

# GEOLOGY

## Geology

The **bachelor of science major in Geology** prepares the student for a professional career and/or graduate study in the geological sciences. Graduates work to understand natural processes on Earth and other planets. They are able to apply their knowledge of forces and factors that shape the Earth to reconstruct past environments and anticipate future problems. Graduates provide essential information for solving problems for resource management, environmental protection, and public health, safety, and welfare. They work as consultants on engineering and environmental problems, explorers for new minerals and hydrocarbon resources, researchers, staff members in state and U.S. geological surveys, government regulators, teachers, writers, editors, and museum curators. Graduates are able to integrate field and laboratory data and to prepare reports. They are able to make presentations that include maps and diagrams that illustrate the results of their studies.

**Geology as a Secondary Major:** The Geology program has identified the core of 31 credits of geology courses that can complement a BS degree or major in materials engineering, civil engineering, environmental science, meteorology, or biology for students wishing to earn a secondary major in geology. This pathway to earning a Geology major allows students in these academic programs with affinity to geology to complete both programs. Students should work closely with their advisers in each department to ensure that all requirements are met. These programs prepare students for careers or graduate study in the geosciences. The requirements of the 31 credit core are below. Please review information on the department website and contact the current program head for more information and sample four year plans for the Geology as a secondary major program.

### Required courses in Geology as a Secondary Major

GEOL 100	How the Earth Works	3
or GEOL 101	Environmental Geology: Earth in Crisis	
GEOL 100L	How the Earth Works: Laboratory	1
GEOL 102	History of the Earth	3
GEOL 102L	History of the Earth: Laboratory	1
GEOL 302	Summer Field Studies	6
GEOL 315	Mineralogy and Earth Materials	3
GEOL 315L	Laboratory in Mineralogy and Earth Materials	1
GEOL 316	Optical Mineralogy	1
GEOL 356	Structural Geology and Tectonics	4
GEOL 357	Geological Mapping and Field Methods	1
GEOL 365	Igneous and Metamorphic Petrology	3

GEOL 368	Sedimentary Geology	4
<b>Total Credits</b>		<b>31</b>

**Combined Degrees:** A concurrent program is offered which combines a bachelor of science degree in geology and a master of science degree in geology. This program gives well-qualified Iowa State juniors and seniors the opportunity to begin working on the M.S. degree before completing the B.S. degree, reducing by at least one year the normal time period necessary to complete both degrees separately. Additionally, a concurrent program exists that gives highly motivated and career-focused students the opportunity to receive a bachelor of science in geology and an M.B.A. (master of business administration). Review the department website or contact Dr. Cinzia Cervato for more information regarding these programs.

### Required courses for BS in Geology include:

GEOL 100	How the Earth Works	3
or GEOL 101	Environmental Geology: Earth in Crisis	
GEOL 100L	How the Earth Works: Laboratory	1
GEOL 102	History of the Earth	3
GEOL 102L	History of the Earth: Laboratory	1
GEOL 302	Summer Field Studies	6
GEOL 315	Mineralogy and Earth Materials	3
GEOL 315L	Laboratory in Mineralogy and Earth Materials	1
GEOL 316	Optical Mineralogy	1
GEOL 356	Structural Geology and Tectonics	4
GEOL 357	Geological Mapping and Field Methods	1
GEOL 365	Igneous and Metamorphic Petrology	3
GEOL 368	Sedimentary Geology	4
GEOL 479	Surficial Processes	3
And 9 credits of geology electives		9
<b>Total Credits</b>		<b>43</b>

### Required supporting courses include:

MATH 165	Calculus I	4
MATH 166	Calculus II	4
CHEM 177	General Chemistry I	4
CHEM 177L	Laboratory in General Chemistry I	1
CHEM 178	General Chemistry II	3
CHEM 178L	Laboratory in College Chemistry II	1
PHYS 111	General Physics	5
PHYS 112	General Physics	5

And 6 additional credits of either geology electives or courses from an approved departmental list of science, engineering, and mathematical disciplines outside of geology. 6

**Total Credits** 33

No more than 9 credits in 490 may be counted toward a degree in Geology.

**Communication Proficiency requirement:** According to the university-wide Communication Proficiency Grade Requirement (<http://catalog.iastate.edu/previouscatalogs/2020-2021/collegescurricula/>), students must demonstrate their communication proficiency by earning a grade of C or better in ENGL 250. The department requires a grade of C or better in ENGL 309 or ENGL 314.

ENGL 150	Critical Thinking and Communication	3
ENGL 250	Written, Oral, Visual, and Electronic Composition	3
or ENGL 250H	Written, Oral, Visual, and Electronic Composition: Honors	
One of the following:		3
ENGL 309	Proposal and Report Writing	
ENGL 314	Technical Communication	

**Total Credits** 9

## Minor - Geology

A minor in Geology may be earned by taking 15 credits of geology coursework, including:

GEOL 100	How the Earth Works	3
or GEOL 201	Geology for Engineers and Environmental Scientists	
or GEOL 101	Environmental Geology: Earth in Crisis	
GEOL 100L	How the Earth Works: Laboratory	1
GEOL 102	History of the Earth	3
GEOL 102L	History of the Earth: Laboratory	1

Although many students will take GEOL 100 as the first course in this sequence, GEOL 101 or GEOL 201 may be taken in place of GEOL 100. Note: all students must take GEOL 100L (How the Earth Works: Laboratory). The remainder of the coursework should be at the 300 level or above. The minor must include at least 9 credits that are not used to meet any other department, college, or university requirement.

## FOUR YEAR PLAN

Below is a suggested pathway for new majors.

## Geology, B.S.

### Freshman

Fall	Credits	Spring	Credits
ENGL 150	3	GEOL 102	3
GEOL 100 or 101	3	GEOL 102L	1
GEOL 100L	1	CHEM 178	3
CHEM 177	4	CHEM 178L	1
CHEM 177L	1	MATH 166	4
MATH 165	4	Arts-and- Humanities Choice	3
LIB 160	1		
	<b>17</b>		<b>15</b>

### Sophomore

Fall	Credits	Spring	Credits
ENGL 250	3	GEOL 365	3
GEOL 315	3	Arts-and- Humanities Choice	3
GEOL 315L	1	PHYS 112	5
GEOL 316	1	Science/ Engineering/ Mathematics Choice <sup>1</sup>	3
PHYS 111	5	Elective	3-4
Science/ Engineering/ Mathematics Choice <sup>1</sup>	3		
	<b>16</b>		<b>17-18</b>

### Junior

Fall	Credits	Spring	Credits	Summer	Credits
GEOL 479	3	GEOL 356	4	GEOL 302	6
GEOL 368	4	Foreign Language/ Elective	3-4		
Geology Choice <sup>1</sup>	3	Geology Choice <sup>1</sup>	3		
Foreign Language/ Elective	3-4	Social- Science Choice	3		
GEOL 357	1				
	<b>14-15</b>		<b>13-14</b>		<b>6</b>

**Senior**

Fall	Credits	Spring	Credits
Geology Choice <sup>1</sup>		3 Elective	3
Arts-and-Humanities Choice		3 Arts-and-Humanities Choice	3
Social-Science Choice		3 Social-Science Choice	3
ENGL 309 or 314		3 Elective	3
		<b>12</b>	<b>12</b>

Students in all ISU majors must complete a three-credit course in U.S. diversity and a three-credit course in international perspectives. Check (<http://www.registrar.iastate.edu/courses/div-ip-guide.html>) for a list of approved courses. Discuss with your adviser how the two courses that you select can be applied to your graduation plan.

