

# GEOLOGY (GEOL)

Geology is the study of the Earth. This includes the study of rocks and minerals, topography, the tectonics of the Earth (earthquakes, volcanism, and mountain building), the physical history of the Earth, and the history of life on the Earth. In studying the Earth, the Geology student is closely involved with the related sciences of chemistry, physics, and mathematics. The interrelationship between Earth processes and humanity is stressed in many Geology classes. Western Colorado University is a particularly wonderful place to study Geology because of the natural setting that enables field studies to be utilized in all Geology classes.

The Geology Major successfully prepares students for entry-level positions in the petroleum and mineral industries, in environmental science, or in various government agencies. Students are also well prepared to enter graduate programs in Geology. The program meets or exceeds American Geological Institute standards.

## Program Requirements

The Geology program provides a Comprehensive Major with an area of emphasis selected according to the interests and career goals of the student. These emphases are: environmental geology, geology, geoarchaeology, petroleum geology, and secondary licensure in earth-space science. The program requirements for the various emphases range from 60 to 73 credits.

The Secondary Licensure in Earth-Space Science Emphasis qualifies students for the State of Colorado License in Science Education. Other Geology emphases may also be used for secondary licensure but may require additional classes.

## Program Goals

- Recognition and interpretation of rocks and minerals in the laboratory and in the field: The ability to a) recognize and identify the components of a rock, b) apply accepted classification of the rock using established nomenclature, c) interpretation of the processes responsible for mineral composition and textures observed in the rock, d) using relations from direct field observations, photos, maps or sketches, place the rock into a geological context.
- Understanding of the theory of plate tectonics
- Understanding and application of time and space in Earth history
- Communications in the geosciences
- Geology Comprehensive Major: Environmental Geology Emphasis (<https://catalog.western.edu/undergraduate/programs/geology/geology-comprehensive-environmental-geology/>)
- Geology Comprehensive Major: Geoarchaeology Emphasis (<https://catalog.western.edu/undergraduate/programs/geology/geology-comprehensive-geoarchaeology/>)
- Geology Comprehensive Major: Geology Emphasis (<https://catalog.western.edu/undergraduate/programs/geology/geology-comprehensive-geology/>)
- Geology Comprehensive Major: Petroleum Geology Emphasis (<https://catalog.western.edu/undergraduate/programs/geology/geology-comprehensive-petroleum-geology/>)
- Geology Comprehensive Major: Secondary Licensure in Earth-Space Science Emphasis (<https://catalog.western.edu/undergraduate/programs/geology/geology-comprehensive-secondary-licensure-earth-space-science/>)

- Geology Comprehensive Major: Secondary Licensure in Earth-Space Science Emphasis (with a 3+2 Master of Arts in Education) (<https://catalog.western.edu/undergraduate/programs/geology/geology-comprehensive-secondary-licensure-earth-space-science-3-2/>)
- Geology Minor (<https://catalog.western.edu/undergraduate/programs/geology/geology-minor/>)

## Capstone Course Requirement

One of the following: GEOL 450 Field Geology; EDUC 409 Secondary Student Teaching (Secondary Licensure in Earth-Space Science Emphasis).

## Geology Courses

### GEOL 101. Physical Geology (GT-SC2). (3 Credits)

An introductory class that emphasizes the environmental aspects of geology. The course covers the basic principles of physical geology, such as minerals, rocks, plate tectonics, earthquakes, volcanoes, and origin of landscapes by mass wasting, rivers, glaciers, ground water, and nearshore processes. Throughout this course, focus is on the effect of geology on human society through the study of geologic hazards, energy resources, and mineral resources. GT-SC2

### GEOL 103. Earth and Energy Systems. (3 Credits)

An introduction to Earth and the geological environment with a focus on energy systems. The course will focus on Earth systems processes that control natural energy generation and storage, including fossil fuels, solar, wind, tidal, hydrothermal, and nuclear energy. Societal, political, economic and environmental factors in energy choices are examined. Fundamental geological controls are emphasized.

### GEOL 105. Physical Geology Laboratory (GT-SC1). (1 Credit)

An introduction to identification of minerals and rocks and a discussion of their genesis followed by a study of landscapes formed by mass wasting, rivers, glaciers, ground water, and nearshore processes. Many of these principles are observed on local field trips. Additional course fee applies. Prerequisite or corequisite: GEOL 101 or GEOL 103; or instructor permission. GT-SC1

### GEOL 197. Special Topics. (1-6 Credits)

### GEOL 201. Historical Geology (with laboratory). (3-4 Credits)

A study of the interpretation of the geologic history, structure, and evolution of the Earth with emphasis on methods and concepts rather than factual information. Colorado geologic history and various principles are observed during three or four field trips. Topics and concepts such as geophysics, continental drift, and plate tectonics are integrated into discussions of Earth history. Additional course fee applies. Prerequisites: GEOL 101 or GEOL 103; and GEOL 105; or instructor permission.

