Department of Geology

The Department of Geology

In Geology, you get to apply techniques and knowledge from chemistry, physics, biology, and math to answer important questions about Earth processes, history, and future. Geologists are in demand to evaluate geologic hazards, evaluate natural resources, and develop solutions to environmental challenges confronting our society.

Financial Aid

Undergraduate Scholarships

The department awards scholarships from its endowment to meritorious incoming or continuing students in geology. Scholarships also are awarded to students enrolled in Field Courses. For information, contact the chair.

KU Financial Aid

All undergraduates who wish to be considered for KU financial aid must complete applications with Financial Aid and Scholarships. (https://financialaid.ku.edu/)

Graduate Assistantships, Scholarships, and Fellowships

All prospective graduate students are considered for employment and financial aid. Employment may be in the form of teaching assistantships or research assistantships. Research assistantships may be supported with funds from external grants, KUEA funds, or appointments in other units on campus, such as the Kansas Geologic Survey or the Biodiversity Institute.

Graduate students are eligible for scholarships from the Geology Associates Program, as well as fellowship funds to support living expenses, field/laboratory research, and tuition and fees. Endowed scholarships include the Angino, Hall, Henbest, Holden, Ireland, McGee, Moore, Patterson, Peoples, and Walters scholarship funds. Other scholarships are awarded from donations from individuals and corporations. Scholarships are awarded on the basis of academic excellence; some funds are designated for protected minorities or women.

Through the Selig Fund and other donations, the department supports graduate student field work. Through the McCollum Fund and other donations, the department underwrites partially some other research expenses, such as purchase of time on analytical equipment. Funding requires an acceptable thesis or dissertation proposal. Students who have no other sources of research support are given preference. Degree-seeking students may apply for loans from the Fritz, Horner, and Johns loan funds.

Visit the Graduate Studies website for information about funding opportunities (http://graduate.ku.edu/ku-funding/) for graduate students at KU.

Financial Aid and Scholarships (https://financialaid.ku.edu/) administers grants, loans, and need-based financial aid.

Specialties

The Department of Geology strives in offering a variety of specialties to match student's professional goals and attributes. We have trained faculty in the following specialties: tectonics, geophysics, sedimentology, stratigraphy, carbonates, stable-isotopes, siliciclastic/sequence stratigraphy, geomicrobiology, hydrogeology, paleontology, and petroleum geology. Check out our faculty (http://geo.ku.edu/faculty/)today!

Careers

Career Opportunities

We train students for academic, government, and industry careers across the geosciences. On-campus interviews for industry internship opportunities occur annually.

Practice as a professional geologist often requires course work and training beyond the baccalaureate level.

Licensure

Formal study of geology at an accredited college or university is a principal requirement for becoming licensed to practice geology. During the senior year, students who plan to become licensed geologists should take the Fundamentals of Geology examination, offered twice a year. Information on registration is available from the department office or from the Kansas Board of Technical Professions. After passing the examination and after further practice, candidates can sit for the Practice of Geology examination to become licensed. Regulations for licensure may vary from state to state.

Undergraduate Programs

Geology is an interdisciplinary science that applies the principles of chemistry, physics, biology, and other fields to the study of the earth, its resources, and its natural processes. The field has many subdisciplines and specialties that offer stimulating challenges and careers. KU offers broad undergraduate programs in geology and geophysics but emphasizes research in paleontology, sedimentology, crustal evolution, hydrogeology, geobiology, seismology, applied geophysics, and geomorphology.

Courses for Nonmajors

The department offers several courses of interest to nonmajors who wish to learn more about geology and related areas such as environmental science, natural hazards, oceanography, and economic resources. Principal courses include GEOL 101, GEOL 105, GEOL 121, and GEOL 171. GEOL 103 may be taken in conjunction with either GEOL 101 or GEOL 105 to fulfill the CLAS laboratory science requirement. GEOL 172 may be taken in conjunction with GEOL 171 to fulfill the CLAS laboratory science requirement. GEOL 304, GEOL 360, GEOL 370, and GEOL 552 all offer opportunities to study more specialized aspects of the earth and do not require advanced prerequisites.

Summer Field Courses

All undergraduate degree programs require field courses during 2 summers. Students should plan to take GEOL 360 or GEOL 370 in the summer after completing the introductory course. GEOL 560 (capstone) and GEOL 561 (if required by the program) ideally are taken in the summer between the junior and senior years. Substantial scholarship support is available for geology majors who enroll in those courses.

Combined Degree Programs

A student may combine an interest in geology with a degree in business, education, or journalism.

Graduate Programs

The department offers the M.S. and Ph.D. in geology but permits specialization in a number of areas of geology and in geophysics and hydrogeology. Active areas of instruction and research include geophysics, geomorphology, geochemistry, microbial biogeochemistry, paleontology, sedimentology, tectonics, and petroleum geology. Students also may work with faculty supervisors at the Kansas Geological Survey and at Kansas State University.

Students who are interested in enrolling in graduate level coursework in the Department of Geology without formal admission to a graduate program at KU are encouraged to apply for graduate non-degree seeking student status. See the department's admission webpage (https://geo.ku.edu/graduate-admissions/) for further details

Courses

GEOL 100. Citizen of Planet Earth. 1 Credits.
As citizens of planet Earth, we interact with geology every day, from the minerals in our toothpaste to the metals in our phones to the gasoline in our cars. This class will help you understand the way geology underpins your everyday life, how geological features lead to positive and negative consequences for you and the world around you, and how to synthesize geological information to make decisions about your life, including where to live and what to buy. This class requires no prior geological or scientific knowledge.