LAS majors require a minimum of 120 credits, including a minimum of 45 credits at the 300/400 level. At least 8 credits in the major from 300+ courses must earn grade C or better. The average grade of all courses in the major must be 2.0 or higher. You must also complete the LAS foreign-language requirement.

<sup>1</sup> Choose from list of approved courses available from an adviser or the departmental office.

## Graduate Study

The department offers programs leading to the master of science and doctor of philosophy with majors in Geology, Earth Science, and Meteorology. Students desiring a major in the above fields normally will have a strong undergraduate background in the physical and mathematical sciences. Individuals desiring to enter a graduate program are evaluated by considering their undergraduate preparation and performance along with their expressed goals in the statement of purpose. All prospective students should reach out to individual faculty members who they wish to work with prior to applying.

Programs of study are designed on an individual basis in accordance with requirements of the Graduate College and established requirements for each departmental major. Additional coursework is normally taken in complementary areas such as aerospace engineering, agronomy (soil science), chemistry, civil and construction engineering, computer engineering, computer science, engineering mechanics, environmental science, materials engineering, mathematics, mechanical engineering, microbiology, physics, or statistics. Departmental requirements provide a

strong, broad background in the major and allow considerable flexibility in the program of each individual.

A dissertation is required of all Ph.D. candidates.

M.S. students in Geology are required to complete a thesis. The M.S. in Earth Science is available to students electing the non-thesis (Creative Component) option in Geology or Meteorology. A non-thesis option is also offered for the M.S. degree in Meteorology.

Graduates in Geology specialize in a subdiscipline, but they comprehend and can communicate the basic principles of geology and supporting sciences. They possess the capacity for critical and independent thinking. They are able to write a fundable research proposal, evaluate current relevant literature, carry out the proposed research, and communicate the results of their research to peers at national meetings and to the general public. They work as consultants on engineering and environmental problems, explorers for new minerals and hydrocarbon resources, researchers, teachers, writers, editors, and museum curators.

Course requirements for the MS degree include MTEOR 542, 543, 507 or 518, 552 or 516x, and 502 or 504 or 505 or 605. In addition to the 5 required courses from this list, students must take at least 3 more credits of graduate course work in Meteorology, Agricultural Meteorology, or a field related to their research interests (students will work closely with their POS committee to determine the exact amount of structured course work required – typically this is 18-21 credits). Students without prior synoptic meteorology course work must complete MTEOR 511 and may substitute these credits in place of the required MTEOR 507 or 518 courses.

Graduates in Meteorology have a good comprehension of basic principles, a capacity for critical and independent thought and an ability to communicate effectively with scientific colleagues. They have an appropriate breadth in their understanding of meteorology with a suitable specialization. Graduates are able to undertake thorough research and explain the results in a scientifically reasonable fashion.

**Courses primarily for undergraduates:**

**GEOL 100: How the Earth Works**

(3-0) Cr. 3. F.S.SS.

How does the earth work, what is it made of, and how does it change through time? Plate tectonics, Earth materials, landforms, structures, climate, and natural resources. Emphasis on the observations and hypotheses used to interpret earth system processes. Students may also enroll in Geol 100L.

**GEOL 100L: How the Earth Works: Laboratory**

(0-2) Cr. 1. F.S.

*Prereq: Credit or enrollment in GEOL 100*

Students will gain understanding of how Earth processes affect their lives and how they affect the Earth, and of the complex nature of the Earth and its processes. They will gain a deep knowledge of the methods used to understand the time scales and rates of Earth processes also through an applied research experience on groundwater and surface water.

**GEOL 101: Environmental Geology: Earth in Crisis**

(Cross-listed with ENV S). (3-0) Cr. 3. F.S.SS.

Exploration of the interactions between humans and the geologic environment, and the consequences of those interactions, on local to global scales. Discussion of water, soil, mineral, and energy resources, pollution, climate change, and natural hazards such as earthquakes, volcanism, mass wasting, and flooding.

**GEOL 102: History of the Earth**

(3-0) Cr. 3. S.

*Prereq: GEOL 100 or GEOL 201*

Tectonic, climate, and biological evolution of the Earth. Interactions between the three are emphasized. Methods used to decipher earth history. Students majoring in geology must also enroll in Geol 102L.

**GEOL 102L: History of the Earth: Laboratory**

(0-2) Cr. 1. S.

*Prereq: Credit or enrollment in GEOL 102*

Introduction to the use of sedimentary rocks and fossils in reconstructing the Earth's history.

**GEOL 103: Age of Dinosaurs**

Cr. 1. F.

Introduction to the diversity of dinosaur species. Discussion of basic evolutionary theory and interpretation of fossil evidence. Overview of Mesozoic Earth history including paleogeographic and paleoclimate reconstructions. Course available via the World Wide Web.

**GEOL 105: Gems and Gemstones**

(2-0) Cr. 1. F.

Offered in second half of the semester. Introduction to gems and gemstones, physical and optical properties of gems and gemstones, explanation of where gems come from and how they are found, how to distinguish between synthetic and naturally occurring gems, how the value of gems are determined, and the history of famous gems.

**GEOL 106: Earth and Space Science for Elementary Education Majors**

(Cross-listed with ASTRO). (2-0) Cr. 2. F.S.

*Prereq: Major in elementary or early childhood education.*

Fundamental concepts of Earth and Space Science, including the solar system, weather and climate, water and soils, plate tectonics, and geologic hazards. Online course format.

**GEOL 106L: Earth and Space Science for Elementary Education Majors: Laboratory**

(Cross-listed with ASTRO). (0-2) Cr. 1. F.S.