### GEOL 220. Field Geology of Western North America. (1 Credit)

An introduction to geology in the field for students early in their studies in geology. Provides illustration of basic geologic principles using field trips. Includes preparatory lectures and mandatory field trip. Destinations vary. Additional activity fee applies. Prerequisite/corequisite: GEOL 101 or GEOL 103; or instructor permission.

### GEOL 240. Geology of Energy Resources. (3 Credits)

Principles of geology applied in energy conversion, distribution, production, and reclamation. This class focuses on the geologic occurrence and life-cycle of renewable and non-renewable resources. Students will complete a technical evaluation of the sustainability, efficiency, and conservation issues associated with various energy resources. Prerequisites: GEOL 101 or 103 and GEOL 105; or instructor permission.

**GEOL 297. Special Topics. (1-6 Credits)****GEOL 300. Geology Field Trip. (1-6 Credits)**

Provides students exposure to varied geologic terranes and settings. The course normally consists of preparatory lectures and the actual field trip, followed by a paper, talk, or examination. Students may earn a maximum of six credits under this course title. Prerequisite: GEOL 201 or instructor permission.

**GEOL 302. Geoscience Writing. (2 Credits)**

An introduction to the proper methods and accepted formats of written, graphical, and oral communication in the geological sciences. These skills are addressed through critical evaluation and discussion of the geological literature, by writing reports, review papers and research proposals, and giving oral presentations. Prerequisites: ENG 102 with a grade of C- or above and GEOL 201; or instructor permission.. Corequisite: GEOL 310.

**GEOL 305. Mineralogy (with laboratory). (3-4 Credits)**

An introduction to the study of minerals. Important topics include the crystallography, crystal chemistry, and optics of important rock and ore forming minerals. Emphasis is placed on the crystal chemistry and stability of major silicate mineral groups. The laboratory emphasizes the field identification of minerals and the application of optics to the identification of minerals in thin section. Additional course fee applies. Prerequisites: GEOL 101 or GEOL 103, GEOL 105, and MATH 141. Prerequisite or corequisite: CHEM 111 and CHEM 112. Or instructor permission.

**GEOL 310. Stratigraphy and Sedimentation (with laboratory). (3-4 Credits)**

A study of the basic principles and origins of sedimentary rock units. Topics studied include sub-division of the geologic column and geologic time, depositional systems, stratigraphic nomenclature and rules, principles of correlation, including a review of modern geophysical, geochemical, and chronostratigraphic methods, biostratigraphy, and event stratigraphy. Laboratory includes measurement of sections, examination of depositional systems in the field, and surface and subsurface stratigraphic techniques, including geophysical-log interpretation and computer mapping. Additional course fee applies. Prerequisites: ENG 102 with a minimum grade of C-, GEOL 201; or instructor permission.

**GEOL 311. Igneous and Metamorphic Petrology (with laboratory). (4 Credits)**

An introduction to the study of the materials that make up the solid earth; including the crystal structure, chemistry and stability of major silicate and ore minerals and the formation of igneous and metamorphic rocks. The laboratory emphasizes hand specimen and optical identification of minerals and the petrography of igneous, metamorphic and sedimentary rocks. Additional course fee applies. Prerequisites: ESCI 105, or GEOL 101 or GEOL 103, and GEOL 105; and MATH 141. Prerequisite or corequisite: CHEM 111 and CHEM 112. Or instructor permission.

**GEOL 315. Earth Materials (with laboratory). (4 Credits)**

An introduction to the study of the materials that make up the solid earth; including the crystal structure, chemistry and stability of major silicate and ore minerals and the formation of igneous and metamorphic rocks. The laboratory emphasizes hand specimen and optical identification of minerals and the petrography of igneous, metamorphic and sedimentary rocks. Additional course fee applies. Prerequisites: ESCI 105, or GEOL 101 or GEOL 103, and GEOL 105; and MATH 141. Prerequisite or corequisite: CHEM 111 and CHEM 112. Or instructor permission.

**GEOL 318. Igneous and Metamorphic Petrology (with laboratory). (4 Credits)**

A study of igneous and metamorphic rocks, including their classification, field relations, tectonic setting, phase petrology, mineralogy, and geochemistry. The laboratory emphasizes both field identification of rocks and the use of petrographic microscopes. Several field trips are included. Additional course fee applies. Prerequisite: GEOL 315. Prerequisite or corequisite: CHEM 113 and CHEM 114. Or instructor permission.