GEOL 101. The Way The Earth Works. 3 Credits. GE3N SWT NLEC

Introduction to the principles of earth science. Study of the formation, occurrence, and structure of minerals and rocks; action of streams, oceans, glaciers, and other agents in the formation and modification of the landscape; volcanism, earthquakes, and plate tectonics. Discussion of earth processes in the context of sustainable energy, environmental concerns, climate and other topical issues. This course with GEOL 103 or GEOL 100 satisfies the College laboratory science requirement. Concurrent enrollment in GEOL 103 or GEOL 100 is recommended for students taking both. Geology majors should enroll in GEOL 103. Course may be offered in lecture or online format.

GEOL 103. Geology Fundamentals Laboratory. 2 Credits. LFE SWT NLAB
A course in geologic laboratory studies. This course plus GEOL 101, GEOL 105, GEOL 106, or GEOL 121 satisfies the College laboratory science requirement. Gives students practical, hands-on experience with identifying earth materials (rocks, minerals, fossils), understanding their relationships to earth processes, understanding topographic and geologic maps, interpreting results of surficial processes, and learning about deep-earth processes such as earthquakes. Includes short field trips to see geologic structures and results of local geologic processes. This lab course may be offered in on-campus lab or online format. Prerequisite: Previous or concurrent enrollment in GEOL 101, GEOL 105, GEOL 106 or GEOL 121.

GEOL 105. History of the Earth. 3 Credits. GE3N NLEC
An introduction to the physical and biological history of the earth, the methods used to decipher earth history, and the development of the geological sciences. Concurrent enrollment in GEOL 103 or GEOL 100 is recommended for students taking both. Not open to students who have taken GEOL 304.

GEOL 108. Troubled Waters: Water Resource Issues and Principles. 3 Credits.
Worldwide, water security is necessary for life, and food, industry, and energy production, and is increasingly the source of conflict. This course explores water in the environment and the fundamental interactions between humans and water. Key topics and issues addressed include fundamentals of water and the water cycle; water in geologic processes; water availability, development and sustainability; climate effects including flooding and drought; economics; pollution, disease, sanitation, and health; culture, policy and law, and other challenging issues. Case studies explore examples from Kansas and around the world.

GEOL 115. Gemstones. 3 Credits. GE3N NLEC
The properties, occurrence, description, determination, mineral affinities, and legend and lore of gems, ornamental stones, and gem materials. Concurrent enrollment in GEOL 100 or GEOL 103 is recommended for students taking both.

GEOL 121. Life Through Time: DNA to Dinosaurs. 3 Credits. LFE GE3N NLEC
This course leads students on a journey through time to explore the interconnection between life and the geology of Earth, including our own complex relationship with the world around us. Concurrent enrollment in GEOL 100, GEOL 103 or GEOL 122 is recommended for students taking both.

GEOL 122. Life Through Time: DNA to Dinosaurs Laboratory. 1 Credits. LFE NLAB
This online companion to GEOL 121 allows students a hands-on exploration of the principles and practices of paleontology research. Students will be guided through an individual term-length research project--from shaping a research question to collecting and analyzing data to drawing conclusions to presenting in front of an audience. This lab will not only allow students to explore the fossil record but it will bring them into the scientific conversation. Prerequisite: Corequisite: Students must be concurrently enrolled in GEOL 121.

GEOL 142. Oceanography. 4 Credits. GE3N NPS
An introduction to the origin, nature, and dynamics of the world's oceans, including aspects of geology, chemistry, biology, physics, and meteorology that are involved in ocean processes. The relations between the oceans and humans in the past, present, and future, and instruction in scientific reasoning as it applies to oceanography. Laboratory exercises in critical thinking about oceanography. This course cannot be taken if a student has completed GEOL 301.

GEOL 151. Environmental Geology. 3 Credits. GE3N NLEC
An introductory course dealing with the implications of geologic processes and materials for civilization. Topics to be considered include: geologic hazards such as floods, landslides, earthquakes, and volcanism; the availability of water, mineral, and energy resources; and the environmental impact of resource utilization. The importance of recognizing geologic constraints in land use planning and engineering projects is emphasized and illustrated by examples. Concurrent enrollment in GEOL103 or GEOL 100 is recommended for students taking both.

GEOL 171. Earthquakes and Natural Disasters. 3 Credits. GE3N NLEC
Addresses the subject of natural disasters with concentration on earthquake effects and their mitigation. Briefly treats volcanic eruptions, tidal waves, floods, global warming, severe weather, and catastrophic meteorite impacts from the perspective of geological and human significance. Provides a basic background into earth-science processes. Concurrent enrollment in GEOL 100,GEOL 103, or GEOL 172 is recommended for students taking both.

GEOL 172. Earthquakes and Natural Disasters Laboratory. 1 Credits. NLAB
This online companion to GEOL 171 allows students a hands-on exploration of the principles and practices of geologic and geophysical research. Students will be guided through an individual term-length research project--from shaping a research question to collecting and analyzing data to drawing conclusions to presenting in front of an audience. This lab will not only allow students to explore details of natural disasters, but it will bring them into the scientific conversation. Prerequisite: Corequisite: GEOL 171.

GEOL 190. Introduction to Quantitative Geoscience. 3 Credits. GE12
This applied, introductory-level program will explore topics in geology, hydrogeology, physics, chemistry, and biology from a mathematical perspective. The course is designed for students with a desire to expand their mathematical skills, building on practical applications in the natural sciences. The study of lab and field sciences and mathematical problem-solving through rigorous, quantitative, and interdisciplinary investigations will be emphasized. The course will take students from a review of arithmetic and algebraic manipulations, to the use of logarithms, and functions, through series, trigonometry and graphing, and finish with an introduction to the elements of calculus and statistics. The course will utilize Excel as platform for calculating and graphing numerical examples of the problems presented. We expect students in this course to emerge with confidence in the basic use of mathematics commonly applied to investigate and model the natural world. Prerequisite: MATH 002, or two years of high school algebra and a score of 22 or higher on ACT mathematics, or a qualifying score on the mathematics placement test.