*Prereq: Restricted to elementary and early childhood education majors; to be taken concurrently with GEOL 106/ASTRO 106*

Inquiry-based lab exploring fundamental concepts of Earth and Space Science, including the solar system, weather and climate, water and soils, plate tectonics, and geologic hazards. Must be taken concurrently with GEOL/ASTRO 106.

**GEOL 108: Introduction to Oceanography**

(Cross-listed with ENV S). (3-0) Cr. 3. F.

Introduction to the study of oceans and the processes that helped shape them. A major focus is on how the oceans work, with special attention on geological, chemical, and biological processes. Ocean circulation and its influence on climate. Life of the oceans. Use and misuse of ocean resources. Anthropogenic impacts on the oceanic environment.

**GEOL 111: Geological Disasters**

(Cross-listed with ENV S). (1-0) Cr. 1. F.S.SS.

Introduction to the catastrophic geologic processes with the potential to devastate human populations that continue to expand into regions at greatest risk from geologic hazards. Selected case studies and discussion of plate tectonics, climate, and earth processes explain the driving forces behind natural hazards such as earthquakes, tsunamis, volcanic eruptions, landslides, and floods.

**GEOL 112: Geoscience Orientation**

(Cross-listed with MTEOR). (1-0) Cr. 1. F.

Orientation course for students enrolled in the Earth, Wind and Fire Learning Community. Provides an introduction to Iowa State University and meteorology, geology, and Earth science programs for students enrolled in the department's learning community. Activities include academic and social activities, talks and presentations on academic success, resume writing, and study abroad, as well as research talks by faculty members.

**GEOL 113: Spring Geoscience Orientation for Earth, Wind and Fire****Learning Community**

(Cross-listed with MTEOR). (1-0) Cr. 1. S.

Spring orientation course for students enrolled in the "Earth, Wind and Fire" Learning Community. Develop and apply quantitative, data-analysis, management, and communication skills on an authentic research project in a team to focus on professionalism and resilience. Introduction to interview strategies and the importance of creating a professional image on social media. Academic and social events, plus two field trips.

**GEOL 160: Water Resources of the World**

(Cross-listed with AGRON, ENV S, MTEOR). (3-0) Cr. 3. S.

Study of the occurrence, history, development, and management of world water resources. Basic hydrologic principles including climate, surface water, groundwater, and water quality. Historical and current perspectives on water policy, use, and the role of water in society and the environment. Meets International Perspectives Requirement.

**GEOL 201: Geology for Engineers and Environmental Scientists**

(2-2) Cr. 3. F.

Introduction to Earth materials and processes with emphasis on engineering and environmental applications.

**GEOL 290: Independent Study**

Cr. 1-3. Repeatable.

*Prereq: Permission of instructor*

Independent study for freshman and sophomore students.

**GEOL 298: Cooperative Education**

Cr. R. F.S.SS.

*Prereq: GEOL 100 or GEOL 201, GEOL 100L, GEOL 102, GEOL 102L, and permission of the department cooperative education coordinator; sophomore classification*

Required of all cooperative education students. Students must register for this course prior to commencing the work period.

**GEOL 302: Summer Field Studies**

Cr. 6. SS.

*Prereq: GEOL 102, GEOL 356, GEOL 368*

Geologic mapping; structural, stratigraphic, sedimentologic, metamorphic, geomorphic, and environmental analyses. Study areas in the Bighorn Basin and Wind River Range and excursions to Yellowstone and Grand Teton National Parks. A 6-week summer field course required of all geology majors.

**GEOL 315: Mineralogy and Earth Materials**

(3-0) Cr. 3. F.

*Prereq: GEOL 100 or GEOL 201, CHEM 177*

Introduction to mineral classification, elementary crystal chemistry, crystal growth and morphology, mineral stability, and mineral associations.

**GEOL 315L: Laboratory in Mineralogy and Earth Materials**

(0-3) Cr. 1. F.

*Prereq: GEOL 100 or GEOL 201*

Mineral identification methods, especially hand-specimen identification.

**GEOL 316: Optical Mineralogy**

(1-2) Cr. 1. F.

*Prereq: GEOL 100 or GEOL 201, CHEM 177, credit or enrollment in GEOL 315*

Laboratory problems in mineral-identification methods utilizing optical microscopic techniques.

**GEOL 324: Energy and the Environment**

(Cross-listed with ENSCI, ENV S, MTEOR). (3-0) Cr. 3. S.

*Prereq: CHEM 163 or CHEM 177, MATH 140*

Exploration of the origin of Earth's energy resources and the environmental and climatic impacts of energy acquisition and consumption. Renewable and non-renewable energy resources within an Earth-system context. Various environmentally-relevant topics such as water quality and availability, habitat destruction, greenhouse-gas emissions, and health and safety hazards to wildlife and human communities.

**GEOL 356: Structural Geology and Tectonics**

(3-3) Cr. 4. S.

*Prereq: GEOL 100 or GEOL 201; PHYS 111*

Principles of stress, strain, and rheology. Brittle and ductile behavior of rocks. Mechanics of formation, description, and classification of fractures, faults, folds, foliation, and lineation. From micro-structures to tectonic processes. Laboratory includes application of learned concepts to real-world scenarios, geometrical techniques to solve structural problems.

**GEOL 357: Geological Mapping and Field Methods**

Cr. 1. S.

*Prereq: GEOL 100 or GEOL 201; PHYS 111*

Generation and interpretation of geological maps via a combination of laboratory and field exercises. Developing skills in 3D thinking, cross-section construction, stereonet analysis, field data collection, and communicating scientific results.

**GEOL 365: Igneous and Metamorphic Petrology**

(2-3) Cr. 3. S.

*Prereq: GEOL 315, GEOL 315L, GEOL 316*

Nature and origin of igneous and metamorphic rocks. Emphasis on important rock-forming environments and processes and their influence on rock characteristics. Laboratory includes thin section study of rock textures and mineralogy and the interpretation of these features.

**GEOL 368: Sedimentary Geology**

(3-3) Cr. 4. F.

*Prereq: GEOL 102*

Exploration of the interplay between weathering, sedimentation, sea-level change, tectonics, and life through time that creates sedimentary rocks and stratigraphic packages. Understanding of the historical development of sedimentary geology through the development of petrography, paleontology, deep earth sampling, geophysical technologies, and geochemistry. Field and laboratory problem sets illuminate lecture material.

**GEOL 398: Cooperative Education**

Cr. R. F.S.SS.

*Prereq: GEOL 100 or GEOL 201, GEOL 100L, GEOL 102, GEOL 102L, and permission of the department cooperative education coordinator; junior classification*

Required of all cooperative education students. Students must register for this course prior to commencing each work period.

