Geology

Mian Liu
101 Geological Sciences
573-882-3784
lium@missouri.edu

Faculty

Professor M. Appold**, M. Liu**, K. G. MacLeod**, E. A. Sandvol**
Associate Professor F. G. Gomez**, J. W. Huntley**, J. Schiffbauer**
Assistant Professor M. Barquero-Molina*, T. Bidgoli**, S. Jacquet**, H. Lamadrid, T. Selly*

* Graduate Faculty Member - membership is required to teach graduate-level courses, chair master's thesis committees, and serve on doctoral examination and dissertation committees.
** Doctoral Faculty Member - membership is required to chair doctoral examination or dissertation committees. Graduate faculty membership is a prerequisite for Doctoral faculty membership.

Undergraduate

The Department of Geological Sciences offers two undergraduate degree programs, a Bachelor of Arts and a Bachelor of Science, both with major in Geological Sciences (http://catalog.missouri.edu/collegeofartsandscience/geologicalsciences/).

Graduate

• MS in Geology (http://catalog.missouri.edu/collegeofartsandscience/geology/ms-geology/)
• PhD in Geology (http://catalog.missouri.edu/collegeofartsandscience/geology/phd-geology/)

Department of Geological Sciences
101 Geological Sciences Building
(573) 882-6785
https://geology.missouri.edu/graduate-program (https://geology.missouri.edu/graduate-program/)

Director of Graduate Studies: Francisco Gomez

About the Geological Sciences Program

The areas of research covered by faculty are broad and diverse, with strong research expertise in the general areas of geochemistry, petrology, paleontology, and geophysics-tectonics. These strengths allow us to focus on problems identified by the National Research Council to be socially relevant and to be fundamental to an understanding of earth processes. Dynamic faculty, along with their students, are making significant contributions to numerous areas of basic and applied research. This research is supported by excellent, state-of-the-art analytical facilities in the department and on campus. Our graduate program prepares students for a wide range of professions within the geological sciences; students have been placed in private, federal, state, and academic institutions. Prospective students are encouraged to contact any faculty member directly for additional information.

Areas of Specialization

The areas of specialization are geophysics, geochronology, hydrogeology, engineering geology, igneous/metamorphic petrology, isotope geochemistry, ore deposits, paleoclimatology, paleoecology, paleontology, sedimentary geology/stratigraphy, structural geology, and tectonics.

Facilities and Resources

The Geological Sciences Building houses many different research laboratories, as well as classrooms and an excellent geology library. Equipment is available for supervised student use in many fields. The Geology Field Camp is in the Wind River Mountains near Lander, Wyoming. See the Department website at https://geology.missouri.edu/graduate-program (https://geology.missouri.edu/graduate-program/).

About the Degrees

The master's degree program includes a thesis and a non-thesis option, both of which require 30 credit hours beyond the bachelor's degree. The thesis option is accomplished by taking 18 to 21 graduate course credits and preparing a written thesis involving 9-12 credits of research or problems credits. Students have until the middle of their second semester in residence at the university to choose a supervisor and a thesis topic. The non-thesis track requires 27 hours of graduate course credits plus 3 hours of research credit leading to completion of a smaller-scale research project.

The doctoral degree requires 72 hours beyond a bachelor's degree, and may include as many as 24 hours credit from a prior master's degree. Doctoral candidates must pass a qualifying exam during their first year in residence to assess their general background so that a meaningful program of study can be constructed. The usual doctoral program involves courses within and outside the department, and researching the dissertation topic prior to taking the comprehensive examination by the end of the second year. The results of the dissertation research are presented to the faculty and graduate students when the student has completed the project.

Financial Aid from the Program

Some programs require an extra form or statement from those who wish to be considered for internal assistantships, fellowships or other funding packages. Check the program website or ask the program contact for details.

GEOL 1050: Planet Earth
An introduction to Earth Science. Topics include: evidence for continental drift and plate tectonics, causes and prediction of natural hazards, the scale of geological time.