GEOL 301. Introduction to Oceanography. 3 Credits. GE3N
The online course is an introduction to the earth and its oceans, including a discussion of the history of ocean exploration using the approach of the scientific method. The course will explore theories that describe the origin of the solar system, the earth, the atmosphere, and the oceans, in addition to a discussion of the origin of life on the earth. The course will cover the essential physics, chemistry, geology, biology, and the concepts of plate tectonics, as applied to understanding the oceans and seas. This course cannot be taken if a student has completed GEOL 302.

GEOL 304. Historical Geology. 3 Credits.
An introduction to the physical and biological history of the Earth, the methods used to decipher earth history, and the development of the geological sciences. Concepts of lithostratigraphy, chemostratigraphy and biostratigraphy, and methods of analysis of stratigraphic data focus on the interpretation of Earth history. Prerequisite: GEOL 101 and GEOL 103.

GEOL 311. Mineralogy and Structure of the Earth. 3 Credits. LFE
Basic identification and properties of rocks and minerals in the context of whole-earth structure and evolution. Includes basic chemical equilibria for rock and mineral systems and their bearing on processes involved with formation and evolution of Earth's crust, mantle, and core. Two lectures and one lab per week. Prerequisite: GEOL 101, CHEM 130, and eligibility for MATH 125 or MATH 115.

GEOL 312. Mineral Structures and Equilibria Laboratory. 1 Credits. LFE
A laboratory to accompany GEOL 311. Presents more rigorous analysis of the structures, compositions, and chemical equilibria governing the formation and stability of common rock-forming mineral systems. Prerequisite: GEOL 311 (may be taken concurrently), CHEM 130, and eligibility for MATH 125 or MATH 115.

GEOL 316. Geochemistry. 3 Credits.
The course is intended to be an introduction to all types of geochemistry. It focuses on the chemistry of the natural world and the chemical evolution of the Earth over geological time. The course is composed of three modules: (a) geochemical fundamentals; (b) natural and anthropogenically perturbed aspects of the Earth's hydrosphere and its interaction with surficial rocks, sediments, soils, the biosphere and the atmosphere and (c) the origin and evolution of Earth (crust-mantle-core) and the solar system through nuclear and high temperature chemical processes. Prerequisite: GEOL 101, CHEM 130 or 190; and eligibility for MATH 115.

GEOL 331. Sedimentology and Stratigraphy. 4 Credits. LFE
Basic principles used in the study of sedimentology and stratigraphy. Physical, chemical, and biological processes in sedimentary environments applied to the recognition of the depositional environment, preservation, and alteration of sedimentary rocks. Field and laboratory study of sedimentary rocks with emphasis on interpretation of original depositional environments and preservation in the stratigraphic record. Prerequisite: GEOL 101 and GEOL 103; and GEOL 304 or taken concurrently.

GEOL 332. Sedimentology for Petroleum Engineers. 4 Credits.
This course is designed for Petroleum Engineering majors. It covers basic principles used in the study of sedimentary environments. Topics include classification of sedimentary rocks, diagenesis and the alteration of sedimentary rocks. Surface processes and recognition of depositional environments in the rock record is emphasized. Basic concepts of stratigraphy are introduced. Emphasis is placed on practical examples relating to petroleum reservoirs. Lecture, lab and field trips. Prerequisite: GEOL 101 and GEOL 103 and Petroleum Engineering Major.

GEOL 360. Field Investigation. 2 Credits.
Summer session. A field-geology course that provides beginning geology students with an initial understanding of the nature of geological evidence in the field, the breadth of geological phenomena, and the importance of the interplay of information from many geological disciplines in solving problems. Given at various geologically diverse locations. Fee. Prerequisite: GEOL 101.

GEOL 370. Study Abroad in Greece: Natural Environment and Civilizations. 3 Credits. AE42 GLBC
This course examines the profound influence of the natural environment on the development of civilizations and the course of history. Geologic processes responsible for natural resources, water, landscapes, natural hazards and climate are presented in the context of their impact on ancient Greek society. The class visits sites of geologic and historic interest such as Athens, Delphi, Mycenae and the Aegean Sea islands including Santorini volcano. Examples from other eras and regions of the world are discussed along with present-day analogues. Prerequisite: An introductory geology course or permission of the instructor.

GEOL 391. Special Studies in Geology. 1-6 Credits.
Special reports upon subjects in which students have a particular interest. Prerequisite: Fifteen hours of geology.

GEOL 399. Senior Honors Research. 2-5 Credits. AE61 CAP
Normally two to five hours in any one semester with a maximum of eight hours. An undergraduate research course, in any of the fields of geology, open by permission of the department to seniors in the College who have an average grade of B or higher in geology courses. Prerequisite: Thirty hours of geology, five of which may be taken concurrently with this course.

GEOL 501. Simple Error Analysis for Earth Scientists. 3 Credits.
This course covers basic error analysis as it applies to geology. The course will emphasize the description and propagation of errors in data collection and reduction. Subjects include: how to report data and associated errors, error propagation in simple and complex equations, the Normal, Gaussian, and Poisson distributions, linear and higher order

regression, and X-squared test. The course includes the use of MATLAB with accompanying assignments. Prerequisite: GEOL 101.

GEOL 502. Linear Algebra for Earth Scientists. 3 Credits.
This course covers basic linear algebra as it applies to geology and emphasizes the description and use of linear algebra to solve geologic problems. Subjects include: how to solve systems of equations, determinants, inversion, vector spaces, matrix manipulation, eigenvectors and values, least squares solutions, and orthogonality. The course includes the use of MATLAB with accompanying assignments. Prerequisite: GEOL 101.

GEOL 503. Numerical Methods in the Earth Sciences. 2-3 Credits.

The class will provide an introduction to writing and testing code in the numerical computing environment MATLAB, using examples from Earth Science disciplines to introduce basic concepts and develop progressively more complex code. Prerequisite: MATH 125 and prior completion or co-enrollment in GEOL 502.