**GEOL 402: Watershed Hydrology**

(Dual-listed with GEOL 502). (Cross-listed with ENSCI, MTEOR, NREM).

(2-3) Cr. 3. F.

*Prereq: Four courses in physical or biological sciences or engineering; junior standing*

Examination of watersheds as systems, emphasizing the surface components of the hydrologic cycle. Combines qualitative understanding of hydrological processes and uncertainty with quantitative representation. Laboratory emphasizes field investigation and measurement of watershed processes.

**GEOL 406: Geology Field Course**

Cr. 1-2. Repeatable, maximum of 2 times. F.S.

*Prereq: GEOL 100 or GEOL 201*

Weekly seminar introduces students to a selected geological region or theme that is visited on a required ten-day field excursion. Introduction to field-safety leadership.

**GEOL 409: Field Methods in Hydrogeology**

(Dual-listed with GEOL 509). (Cross-listed with ENSCI). (0-4) Cr. 3. Alt. SS., offered even-numbered years.

*Prereq: GEOL/ENSCI 402 or GEOL/ENSCI 411 or C E 473*

Introduction to field methods used in groundwater investigations. In-field implementation of pumping tests, slug tests, monitoring well installation and drilling techniques, geochemical and water quality sampling, seepage meters, minipiezometers, stream gaging, and electronic instrumentation for data collection. Field trips to investigate water resource, water quality, and remediation projects.

**GEOL 411: Hydrogeology**

(Dual-listed with GEOL 511). (Cross-listed with ENSCI). (3-2) Cr. 4. F.

*Prereq: Four courses in biological or physical sciences*

Physical principles of groundwater flow, nature and origin of aquifers and confining units, well hydraulics, groundwater modeling, and contaminant transport. Lab emphasizes applied field and laboratory methods for hydrogeological investigations.

**GEOL 412: Micropaleontology**

(Dual-listed with GEOL 512). (Cross-listed with ENSCI). Cr. 3. Alt. F., offered even-numbered years.

*Prereq: GEOL 102 and GEOL 102L*

Evolution, identification and utility of major microfossil groups from the Mesozoic to present. Focus on Cenozoic applications including biostratigraphy, paleoclimate, and paleothermometry using assemblages, stable isotopes, Mg/Ca, and molecular fossils. Laboratory includes processing and analysis of specific microfossils. Major groups covered include foraminifera, calcareous nannofossils, sponge spicules, diatoms, radiolarians, and silicoflagellates.

**GEOL 413: Applied and Environmental Geophysics**

(Dual-listed with GEOL 513). (Cross-listed with C E, ENSCI). (2-2) Cr. 3. Alt. S., offered odd-numbered years.

*Prereq: GEOL 100 or GEOL 201, algebra and trigonometry*

Seismic, gravity, magnetic, resistivity, electromagnetic, and ground-penetrating radar techniques for shallow subsurface investigations and imaging. Data interpretation methods. Lab emphasizes computer interpretation packages. Field work with seismic - and resistivity-imaging systems and radar.

**GEOL 414: Applied Groundwater Flow Modeling**

(Dual-listed with GEOL 514). (Cross-listed with ENSCI). (2-2) Cr. 3. Alt. S., offered even-numbered years.

*Prereq: GEOL 411 or C E 473; MATH 165 or MATH 181*

Introduction to the principles of modeling groundwater flow systems. Finite-difference and analytic-element methods, spreadsheet models, boundary conditions, calibration, sensitivity analysis, parameter estimation, particle tracking, and post-audit analysis. Application of MODFLOW to regional flow-system analysis. Computer laboratory emphasizes assigned problems that illustrate topics discussed in the course.

**GEOL 415: Paleoclimatology**

(Dual-listed with GEOL 515). (Cross-listed with ENSCI). (3-0) Cr. 3. Alt. S., offered odd-numbered years.

*Prereq: Four courses in biological or physical science*

Introduction to mechanisms that drive climate, including the interplay between oceanic and atmospheric circulation and fluctuation in Earth's orbital parameters. Examination and analysis of past climate records ranging from historical documentation to ecological and geochemical proxies (e.g. tree ring analysis; O and C isotopes of skeletal carbonates and soils). Dating methods used to constrain and correlate climatic periods; utility of computer models to reconstruct past climates and predict future climate change. Emphasis placed on paleoclimatology and paleoecology of the late Quaternary (last ~1 million years).

**GEOL 416: Hydrologic Modeling and Analysis**

(Dual-listed with GEOL 516). (Cross-listed with ENSCI, MTEOR). (2-3) Cr. 3. Alt. S., offered odd-numbered years.

*Prereq: Four courses in Earth science, meteorology, or engineering; junior standing*

Study of the basic principles of hydrologic modeling, including rainfall-runoff analysis, lumped and distributed modeling, conceptual and physical models, parameter estimation and sensitivity analysis, input and validation data, uncertainty analysis, and the use of models in surface water hydrology. A range of common models are applied to study hydrologic topics such as flood forecasting and land use change impacts. Previous experience with Matlab or other programming language is needed.

**GEOL 419: Aqueous and Environmental Geochemistry**

(Dual-listed with GEOL 519). (Cross-listed with ENSCI). (2-2) Cr. 3. S.

*Prereq: CHEM 178, CHEM 178L; junior classification*

Geochemistry of natural waters and water-rock interactions. Acid-base equilibria, carbonate chemistry and buffer systems, mineral dissolution and precipitation, sorption, ion exchange, and redox reactions. Introduction to thermodynamics and kinetics. Laboratory emphasizes chemical analysis of waters and computer modeling.

**GEOL 420: Mineral Resources**

(Dual-listed with GEOL 520). (2-3) Cr. 3. Alt. F., offered even-numbered years.

*Prereq: GEOL 365*

Geology and geochemistry of non-metallic and metallic ore deposits. Major processes that concentrate metals in the Earth. Geochemical conditions of ore formation using stable-isotope and fluid-inclusion studies. Laboratory emphasizes the study of metallic ores.

**GEOL 426: Stable Isotopes in the Environment**

(Dual-listed with GEOL 526). (Cross-listed with ENSCI). (3-0) Cr. 3. Alt. S., offered even-numbered years.

*Prereq: Four courses in biological or physical science*

Introduction to the theory, methods and applications of stable isotopes. Primary focus on the origin, natural abundance, and fractionation of carbon, hydrogen, oxygen, nitrogen isotopes. Applications of isotopic occurrence for elucidation of physical, chemical, biological, and environmental processes. Effects of plant physiology, photosynthesis, trophic structure, diffusion, evaporation, chemical precipitation, soil and atmospheric processes, and environmental factors on isotope abundance.

