

Geological Sciences (GEO)

GEO 401 Physical Geology 4 Hours

Nature, properties, and distribution of crustal materials; surficial processes; internal processes; origin of continents, oceans, and ocean basins; mineral and fuel resources.

GEO 302C Climate: Past, Present, and Future 3 Hours

Explore the science of climate change. Examine the history of Earth's climate and the factors driving its changes. Discuss the Earth's climate history and the processes driving climate change; physical concepts governing heat and mass transfers in the atmosphere; the role of oceans in climate systems; temporal scales of climate change, from tectonic to millennial; anthropogenic global warming and human impacts on climate; health and ecosystem impacts of climate change; and methods for observing, modeling, and predicting climate change.

GEO 302D Age of Dinosaurs 3 Hours

Introduction to the study of life and why it matters. Explore the general principles of natural history, focusing on the natural history of dinosaurs. Discuss the basics of geology, anatomy, paleontology, and evolutionary theory, followed by the application of this knowledge, in tracing the evolutionary history of Dinosauria.

GEO 302E Earth, Wind, and Fire 3 Hours

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.

GEO 302G Earth Science and Sustainability 3 Hours

Explore grand challenges in earth science that affect sustainability and society, including climate change, energy production, water availability, and natural hazards. Examine authentic data, simple models, and maps used in geoscience gathering, analysis, and real-world applications.

GEO 302J Crisis of Our Planet 3 Hours

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.

GEO 302K Selected Topics in Geological Sciences 3 Hours

The impact of geological processes on human activity; geologic topics of popular interest.

GEO 302M The Age of Mammals 3 Hours

Introduction to paleontology and natural history for nonscience majors. Explore basic geological processes, fossilization, and the fossil record. Examine the evolution and diversification of mammals, interactions between physical and biological processes, and the impact of climate change and human activities on mammalian communities. Focus on the mammalian skeleton, common Texas mammals, and geobiological processes that shaped mammalian evolution and diversification.

GEO 302N Geology of National Parks 3 Hours

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.

GEO 302P Sustaining a Planet 3 Hours

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.

GEO 302Q Gems and Gem Minerals 3 Hours

Utilize gemstones, gold, and fine minerals as inspiration to learn optics, geologic processes that control occurrence, and crystallography. Discuss economic factors and societal impacts associated with gem and mineral deposits, along with gemstone identification using the physical and optical properties of the minerals and faceting gemstones using lapidary equipment.

GEO 302T Climate and the Energy Transition 3 Hours

Explore how humankind's use of carbon-based fuels drives climate change and powers our civilization. Examine how to transition to a carbon-neutral energy future, have sustainable economic growth, and feed 9.8 billion people in 2050.

GEO 303 Introduction to Geology 3 Hours

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.

GEO 303C Introduction to the Solar System 3 Hours

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.

GEO 303E Earth in 2100 3 Hours

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.

GEO 405 Life through Time 4 Hours

Examine the fundamentals of how life evolved, and the history of the development of Earth throughout geological time.

GEO 305E Energy and the Environment 3 Hours

A survey of all forms of current and potential sources of energy, and how these might impact the earth's environment.

GEO 306P Geology and Sustainability 3 Hours

Examines sustainability and environmental science from an interdisciplinary perspective.

GEO 110C, 210C, 310C Topics in Conference Course 1-3 Hours

Supervised study of selected topics in geological sciences, by individual arrangement with the instructor.

GEO 110T, 210T, 310T Undergraduate Topics in Geological Sciences 1-3 Hours

Selected undergraduate topics in geological sciences.

GEO 211 Emerging Scholars in Geological Sciences 2 Hours
Introduction to research areas in the geological sciences, with emphasis on the skills needed for success in graduate school and the professional workplace.

GEO 311D Geodata 3 Hours
Examine a broad array of subjects related to data analysis and interpretation in the geosciences. Designed for lower division undergraduates to build a foundation in quantitative skills (spatial analysis, regressions, simple coding concepts) that have direct application to geoscience problems.

GEO 012N JSG Geosciences Mentors Program - First-year 0 Hours
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.

GEO 114G Geophysics Colloquium 1 Hour
Introduction to geophysics to examine applications and discover career opportunities.

GEO 315L Earth From Lab to Planet 3 Hours
Explore the constitutive laws (e.g. elasticity, friction, viscosity) 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. Build skills in data analysis and simulation through python-based coding. 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.

GEO 416E Solid Earth Processes 4 Hours
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.

GEO 416K Earth Materials 4 Hours
Introduction to minerals, mineral study techniques, igneous and metamorphic rocks and ore deposits, and formation processes.

GEO 416M Sedimentary Rocks 4 Hours
Description and interpretation of sedimentary rocks in hand specimen and thin section; characteristics of sedimentary rocks deposited in different environments.