GEOL 504. Inverse Problems for Geoscientists. 3 Credits.
This course will cover a variety of mathematical methods for fitting models of underlying physical processes to data. This course is aimed specifically at geoscientists, with examples taken from geophysical problems such as seismic tomography. The specific topics to be covered will vary a bit based on the interests of those in the class. We are sure to cover Linear Regression and Least Squares, Tikhonov Regularization, and bounded constraints. Other topics include Kalman Filters for time-dependent inversion of time series data, Markov-Chain Monte Carlo Methods from non-linear problems, and other non-linear optimization methods. Problem sets will be assigned in MATLAB, previous MATLAB experience highly recommended. Prerequisite: GEOL 501 OR MATH 526; GEOL 502 OR MATH 290 or MATH 291; MATH 220 or MATH 320 equivalent; GEOL 503 or equivalent MATLAB experience.

GEOL 511. Raman Spectroscopy of Crystalline Solids. 3 Credits.
This course introduces students to Raman scattering in crystalline solids. This class with cover light and polarization of light, phonons and magnons, Raman scattering, Raman Tensor, wave vectors and k space, reciprocal space and Brillouin zones (and zone edge), group theory and character tables, polarized Raman scattering (symmetry of zone center phonons), Frohlick intraband electro-optical coupling and other multi-phonon Resonance Raman mechanisms in crystalline solids, and phonon confinement in nanomaterials. Prerequisite: GEOL 311 or PHSX 212.

GEOL 512. Igneous and Metamorphic Petrology. 3 Credits.
The study of minerals, rocks and fluids within the earth's crust and mantle to elucidate their mechanisms of formation and the pressure-temperature-composition conditions within the earth. The course emphasizes equilibrium thermodynamics, phase equilibria, fractionation mechanisms, tectonic control of petrogenesis, and quantitative analysis of mineral parageneses. Prerequisite: GEOL 311 and first semester calculus, or permission of instructor.

GEOL 513. Petrology Laboratory. 1 Credits. LFE
A laboratory course to accompany GEOL 512. Material covered will include the use of the polarizing microscope in study of rocks in thin sections; identification of rock-forming minerals in thin section; study of textures as guides to the crystallization process; calculations of chemical changes during fractional crystallization and partial melting. Students will also make extensive study of igneous and metamorphic rocks in hand specimens, accompanied by thin section study, with emphasis on composition, texture, and structure. Prerequisite: GEOL 312. Corequisite: GEOL 512.

GEOL 521. Paleontology. 3 Credits.
A study of the structure and evolution of ancient life; the nature and diversity of life through time; the interactions of ancient organisms with their environments and the information that the study of fossils provides about ancient environments; the use of fossils to determine the ages of rocks and the timing of past events in earth history; and the patterns of extinction through time. (Same as BIOL 622.) Prerequisite: BIOL 100, BIOL 101, BIOL 152, BIOL 153, GEOL 105, or GEOL 304.

GEOL 523. Paleontology Laboratory. 1 Credits. LFE
Laboratory course in the study of fossils with emphasis on the practice of paleontology and the morphology of ancient organisms. (Same as BIOL 623.)

GEOL 524. Mammalian Paleontology. 3 Credits.
Evolution of mammals, and anatomical modifications involved in the process as ascertained from the fossil record. Lectures and laboratory. (Same as BIOL 524.) Prerequisite: One of the following: BIOL 225, BIOL 412, BIOL 413, GEOL 304, GEOL 521, or consent of the instructor.

GEOL 533. Shales and Other Mudstones. 3 Credits.
This course defines mudstones and shales. Deposition and constituents of fine-grained sediment; geochemistry, diagenesis and lithification of such deposits. Organic constituents of mudstone and their function as sources of crude oil and natural gas. Petrophysics and mechanical properties of mudstones and their potential as reservoirs of hydrocarbons. Not open to students with credit in GEOL 733. Prerequisite: GEOL 331.

GEOL 535. Petroleum and Subsurface Geology. 4 Credits. LFE
A general study of the occurrence, properties, origin, and migration of petroleum. Studies of various oil fields and oil-bearing basins. Laboratory studies include well logs, subsurface mapping, and cross-sections. Prerequisite: GEOL 331 or GEOL 332, and either GEOL 562 or C&PE 327, or permission of instructor.

GEOL 536. Geological Log Analysis. 1 Credits.
Application of well logging measurements to interpretation subsurface. Not open to students who have completed or are taking C&PE 528. Prerequisite: GEOL 101.

GEOL 538. Basin Analysis. 3 Credits.
Overview of sedimentary basins, mechanisms of basin formation, and basin evolution through time. Topics include lithospheric stretching and flexure to form sedimentary basins, geohistory analysis and backstripping, and thermal history and controls on basin fill. This course consists of lectures, exercises, and a field trip. This course is available at both the 500 and 700 level with additional assignments required at the 700 level. Not open to students with credit in GEOL 738. Prerequisite: GEOL 331 and GEOL 562.

GEOL 539. Sequence Stratigraphy. 3 Credits.
Principles and practical applications of sequence stratigraphy, the process of studying and correlating depositionally linked stratal successions in a chronostratigraphic framework. The concepts of depositional sequences, parasequences, bounding surfaces, systems tracts and incised valleys are studied through class exercises and a regional field trip. Seismic stratigraphic techniques and concepts are covered in the latter part of the course. This course is available at both the 500 and 700 level with additional assignments required at the 700 level. Not open to students with credit in GEOL 739. Prerequisite: GEOL 331 or GEOL 332.

GEOL 541. Geomorphology. 4 Credits. LFE
A critical study of land forms in relation to tectonics, climatic environment, and geologic processes. The use of geomorphic methods in the interpretation of Cenozoic history is emphasized. Laboratory exercises in analysis of field observations, maps, and photographs. Required field trip

and fee. (Same as GEOG 541.) Prerequisite: GEOL 101 and GEOL 103, GEOG 104 and GEOG 105, or GEOL 103 and GEOL 304.