**GEOL 439: Seismic Methods in Geology, Engineering, and Petroleum Exploration**

(Dual-listed with GEOL 539). (Cross-listed with C E). (2-2) Cr. 3. Alt. S., offered even-numbered years.

*Prereq: GEOL 100 or GEOL 201, algebra and trigonometry*

Physics of elastic-wave propagation. Seismic surveys in environmental imaging, engineering, and petroleum exploration. Reflection and refraction techniques. Data collection, processing, and geological interpretation. Field work with state-of-the-art equipment.

**GEOL 444: Petroleum Geoscience and Engineering**

(Dual-listed with GEOL 544). (2-2) Cr. 3. Alt. S., offered even-numbered years.

The geoscience and engineering aspects of exploration, development, and production of hydrocarbon resources around the world, as well as the historical and legal frameworks through which the industry has developed. Broader discussions of safety, risk, uncertainty, cost, and integrity as relevant to the petroleum industry.

**GEOL 452: GIS for Geoscientists**

(Dual-listed with GEOL 552). (Cross-listed with AGRON, ENSCI). (2-2) Cr. 3. F.S.

*Prereq: GEOL 100, GEOL 201 or equivalent*

Introduction to geographic information systems (GIS) using ArcGIS Pro with particular emphasis on geoscientific data. Emphasizes typical GIS operations and analyses in the geosciences to prepare students for advanced GIS courses.

**GEOL 468: Applied Geostatistics for Geoscientists**

(Dual-listed with GEOL 568). (Cross-listed with ENSCI, MTEOR). Cr. 3. F.

*Prereq: GEOL 452, C R P 351, C R P 452, NREM 345, or NREM 446*

Introduction to geospatial data collection, analysis, interpretation, and presentation. Geospatial techniques including geographic information systems (GIS), remote sensing (RS), and global positioning systems (GPS). Study of applied geostatistical analysis (e.g., interpolation and spatial regression).

**GEOL 474: Glacial and Quaternary Geology**

(Dual-listed with GEOL 574). (2-2) Cr. 3. Alt. S., offered odd-numbered years.

*Prereq: GEOL 100 or GEOL 201 or equivalent experience*

The study of glaciers and glacial processes. Discussion of glaciology, glacial sediment transport, glacial landforms, and Quaternary history. Laboratory emphasizes topographic map interpretation and the Quaternary landscapes of Iowa.

**GEOL 479: Surficial Processes**

(Dual-listed with GEOL 579). (Cross-listed with ENSCI). (2-3) Cr. 3. F.

*Prereq: GEOL 100 and GEOL 100L; or GEOL 201; or equivalent experience.*

The study of physical processes that shape Earth's surface. Topics include weathering, sediment transport, and landform genesis with emphasis on fluvial, glacial, hillslope, eolian, and coastal processes. Applications to engineering and environmental problems. Laboratory includes topographic map interpretation and local field trips.

**GEOL 483: Environmental Biogeochemistry**

(Cross-listed with BIOL, ENSCI). Cr. 3. Alt. S., offered odd-numbered years.

*Prereq: Combined 12 credits in biology, chemistry, and physics.*

An exploration of biological, physical and geochemical impacts on the structure and function of ecosystems from local to global scales. Emphasis on the cycles of carbon, nitrogen, phosphorus, sulfur, and metals, and how these have been impacted by human activity. Topics may include biological feedbacks to climate change, microbial physiology and redox reactions, plant/soil feedbacks, terrestrial/aquatic linkages, early Earth processes and the origins of life.

**GEOL 487: Microbial Ecology**

(Dual-listed with GEOL 587). (Cross-listed with BIOL, ENSCI, MICRO). (3-0) Cr. 3. F.

*Prereq: Six credits in biology and 6 credits in chemistry*

Introduction to major functional groups of autotrophic and heterotrophic microorganisms and their roles in natural and environmental systems. Consequences of microbial activity on water chemistry, weathering, and precipitation/dissolution reactions will be emphasized.

**GEOL 488: GIS for Geoscientists II**

(Dual-listed with GEOL 588). (Cross-listed with AGRON, ENSCI). (2-2) Cr. 3.

Alt. S., offered odd-numbered years.

*Prereq: GIS course, such as GEOL 452, CRP 451, CRP 452, NREM 345, NREM 446, AE 408 or equivalent*

GIS course with focus on the spatial analysis and modeling of raster data and triangulated irregular network (TIN) data. Uses ArcGIS and various extensions, such as Spatial Analyst, 3D Analyst, and ArcScene. Includes practical exercises during lectures, lab exercises, homework assignments, and (for GEOL 588) a class project.

**GEOL 489: Survey of Remote Sensing Technologies**

(Dual-listed with GEOL 589). (Cross-listed with E E, MTEOR, NREM). (3-0) Cr. 3. F.

*Prereq: Four courses in physical or biological sciences or engineering*

Electromagnetic-radiation principles, active and passive sensors, multispectral and hyperspectral sensors, imaging radar, SAR, thermal imaging, lidar. Examples of applications. Also offered online S.

**GEOL 489L: Satellite Remote Sensing Laboratory**

(Dual-listed with GEOL 589L). (Cross-listed with E E, MTEOR, NREM). (0-3) Cr. 1. F.

*Prereq: Completion or concurrent enrollment in MTEOR/GEOL/NREM/EE 489/589*

Processing and analysis of satellite sensor data (optical and radar). Provides practical applications in an environmental context.

**GEOL 490: Independent Study**

Cr. 1-3. Repeatable, maximum of 9 credits.

*Prereq: 6 credits in geology and permission of instructor*

Independent study for senior students. No more than 9 credits of Geol 490 may be counted toward graduation.

**GEOL 495: Undergraduate Seminar**

Cr. 1. F.S.

*Prereq: Junior or senior classification*

Weekly seminar on topics of current research interest. Requires written summaries of three presentations of choice.

**GEOL 498: Cooperative Education**

Cr. R. F.S.SS.

*Prereq: Geol 100 or GEOL 201, GEOL 100L, GEOL 102, GEOL 102L, and permission of the department cooperative education coordinator; senior classification*

Required of all cooperative education students. Students must register for this course prior to commencing each work period.

**Courses primarily for graduate students, open to qualified undergraduates:**



**GEOL 502: Watershed Hydrology**

(Dual-listed with GEOL 402). (Cross-listed with ENSCI, MTEOR, NREM).  
(2-3) Cr. 3. F.

*Prereq: Four courses in physical or biological sciences or engineering; junior standing*

Examination of watersheds as systems, emphasizing the surface components of the hydrologic cycle. Combines qualitative understanding of hydrological processes and uncertainty with quantitative representation. Laboratory emphasizes field investigation and measurement of watershed processes.

