

# GEOLOGY (GEOL)

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## **GEOL102. INTRODUCTION TO GEOLOGICAL ENGINEERING. 1.0 Semester Hr.**

(II) Presentations by faculty members and outside professionals of case studies to provide a comprehensive overview of the fields of Geology and Geological Engineering and the preparation necessary to pursue careers in those fields. A short paper on an academic professional path will be required. Prerequisite: GEGN101 or concurrent enrollment. 1 hour lecture; 1 semester hour.

## **GEOL198. SEMINAR IN GEOLOGY OR GEOLOGICAL ENGINEERING. 1-6 Semester Hr.**

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

## **GEOL199. INDEPENDENT STUDY IN GEOLOGY. 1-6 Semester Hr.**

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

## **GEOL201. PLATE TECTONICS. 3.0 Semester Hrs.**

(II) An introduction to the theory of plate tectonics as a first-order framework with which the temporal and spatial evolution of the Earth's surface and interior may be described and understood. Key topics include the mechanisms of mountain building, crustal growth and destruction, volcanism and seismicity in intraplate and plate-margin settings, and secular changes in plate tectonic processes and products over geological time. Laboratory exercises will involve individual and group exercises that utilize qualitative and quantitative analysis of geophysical, geochemical, geochronological, and petrological datasets to constrain the large-scale dynamics of the Earth. Prerequisite: GEGN101. 2 hours lecture, 3 hours lab; 3 semester hours.

## **GEOL298. SPECIAL TOPICS. 1-6 Semester Hr.**

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

## **GEOL308. INTRODUCTORY APPLIED STRUCTURAL GEOLOGY. 3.0 Semester Hrs.**

(II) Nature and origin of structural features of Earth's crust emphasizing structural controls on oil and gas entrapment. Structural patterns and associations are discussed in context of plate tectonic theories, using examples from across the globe. In class exercises and field projects in structural geometry, mapping and cross section construction and seismic reflection data interpretation. Course required of all PEGN and GPGN students. Prerequisite: GEGN101. 3 hours lecture; 3 semester hours.

## **GEOL309. STRUCTURAL GEOLOGY AND TECTONICS. 4.0 Semester Hrs.**

(I) (WI) Recognition, habitat, and origin of deformational structures related to stresses and strains (rock mechanics and microstructures) and plate tectonics. Structural development of mountain belts, rift, strike-slip and salt systems. Comprehensive field and laboratory projects use descriptive geometry, stereographic projection, structural contours, map and cross section construction, air photo interpretation, and seismic reflection data analysis. Required of Geological Engineers. Prerequisite: GEGN101, GEGN203, GEGN204, GEGN205 and GEGN206 or GPGN200. 3 hours lecture, 3 hours lab; 4 semester hours.

## **GEOL310. EARTH MATERIALS. 3.0 Semester Hrs.**

(I) Introduction to Earth Materials, emphasizing the structure, formation, distribution and engineering behavior of minerals and rocks. Structural features and processes are related to stress/strain theory and rock mechanics principles. Laboratories and field exercises emphasize the recognition, description and engineering evaluation of natural materials. Lectures and case study exercises present the knowledge of natural materials and processes necessary for mining engineering careers. Prerequisites: GEGN101. 2 hours lecture; 3 hours lab; 3 semester hours.

## **GEOL311. MINING GEOLOGY. 3.0 Semester Hrs.**

(II) Introduction to Mining Geology, emphasizing the formation, distribution, engineering behavior, exploration for and geological aspects of development of ore materials. Laboratories emphasize the recognition, description and engineering evaluation of ores and their hosts. Lectures and case study exercises present the knowledge of ores and ore-forming processes necessary for mining engineering careers. Prerequisites: GEGN101 and GEOL310 or MNGN310. 2 hours lecture; 3 hours lab; 3 semester hours.

## **GEOL314. STRATIGRAPHY. 4.0 Semester Hrs.**

(II) Lectures and laboratory and field exercises in concepts of stratigraphy and biostratigraphy, facies associations in various depositional environments, sedimentary rock sequences and geometries in sedimentary basins, and geohistory analysis of sedimentary basins. Prerequisites: GEGN101, GEGN203 or GEGN204, GEGN205. 3 hours lecture, 3 hours lab; 4 semester hours.