GEO 316P Sedimentary Rocks 3 Hours
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.

GEO 416S Earth and Planetary Processes Through Time 4 Hours
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.

GEO 416W Climate, Water, and the Environment 4 Hours
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.

GEO 119S, 219S, 319S, 419S, 519S, 619S, 719S, 819S, 919S Topics in Geological Sciences 1-9 Hours
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 Earth and Planetary 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.

GEO 420F Classic Geology in Scotland 4 Hours
Introduction to the founding concepts of geology. Students use advanced field technologies while studying the geology of Scotland on all scales of size.

GEO 420H Honors Introductory Geology 4 Hours
An accelerated introductory course on the composition, structure, and history of the earth.

GEO 420K Introduction to Field and Stratigraphic Methods 4 Hours
Field observation of geological processes and study of the mineralogy, petrology, stratigraphy, paleontology, and structural geology of central Texas.

GEO 320L Introductory Field Geology 3 Hours
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.

GEO 320S Introduction to Atmospheric Sciences 3 Hours
Introduction to atmospheric science, including atmospheric radiation, circulation systems, thermodynamics, and cloud and precipitation processes. Discuss tornadoes, hurricanes, weather systems, and contemporary climate change to provide an opportunity to relate basic principles to real-world phenomena.

GEO 322E Scientific Research Design 3 Hours
Examine principles of experimental design including formulation of target questions and method choice in a unique, interdisciplinary, community context. Focus on honing principles of experimental design (including formulation of target questions and method choice), scientific writing, as well as introducing tool kits for data analysis, statistical approaches, and data visualization.

GEO 322J Transitions in the History of Life 3 Hours
Introduction to major perturbations in the history of life; specifically, mass extinctions and carbon-cycle perturbations (hyperthermal, anoxic, and acidification events). Discuss kill mechanisms (impacts, large igneous provinces, glaciations) and the subsequent environmental perturbations and ecological ramifications. Examine biotic crises in the past, with an eye to future ecosystem collapse, as well as the environmental and paleobiological responses to these events.

GEO 422K Paleobiology 4 Hours
Systematics, biostratigraphy, paleoecology, and evolution of fossil organisms.

GEO 322M Basin GeoMechanics 3 Hours

Develop the technical foundation and physical insight to explore how stress and pressure drive geologic and human-induced processes. Examine applications including CO₂ sequestration, geothermal energy, hydraulic-fracturing, faulting, geopressure development, hydrocarbon entrapment, subsidence and compaction, slope stability, and borehole stability.

GEO 322S Development and Evolution of the Vertebrate Skeleton 3 Hours

Introduction to the organization and development of the vertebrate skeleton; survey of vertebrate history.

GEO 022T JSG Geosciences Mentors Program - Transfer 0 Hours

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.

GEO 322V Morphology of the Vertebrate Skeleton 3 Hours

Explore the vertebrate skeleton. Access hundreds of specimens for hands-on learning of the vertebrate skeleton. Focus on identification of skeletal elements and their proper placement in major vertebrate groups.

GEO 325C Continuum Mechanics 3 Hours

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.

GEO 325G Computational Applications in the Geosciences 3 Hours

An introduction to programming in MATLAB and applications to simulation of physical processes and data analysis in the geosciences.

GEO 325J Programming in FORTRAN and MATLAB 3 Hours

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.

GEO 325K Computational Methods 3 Hours

Examine numerical methods for data analysis. Discuss digital data representation, convolution, the discrete Fourier transform, design of commonly used filters, and least-squares estimation.

GEO 325M Numerical Modeling in the Geosciences 3 Hours

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.

GEO 425P Modeling Flow and Transport in Porous Media 4 Hours

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.

GEO 326D Earth in Deep Time 3 Hours

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.

GEO 426P Igneous and Metamorphic Petrology 4 Hours

Examine the fundamental ways in which igneous and metamorphic rocks record processes occurring within our dynamic Earth, and how compositions and textures of minerals relate to the conditions from which they form. Learn how to identify igneous and metamorphic minerals in hand specimen and thin section, and how their textures record the pressures and temperatures of the Earth's interior.

GEO 327G Geographic Information System and Global Positioning System Applications in Earth Sciences 3 Hours

Develop Geographic Information Systems (GIS) skills using Esri's ArcGIS Pro software, working on real-world challenges relevant to geoscience, environmental science, and energy resources. Focus on GIS fundamentals, spatial reference systems, map projections, cartographic principles, remote sensing data (Landsat, LiDAR) and both vector and raster data analysis. Explore geospatial data resources and apply techniques in vector and raster-based analysis to generate maps and spatial models.