**GEOL 506: Geology Field Course**

Cr. 1-2. Repeatable, maximum of 2 times. F.S.

*Prereq: Graduate classification*

Weekly seminar introduces students to a selected geological region or theme that is visited on a required ten-day field excursion. Graduate students are expected to assist in field teaching and safety leadership.

**GEOL 507: Midwestern Geology Field Trip**

Cr. 1. Repeatable, maximum of 4 times. F.

*Prereq: GEOL 365*

On-site inspection of various ore deposits, mining operations, and terrains dominated by igneous or metamorphic rocks. Offered on a satisfactory-fail basis only.

**GEOL 509: Field Methods in Hydrogeology**

(Dual-listed with GEOL 409). (Cross-listed with ENSCI). (0-4) Cr. 3. Alt. SS., offered even-numbered years.

*Prereq: GEOL/ENSCI 402 or GEOL/ENSCI 411 or C E 473*

Introduction to field methods used in groundwater investigations. In-field implementation of pumping tests, slug tests, monitoring well installation and drilling techniques, geochemical and water quality sampling, seepage meters, minipiezometers, stream gaging, and electronic instrumentation for data collection. Field trips to investigate water resource, water quality, and remediation projects.

**GEOL 511: Hydrogeology**

(Dual-listed with GEOL 411). (Cross-listed with ENSCI). (3-2) Cr. 4. F.

*Prereq: Four courses in biological or physical sciences*

Physical principles of groundwater flow, nature and origin of aquifers and confining units, well hydraulics, groundwater modeling, and contaminant transport. Lab emphasizes applied field and laboratory methods for hydrogeological investigations.

**GEOL 512: Micropaleontology**

(Dual-listed with GEOL 412). Cr. 3. Alt. F., offered even-numbered years.

*Prereq: GEOL 102 and GEOL 102L*

Evolution, identification and utility of major microfossil groups from the Mesozoic to present. Focus on Cenozoic applications including biostratigraphy, paleoclimate, and paleothermometry using assemblages, stable isotopes, Mg/Ca, and molecular fossils. Laboratory includes processing and analysis of specific microfossils. Major groups covered include foraminifera, calcareous nanofossils, sponge spicules, diatoms, radiolarians, and silicoflagellates.

**GEOL 513: Applied and Environmental Geophysics**

(Dual-listed with GEOL 413). (Cross-listed with C E, ENSCI). (2-2) Cr. 3. Alt. S., offered odd-numbered years.

*Prereq: GEOL 100 or GEOL 201, algebra and trigonometry*

Seismic, gravity, magnetic, resistivity, electromagnetic, and ground-penetrating radar techniques for shallow subsurface investigations and imaging. Data interpretation methods. Lab emphasizes computer interpretation packages. Field work with seismic - and resistivity-imaging systems and radar.

**GEOL 514: Applied Groundwater Flow Modeling**

(Dual-listed with GEOL 414). (Cross-listed with ENSCI). (2-2) Cr. 3. Alt. S., offered even-numbered years.

*Prereq: GEOL 411 or C E 473; MATH 165 or MATH 181*

Introduction to the principles of modeling groundwater flow systems. Finite-difference and analytic-element methods, spreadsheet models, boundary conditions, calibration, sensitivity analysis, parameter estimation, particle tracking, and post-audit analysis. Application of MODFLOW to regional flow-system analysis. Computer laboratory emphasizes assigned problems that illustrate topics discussed in the course.

**GEOL 515: Paleoclimatology**

(Dual-listed with GEOL 415). (Cross-listed with ENSCI). (3-0) Cr. 3. Alt. S., offered odd-numbered years.

*Prereq: Four courses in biological or physical science*

Introduction to mechanisms that drive climate, including the interplay between oceanic and atmospheric circulation and fluctuation in Earth's orbital parameters. Examination and analysis of past climate records ranging from historical documentation to ecological and geochemical proxies (e.g. tree ring analysis; O and C isotopes of skeletal carbonates and soils). Dating methods used to constrain and correlate climatic periods; utility of computer models to reconstruct past climates and predict future climate change. Emphasis placed on paleoclimatology and paleoecology of the late Quaternary (last ~ 1 million years).

**GEOL 516: Hydrologic Modeling and Analysis**

(Dual-listed with GEOL 416). (Cross-listed with ENSCI, MTEOR). (2-3) Cr. 3. Alt. S., offered odd-numbered years.

*Prereq: Four courses in earth science, meteorology, or engineering; junior standing*

Study of the basic principles of hydrologic modeling, including rainfall-runoff analysis, lumped and distributed modeling, conceptual and physical models, parameter estimation and sensitivity analysis, input and validation data, uncertainty analysis, and the use of models in surface water hydrology. A range of common models are applied to study hydrologic topics such as flood forecasting and land use change impacts. Previous experience with Matlab or other programming language is needed.

**GEOL 519: Aqueous and Environmental Geochemistry**

(Dual-listed with GEOL 419). (Cross-listed with ENSCI). (2-2) Cr. 3. S.

*Prereq: CHEM 178, CHEM 178L; junior classification*

Geochemistry of natural waters and water-rock interactions. Acid-base equilibria, carbonate chemistry and buffer systems, mineral dissolution and precipitation, sorption, ion exchange, and redox reactions. Introduction to thermodynamics and kinetics. Laboratory emphasizes chemical analysis of waters and computer modeling.

**GEOL 520: Mineral Resources**

(Dual-listed with GEOL 420). (2-3) Cr. 3. Alt. F., offered even-numbered years.

*Prereq: GEOL 365*

Geology and geochemistry of non-metallic and metallic ore deposits. Major processes that concentrate metals in the Earth. Geochemical conditions of ore formation using stable-isotope and fluid-inclusion studies. Laboratory emphasizes the study of metallic ores.

**GEOL 526: Stable Isotopes in the Environment**

(Dual-listed with GEOL 426). (Cross-listed with ENSCI). (3-0) Cr. 3. Alt. S., offered even-numbered years.

*Prereq: Four courses in biological or physical science*

Introduction to the theory, methods and applications of stable isotopes. Primary focus on the origin, natural abundance, and fractionation of carbon, hydrogen, oxygen, nitrogen isotopes. Applications of isotopic occurrence for elucidation of physical, chemical, biological, and environmental processes. Effects of plant physiology, photosynthesis, trophic structure, diffusion, evaporation, chemical precipitation, soil and atmospheric processes, and environmental factors on isotope abundance.

