater. Focus on the physical processes that govern the movement of water in variably saturated porous media, and the exchange of mass and energy at Earth's surface. Explore theoretical and applied aspects, measurement techniques and computational tools, and environmental challenges of the vadose zone. Geological Sciences 391 (Topic: Vadose Zone Hydrology) and 398W (Topic 1) may not both be counted.

Topic 2: Paleoclimate. Introduction to paleoclimatology, the study of Earth's past climate. Examine a broad spectrum of geological archives of climate change including those from the oceans, the land, and the cryosphere. Geological Sciences 398W (Topic 2) and 391 (Topic: Paleoclimatology) may not both be counted.

Topic 3: Dynamics of Polar Systems. Examine the fundamental physics that govern dynamics of ice sheets, oceans, and sea ice from a theoretical viewpoint that is supported with as many observations as possible. Geological Sciences 398W (Topic 3) and 391 (Topic: Dynamics of Polar Systems) may not both be counted.

Topic 4: Statistical Data Analysis. Examine the statistical, scientific, and computational approaches used to test hypotheses concerning the physics governing observed changes in the Earth System. Explore concepts in linear algebra and statistics such as regression, least-squares inversion, singular spectral analysis, Bayesian inference, Markov Chain Monte Carlo sampling, and test statistics to survey the existence of a discernable influence of humanity on the observational record of climate. Geological Sciences 391 (Topic: Statistical Data Analysis) and 398W (Topic 4) may not both be counted.

GEO 399W, 699W, 999W. Dissertation.

May be repeated for credit. Offered on the credit/no credit basis only.

Prerequisite: Admission to candidacy for the doctoral degree.

Professional Courses