GEOL 542. Energy and Society. 3 Credits. AE51
In this course, you will gain the necessary understanding of energy technologies and policies to evaluate options for energy usage and its socioeconomic and environmental impacts. You will analyze different opportunities and impacts of energy systems that exist within and between groups defined by national, regional, household, ethnic, and gender distinctions. Analysis of the range of current and future energy choices will be stressed, as well as the role of energy in determining local environmental conditions and global climate. Prerequisite: A course in Biology, Chemistry, Physics, or Geology.

GEOL 543. Environmental Ethics: A View from the National Parks. 3 Credits. AE51
To what extent are our National Parks protected from pollution, invasive species, mining, climate change and tourism? In this course you will learn about the geologic processes that form our National Parks as well as the competing interests that stakeholders have on the land. Prerequisite: A course in Biology, Chemistry, Physics, or Geology.

GEOL 548. Geology and Culture of Polynesia. 3 Credits. AE42
Polynesia, encompassing over 1,000 islands in the southern and central Pacific Ocean, was the last region of the Earth to be settled by humans. Around 3000-1000 BCE, people from northwest Melanesia first reached one of these islands, and over the next few centuries spread to colonize all of the islands. However, despite the fact that all of the Polynesian islands were settled by colonists who stemmed from a single population with a shared culture, language, technology, and agriculture, the cultures of these islands are incredibly rich and varied. In this course we will examine some of the cultural mores and practices of the Polynesian islands, including how these were shaped by the climate, geology, soil, hydrology, and marine resources of each individual island. In this course we will examine these factors and assess their potential impact on the cultures present in the region. Prerequisite: A course in Biology, Chemistry, Physics, or Geology.

GEOL 552. Introduction to Hydrogeology. 3 Credits.
Physical description of hydrogeologic media. Elementary groundwater hydraulics: analytical and graphical solutions for steady-state application. Well hydraulics and pumping tests. Basic groundwater geology. Effects of topography and geology on regional flow systems. Field and numerical delineation and analysis of groundwater flow systems and applications. Chemical characteristics of groundwaters and their relationship to aquifer geology and hydrology. Investigations of groundwater quality and contamination. Prerequisite: Two semesters each of calculus, physics, and chemistry.

GEOL 554. Contaminants in Groundwater. 3 Credits.
This course introduces the basics of groundwater flow, water quality, and contaminant transport from a qualitative perspective. The course also surveys common groundwater pollutants, such as heavy metals, organic compounds, radionuclides, salts, non-aqueous phase liquids, risk analysis, and forensic hydrogeology. Students are expected to work together to complete weekly reading assignments. A course field trip forms the basis for a term report that is expected to incorporate concepts and tools covered during the lectures and readings. This course requires no calculations, but mathematical and chemical terms are presented. Prerequisite: One semester of general chemistry, and at least one 100 level course or higher in Geology or physical geography (GEOG 104 or GEOG 105), or permission of the instructor.

GEOL 555. Climate Science. 3 Credits.
This course explores the science of climate change. Students will learn how the climate system works; what factors cause climate to change across different time scales and how those factors interact; how scientists use models, observations and theory to make predictions about future climate; and the possible consequences of climate change for our planet. Students will learn how climate change today is different from past climate cycles and how satellites and other technologies are revealing the global signals of a changing climate. Finally, the course looks at the connection between human activity and the current warming trend and considers some of the potential social, economic and environmental consequences of climate change. Prerequisite: A course in Biology, Chemistry, Physics, Environmental Studies, Geography, or Geology.

GEOL 556. Field Methods in Hydrology. 3 Credits.
The course offers an overview on basic field methods for characterization of hydrologic systems. Topics to be covered include physical and chemical characterization techniques, such as: how to measure water levels; perform single well and aquifer tests; unsaturated zone parameterization; inorganic, organic, isotopic, and dissolved gas characterization; groundwater-surface water characterization techniques, and geophysical techniques for hydrogeology. Additionally, the class will visit a variety of sites of hydrogeologic interest. Prerequisite: GEOL 552 or permission from instructor.

GEOL 557. Environmental Site Operations, Management, and Safety: HAZWOPER Health and Safety Standards. 3 Credits.
On-site investigation of contaminated soil and water requires training in site operations and responses to emergencies involving releases of hazardous substances for scientists, workers, and employers. This course will introduce contaminant toxicology, hazard identification, site operations and management, and provide an overview of related regulations. Monitoring equipment, drum and container sampling, decontamination, and confined space designations will be taught. General safety hazards, personal protective equipment and levels of protection, drill rig safety, hazard communication and medical surveillance, and development of health & safety plans, will also be addressed. The course satisfies the Occupational Safety and Health Administration (OSHA) Hazardous Waste Operations and Emergency Response (HAZWOPER) 40-Hour requirment, following General Industry (29 CFR 1910.120) and Construction Industry (29 CFR 1926.65) regulations. A required "hands on" training exercise is conducted at Edwards campus on the first Saturday in March. Prerequisite: CHEM 130 and GEOL 101, GEOG 104, BIOL 100 or an introductory engineering course.

GEOL 558. Applied Groundwater Modeling. 3 Credits.
This course focuses on how to construct simple to complex computer models of groundwater systems and systems in which water flows between groundwater and surface water bodies such as springs, streams and lakes. We consider water flow, transport of solutes, density effects (from saltwater or brines), and the use of groundwater and surface water (demand-driven, supply-limited problems), and managed aquifer recharge (MAR). We consider three aspects of model development: (1) how to compare the computer models we construct to the systems modelers intend them to represent, (2) how accurate the models are likely to be and how uncertainty can be quantified, and (3) how useful the models are in practice. Prerequisite: GEOL 101 or permission from instructor.