GEO 428 Structural Geology 4 Hours

Study how and why rocks deform. Develop a practical toolset to quantify the mechanisms, magnitude, and timing of tectonic deformation by studying the rock record. Explore the physics underpinning how features such as faults, fractures, folds, and crystallographic fabrics initiate and evolve due to variation in tectonic forces, rock material properties, and pressure-temperature conditions.

GEO 328W Vadose Zone Hydrology 3 Hours

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.

GEO 129S, 229S, 329S, 429S, 529S, 629S, 729S, 829S, 929S Topics in Geological Sciences 1-9 Hours

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 Earth and Planetary 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.

GEO 329W Hydrogeology Cooperative (Geological Sciences) 3 Hours

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.

GEO 330K Energy Exploration 3 Hours

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.

GEO 331K Petrology and Plate Tectonics 3 Hours

Sedimentation, metamorphism, igneous activity, and deformation patterns at rift zones, subduction zones, and transform margins.

GEO 335 Geology and Mineral Resources of Texas 3 Hours

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.

GEO 135J Jackson Scholars Seminar 1 Hour

Discuss professional development skills, scholarship, research, and outreach.

GEO 336C CO₂ Storage in Geological Formations 3 Hours

Explore how capturing and storing carbon dioxide (CO₂) underground is an important means of mitigating climate change. Examine the geological and environmental aspects of CO₂ injection, sequestration, and monitoring that control the success of real CO₂ storage projects.

GEO 337T Global Tectonics 3 Hours

Examine tectonic processes within the dynamic Earth, with a focus on plate boundary processes. Discuss fundamentals of plate tectonics; plate motion, driving forces, and mantle convection; evolution of plate margins including convergent, transform, rifting, and mid-ocean ridge spreading centers, triple junctions and collisional orogenesis; plate reconstructions; earthquakes and focal mechanisms; structure and geochemistry of the Earth's interior. Explore challenging questions of onset of plate tectonics, subduction initiation, and tectonics on other planets.

GEO 338J Marine Geology 3 Hours

Impart an understanding of the fundamental way in which marine geologic processes affect the overall Earth System via a survey of the field of marine geology. Explore the structure and evolution of 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.

GEO 338T Marine Tectonics 3 Hours

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.

GEO 338W Paleoclimate 3 Hours

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.

GEO 339T Continental Tectonics 3 Hours

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.

GEO 340T Geoclimatology 3 Hours

Examination of the climate records encoded in sedimentary archives through geologic time.

GEO 341 Mineral Resources, Society, and the Environment 3 Hours

Nature and origin of mineral resources; their discovery, extraction, and uses; and their relationship to global history, economics, and the environment.

GEO 341F Microstructures and Rock Rheology 3 Hours

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.

GEO 341G Geomicrobiology 3 Hours

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.

GEO 343Q Fundamentals and Applications of Inductively Coupled Plasma Mass Spectrometry 3 Hours

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.

GEO 344K Marine Mining and Minerals 3 Hours

Overview of seafloor mineral deposits, their exploration, and mining.

GEO 344U Quantitative Seismic Interpretation 3 Hours

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.

GEO 145E Professional Ethics in Geosciences 1 Hour

Explore supervised study devoted to the subject of professional ethics, personal integrity, scientific communication ethics and societal implications related to the geosciences. Discuss subject matter and ethical conundrums that will vary to maintain societal and scientific relevance.

GEO 346C Introduction to Physical and Chemical Hydrogeology 3 Hours

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.

GEO 347D Global Warming 3 Hours

Discussion of the fundamental sciences of global warming, including an active investigation of contemporary climate change issues.

GEO 347G Climate System Modeling 3 Hours

Study the basic theory of weather/climate system modeling using state-of-the-art regional climate models in a variety of applications. Discuss paleoclimate, contemporary, and/or future climate prediction due to changes in greenhouse gas concentrations.

GEO 347K Gems and Gem Minerals 3 Hours

Crystallography, occurrence, and identification of gem minerals and materials; artificial gems; simple cutting and polishing; history of gems and gemology.

GEO 347P Climate System Physics 3 Hours

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.

GEO 348K Marine Geology and Geophysics Field Course 3 Hours

Hands-on, team-based instruction in the collection and processing of marine geological and geophysical data along the Gulf of Mexico coast.

GEO 348P Field Methods in Planetary Geology 3 Hours

Field studies combined with remote sensing to support studies of remote imagery from planetary missions.

GEO 349C Introduction to the Cryosphere 3 Hours

Explore how the cryosphere (ice sheets, glaciers, snow, and ice) interacts within the Earth system. Discuss ice physics, the geologic record of glaciation and glacial landscapes, and the relationship between glaciers and climate in the past, present, and future.

GEO 350D Ice Dynamics 3 Hours

Physics of ice motion, basal processes, glacial hydrology, and unstable flow.