**GEOL 539: Seismic Methods in Geology, Engineering, and Petroleum Exploration**

(Dual-listed with GEOL 439). (Cross-listed with C E). (2-2) Cr. 3. Alt. S., offered even-numbered years.

*Prereq: GEOL 100 or GEOL 201, algebra and trigonometry*

Physics of elastic-wave propagation. Seismic surveys in environmental imaging, engineering, and petroleum exploration. Reflection and refraction techniques. Data collection, processing, and geological interpretation. Field work with state-of-the-art equipment.

**GEOL 544: Petroleum Geoscience and Engineering**

(Dual-listed with GEOL 444). (2-2) Cr. 3. Alt. S., offered even-numbered years.

The geoscience and engineering aspects of exploration, development, and production of hydrocarbon resources around the world, as well as the historical and legal frameworks through which the industry has developed. Broader discussions of safety, risk, uncertainty, cost, and integrity as relevant to the petroleum industry.

**GEOL 552: GIS for Geoscientists**

(Dual-listed with GEOL 452). (Cross-listed with AGRON, ENSCI). (2-2) Cr. 3. F.S.

*Prereq: GEOL 100, GEOL 201 or equivalent*

Introduction to geographic information systems (GIS) using ArcGIS Pro with particular emphasis on geoscientific data. Emphasizes typical GIS operations and analyses in the geosciences to prepare students for advanced GIS courses.

**GEOL 555: Environmental Soil Mineralogy**

(Cross-listed with AGRON). (3-0) Cr. 3. Alt. S., offered odd-numbered years.

*Prereq: AGRON 473, CHEM 178. Recommend: GEOL 311*

Structure and behavior of clay minerals, humic substances and biochar in soil environments, with emphasis on reactions and environmental implications.

**GEOL 558: Introduction to the 3D Visualization of Scientific Data**

(Cross-listed with COM S, HCI). (2-2) Cr. 3. Alt. F., offered even-numbered years.

*Prereq: Graduate-student standing in the mathematical or natural sciences or engineering; basic programming knowledge*

Introduction to visualizing scientific information with 3D computer graphics and their foundation in human perception. Overview of different visualization techniques and examples of 3D visualization projects from different disciplines (natural sciences, medicine, and engineering). Class project in interactive 3D visualization using the ParaView, Mayavi, TVTK, VTK or a similar system.

**GEOL 568: Applied Geostatistics for Geoscientists**

(Dual-listed with GEOL 468). (Cross-listed with ENSCI, MTEOR). Cr. 3. F.

*Prereq: GEOL 452, C R P 351, C R P 452, NREM 345, or NREM 446*

Introduction to geospatial data collection, analysis, interpretation, and presentation. Geospatial techniques including geographic information systems (GIS), remote sensing (RS), and global positioning systems (GPS). Study of applied geostatistical analysis (e.g., interpolation and spatial regression).

**GEOL 574: Glacial and Quaternary Geology**

(Dual-listed with GEOL 474). (2-2) Cr. 3. Alt. S., offered odd-numbered

years.

*Prereq: GEOL 100 or GEOL 201 or equivalent experience*

The study of glaciers and glacial processes. Discussion of glaciology, glacial sediment transport, glacial landforms, and Quaternary history. Laboratory emphasizes topographic map interpretation and the Quaternary landscapes of Iowa.

**GEOL 579: Surficial Processes**

(Dual-listed with GEOL 479). (Cross-listed with ENSCI). (2-3) Cr. 3. F.

*Prereq: GEOL 100 and GEOL 100L; or GEOL 201; or equivalent experience.*

The study of physical processes that shape Earth's surface. Topics include weathering, sediment transport, and landform genesis with emphasis on fluvial, glacial, hillslope, eolian, and coastal processes. Applications to engineering and environmental problems. Laboratory includes topographic map interpretation and local field trips.

**GEOL 587: Microbial Ecology**

(Dual-listed with GEOL 487). (Cross-listed with EEOB, ENSCI, MICRO).

(3-0) Cr. 3. F.

*Prereq: Six credits in biology and 6 credits in chemistry*

Introduction to major functional groups of autotrophic and heterotrophic microorganisms and their roles in natural and environmental systems. Consequences of microbial activity on water chemistry, weathering, and precipitation/dissolution reactions will be emphasized.

**GEOL 588: GIS for Geoscientists II**

(Dual-listed with GEOL 488). (Cross-listed with AGRON, ENSCI). (2-2) Cr. 3.

Alt. S., offered odd-numbered years.

*Prereq: GIS course, such as GEOL 452, CRP 451, CRP 452, NREM 345, NREM 446, AE 408 or equivalent*

GIS course with focus on the spatial analysis and modeling of raster data and triangulated irregular network (TIN) data. Uses ArcGIS and various extensions, such as Spatial Analyst, 3D Analyst, and ArcScene. Includes practical exercises during lectures, lab exercises, homework assignments, and (for GEOL 588) a class project.

**GEOL 589: Survey of Remote Sensing Technologies**

(Dual-listed with GEOL 489). (Cross-listed with E E, MTEOR, NREM). (3-0)

Cr. 3. F.

*Prereq: Four courses in physical or biological sciences or engineering*

Electromagnetic-radiation principles, active and passive sensors, multispectral and hyperspectral sensors, imaging radar, SAR, thermal imaging, lidar. Examples of applications. Also offered online S.

**GEOL 589L: Satellite Remote Sensing Laboratory**

(Dual-listed with GEOL 489L). (Cross-listed with E E, MTEOR, NREM). (0-3)

Cr. 1. F.

*Prereq: Completion or concurrent enrollment in MTEOR/GEOL/NREM/EE 489/589*

Processing and analysis of satellite sensor data (optical and radar).

Provides practical applications in an environmental context.

**GEOL 590: Special Topics**

Cr. 1-3. Repeatable.

*Prereq: Permission of instructor*

**GEOL 590A: Special Topics: Surficial Processes**

Cr. 1-3. Repeatable.

*Prereq: Permission of instructor*

**GEOL 590B: Special Topics: Stratigraphy**

Cr. 1-3. Repeatable.

*Prereq: Permission of instructor*

**GEOL 590C: Special Topics: Sedimentation**

Cr. 1-3. Repeatable.

*Prereq: Permission of instructor*

**GEOL 590D: Special Topics: Paleontology**

Cr. 1-3. Repeatable.

*Prereq: Permission of instructor*

**GEOL 590E: Special Topics: Petrology**

Cr. 1-3. Repeatable.

*Prereq: Permission of instructor*

**GEOL 590F: Special Topics: Structural Geology**

Cr. 1-3. Repeatable.

*Prereq: Permission of instructor*

**GEOL 590G: Special Topics: Geochemistry**

Cr. 1-3. Repeatable.