## **GEOL315. SEDIMENTOLOGY AND STRATIGRAPHY. 3.0 Semester Hrs.**

(I) Integrated lecture, laboratory and field exercises on the genesis of sedimentary rocks as related to subsurface porosity and permeability development and distribution for non-geology majors. Emphasis is placed on siliciclastic systems of varying degrees of heterogeneity. Topics include diagenesis, facies analysis, correlation techniques, and sequence and seismic stratigraphy. Application to hydrocarbon exploitation stressed throughout the course. Required of all PEGN students. Prerequisite: GEGN101, PEGN308. 2 hours lecture, 3 hours lab; 3 semester hours.

## **GEOL321. MINERALOGY AND MINERAL CHARACTERIZATION. 3.0 Semester Hrs.**

(I) Principles of mineralogy and mineral characterization. Crystallography of naturally occurring materials. Principles of crystal chemistry. Interrelationships among mineral structure, external shape, chemical composition, and physical properties. Introduction to mineral stability. Laboratories emphasize analytical methods, including X-ray diffraction, scanning electron microscopy, and optical microscopy. Prerequisite: GEGN101, CHGN122 or CHGN125, GEGN206. 2 hours lecture, 3 hours lab; 3 semester hours.

**GEOL398. SPECIAL TOPICS. 1-6 Semester Hr.**

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

**GEOL399. INDEPENDENT STUDY IN GEOLOGY. 1-6 Semester Hr.**

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

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**GEOL410. PLANETARY GEOLOGY. 3.0 Semester Hrs.**

Introduction to the geology of planets, moons, and other bodies within and beyond our solar system. Focusing on topics such as (a) the origin and composition of our solar system and its constituent materials, (b) geologic processes occurring on planetary surfaces (e.g. cratering) and shallow and deep interiors (e.g. volcanism, mantle convection), (c) methods of solar system exploration, and potential for resource discovery and utilization on near-neighbors and asteroids, and (d) comparative planetology (thermal histories, evidence for plate tectonics, origin and retention of atmospheres, exobiology).

**GEOL443. UNDERGRADUATE FIELD SEMINAR. 1-3 Semester Hr.**

Special advanced classroom and field programs emphasizing detailed study of some aspects of the geology of an area or region. Field studies normally conducted away from the Golden campus. Classroom course content dependent on area of study. Fees assessed for field and living expenses and transportation. 1 to 3 semester hours; may be repeated for credit.

**GEOL444. INVERTEBRATE PALEONTOLOGY. 3.0 Semester Hrs.**

(II) Fossils are the basis for establishing global correlation among Phanerozoic sedimentary rocks, and thus are critical to the reconstruction of the past 550 million years of Earth history. This is a lecture elective course that will aid in rounding out undergraduate Earth science/engineering geological knowledge. Fossil preservation, taphonomy, evolution, mass extinctions, biostratigraphy, graphic correlation, invertebrate phyla and their geologic history and evolution. Prerequisites: GEGN204, GEGN205, GEGN206. 3 hours lecture; 3 semester hours.

**GEOL470. APPLICATIONS OF SATELLITE REMOTE SENSING. 3.0 Semester Hrs.**

(II) Students are introduced to geoscience applications of satellite remote sensing. Introductory lectures provide background on satellites, sensors, methodology, and diverse applications. One or more areas of application are presented from a systems perspective. Guest lecturers from academia, industry, and government agencies present case studies focusing on applications, which vary from semester to semester. Students do independent term projects, under the supervision of a faculty member or guest lecturer, that are presented both written and orally at the end of the term. Prerequisites: PHGN200 and MATH225. 3 hours lecture; 3 semester hours.

**GEOL498. SEMINAR IN GEOLOGY OR GEOLOGICAL ENGINEERING. 1-6 Semester Hr.**

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

**GEOL499. INDEPENDENT STUDY IN GEOLOGY. 1-6 Semester Hr.**

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

**GEOL501. APPLIED STRATIGRAPHY. 4.0 Semester Hrs.**

(I) Review of basic concepts in siliciclastic and carbonate sedimentology and stratigraphy. Introduction to advanced concepts and their application to exploration and development of fossil fuels and stratiform mineral deposits. Modern facies models and sequence-stratigraphic concepts applied to solving stratigraphic problems in field and subsurface settings. Prerequisites: GEOL314 or equivalent. 3 hours lecture, 4 hours lab; 4 semester hours.