GEO 350L Topics in Lithosphere and Deep Earth 3 Hours

GEO 350L.1 Tectonic Geodynamics 3 Hours

Discuss the processes that determine the evolution of the solid Earth system, combining views from the fields of tectonics, structural geology, and geodynamics. Understand the why of earthquakes, plate motions, subduction, orogeny, and lithospheric deformation including topography. Integrate geophysical and geological constraints from key regional settings to global scales to explore the links between theory and observations.

GEO 350L.2 Geophysics Seminar I 3 Hours

GEO 350L.3 Geophysics Seminar II 3 Hours

GEO 350S Topics in Subsurface, Surface, and Life 3 Hours

GEO 350T Tectonic Geodynamics 3 Hours

Discuss the processes that determine the evolution of the solid Earth system, combining views from the fields of tectonics, structural geology, and geodynamics. Understand the why of earthquakes, plate motions, subduction, orogeny, and lithospheric deformation including topography. Integrate geophysical and geological constraints from key regional settings to global scales to explore the links between theory and observations.

GEO 350W Topics in Water, Climate, and Environment 3 Hours

GEO 350W.1 Dynamics of Polar Systems 3 Hours

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.

GEO 350W.4 Statistical Data Analysis 3 Hours

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 3 Hours

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.

GEO 354 Physics of Earth 3 Hours

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.

GEO 355G Geodynamics of the Lithosphere and Mantle 3 Hours

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.

GEO 455S Introduction to Remote Sensing for Geoscientists 4 Hours

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.

GEO 356S Ins and Outs of Subduction Zones 3 Hours

Discuss subduction zones, including the thermal and seismic structure of subduction zones, volatile and geochemical cycling, petrology of the subducting slab, seismicity, mantle wedge dynamics, volcanism, and the start of plate tectonics.

GEO 358K Volcanology 3 Hours

Discuss eruptive processes and products of volcanoes, using methods and concepts from mineralogy, petrology, fluid dynamics, depositional processes, geomorphology, stratigraphy, structural geology, field mapping, remote sensing, geochemical monitoring, and seismology. Examine the prediction and reduction of volcanic hazards; challenges faced by geologists in communicating with the public, decision-makers, and the media; and other impacts that volcanoes have on society, including the Earth's climate.

GEO 660 Field Geology 6 Hours

Learn to identify sedimentary structures, measure and describe stratigraphy, interpret physical and environmental conditions in rock deposits, and develop foundational skills in geologic mapping and cross-section construction. Perform fieldwork including the use of UAV, LiDAR, and remote sensing data to enhance mapping and interpretation. Explore the geologic history and tectonic evolution of the Rocky Mountains and collect field and structural data to develop geologic maps, cross sections, and other geological products, interpreting the formation of folds, faults, rock fabrics, and associated features. Gain an understanding of crustal tectonics and the landform evolution of the region.

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

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.

GEO 661 Geophysics Field Camp 6 Hours

Field studies for geophysics majors, including seismic, magnetic, electrical, gravity, and other techniques; related data processing and interpretation.

GEO 363S Sedimentary Basin Analysis 3 Hours

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.

GEO 364P Physical Oceanography 3 Hours

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.

GEO 465K Seismic Exploration 4 Hours

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.

GEO 365N Seismic Data Processing 3 Hours

Reduction of seismic data from field records to final geologic images, using real data sets and open-source data analysis software.

GEO 365P Potential Field Applications in Geophysics 3 Hours

Introduction to the theory, measurement, and application of gravity and magnetic and electric fields to exploration and global-scale problems.

GEO 365Q Geomorphology Process and Form 3 Hours

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.

GEO 366M Mathematical Methods in Geophysics 3 Hours

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.

GEO 366P Planetary Geology and Geophysics 3 Hours

Introduction to planetary geology, with an emphasis on geophysical observations of terrestrial planets in our solar system. Discuss missions, instruments, techniques, and incorporation of mission data in projects.

GEO 367M Morphodynamics and Quantitative Stratigraphy 3 Hours

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.

GEO 468K Geophysics for Geological Sciences Majors 4 Hours

A survey of seismic, magnetic, gravitational, and other geophysical tools and their application to exploration and global-scale problems.

GEO 369E Evolution of Reef Ecosystems 3 Hours

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. Explore ocean chemistry, how organisms biomineralize a skeleton, symbiosis, ecology, mass extinctions, as well as current and future threats to reef health.

GEO 370E Ecohydrology and Biometeorology 3 Hours

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.

GEO 370K Sedimentology 3 Hours

Processes of sediment formation, transportation, and deposition; textures, structures, and facies of sedimentary rocks.

GEO 370Q Morphodynamics and Quantitative Stratigraphy 3 Hours

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.

GEO 171C, 271C, 371C Topics in Conference Course 1-3 Hours

Supervised study of selected topics in geological sciences, by individual arrangement with the department and instructor.