**GEOL 320. Geomorphology (with laboratory). (4 Credits)**

A study of the processes that create the landforms we see at the Earth's surface. In particular, processes associated with modern and ice-age climate are studied including erosion and weathering, soil formation; flooding, glaciation, and mass wasting. The laboratory emphasizes field-observation and data-collection techniques, and the interpretation of aerial photographs. Additional course fee applies. Prerequisites: ESCI 105, or GEOL 101 or GEOL 103, and GEOL 105; and CHEM 101 or CHEM 111; or instructor permission.

**GEOL 335. Introduction to Engineering Geology. (3 Credits)**

An introduction to the fundamentals, methods, and techniques used in engineering geology. This course explores investigation methods, and characterization of the engineering properties of geological materials. We investigate the mechanics of soil and rock as engineering materials. This class introduces the specific field methods used in engineering geology for assessment of foundations, slopes, dams, tunnels, and other earth structures. Prerequisites: GEOL 345, and either PHYS 170 & PHYS 185 or PHYS 190 & PHYS 185. Or instructor permission.

**GEOL 343. Introduction to Geophysics. (3 Credits)**

An introduction to geophysics and the techniques used in environmental geology, mineral and petroleum exploration and engineering geology. Labs and projects emphasize the interpretation of real-world data. Methods studied include seismic, potential fields, heat flow, electrical, magnetic and well logging. Students gain proficiency in the use of advanced modeling and interpretation software. Prerequisites: PHYS 170 & PHYS 185 or PHYS 190 & PHYS 185. Pre/Corequisite: GEOL 345; or instructor permission.

**GEOL 345. Structural Geology (with laboratory). (4 Credits)**

A study of the deformation of the Earth's crust. The course begins with a study of the forces and movements within the crust which cause folding and faulting of rocks and a description of the resulting structures. These topics are followed by an analysis of the regional tectonic patterns of the Earth's surface and theories for their origin. Additional course fee applies. Prerequisites: GEOL 201 and GEOL 315 with a minimum grade of C- and MATH 141. Or instructor permission.

**GEOL 346. Subsurface Geology (with laboratory). (4 Credits)**

An advanced undergraduate course in subsurface structural and stratigraphic methods pertinent to petroleum, groundwater, environmental, and tectonics investigations. Traditional and computer-assisted techniques are used. Students gain experience in integrating surface geology with subsurface well and geophysical data, understanding and managing subsurface data types, the principles and application of petrophysics, subsurface mapping methods, core and cuttings description and interpretation, and case studies of oil and gas fields. Field exercises emphasize the integration of surface and subsurface data. Additional course fee applies. Prerequisite: GEOL 345, or instructor permission.

**GEOL 352. Applied Geophysics (with laboratory). (3 Credits)**

The theoretical and practical application of physics to geology with an emphasis on the shallow subsurface. Exercises emphasize the interpretation of real-world data and cover the topics of seismic, potential fields, heat flow, electrical, wireline, and ground penetrating radar methods. Students gain proficiency in the use of several advanced analysis and modeling software packages and the application of geophysics to solving problems in stratigraphy, structure, hydrology, environmental geology, mining, and oil and gas. Prerequisites: GEOL 345, and either PHYS 170 & PHYS 185 or PHYS 190 & PHYS 185. Or instructor permission.

**GEOL 360. Isotope Geochemistry. (3 Credits)**

A study of the distribution and movement of chemical elements and isotopes in the geologic environment. Topics include nucleosynthetic processes and the isotopic abundances of the elements; geochronology using radioactive decay schemes, including U-Pb, Rb-Sr, Sm-Nd, K-Ar, U-series isotopes, and cosmogenic isotopes; trace element partitioning; and the use of stable isotopes in geothermometry and ore petrogenesis. Examples illustrate the use of radiogenic and stable isotopes in petrology and their application to study of the Earth and Solar system and the evolution of the crust and mantle. Additional course fee applies. Prerequisites: GEOL 315 with a C- or better and CHEM 113 and 114. Or instructor permission.

**GEOL 362. Environmental Geochemistry. (3 Credits)**

An advanced geology course covering the low-temperature chemistry of the near-surface geologic environment. Topics include equilibrium thermodynamics, natural-water geochemistry, the carbonate system, mineral weathering, basic organic geochemistry and the evolution of Earth's atmosphere. Students gain quantitative problem-solving skills through comprehensive problem sets and the collection and analysis of real-world geochemical data. Prerequisite: CHEM 113 and 114; ESCI 105 or GEOL 101 or GEOL 103. Or instructor permission.