GEOL 560. Introductory Field Geology. 3 Credits. AE61 CAP
Summer session. The study of the principles of field geology and the application of field methods to solve geological problems. Includes use of topographic maps and aerial photographs for geological mapping, the study of stratigraphic methods by measuring sections, and working field trips to areas of regional geological interest. Given at the University of Kansas Geology Field Camp near Canon City, Colorado. Fee. Prerequisite: GEOL 331, GEOL 360, and GEOL 562, or consent of instructor.

GEOL 561. Field Geology. 3 Credits.
Summer session. The application of the principles of field geology to solve complex geological problems in the field. Given at the University of Kansas Geology Field Camp near Canon City, Colorado, or at other sites as appropriate. Fee. Prerequisite: GEOL 560.

GEOL 562. Structural Geology. 4 Credits. LFE
A study of primary and secondary rock-structures and their genesis. Includes techniques of structural analysis and introduces mechanics of rock deformations. Lectures, laboratory, and required field trip. Prerequisite: GEOL 311; PHSX 114, or PHSX 211 and PHSX 216; and MATH 115 or MATH 126.

GEOL 563. Tectonics and Regional Geology. 3 Credits.
Topics vary with demand and include fundamental features of plate tectonics, interpretation and distribution of regional geology of mountain belts with emphasis on tectonic setting and processes, regional geology, and tectonics of selected mountain belts. Prerequisite: GEOL 562, GEOL 512, or GEOL 331, and GEOL 572.

GEOL 572. Geophysics. 3 Credits.
Introductory study of gravitational, magnetic, seismic, electrical, and thermal properties of the earth. Measurements, interpretation, and applications to exploration, earth structure, and global tectonics. Prerequisite: An introductory course in geology; MATH 116 or MATH 126; and PHSX 115 or PHSX 212 and PHSX 236. PHSX 115 or PHSX 212 may be taken concurrently.

GEOL 578. Seismic Data Analysis and Interpretation. 3 Credits.
Interpretation methods applied to seismic exploration and reservoir characterization. Topics include: rock physics, the convolutional model, synthetic seismograms, seismic response of hydrocarbon reservoirs, resolution, seismic velocity, depth conversion, seismic attributes, AVO, inversion, seismic anisotropy, 3-D & 4-D interpretation, S-wave and converted wave interpretation, laboratory use of commercial seismic interpretation software. Prerequisite: GEOL 572 or consent of the instructor.

GEOL 591. Topics in Geology: _____. 1-5 Credits.
May include lectures, discussions, readings, laboratory, and field work in geology. Will be given as needed. May be taken more than once.

GEOL 599. Preparation for Professional Geologist Licensure Exams. 1 Credits.
This one-credit hour course is intended for students seeking professional geology licensure. The course reviews fundamental geologic concepts that are emphasized on the Association of State Boards of Geology (ASBOG) Fundamentals of Geology (FG) exam, but also may be used to prepare for the ASBOG Practice of Geology (PG) exam, or exams required to gain licensure in non-ASBOG states. Prerequisite: 30 hours of coursework in geology or consent of instructor.

GEOL 701. Graduate Students Professional Skills & Ethics. 2 Credits.
Graduate students develop a set of skills that promote their success in subsequent professional endeavors during their time in degree. Acquiring these skills early in their graduate training can facilitate progress through their degree as well as enrich preparation for their professional activities. The course will cover best teaching practices in the classroom and field, scientific ethics, diversity and inclusion in the workplace, and work-life balance as well as an introduction to basic KU Geology administrative structure. In the second half of the semester, students will develop, peer review, and complete a draft of the student's research proposal.

GEOL 715. Geochemistry. 3 Credits.
Application of chemical equilibria and kinetics to geological environments and processes, with emphasis on processes involving solution equilibria. Includes introduction to thermodynamic aspects of equilibria.

GEOL 717. Geochronology. 3 Credits.
Principles and applications of natural radioactive systems for geochronology and cosmochronology, including use of radiogenic isotopes as geochemical tracers. Prerequisite: GEOL 512 or consent of instructor.

GEOL 718. Stable Isotope Geochemistry. 1-3 Credits.
Principles and applications of equilibria among stable isotopes in the geological environment, with emphasis on the isotopic systems of hydrogen, carbon, and oxygen. Prerequisite: GEOL 715 or consent of instructor.

GEOL 723. Museum Internship. 1-6 Credits.
Provides directed, practical experience in research, collection, care, and management, public education, and exhibits with emphasis to suit the particular requirements of each student. Graded on a satisfactory/unsatisfactory basis. (Same as AMS 799, ANTH 799, and MUSE 799.)

GEOL 728. Paleopedology. 3 Credits.
Paleopedology is the study of ancient soils preserved in the geologic record. The course covers concepts of paleopedology and its applications to the interpretation of paleoenvironmental, paleoecologic, and paleohydrogeologic settings and its use in sequence stratigraphy and paleoclimatology. Prerequisite: GEOL 331; or consent of the instructor.

GEOL 729. Ichnology. 3 Credits.
Ichnology is the study of organism-substrate interactions. The class will cover concepts and applications of ichnology in the marine and continental realms, including the behavior of such organisms as microbes, plants, invertebrates, and vertebrates preserved in the geologic record as trace fossils. Ichnology is applied in geology and in the petroleum industry to interpret ancient environments, hydrogeology, ecology, and climate. Prerequisite: GEOL 331 or GEOL 521; or consent of the instructor.

GEOL 731. Terrigenous Depositional Systems. 4 Credits.
Processes that operate in recent sedimentary environments, responses of sediment to those processes, and criteria for determining depositional environments of ancient sedimentary rocks. Lectures, practical exercises, and field trips. Prerequisite: GEOL 331.

GEOL 732. Carbonate Depositional Systems. 3 Credits.
Patterns and processes of contemporaneous carbonate deposition and diagenesis, depositional models; applications to interpretation of carbonate rocks. Lecture, discussion, laboratory and field trips.