Credit Hours: 3

GEOL 1100: Introduction to the Earth with Laboratory
Three lectures, 2-hours lab. Earth processes and products and their impact on human needs and the environment. One field trip. For the Mizzou Online sections, there will not be required lectures, lab, and field trip.

Credit Hours: 4

GEOL 1120: Laboratory Investigations of the Earth
This hybrid-lab course introduces basic methods of earth science investigation and inquiry with an emphasis on earth sciences. Key concepts include basic scientific methodology, earth materials and processes, and the societal relevance of geoscience research and application. Upon completion of the course, the successful student will
have learned to apply course material to improve thinking, problem solving and decision-making. Graded on A-F basis only.

**Credit Hours:** 2  
**Recommended:** GEOL 1050 as a corequisite (although the course will be a stand-alone introduction to the geosciences)

### GEOL 1200: Environmental Geology with Laboratory
The interaction between geologic processes and human society. Topics include mineral, water, and energy resources, volcanic hazards, earthquakes, landslides, floods, coastal erosion, pollution problems and environmental management.

**Credit Hours:** 4

### GEOL 1250: The World's Oceans
An interdisciplinary introduction to oceanography. Topics include: geologic evolution of ocean basins, properties of seawater, ocean circulation (waves, tides, and currents), marine ecosystems, instability of beaches and coastlines, coastal development and engineering.

**Credit Hours:** 3

### GEOL 1400: Themes in Geology
5-week course organized around a central theme or topic, up to 3 different sections can be taken for credit.

**Credit Hour:** 1

### GEOL 2100: Independent Study in Geology
Directed Library research in geological topics, under the supervision of faculty sponsor. May be repeated for a maximum of 3 hours credit.

**Credit Hour:** 1-3  
**Prerequisites:** instructor's consent

### GEOL 2110: Introduction to Soil Science with Laboratory
(same as SOIL 2110). Introduction to Soil Science with emphasis placed on physical, biological, and chemical properties and applications to land use, plant growth, and environmental problems with laboratory application of these concepts.

**Credit Hours:** 5  
**Prerequisites:** CHEM 1320

### GEOL 2120H: Faults and Earthquakes: Past, Present, and Future - Honors
Seminar in science and societal ramifications of earthquakes. Geologic background includes causes, behavior, and distribution of faults. Student-led discussions cover historical disasters, economic, political, psychological, and cultural perspectives.

**Credit Hours:** 3  
**Prerequisites:** ENGLISH 1000  
**Recommended:** Honors eligibility

### GEOL 2130: Physical Geology for Scientists and Engineers
Introduction to physical geology and Earth processes with a focus on applications and societal relevance. In addition to basic geologic processes, physical principles will illustrate the interactions between geology and engineering, using a calculus-based approach.

**Credit Hours:** 4  
**Prerequisites:** MATH 1500

### GEOL 2150: The Age of the Dinosaurs
Study of the evolution of dinosaurs during the Mesozoic Era. New information on dinosaur life habits, food resources, dispersal by plate tectonics, and theories of extinction will be covered.

**Credit Hours:** 3  
**Prerequisites:** 1000-level science course

### GEOL 2160H: Volcanoes and the Human Environment - Honors
(same as GN_HON 2450H). This course gives students an understanding of how volcanoes work, how they are studied, and how they have impacted human cultures. Students will gain appreciation of volcanology as a broad scientific discipline within geology and the role that science plays in public policy. Graded on A/F basis only.

**Credit Hours:** 3  
**Recommended:** Honors eligibility required

### GEOL 2220: Seminar: Headline Topics in the Geological Sciences
(same as GEOL 2220H). Seminar organized around a central theme that is the focus of intense ongoing research and public debate.

**Credit Hours:** 3

### GEOL 2220H: Honors Seminar: Headline Topics in the Geological Science
Seminar organized around a central theme that is the focus of intense ongoing research and public debate.