**GEOL 380. Paleoclimatology. (3 Credits)**

A study of Earth's climate system, the major climatic changes that have occurred throughout the Quaternary Period (last 2.6 million years), and the mechanisms that drive global and regional climate change. Current and projected anthropogenic climate change will be studied in light of the paleoclimatic record. Prerequisites: BIOL 130 or BIOL 151 or ESCI 105 or GEOL 101 or GEOL 103; and CHEM 101 or 111; or instructor permission.

**GEOL 392. Geology Independent Study. (1-4 Credits)****GEOL 397. Special Topics. (1-6 Credits)****GEOL 401. Career Pathways in Geology. (1 Credit)**

Exploration of post-baccalaureate degree options. Students will receive guidance in finding and applying to graduate degree programs and job opportunities. This combined on line and face-to-face course will also provide a comprehensive review of material required by the Association of State Board of Geology (ASBOG) for the Fundamentals of Geology Exam (FGE). The FGE is the first step to becoming a licensed professional geologist. When available guest speakers will meet with students to discuss their career paths and experiences. Prerequisites: minimum junior standing or instructor permission.

**GEOL 411. Research in Volcanology and Petrology (with laboratory). (3 Credits)**

An examination of the physical volcanology, petrology, and petrogenesis of volcanic rocks. A strong emphasis is placed on fieldwork and the description of the volcanic rocks of the Gunnison Basin and adjacent regions. The course is topical in nature and emphasizes individual and/or group research projects through study of the geologic literature, the collection of geologic data, and the presentation of results. Prerequisite: GEOL 311 or instructor permission.

**GEOL 420. Research in Geomorphology (with laboratory). (3 Credits)**

An advanced study of geomorphology. Topics may include fluvial, glacial, mass movement, neotectonic, and eolian processes and landforms as well as weathering and soils. The course is topical in nature and emphasizes individual and/or group research projects through study of the geologic literature, the collection of geologic data, and the presentation of results. Prerequisites: GEOL 320, GEOL 345, and GEOG 340. Or instructor permission.

**GEOL 430. Hydrogeology (with laboratory). (3 Credits)**

A study of the occurrence, movement and chemical properties of surface water and groundwater. Topics include the hydrologic cycle, surface-water hydrology, principles of ground water flow, groundwater flow to wells and natural water chemistry. Laboratory assignments focus on quantitative analysis and modeling of surface and groundwater data. Additional course fee applies. Prerequisites: ESCI 105, or GEOL 101 or GEOL 103, and GEOL 105; and CHEM 111; and MATH 151. Prerequisite or corequisite: PHYS 140 or PHYS 170 or PHYS 190. Or instructor permission.

**GEOL 435. Research in Structure and Tectonics (with laboratory). (3 Credits)**

Advanced study of structural geology and tectonic processes, rheology and rock failure/deformation, and the relationships between plate boundaries, structural deformation and basin formation and fill. A strong emphasis is placed on field relations and structural analysis of outcrop and subsurface data. The course is topical in nature and requires individual and/or group research projects through the study of the geologic literature, the collection and analysis of geologic data, and the presentation of results. Additional course fee applies. Prerequisites: GEOL 310 and GEOL 345. Or instructor permission.

**GEOL 450. Field Geology. (4 Credits)**

An emphasis on field observation, proper geologic mapping techniques; on both maps and aerial photos; and interpretation and synthesis of field data into-a report. Different geologic terrains in Colorado or other states are examined. Ideally, this course should be taken during the Summer semester, immediately prior to the senior year. Additional course fee applies. Prerequisites: GEOL 310, GEOL 315 and GEOL 345; or instructor permission.

**GEOL 452. Advanced Field Geology. (2 Credits)**

A study of advanced geological field techniques and special field problems that concentrate on the interpretation of rock types and structures, their distributions, and the collection of field data. Students will interpret field data and make connections between their field observations and the tectonic evolution of the Western United States. Additional course fee applies. Prerequisite: GEOL 450 with a minimum grade of C-, or instructor permission.

**GEOL 455. Petroleum Geology (with laboratory). (4 Credits)**

The petroleum system and modern exploration techniques including detailed study of petroleum source rocks, their deposition, thermal maturation and the chemical and physical characteristics of hydrocarbons, hydrocarbon migration, accumulation and retention, reservoir types and properties. Current techniques used in hydrocarbon exploration and resource assessment are taught through laboratory projects using real-world data and industry standard software tools. Additional course fee applies. Prerequisite: GEOL 346 or instructor permission.