GEOL 733. Shales and Other Mudstones. 3 Credits.
This course defines mudstones and shales. Deposition and constituents of fine-grained sediment; geochemistry, diagenesis and lithification such of deposits. Organic constituents of mudstone and their function as sources of crude oil and natural gas. Petrophysics and mechanical properties of mudstones and their potential as reservoirs of hydrocarbons. Not open to students with credit in GEOL 533. Prerequisite: GEOL 331.

GEOL 738. Basin Analysis. 3 Credits.
Overview of sedimentary basins, mechanisms of basin formation, and basin evolution through time. Topics include lithospheric stretching and flexure to form sedimentary basins, geohistory analysis and backstripping, and thermal history and controls on basin fill. This course consists of lectures, exercises, and a field trip. This course is available at both the 500 and 700 level with additional assignments required at the 700 level. Not open to students with credit in GEOL 538. Prerequisite: GEOL 331 and GEOL 562.

GEOL 739. Sequence Stratigraphy. 3 Credits.

Principles and practical applications of sequence stratigraphy, the process of studying and correlating depositionally linked stratal successions in a chronostratigraphic framework. The concepts of depositional sequences, parasequences, bounding surfaces, systems tracts and incised valleys are studied through class exercises and a regional field trip. Seismic stratigraphic techniques and concepts are covered in the latter part of the course. This course is available at both the 500 and 700 level with additional assignments required at the 700 level. Not open to students with credit in GEOL 539. Prerequisite: GEOL 331 or GEOL 332.

GEOL 751. Physical Hydrogeology. 3 Credits.
Study of fluid flow in subsurface hydrologic systems. Investigation of the ground water environment including porosity, and hydraulic conductivity and their relationship to typical geologic materials. Examination of Darcy's law and the continuity equation leading to the general flow equations. Discussion of typical hydraulic testing methods to estimate aquifer parameters in various situations and apply these to water resource problems. Study of the basic mechanisms that determine the behavior of typical regional flow systems. (Same as CE 752.)

GEOL 753. Chemical and Microbial Hydrogeology. 3 Credits.
Lecture and discussion of chemical and microbiological controls on groundwater chemistry. Topics include thermodynamic and microbiological controls on water-rock reactions; kinetics; and microbiological, chemical and isotopic tools for interpreting water chemistry with respect to chemical weathering and shallow diagenesis. Origins of water chemistry, changes along groundwater flow paths, and an introduction to contaminant biogeochemistry will be discussed through the processes of speciation, solubility, sorption, ion exchange, oxidation-reduction, elemental and isotopic partitioning, microbial metabolic processes and microbial ecology. An overview of the basics of environmental microbiology, including cell structure and function, microbial metabolism and respiration, microbial genetics and kinetics of microbial growth will be covered. (Same as CE 753.) Prerequisite: One year of chemistry, one year of calculus, one year of biology, an introductory course in hydrogeology, or consent of the instructors.

GEOL 754. Contaminant Transport. 3 Credits.
A study of the transport of conservative and non-conservative pollutants in subsurface waters. Case studies are used to illustrate and develop a conceptual understanding of such processes as diffusion, advection, dispersion, retardation, chemical reactions, and biodegradation. Computer models are developed and used to quantify these processes. (Same as CE 754.) Prerequisite: Introductory Hydrogeology or consent of instructor.

GEOL 755. Site Assessment. 3 Credits.
Site Assessment encompasses both the academic and applied aspects of environmental geology. The student is presented with the historical, regulatory and risk characteristics of environmental issues as well as specific geologic principles such as GIS and remote sensing, geophysics, geomorphology and surface and groundwater practices. Site assessment concepts include surface and subsurface sampling, analyses and interpretations, conceptual site models, environmental geologic forensics, and environmental Phase I site assessments (USEPA and ASTM). Environmental geology project management principles and practices are examined in detail. These core aspects of the course form the basic structure in understanding and applying environmental remediation and state-of-the-art/state-of-the-practice processes. Case studies are researched and analyzed for the assessment phase of the program.

GEOL 758. Applied Groundwater Modeling. 3 Credits.
This course focuses on how to construct simple to complex computer models of groundwater systems and systems in which water flows between groundwater and surface water bodies such as springs, streams and lakes. We consider water flow, transport of solutes, and density effects (from saltwater or brines). We consider the conjunctive use of groundwater and surface water (demand-driven, supply-limited problems), and managed aquifer recharge (MAR). We consider three aspects of model development: (1) how to compare the computer models we construct to the systems modelers intend them to represent, (2) how accurate the models are likely to be and how uncertainty can be quantified, and (3) how useful the models are in practice. (Same as CE 731.) Prerequisite: GEOL 751 or CE 752, or approved by the professor.

GEOL 761. Topics in Regional Field Geology: _____. 1-5 Credits.
A detailed field study of a carefully selected area that includes features of several phases of geology. Field trip fee. Prerequisite: GEOL 561 or equivalent and departmental approval.

GEOL 771. Advanced Geophysics: _____. 1-3 Credits.
Topics to vary with demand and include heat flow, wave propagation, synthetic seismograms, groundwater exploration, geothermal exploration, electrical methods in exploration, rock mechanics-tectonophysics, rock magnetism, geomagnetism, paleomagnetism, geophysical inverse theory, and others upon sufficient demand. May be repeated for different topics. (Same as PHSX 727.) Prerequisite: GEOL 572 or consent of instructor.

GEOL 773. Seismology. 3 Credits.
General theory of seismic waves, wave field extrapolation (migration) by finite difference methods, construction of travel-time curves, reflection and attenuation of coefficients, earthquake source mechanism, distribution and forecasting of earthquakes. Prerequisite: MATH 250/AE 250/ARCE 250/CE 250/C&PE 250/EECS 250/EPHX 250/ME 250 and GEOL 572.