**Credit Hours:** 3  
**Prerequisites:** ENGLISH 1000  
**Recommended:** Honors eligibility

### GEOL 2300: Earth Systems and Global Change
Study of the earth as a whole, taking into account the many interwoven components of the geosphere, hydrosphere, atmosphere and biosphere.

**Credit Hours:** 3  
**Recommended:** 1000-level Science course

### GEOL 2350: Historical Geology
Summary of principles and techniques used in reconstructing Earth's history. Survey of major events that have affected Earth and its inhabitants. Review of geologic history of North America.

**Credit Hours:** 3  
**Prerequisites:** GEOL 1100 or GEOL 2130 or GEOL 1200

### GEOL 2360: Historical Geology Laboratory
A laboratory course designed to improve understanding of Earth History by examination of maps and mineral, rock, sediment and fossil samples.

**Credit Hour:** 1  
**Prerequisites:** GEOL 1100 or GEOL 2130 or GEOL 1200  
**Corequisites:** GEOL 2350
GEOL 2400: Surficial Earth Processes and Products with Laboratory
Semi-quantitative analysis of geologic processes that shape the earth's surface. Includes topics in sedimentation and geomorphology.
Credit Hours: 4
Prerequisites: GEOL 1100 or GEOL 2130 or GEOL 1200, and MATH 1100

GEOL 2450: Global Water Cycle
Study of environmental geochemical factors controlling the composition of natural waters, and sources of water's constituents (natural or human-produced). Math Reasoning Proficiency Course.
Credit Hours: 3
Prerequisites: MATH 1100
Recommended: 1000-level science course

GEOL 2500: Regional Geology Field Trip
Field based study of a particular geologic region, including classroom preparation prior to the field trip. The trip will last 7-10 days, either during Spring Break or immediately after finals week. May be repeated for credit.
Credit Hours: 3
Prerequisites: GEOL 1100 or GEOL 2130 or GEOL 1200

GEOL 2600: Mineral and Energy Resources of the Earth
This course examines the geology of Earth's major mineral and energy resources—their origin, distribution, and characteristics—and societal implications of their use and abundance. Major topics: fossil fuels, nuclear energy, base & precious metals, non-metallic minerals, water.
Credit Hours: 3

GEOL 3085: Problems in Geological Sciences
Problems in Geological Sciences.
Credit Hour: 1-5
Prerequisites: instructor's consent

GEOL 3102: Topics in Geological Sciences-Biological/Physical/Mathematics
Organized study of selected topics. Subject and earnable credit may vary. Departmental consent for repetition.
Credit Hour: 1-99
Prerequisites: junior standing or higher and instructor's consent

GEOL 3110: Geology of Missouri
The physical, historical, and environmental geology of Missouri are described, discussed and interpreted.
Credit Hours: 3
Prerequisites: ENGLISH 1000 and either GEOL 1100 or GEOL 1200

GEOL 3250: Mineralogy
Introduction to crystallography, crystal chemistry and crystal structures. Systematic study of mineral groups. Includes identification of minerals by physical, chemical and optical properties.
Credit Hours: 5

GEOL 3300: Introduction to Geochemistry
Credit Hours: 3
Prerequisites or Corequisites: CHEM 1330
Prerequisites: MATH 1400 or MATH 1500, and GEOL 1100 or GEOL 2130 or GEOL 1200

GEOL 3550: Introduction to Paleontology with Laboratory
Study of the morphology, paleontology, patterns of evolution, and causes of extinction in geologically important groups of invertebrate and vertebrate fossils. Lab concentrates on identification of biostratigraphically important fossils (mostly invertebrates). Several half-day field trips.
Credit Hours: 4
Prerequisites: GEOL 1100 or GEOL 2130 or GEOL 1200

GEOL 3800: Sedimentology and Stratigraphy with Lab
Mechanics of sediment transport by fluid flow and gravity flow, origins of stratification and sedimentary structures, facies characteristics depositional environments.
Credit Hours: 4
Prerequisites: GEOL 3250