**GEOL 456. Petroleum Geology of Unconventional Resources (with laboratory). (4 Credits)**

The geology of unconventional resources, the identification and mapping of resource plays, a survey of current industry development and resource estimation techniques, and an introduction to play and project economics. Unconventional and emerging petroleum plays including shale reservoirs for oil and gas, heavy oil and bitumen deposits, coal bed methane, and hybrid reservoirs are emphasized. Projects include play mapping and analysis, rock mechanics, reservoir stimulation and EOR techniques, decline curve analysis and forecasting, and integrate sustainability and environment/stakeholder management best practices. Prerequisite: GEOL 346 or instructor permission.

**GEOL 465. Research in Basin Analysis (with laboratory). (3 Credits)**

A study of sedimentary processes and environments, including the tectonic origin of sedimentary basins. This includes the most common terrestrial and marine depositional systems and their relationships. A strong emphasis is placed on field relations and research on the sedimentary rocks of Western Colorado and the Colorado Plateau. The course is topical in nature and requires individual and/or group research projects through the study of the geologic literature, the collection of geologic data in the field, and the presentation of results. Additional course fee applies. Prerequisites: GEOL 310 and GEOL 345. Or instructor permission.

**GEOL 493. Independent Study in Geology. (1-4 Credits)**

Advanced undergraduates can engage in independent research projects under the direction of a faculty member. Topics may include any research specialty in geology or geophysics depending on the mutual interests of the student and faculty.

**GEOL 495. Geology Seminar. (1 Credit)**

A seminar where advanced undergraduate students can develop critical reading and thinking skill through discussion and presentation of research literature. Topics are chosen from the current research literature. A student may earn a maximum of four credits under this course title. Prerequisite: GEOL 310, GEOL 315, GEOL 320, or GEOL 345. Or instructor permission.

**GEOL 497. Special Topics. (1-6 Credits)****GEOL 600. Introduction to Energy Resources. (1 Credit)**

This field course provides a science-based comparison and analysis of energy budgets and resources and includes discussion of both renewable and non-renewable resources. Prerequisite: Admission to Graduate Certificate in Energy Geoscience program.

**GEOL 605. Energy Systems Geoscience. (3 Credits)**

A science-based survey of modern energy systems including fossil fuels and alternative energy sources, a comparison of the energy density of energy source options, and Earth resource dependencies of alternative Energy sources. Prerequisite: Admission to Graduate Certificate in Energy Geoscience program; or instructor permission.

**GEOL 610. Geology of Carbon and Hydrogen Storage. (3 Credits)**

This course covers the subsurface aspects of carbon and hydrogen storage and provides participants with background in site selection, site evaluation, permitting, monitoring, and ESG. Prerequisite: Admission to Graduate Certificate in Energy Geoscience program; or instructor permission.

**GEOL 615. Geothermal Resources. (3 Credits)**

Geothermal energy resources and their utilization, based on geoscience and engineering perspectives. Geoscience topics include worldwide occurrences of resources and their classification, heat and mass transfer, geothermal reservoirs, hydrothermal geochemistry, exploration methods, and resource assessment. Engineering topics include thermodynamics of water, power cycles, electricity generation, drilling and well measurements, reservoir-surface engineering, and direct utilization. Economic and environmental considerations and case studies are also presented. Prerequisite: Admission to Graduate Certificate in Energy Geoscience program or instructor permission.

**GEOL 620. Energy Minerals. (3 Credits)**

An advanced course in the geoscience of minerals and other Earth Materials crucial to alternative energy transitions, including Critical Minerals, non-hydrocarbon gasses and fluids, and the economics and methods of extraction and utilization. Prerequisite: Admission to Graduate Certificate in Energy Geoscience program or instructor permission.

**GEOL 695. Seminar in Energy Economics. (1 Credit)**

Asynchronous seminar style course in the economics of energy, fossil fuels, and alternative energy sources. Students will discuss and analyze case studies to understand the various economic considerations and drivers of the energy industry and the economic factors associated with the ongoing energy transition. Prerequisite: Admission to Graduate Certificate program or instructor permission.

**GEOL 696. Seminar in ESG. (1 Credit)**

Asynchronous seminar style course in Environment, Social and Governance factors affecting energy choices and the decisions and actions taken by energy producing entities. The course is delivered by Western faculty and invited speakers. Prerequisite: Admission to Graduate Certificate in Energy Geoscience program or instructor permission.

**GEOL 697. Special Topics. (1-3 Credits)**

Prerequisite: Admission to Graduate Certificate in Energy Geoscience program or instructor permission.