*Prereq: Permission of instructor*

**GEOL 590H: Special Topics: Hydrogeology**

Cr. 1-3. Repeatable.

*Prereq: Permission of instructor*

**GEOL 590I: Special Topics: Earth Science**

Cr. 1-3. Repeatable.

*Prereq: Permission of instructor*

**GEOL 590J: Special Topics: Mineral Resources**

Cr. 1-3. Repeatable.

*Prereq: Permission of instructor*

**GEOL 590K: Special Topics: Geophysics**

Cr. 1-3. Repeatable.

*Prereq: Permission of instructor*

**GEOL 590L: Special Topics: Mineralogy**

Cr. 1-3. Repeatable.

*Prereq: Permission of instructor*

**GEOL 590M: Special Topics: Tectonics**

Cr. 1-3. Repeatable.

*Prereq: Permission of instructor*

**GEOL 590N: Special Topics: Paleoecology and Paleoclimatology**

Cr. 1-3. Repeatable.

*Prereq: Permission of instructor*

**GEOL 590O: Special Topics: Isotope Geochemistry**

Cr. 1-3. Repeatable.

*Prereq: Permission of instructor*

**GEOL 590P: Special Topics: Computational Methods and GIS**

Cr. 1-3. Repeatable.

*Prereq: Permission of instructor*

**GEOL 590R: Special Topics: Surface Hydrology**

Cr. 1-3. Repeatable.

*Prereq: Permission of instructor*

**GEOL 590S: Special Topics: Oceanography**

Cr. 1-3. Repeatable.

*Prereq: Permission of instructor*

**GEOL 595: Graduate Seminar**

(Cross-listed with MTEOR). Cr. 1. Repeatable. F.S.

*Prereq: Senior or graduate classification*

Weekly seminar on topics of current research interest. All students seeking a graduate degree must enroll during each semester of residence. Students pursuing a non-thesis option for the M.S. in Earth Science must enroll for one semester. Offered on a satisfactory-fail basis only.

**GEOL 595A: Graduate Seminar: Presentation Required**

(Cross-listed with MTEOR). (1-0) Cr. 1. Repeatable. F.S.

*Prereq: Senior or graduate classification*

Weekly seminar on topics of current research interest. All students seeking a graduate degree must enroll during each semester of residence. Students pursuing a non-thesis option for the M.S. in Earth Science must enroll for one semester. Offered on a satisfactory-fail basis only.

**GEOL 595B: Graduate Seminar: Attendance Only**

(Cross-listed with MTEOR). Cr. R. Repeatable. F.S.

*Prereq: Senior or graduate classification*

Attendance only. Weekly seminar on topics of current research interest. All students seeking a graduate degree must enroll during each semester of residence. Students pursuing a non-thesis option for the M.S. in Earth Science must enroll for one semester. Offered on a satisfactory-fail basis only.

**GEOL 599: Creative Component**

Cr. arr. Repeatable.

**Courses for graduate students:**

**GEOL 610: Advanced Seminar**

Cr. 1-3. Repeatable. F.S.

*Prereq: Graduate standing and permission of instructor*

**GEOL 610A: Advanced Seminar: Earth Materials**

Cr. 1-3. Repeatable. F.S.

*Prereq: Graduate standing and permission of instructor*

**GEOL 610B: Advanced Seminar: Economic Geology**

Cr. 1-3. Repeatable. F.S.

*Prereq: Graduate standing and permission of instructor*

**GEOL 610C: Advanced Seminar: Environmental Geochemistry**

Cr. 1-3. Repeatable. F.S.

*Prereq: Graduate standing and permission of instructor*

**GEOL 610D: Advanced Seminar: Geophysics**

Cr. 1-3. Repeatable. F.S.

*Prereq: Graduate standing and permission of instructor*

**GEOL 610E: Advanced Seminar: Geotectonics**

Cr. 1-3. Repeatable. F.S.

*Prereq: Graduate standing and permission of instructor*

**GEOL 610F: Advanced Seminar: Hydrogeology**

Cr. 1-3. Repeatable. F.S.

*Prereq: Graduate standing and permission of instructor*

**GEOL 610G: Advanced Seminar: Surficial Processes**

Cr. 1-3. Repeatable. F.S.

*Prereq: Graduate standing and permission of instructor***GEOL 610H: Advanced Seminar: Sedimentation and Stratigraphy**

Cr. 1-3. Repeatable. F.S.

*Prereq: Graduate standing and permission of instructor***GEOL 610I: Advanced Seminar: Paleocology and Paleoclimatology**

Cr. 1-3. Repeatable. F.S.

*Prereq: Graduate standing and permission of instructor***GEOL 610J: Advanced Seminar: Isotope Geochemistry**

Cr. 1-3. Repeatable. F.S.

*Prereq: Graduate standing and permission of instructor***GEOL 610K: Advanced Seminar: Computational Methods and GIS**

Cr. 1-3. Repeatable. F.S.

*Prereq: Graduate standing and permission of instructor***GEOL 699: Research**

Cr. arr. Repeatable.

**GEOL 699A: Research: Surficial Processes**

Cr. arr. Repeatable.

**GEOL 699B: Research: Stratigraphy**

Cr. arr. Repeatable.

**GEOL 699C: Research: Sedimentation**

Cr. arr. Repeatable.

**GEOL 699D: Research: Paleontology**

Cr. arr. Repeatable.

**GEOL 699E: Research: Petrology**

Cr. arr. Repeatable.

**GEOL 699F: Research: Structural Geology**

Cr. arr. Repeatable.

**GEOL 699G: Research: Geochemistry**

Cr. arr. Repeatable.

**GEOL 699H: Research: Hydrogeology**

Cr. arr. Repeatable.

**GEOL 699I: Research: Earth Science**

Cr. arr. Repeatable.

**GEOL 699J: Research: Mineral Resources**

Cr. arr. Repeatable.

**GEOL 699K: Research: Geophysics**

Cr. arr. Repeatable.

**GEOL 699L: Research: Mineralogy**

Cr. arr. Repeatable.

**GEOL 699M: Research: Tectonics**

Cr. arr. Repeatable.

**GEOL 699N: Research: Paleocology and Paleoclimatology**

Cr. arr. Repeatable.

**GEOL 699O: Research: Isotope Geochemistry**

Cr. arr. Repeatable.

**GEOL 699P: Research: Computational Methods and GIS**

Cr. arr. Repeatable.

**GEOL 699R: Research: Surface Hydrology**

Cr. arr. Repeatable.

**GEOL 699S: Research: Geoscience Education**

Cr. arr. Repeatable.