GEOL 4002: Topics in Geological Sciences-Biological Science
Organized study of selected topics. Subjects and earnable credit may vary. May be repeated with departmental consent.
Credit Hour: 1-99
Prerequisites: instructor's consent

GEOL 4006: Topics in Geological Sciences-Mathematical Science
Organized study of selected topics. Subjects and earnable credit may vary. May be repeated with departmental consent.
Credit Hour: 1-99
Prerequisites: instructor's consent

GEOL 4007: Topics in Geological Sciences-Physical Science
Organized study of selected topics. Subjects and earnable credit may vary. May be repeated with departmental consent.
Credit Hour: 1-99
Prerequisites: instructor's consent

GEOL 4100: Groundwater Hydrology
Analysis of groundwater occurrence, flow, recovery, and solute transport within shallow levels of the Earth's crust.
Credit Hours: 3
Prerequisites: GEOL 1100 or GEOL 2130 or GEOL 1200, and PHYSCS 1210 or PHYSCS 2750, and MATH 1400 or MATH 1500
GEOL 4120: Engineering Geology
(cross-leveled with GEOL 7120). Fundamentals of earth materials and geological processes and their applications in engineering works and environmental sciences. Includes properties of minerals and rocks, rock and soil mechanics, surficial geological processes, and practice of engineering.
Credit Hours: 3
Prerequisites: GEOL 1100 or GEOL 2130 or GEOL 1200, and MATH 1500, or instructor's consent

GEOL 4130: Groundwater Modeling
(cross-leveled with GEOL 7130). Use of leading groundwater flow and contamination modeling software. Theory of groundwater flow, solute transport, and selected numerical solution techniques. Applications to water resource, environmental, and geological problems.
Credit Hours: 3
Prerequisites: GEOL 4100 or equivalent

GEOL 4150: Structural Geology
(cross-leveled with GEOL 7150). The mechanical behavior of earth materials. Analysis of the geometry and mechanics of faults, fractures, and folds. Laboratory includes problems on stresses and strains associated with deformation, geometric analysis of deformation structures, and interpretation of geologic maps.
Credit Hours: 4
Prerequisites: GEOL 1100 or GEOL 2130 or GEOL 1200 and MATH 1140 or MATH 1160 or MATH 1500

GEOL 4180: Solar System Science
(same as PHYS CS 4180, ASTRON 4180; cross-leveled with GEOL 7180). Investigates physical states, interior structures and comparative geology of solar systems bodies: planets, moons, asteroids, comets, sun. Solar system formation and evolution.
Credit Hours: 3
Prerequisites: MATH 1700 and PHYS CS 1220 or PHYS CS 2760 or instructor's consent

GEOL 4200: Economic Geology with Laboratory
Geochemistry of ore deposits. Introduction to types of mineral deposits, genesis of ore, and current areas of research. Laboratory emphasizes hand-specimen and polished-section studies of a wide variety of ore deposit types.
Credit Hours: 4
Prerequisites: GEOL 4900

GEOL 4300: Introduction to Low-Temperature Geochemistry
Introduction to the chemical alteration of rock-forming minerals in weathering environments and to factors controlling the chemical composition of subsurface water.
Credit Hours: 3
Prerequisites: GEOL 3300 or instructor's consent

GEOL 4318: Environmental Soil Chemistry
(same as SOIL 4318 and ENV_SC 4318; cross-leveled with GEOL 7318, SOIL 7318, ENV_SC 7318). Study of chemical constituents and processes occurring in soils. Topics include soil minerals and weathering processes, organic matter, solution chemistry, oxidation-reduction reactions and adsorption processes.
Credit Hours: 3
Prerequisites: SOIL 2100 or GEOL 2400, CHEM 1320 and CHEM 1330. Junior standing or instructor's consent