GEO 171H Honors Research Methods I 1 Hour

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.

GEO 371S Geological Sciences Research Methods 3 Hours

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.

GEO 171T, 271T, 371T, 471T, 571T, 671T Topics in Geological Sciences: Undergraduate Seminar 1-6 Hours

GEO 172H Honors Research Methods II 1 Hour

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.

GEO 372S Geochemical Problem Solving with Atoms and Ions 3 Hours

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.

GEO 173H Honors Research Methods III 1 Hour

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.

GEO 376C Isotope Geology 3 Hours

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.

GEO 376E Environmental Isotope Geochemistry 3 Hours

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.

GEO 476K Groundwater Hydrology 4 Hours

Introduction to subsurface hydrology, emphasizing geological controls on groundwater flow; quantitative methods of analyzing aquifer systems; regional hydrology; water quality and pollution.

GEO 376L Field Methods in Groundwater Hydrology 3 Hours

Train in and experience hydrology field methods as well as data handling and analysis. Learn methods including drilling and well installation, well logging, hydraulic testing, stream gauging, near-surface geophysics, water sampling and analysis, soil sampling and analysis, hydrologic monitoring and mapping of water tables and flow paths, hydrometeorological measurements, and general mapping and surveying. Train on sampling and safe operation of instrumentation.

GEO 476M Aqueous Geochemistry 4 Hours

Explore aqueous geochemistry. Examine basic thermodynamics, kinetics, mineral solubility, acid-base chemistry, the carbonate system, surface chemistry, silicate mineral weathering, redox chemistry, and aqueous complexes. Learn the computer program PHREEQC.

GEO 376S Physical Hydrology 3 Hours

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.

GEO 376T High-Temperature Geochemistry 3 Hours

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.

GEO 476W Hydrogeophysics 4 Hours

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.

GEO 377K Applied Karst Hydrogeology 3 Hours

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.

GEO 377P Physical Climatology 3 Hours

Explore climate science through the lens of physical principles and Earth system science. Examine the key components of the Earth system—the atmosphere, hydrosphere, lithosphere, cryosphere, and biosphere—their interactions, and their responses to both natural and human-induced forcing. Discuss radiation, energy balance, and atmospheric/oceanic general circulation; the hydrological cycle, with a focus on surface hydrology and land-atmosphere interactions; climate feedbacks, sensitivity, and variability across temporal scales (past, present, and future). Focus on human impacts on the climate system, including urbanization, irrigation, industrialization, air pollution, and tropical deforestation.

GEO 378D Introduction to Machine Learning and Geosciences 3 Hours

Explore an overview of commonly used machine learning algorithms for Geosciences applications.

GEO 679G Special Studies in Geophysics Research, Fieldwork, or Internship 6 Hours

Special research projects, field studies, or geophysical/industrial internship. Assigned reading with written and oral report.

GEO 379H Honors Thesis in Geological Sciences 3 Hours

Supervised research project resulting in an honors thesis with an oral defense.

GEO 679J Internship in Hydrogeology 6 Hours

Special hydrogeological studies under the joint supervision of industry professionals and faculty members. Students present a written report.

GEO 279K, 379K Special Topics in Advanced Geological Sciences 2-3 Hours

Special emphasis on recent developments in geosciences.

GEO 479M Mammalogy 4 Hours

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.

GEO 379N, 679N Geosciences Internship 3,6 Hours

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.

GEO 379S Geological Sciences Senior Thesis 3 Hours

Second course in a two-course sequence focused on supervised student research and preparation of a final report on research activities.

GEO 380C Advanced Structural Geology 3 Hours

Origin of earth structures, solution of advanced structural problems, newest techniques, field techniques, and field problems.

GEO 380F Seismology II 3 Hours

Basic seismology theory and its application to the study of the interior of the Earth (crust, mantle, and core), earthquakes, and plate tectonics.

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

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.

GEO 380J Mathematical Methods in Geophysics 3 Hours

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.

GEO 380N Sequence Stratigraphy 3 Hours

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.

GEO 380P Advanced Reservoir Characterization: Carbonates 3 Hours

Advanced instruction in the integration of geologic and engineering methods for building 3-D reservoir models of carbonate reservoirs.

GEO 380R Dynamics of Sedimentary Systems I 3 Hours

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.

GEO 380S Dynamics of Sedimentary Systems II 3 Hours

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.

GEO 380T Geoclimatology 3 Hours

Examines climate records encoded in sedimentary archives through geologic time.

GEO 381C Structural Petrology 3 Hours

Deformation processes from atomic to macroscopic level, resultant textures and fabrics, and conditions required to produce such deformation.

GEO 381E Brittle Structure 3 Hours

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.