GEOL 780. Conservation Principles and Practices. 3 Credits.
This course will acquaint the future museum professional with problems in conserving all types of collections. Philosophical and ethical approaches will be discussed, as well as the changing practices regarding conservation techniques. Emphasis will be placed on detection and identification of causes of deterioration in objects made of organic and inorganic materials, and how these problems can be remedied. Storage and care of objects will also be considered. (Same as AMS 714, BIOL 700, HIST 722 and MUSE 706.) Prerequisite: Museum Studies student or consent of instructor.

GEOL 781. Introduction to Museum Exhibits. 3 Credits.
Presentation of principles and practices of exhibit management, design, and production. Topics will include developing a master plan for museum exhibits; concept development; design, installation, and maintenance of exhibits; design theory; design process; label writing and editing; selection of materials architectural requirements and building codes; cost estimating; publicity; security; and exhibit evaluation. Consideration will be given to exhibition problems in public and private museums in the areas of anthropology, art, history, natural history, and technology. (Same as AMS 700, BIOL 787, HIST 723, and MUSE 703.) Prerequisite: Museum Studies student or consent of instructor.

GEOL 783. Museum Management. 3 Credits.
Lecture, discussion, and laboratory exercises on the nature of museums as organizations; accounting, budget cycles, personnel management, and related topics will be presented using, as appropriate, case studies and a simulated museum organization model. (Same as AMS 731, BIOL 785, HIST 728, and MUSE 701.) Prerequisite: Museum Studies student or consent of instructor.

GEOL 784. Introduction to Museum Public Education. 3 Credits.
Consideration of the goals of an institution's public education services, developing programs, identifying potential audiences, developing audiences, and funding. Workshops and demonstrations are designed for students to gain practical experience working with various programs and

developing model programs. (Same as AMS 797, BIOL 784, HIST 721, and MUSE 705.) Prerequisite: Museum Studies student or consent of instructor.

GEOL 785. Introduction to Collections Management and Utilization. 3 Credits.
This course examines the roles collections play in fulfilling a museum's mission; the obligations ownership/preservation of collections materials create for a museum; and the policies, practices, and professional standards that museums are required to put in place. The course will cover utilization of collections for research, education, and public engagement; address how that utilization informs the need for and structure of collections policies, and introduce the basic practices of professional collections management. (Same as ANTH 798, AMS 730, BIOL 798, HIST 725, and MUSE 704.) Prerequisite: Museum Studies student or consent of instructor.

GEOL 791. Advanced Topics in Geology: _____. 1-5 Credits.
Selected offerings in geology. Intended primarily for graduate students and qualified seniors. May include lectures, discussions, reading, laboratory and field work. May be taken more than once.

GEOL 814. Professional Science Masters Environmental Geology Capstone I. 1 Credits.
A culminating experience to develop a workforce project and produce a written report to be presented orally to a committee that may include an industry member. Students will develop an applied workforce project in the student's place of employment for full-time employees, or an internship or similar individual project for full-time students or students who are not employed in the area of study. This course will initiate the process of project development and will be taken prior to a student's final semester. This project is to be continued in GEOL 815 in the last semester of the student's graduate career. Prerequisite: Minimum 20 credit hours completed in program.

GEOL 815. Professional Science Masters Environmental Geology Capstone II. 2 Credits.
A culminating experience to develop a workforce project and produce a written report to be presented orally to a committee that may include an industry member. Students will develop an applied workforce project in the student's place of employment for full-time employees, an internship or similar individual project for full-time students or students who are not employed in the area of study. The students will compile their project results in a formal written report and will give an oral presentation to the Environmental Studies faculty (2 minimum) and the student's employer or mentor. Prerequisite: GEOL 814.

GEOL 837. Geoscience and Petroleum Engineering. 3 Credits.
Advanced geological, geophysical, and engineering characterization of a petroleum reservoir. Includes mapping; petrophysical, production, and pressure analysis; and numerical modeling. Considers economic analysis of steps to improve recovery.

GEOL 851. Field and Laboratory Methods: Physical Hydrogeology. 1 Credits.
Introduction to field and laboratory methods commonly used in physical hydrogeology. Practical experience with common water level measurement techniques, various well pumping techniques, well installation and geologic core sampling, and hydraulic testing. Prerequisite: Introductory course in hydrogeology and familiarity with computer use for data processing, or consent of instructor.

GEOL 853. Field and Laboratory Methods: Chemical Hydrogeology. 1 Credits.
Practical experience in measuring unstable chemical parameters in groundwater, including pH, Eh, dissolved oxygen, temperature, alkalinity, specific conductance, and turbidity. Practical experience in collecting water samples for chemical analysis, choosing appropriate sample containers and preservation methods, and special techniques for collecting samples for determination of parameters sensitive to environmental changes such as oxygen level or temperature. Prerequisite: GEOL 753 (may be taken concurrently) or equivalent, or consent of the instructor.

GEOL 855. Field and Laboratory Methods: Environmental Geophysics. 1 Credits.
Introduction to the application of geophysical methods to environmental investigations. Practical experience in designing, conducting, and interpreting information obtained using downhole and shallow surface geophysical methods will be addressed. Prerequisite: Introductory course in hydrogeology or consent of instructor.

GEOL 856. Field and Laboratory Methods Special Topics: _____. 1 Credits.
Practical experience in a special topic in Environmental Geology. Course may be repeated if topic varies.

GEOL 891. Special Studies in Geology. 1-5 Credits.
May be repeated.

GEOL 899. Master's Thesis. 1-12 Credits.
Thesis Hours. Graded on a satisfactory progress/limited progress/no progress basis. Prerequisite: Graduate standing.

GEOL 999. Doctoral Dissertation. 1-12 Credits.
Dissertation Hours. Graded on a satisfactory progress/limited progress/no progress basis. Prerequisite: Graduate standing.