GEOL 4350: Taphonomy
(cross-leveled with GEOL 7350). The purposes of this course are to 1) analyze patterns in the history of life and 2) to recognize the biased processes that led to its preservation. We will accomplish these goals by examining two disparate fossil preservation pathways: 1) Konzervat lagerstätten: fossil deposits that are notorious for the exceptional and rare preservation of soft tissues and 2) Konzentrat lagerstätten: fossil deposits that are exceptional for the enormous amount of fossilized skeletal material they contain. Through careful examination of both the rare and the hyper-abundant, we can address the fundamental question of paleobiology: how literally can the fossil record be read as the history of life? Graded on A-F basis only.
Credit Hours: 3
Prerequisites: GEOL 2350, GEOL 2360

GEOL 4370: Conservation Paleobiology
(cross-leveled with GEOL 7370). Humans are having an undeniable influence on Earth systems, including the biosphere. Climate change, habitat destruction, over-hunting/harvesting, pollution, and invasive species are among the primary stressors of modern biodiversity. How have ecosystems responded to such stressors in the past? How do we determine what a "pristine" ecosystem looks like when planning ecosystem restoration? Paleontologists are uniquely equipped to address these questions using the fossil record. In this course we will review the important questions in this emerging discipline, learn about the tools used to address these questions, and learn from case studies involving invertebrate, vertebrate, and plant fossils from a variety of environments.
Credit Hours: 3

GEOL 4500: Organic Geochemistry
(cross-leveled with GEOL 7500). Topics include chemistry of petroleum-forming reactions and their kinetic parameters; use of organic-chemical criteria in source-rock evaluation; carbon isotope fractionation in organic precursors of biological molecules; early history of earth's atmosphere.
Credit Hours: 3
Prerequisites: instructor's consent

GEOL 4650: Plate Tectonics
(cross-leveled with GEOL 7650). Formation, evolution, and structure of the earth. Rules, causes, and implications of plate tectonics with emphasis on present-day features.
Credit Hours: 3
Prerequisites: GEOL 3250 or GEOL 4150 or instructor's consent

GEOL 4650W: Plate Tectonics - Writing Intensive
Formation, evolution, and structure of the earth. Rules, causes, and implications of plate tectonics with emphasis on present-day features.
Credit Hours: 3
Prerequisites: GEOL 3250 or GEOL 3650 or instructor's consent
GEOL 4680: Neotectonics and Earthquake Geology
(cross-leveled with GEOL 7680). Introduction to techniques and concepts of active crustal deformation from the geological and geodetic perspectives. Topics include tectonic geomorphology, paleoseismology, Quaternary dating, tectonic geodesy, numerical models of faults, and earthquake hazard assessment.

Credit Hours: 3
Prerequisites: GEOL 3650 or GEOL 4650

GEOL 4750: Microanalysis for Geological Sciences
(cross-leveled with GEOL 7750). This course is intended to provide a working knowledge of electron and X-ray microbeam analytical instruments - both in principle and in practice. Lectures will focus on the physics of how these instruments collect data, and how these data can be interpreted. In addition, students will gain hands-on experience with operating these instruments, specifically on their own samples, as well as preparing their samples for microanalysis and interpreting/manipulating the resulting data. Graded on A-F basis only.

Credit Hours: 3
Prerequisites: Instructor's Consent (instrument time is limited so enrollment must also be limited)

GEOL 4800: Introduction to Geophysics
(cross-leveled with GEOL 7800). Introduction to the fundamentals of geophysical methods and their applications in geology, environmental studies, and exploration. Topics include seismic, gravity, magnetic, and electric methods.

Credit Hours: 3
Prerequisites: GEOL 1100 or GEOL 2130 or GEOL 1200 and MATH 1700 or instructor's consent

GEOL 4900: Igneous and Metamorphic Petrology with Laboratory
Introduction to igneous and metamorphic rock associations and rock-forming processes. Emphasis on understanding the evolution of the Earth in view of igneous and metamorphic rock petrogenesis.