GEO 381F Microstructures and Rock Rheology 3 Hours

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.

GEO 381G Geomicrobiology 3 Hours

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.

GEO 381J Marine Geology 3 Hours

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.

GEO 381P Plate Margins 3 Hours

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.

GEO 381R Regional Studies in Mineral Resources Geology 3 Hours

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.

GEO 381S Tectonic Problems 3 Hours

Explore the origin of regional structural features, complex and controversial structures, and the tectonic control of ore deposits.

GEO 381T Marine Tectonics 3 Hours

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.

GEO 382C Groundwater Field Methods 3 Hours

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.

GEO 382D Crustal Geofluids 3 Hours

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.

GEO 382E Scientific Research Design 3 Hours

Explore the principles of experimental design including formulation of target questions and method choice in an interdisciplinary, community context.

GEO 382F Fractured Rock Hydrology and Mechanics 3 Hours

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.

GEO 382G Fluid Physics for Geologists 3 Hours

Flow and transport phenomena within an earth science context. Includes extensive use of Maple, MATLAB, and COMSOL Multiphysics.

GEO 382M Programming in FORTRAN and MATLAB 3 Hours

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.

GEO 382P Physical Oceanography 3 Hours

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.

GEO 382S Physical Hydrology 3 Hours

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.

GEO 382T Continental Tectonics 3 Hours

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.

GEO 382W Hydrogeophysics 3 Hours

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.

GEO 383 Clastic Depositional Systems 3 Hours

Explore the processes and products of siliciclastic environments, including rivers, deltas, coastal systems, and deep-marine systems, with an emphasis on facies analysis, stratigraphic architecture, and sedimentary petrology. Develop the skills necessary to analyze sedimentary systems at multiple scales—from depositional environments to basin-wide correlations—emphasizing the integration of sedimentological, stratigraphical, and petrological data. Discuss the tectonic, climatic, and eustatic controls on facies transitions and provenance characterization.

GEO 383C Topics in Geology and Hydrology 3 Hours

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.

GEO 383D Numerical Methods I: Computational Methods in Geological Sciences 3 Hours

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.

GEO 383E Digital Methods in Hydrogeology 3 Hours

Applications of mathematical software to earth science problems, with emphasis on hydrogeologic problems. Includes a brief introduction to numerical methods.

GEO 383F Holocene-Pleistocene Sedimentology and Stratigraphic-Structural Evolution of the Caicos Platform 3 Hours

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.

GEO 383G Geochemistry of Sedimentary Rocks 3 Hours

The hydrologic cycle, the early diagenesis, carbonate sediments, chemical sediments, and burial processes.

GEO 383K Paleogeology 3 Hours

Relationships of fossil animals and plants to their environments and to the sedimentary deposits in which they occur.

GEO 383L Petrography of Sandstones 3 Hours

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.

GEO 383M Petrology of Carbonates and Evaporites 3 Hours

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.

GEO 383N Depositional Systems: Carbonates and Evaporites 3 Hours

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.

GEO 383P Potential Field Applications in Geophysics 3 Hours

Introduction to the theory, measurement, and application of gravity and magnetic and electric fields to exploration and global-scale problems.

GEO 383R Reservoir Geology and Advanced Recovery 3 Hours

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.

GEO 383S Sedimentary Basin Analysis 3 Hours

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.

GEO 383T Tectonic and Climatic Interactions in Foreland Basins 3 Hours

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.

GEO 383U Dynamic Field Stratigraphy 3 Hours

Field-based evaluation of the dynamics of the stratigraphic record, with implications for sedimentary, tectonic, and climatic processes.

GEO 384C Seismology I 3 Hours

Research seismic methods of exploration for petroleum and minerals and subsurface storage of fluids.

GEO 384D Physics of Earth 3 Hours

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.

GEO 384E Seismic Migration and Inversion 3 Hours

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.

GEO 384F Finite Element Methods in Geophysics 3 Hours

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.

GEO 384G Subsurface Mapping and Petroleum Workstations 3 Hours

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.

GEO 384H Multidimensional Data Analysis in Geosciences 3 Hours

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.

GEO 384M Inverse Theory 3 Hours

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.

GEO 384N Rock Physics 3 Hours

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.

GEO 384R Geophysical Time Series Analysis 3 Hours

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.

GEO 384S Seismic Data Processing 3 Hours

Reduction of seismic data from field records to final geologic images, using real data sets and open-source data analysis software.

GEO 384T Seismic Lithology 3 Hours

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.

GEO 384U Quantitative Seismic Interpretation 3 Hours

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.

GEO 384W Seismic Imaging 3 Hours

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.

GEO 185G Geophysics Colloquium 1 Hour

Exploration of a variety of problems in modern geophysics.

GEO 385Q Geomorphology Process and Form 3 Hours

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.