Credit Hours: 4
Prerequisites: GEOL 3250
Recommended: GEOL 3300

GEOL 4950: Senior Thesis
Research conducted in an area of the Geological Sciences under the auspices of a member of the faculty. Under normal circumstances, this research should be completed over two semesters. May be repeated for a maximum of 3 hours credit.

Credit Hour: 1-3

GEOL 4992: Geology Field Camp

Credit Hours: 6
Recommended: GEOL 2350, GEOL 4150, and GEOL 3800

GEOL 7002: Topics in Geological Sciences-Biological/Physical/Mathematics
Organized study of selected topics. Subjects and earnable credit may vary. May be repeated with departmental consent.

Credit Hour: 1-99
Prerequisites: instructor's consent

GEOL 7085: Problems in Geological Sciences
Credit Hour: 1-8
Prerequisites: instructor's consent

GEOL 7100: Groundwater Hydrology
(cross-leveled with GEOL 4100). Analysis of groundwater occurrence, flow, recovery, and solute transport within shallow levels of the Earth's crust.

Credit Hours: 3
Prerequisites: GEOL 1100 or GEOL 2130 or GEOL 1200, and PHYSCS 1210 or PHYSCS 2750, and MATH 1400 or MATH 1500

GEOL 7120: Engineering Geology
(cross-leveled with GEOL 4120). Fundamentals of earth materials and geological processes and their applications in engineering works and environmental sciences. Includes properties of minerals and rocks, rock and soil mechanics, surficial geological processes, and practice of engineering.

Credit Hours: 3
Prerequisites: GEOL 1100 or GEOL 2130 or GEOL 1200 and MATH 1500, or instructor's consent

GEOL 7130: Groundwater Modeling
(cross-leveled with GEOL 4130). Use of leading groundwater flow and contamination modeling software. Theory of groundwater flow, solute transport, and selected numerical solution techniques. Applications to water resource, environmental, and geological problems.

Credit Hours: 3
Prerequisites: GEOL 4100 or equivalent

GEOL 7150: Structural Geology
(cross-leveled with GEOL 4150) The mechanical behavior of earth materials. Analysis of the geometry and mechanics of faults, fractures, and folds. Laboratory includes problems on stresses and strains associated with deformation, geometric analysis of deformation structures, and interpretation of geologic maps.

Credit Hours: 4
Prerequisites: instructor's consent and GEOL 1100 or GEOL 2130 or GEOL 1200 and MATH 1140 or MATH 1160 or MATH 1500

GEOL 7180: Solar System Science
(same as PHYSCS 7180 and ASTRON 7180). Investigates physical states, interior structures and comparative geology of solar systems bodies: planets, moons, asteroids, comets, sun. Solar system formation and evolution.