GEO 485S Introduction to Remote Sensing for Geoscientists 4 Hours

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.

GEO 385T Global Tectonics 3 Hours

Examine tectonic processes within the dynamic Earth, with a focus on plate boundary processes. Discuss fundamentals of plate tectonics; plate motion, driving forces, and mantle convection; evolution of plate margins including convergent, transform, rifting, and mid-ocean ridge spreading centers, triple junctions and collisional orogenesis; plate reconstructions; earthquakes and focal mechanisms; structure and geochemistry of the Earth's interior. Explore challenging questions of onset of plate tectonics, subduction initiation, and tectonics on other planets.

GEO 386 Metamorphic Petrology 3 Hours

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.

GEO 386D Earth in Deep Time 3 Hours

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.

GEO 386E Economic Geology 3 Hours

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.

GEO 386G Geographic Information System and Global Positioning System Applications in Earth Sciences 3 Hours

Examine the theory and application of Geographic Information System (GIS) and Global Positioning System (GPS) technologies in earth science. Implement data collection, mapping, and analysis through labs and practical exercises. Discuss map projections, cartographic principles, remote sensing, spatial analysis, and geospatial data resources in the context of earth science applications.

GEO 386K Igneous Petrology 3 Hours

Origin, differentiation, and crystallization of igneous rocks.

GEO 386R Geology of Earth Resources 3 Hours

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.

GEO 386S Ins and Outs of Subduction Zones 3 Hours

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.

GEO 386T Topics in Volcanology 3 Hours

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.

GEO 387C Aqueous Geochemistry 3 Hours

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.

GEO 387D Climate Dynamics 3 Hours

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.

GEO 387E Environmental Organic Geochemistry 3 Hours

Environmental and organic chemistry of organic contaminants in groundwater and soils.

GEO 387G Climate System Modeling 3 Hours

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.

GEO 387H Physical Climatology 3 Hours

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.

GEO 387P Climate System Physics 3 Hours

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.

GEO 388C Basin GeoMechanics 3 Hours

Develop the technical foundation and physical insight to explore how stress and pressure drive geologic and human-induced processes. Examine applications including CO₂ sequestration, geothermal energy, hydraulic-fracturing, faulting, geopressure development, hydrocarbon entrapment, subsidence and compaction, slope stability, and borehole stability.

GEO 388G Global Biogeochemical Cycles 3 Hours

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.

GEO 388H Environmental Isotope Geochemistry 3 Hours

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.

GEO 388L Isotope Geology 3 Hours

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.

GEO 388P Paleontological Laboratory Techniques 3 Hours

Overview and application of laboratory techniques used for in-depth investigation of the systematics of vertebrates.

GEO 388R Radiogenic Isotopes and Tectonic Processes 3 Hours

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.

GEO 388T High-Temperature Geochemistry 3 Hours

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.

GEO 389E Evolution of Reef Ecosystems 3 Hours

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.

GEO 389J Transitions in the History of Life 3 Hours

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.

GEO 389K Paleontologic Nomenclature and Techniques 3 Hours

Rules of nomenclature: preparation, illustration, and description of Paleozoic invertebrate fossils.

GEO 389M Vertebrate Paleontology: Mammals 3 Hours

Comparative osteology and phylogenetic history of the living and extinct mammals.

GEO 389P Digital Methods in Morphology 3 Hours

The use of digital multimedia for analysis of paleontological problems, with emphasis on three-dimensional high-resolution CT data.

GEO 389R Morphology of the Vertebrate Skeleton 3 Hours

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.

GEO 389S Systematics and Paleontology 3 Hours

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.

GEO 389V Vertebrate Paleontology 3 Hours

Comparative osteology and phylogenetic history of the living and extinct fishes, amphibians, and reptiles.

GEO 390D Seismology III 3 Hours

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.

GEO 390E Ecohydrology and Biometeorology 3 Hours

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.

GEO 390M Thermodynamics of Geologic Processes 3 Hours

Applications of physical chemistry to natural systems; interactions of minerals, solutions, and the atmosphere.

GEO 390Q Morphodynamics and Quantitative Stratigraphy 3 Hours
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.

GEO 390R Analytical Methods: Electron-Microbeam Techniques 3 Hours
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.

GEO 390T Tectonic Problems 3 Hours
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.

GEO 191, 291, 391, 491, 591, 791, 891, 991 Topics in Geological Sciences: Seminar 1,2,3,4,5,7,8,9 Hours

GEO 391C Physical Hydrogeology 3 Hours
Geological controls on groundwater resources; evaluation of aquifers, geothermal systems, and contamination problems; natural hazards caused by human use of groundwater.

GEO 391D Regional Tectonics 3 Hours
Development of tectonic theory culminating in the new global tectonics, and application of theory to selected orogenic areas.