Credit Hours: 3
Prerequisites: MATH 1700 and PHYSCS 1220 or PHYSCS 2760 or instructor's consent
<table>
<thead>
<tr>
<th>Course Code</th>
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<th>Description</th>
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<tbody>
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<td>Economic Geology with Laboratory</td>
<td>Geochemistry of ore deposits. Introduction to types of mineral deposits, genesis of ore, and current areas of research. Laboratory emphasizes hand-specimen and polished-section studies of a wide variety of ore deposit types.</td>
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<td>Environmental Soil Chemistry</td>
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<td>Conservation Paleobiology</td>
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<td>Organic Geochemistry</td>
<td>Topics include chemistry of petroleum-forming reactions and their kinetic parameters; use of organic-chemical criteria in source-rock evaluation; carbon isotope fractionation in organic precursors of biological molecules; early history of earth’s atmosphere.</td>
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<td>Plate Tectonics</td>
<td>Formation, evolution, and structure of the earth. Rules, causes, and implications of plate tectonics with emphasis on present-day features.</td>
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<td>GEOL 3250, GEOL 3650 or instructor's consent</td>
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<td>GEOL 7680</td>
<td>Neotectonics and Earthquake Geology</td>
<td>Introduction to techniques and concepts of active crustal deformation from the geological and geodetic perspectives. Topics include tectonic geomorphology, paleoseismology, Quaternary dating, tectonic geodesy, numerical models of faults, and earthquake hazard assessment.</td>
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<td>GEOL 4150 or GEOL 4650</td>
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<tr>
<td>GEOL 7700</td>
<td>Theoretical Geochemistry</td>
<td>Introduction to theoretical concepts in low and high temperature geochemistry. Topics include thermodynamics of fluids, gases and solids in geological materials, phase diagrams, equilibrium constants, electrolyte theory, oxidation-reduction reactions.</td>
<td>3</td>
<td>GEOL 3250, CHEM 1330 and MATH 1700</td>
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<td>Microanalysis for Geological Sciences</td>
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<tr>
<td>GEOL 7990</td>
<td>Research in Geological Sciences-Masters</td>
<td>Does not lead to dissertation.</td>
<td>1-8</td>
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<tr>
<td>GEOL 8002</td>
<td>Topics in Geological Sciences</td>
<td>Organized study of selected topics. May be repeated with departmental consent.</td>
<td>1-99</td>
<td>PhD standing, instructor's consent</td>
</tr>
<tr>
<td>GEOL 8050</td>
<td>Research in Geological Sciences-Masters Non-Thesis</td>
<td>Research leading to a non-thesis Masters project. Graded on S/U basis only.</td>
<td>1-3</td>
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<td>GEOL 8085</td>
<td>Problems in Geological Sciences</td>
<td></td>
<td>1-8</td>
<td>instructor's consent</td>
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<tr>
<td>GEOL 8100</td>
<td>Continental Tectonics</td>
<td>The structural, metamorphic, and igneous evolution of mountain belts and continental rifts with emphasis on convergent margin settings and terrane accretion processes and products. Case studies are considered from the Precambrian to the recent.</td>
<td>3</td>
<td>GEOL 3650 and GEOL 4900</td>
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<tr>
<td>GEOL 8140</td>
<td>Metamorphic Petrology</td>
<td>Petrography and petrology of metamorphic rocks. Emphasis on textures, mineral assemblages, and mineral chemistry in order to determine the physico-chemical condition of metamorphism.</td>
<td>3</td>
<td>GEOL 3250 and GEOL 4900</td>
</tr>
<tr>
<td>GEOL 8150</td>
<td>Earthquake Seismology</td>
<td>Theory and techniques used in analyzing earthquake seismograms and seismicity data. Ray theory and phase identification for the whole earth. Epicenter determination. Frequency-magnitude relationships. Earthquake source mechanisms and parameters.</td>
<td>3</td>
<td>GEOL 8320</td>
</tr>
<tr>
<td>GEOL 8160</td>
<td>Igneous Petrology</td>
<td>Studies of the origin and evolution of magmas with use of phase equilibria, physical properties, and kinetics.</td>
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<td>GEOL 3250 and GEOL 4900</td>
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<tr>
<td>GEOL 8170</td>
<td>Radiogenic Isotope Geochemistry</td>
<td>Studies of the application of trace element and radiogenic isotope systematics to petrogenesis of rocks.</td>
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<tr>
<td>GEOL 8190</td>
<td>Advanced Paleontology</td>
<td>Principles of taxonomy, biostratigraphy, functional morphology and paleoecology are illustrated by individual projects that combine field collecting, laboratory examination and literature research.</td>
<td>3</td>
<td>GEOL 3550</td>
</tr>
<tr>
<td>GEOL 8200</td>
<td>Advanced Structural Geology</td>
<td>Advanced analysis of deformation structures in rocks. Theory and techniques of stress and strain analysis and their application to the mechanics of formation of faults, folds, shear zones, and rock fabric. Techniques of multideformation structural analysis.</td>
<td>3</td>
<td>GEOL 4150</td>
</tr>
<tr>
<td>GEOL 8240</td>
<td>Hydrogeologic Processes</td>
<td>Quantitative analysis of role of groundwater in major geologic processes. Theory review of fluid flow, heat transport, reactive solute transport in porous media. Applications to sedimentary diagenesis, hydrothermal ore deposits, petroleum migration, earthquakes, magmatism, metamorphism.</td>
<td>3</td>
<td>GEOL 4100 or GEOL 7100 or equivalent</td>
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<tr>
<td>GEOL 8300</td>
<td>Precambrian History</td>
<td>Coupled evolution of the biosphere, lithosphere, hydrosphere, and atmosphere over the span of Precambrian history. Topics will be discussed largely in the context of biological evolutionary events and the fossil record, as well as with a focus on geochemical records.</td>
<td>3</td>
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<tr>
<td>GEOL 8320</td>
<td>Introduction to Seismology</td>
<td>Principles of wave propagation in layered elastic media. Applications of digital signal processing to seismological problems. Emphasis on theoretical basis behind modern analysis techniques.</td>
<td>3</td>
<td>PHYSCS 2760, MATH 4500 and CMP_SC 1050</td>
</tr>
<tr>
<td>GEOL 8400</td>
<td>Ancient Greenhouse Climate</td>
<td>Will explore a wide range of data concerning greenhouse climates and different techniques used in paleoclimatology. Graded on A/F basis only.</td>
<td>3</td>
<td>GEOL 3800, GEOL 3550 and GEOL 4300</td>
</tr>
<tr>
<td>GEOL 8450</td>
<td>Tectonics and Sedimentation</td>
<td>Global survey of modern and ancient convergent plate boundaries with an emphasis on sedimentary facies and structural styles.</td>
<td>3</td>
<td>GEOL 4150, GEOL 3800 and instructor's consent</td>
</tr>
</tbody>
</table>
GEOL 8510: Geodynamics
This course is designed to cover the fundamentals of the quantitative aspects of Plate Tectonics. The study of these subjects is generally referred to as Geodynamics or Geodynamic Theory. This theory revolutionized the earth sciences and the way people think of earth processes. By definition Geodynamics is an interdisciplinary paradigm therefore it is necessary to cover a wide range of topics from heat transfer to gravity. This course will overlap with subjects covered in both Plate Tectonics and Geophysics but we will emphasize the quantitative aspects of this theory in this course.