GEO 391K Applied Karst Hydrogeology 3 Hours
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.

GEO 391Q Topics in Quaternary Geology 3 Hours
Interdisciplinary analysis of Quaternary chronology, environments, climatic changes, and erosional-depositional processes.

GEO 391S Current Topics in Paleobiology 3 Hours
Seminar reviewing recent publications on evolutionary and ecologic theories applied to the fossil record.

GEO 191W Aquifer Testing 1 Hour
Techniques of aquifer evaluation, including pumping tests, laboratory techniques, field mapping, and numerical analysis.

GEO 392F Fundamentals and Applications of ICP-MS 3 Hours
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.

GEO 392M Modern Geological Sciences 3 Hours
General discussion of the entire spectrum of geological sciences.

GEO 392P Python for Geoscience Research 3 Hours
Explore Python 3 programming language for application to scientific research. Examine basic Python and common scientific Python libraries such as numpy, pandas, matplotlib, datetime.

GEO 392S Geochemical Problem Solving with Ions Atoms 3 Hours
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.

GEO 193 Technical Lecture Series 1 Hour
Attendance required of all graduate students in geological sciences.

GEO 393D 3D Analysis of Volumetric Data 3 Hours
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.

GEO 194, 294, 394, 494, 594, 694, 794, 894, 994 Topics in Research in Geological Sciences 1-9 Hours

GEO 494P Modeling Flow and Transport in Porous Media 4 Hours
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.

GEO 395D Ice Dynamics 3 Hours
Physics of ice motion, basal processes, glacial hydrology, and unstable flow.

GEO 395S Seismic Structural Analysis 3 Hours
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 risk.

GEO 396C CO₂ Storage in Geological Formations 3 Hours
Explore how capturing and storing carbon dioxide (CO₂) underground is an important means of mitigating climate change. Examine the geological and environmental aspects of CO₂ injection, sequestration, and monitoring that control the success of real CO₂ storage projects.

GEO 396D Topics in Machine Learning Data Analytics 3 Hours

GEO 396D.1 Introduction to Machine Learning and Geosciences 3 Hours
Explore an overview of commonly used machine learning algorithms for Geosciences applications.

GEO 396D.2 Applications of Data Analysis, Visualization, and Machine Learning 3 Hours
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.

GEO 396D.3 Data Analytics and Geostatistics 3 Hours
Explore data analytics and geostatistics for geosciences applications.

GEO 396D.4 Subsurface Machine Learning 3 Hours
Explore problem formulation, feature engineering, and inferential and predictive machine learning algorithms for geosciences applications.

GEO 396D.5 Machine Learning Research 3 Hours
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.

GEO 397F Marine Geology and Geophysics Field Course 3 Hours
Hands-on, team-based instruction in the collection and processing of marine geological and geophysical data along the Gulf of Mexico coast.

GEO 397L Transitions in the History of Life 3 Hours
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.

GEO 397M Morphodynamics and Quantitative Stratigraphy 3 Hours
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.

GEO 397P Field Methods in Planetary Geology 3 Hours
Field studies combined with remote sensing to support studies of remote imagery from planetary missions.

GEO 297Q Preparing Future Faculty 2 Hours
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.

GEO 698 Thesis 6 Hours

GEO 398C Continuum Mechanics 3 Hours
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.

GEO 398G Geodynamics of the Lithosphere and Mantle 3 Hours
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.

GEO 398L Topics in Lithosphere and Deep Earth 3 Hours

GEO 398L.1 Tectonic Geodynamics 3 Hours
Examine dynamic processes that govern plate tectonics and lithospheric deformation, combining tectonics, structural geology, and geodynamics from the ground up.

GEO 398M Numerical Modeling in the Geosciences 3 Hours
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.

GEO 398P Planetary Geology and Geophysics 3 Hours
Introduction to planetary geology, with an emphasis on geophysical observations of terrestrial planets in our solar system. Discuss missions, instruments, techniques, and incorporation of mission data in projects.

GEO 398R Master's Report 3 Hours
Preparation of a report to fulfill the requirement for the master's degree under the report option.

GEO 398S Topics in Subsurface, Surface, and Life 3 Hours

GEO 298T, 398T Supervised Teaching in Geological Sciences 2-3 Hours
Open to graduate students engaged in laboratory instruction under close supervision of the course instructors.

GEO 398W Topics in Water, Climate, and Environment 3 Hours

GEO 398W.1 Vadose Zone Hydrology 3 Hours
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.

GEO 398W.2 Paleoclimate 3 Hours
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.

GEO 398W.3 Dynamics of Polar Systems 3 Hours
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.

GEO 398W.4 Statistical Data Analysis 3 Hours
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 399W, 699W, 999W Dissertation 3,6,9 Hours