Credit Hours: 3
Prerequisites: MATH 1700, PHYSCS 2760

GEOL 8550: Stable Isotope Geochemistry
Mechanisms and fundamental concepts of fractionation of light stable isotopes in nature. Emphasizes application of hydrogen, carbon, oxygen and sulfur isotopes to igneous, metamorphic and sedimentary rocks, metallic ore deposits, and to natural waters.

Credit Hours: 3
Prerequisites: instructor's consent

GEOL 8650: Thermal Processes in the Solid Earth
Principles of heat transfer in solid earth by conduction, advection and convection. Basic analytic and numerical solutions. Application in Earth's dynamic system, environmental sciences, and geological problems.

Credit Hours: 3
Prerequisites: MATH 1700, PHYSCS 1220 or PHYSCS 2750

GEOL 8750: Silicate Glasses, Liquids and Magmas
Theory of silicate liquid viscosity, heat capacity and configurational entropy, emphasizing the role of volatile components. Applications to magma rheology and eruptive behavior. Lab instruction in viscometry techniques.

Credit Hours: 3
Prerequisites: GEOL 4900 and GEOL 4700, or instructor's consent

GEOL 8800: Applied Numerical Analysis
A study of applied mathematical analysis of spatial and temporal data as applied in the geosciences.

Credit Hours: 3
Prerequisites: MATH 1700 or MATH 2300, PHYSCS 1220 or PHYSCS 2760

GEOL 8990: Research
Does not lead to dissertation.

Credit Hour: 1-8

GEOL 9090: Research in Geological Sciences-Doctoral Dissertation
Preparation of dissertation. Graded on a S/U basis only.

Credit Hour: 1-99