**GEOL502. STRUCTURAL METHODS FOR SEISMIC INTERPRETATION. 3.0 Semester Hrs.**

(I) A practical course that covers the wide variety of structural methods and techniques that are essential to produce a valid and coherent interpretation of 2D and 3D seismic reflection data in structurally complex areas. Topics covered include: Extensional tectonics, fold and thrust belts, salt tectonics, inversion tectonics and strike-slip fault systems. Laboratory exercises are based on seismic datasets from a wide variety of structural regimes from across the globe. The course includes a 4 day field trip to SE Utah. Prerequisite: GEOL309 and GEOL314 or GEOL315, or equivalents. 3 hours lecture/lab; 3 semester hours.

**GEOL503. INTEGRATED GEOLOGICAL INTERPRETATION OF 3D SEISMIC DATA. 3.0 Semester Hrs.**

(II) INTEGRATED GEOLOGICAL INTERPRETATION OF 3D SEISMIC DATA-A PRACTICAL COURSE IN SEISMIC INTERPRETATION OF GLOBAL DATASETS. A practical course in workstation based, integrated geological interpretation of 3D seismic reflection data. Course builds directly on the seismic interpretation skills learnt in the prerequisite GEOL502 Structural Methods for Seismic Interpretation. Key concepts developed in this course are: making internally consistent interpretations of complex 3D datasets and developing integrated geological (structural and stratigraphic) interpretations of 3D seismic data. Prerequisite: GEOL502. 3 hours lecture/lab; 3 semester hours.

**GEOL505. ADVANCED STRUCTURAL GEOLOGY. 3.0 Semester Hrs.**

(I) Advanced Structural Geology builds on basic undergraduate Structural Geology. Structures such as folds, faults, foliations, lineations and shear zones will be considered in detail. The course focuses on microstructures, complex geometries and multiple generations of deformation. The laboratory consists of microscopy, in-class problems, and some field-based problems. Prerequisites: GEGN307, GEOL309, GEGN316, GEOL321, or equivalents. 2 hours lecture, 2 hours lab, and field exercise; 3 semester hours.

**GEOL512. MINERALOGY AND CRYSTAL CHEMISTRY. 3.0 Semester Hrs.**

(I) Relationships among mineral chemistry, structure, crystallography, and physical properties. Systematic treatments of structural representation, defects, mineral stability and phase transitions, solid solutions, substitution mechanisms, and advanced methods of mineral identification and characterization. Applications of principles using petrological and environmental examples. Prerequisites: GEOL321, DCGN209 or equivalent. 2 hours lecture, 3 hours lab; 3 semester hours. Offered alternate years.

**GEOL513. HYDROTHERMAL GEOCHEMISTRY. 3.0 Semester Hrs.**

Equivalent with CHGC513,

(II) Geochemistry of high-temperature aqueous systems. Examines fundamental phase relationships in model systems at elevated temperatures and pressures. Major and trace element behavior during fluid-rock interaction. Theory and application of stable isotopes as applied to hydrothermal mineral deposits. Review of the origin of hydrothermal fluids and mechanisms of transport and deposition of ore minerals. Includes the study of the geochemistry of magmatic aqueous systems, geothermal systems, and submarine hydrothermal vents. Prerequisites: GEGN401. 2 hours lecture, 3 hours lab; 3 semester hours.

**GEOL514. BUSINESS OF ECONOMIC GEOLOGY. 3.0 Semester Hrs.**

Examines the business side of mineral exploration including company structure, fundraising, stock market rules and regulations, and legal environment. Reviews the types of minerals exploration companies, differences between mineral sectors, rules and practices of listing a minerals company on a stock exchange, and legal requirements of listing and presenting data to stockholders. The course is centered on lectures by industry representatives from the Denver area. Includes participation in a technical conference in Vancouver or Toronto and meetings with lawyers, stockbrokers, and geoscientists working in the mineral industry. Prerequisites: GEGN401. 3 hours lecture and seminar; 3 semester hours. Offered alternate years when student demand is sufficient.

**GEOL515. ADVANCED MINERAL DEPOSITS. 3.0 Semester Hrs.**

(I) Geology of mineral systems at a deposit, district, and regional scale formed by magmatic-hydrothermal, sedimentary/basinal, and metamorphic processes. Emphasis will be placed on a systems approach to evaluating metal and sulfur sources, transportation paths, and traps. Systems examined will vary by year and interest of the class. Involves a team-oriented research project that includes review of current literature and laboratory research. Prerequisites: GEGN401. 1 hour lecture, 5 hours lab; 3 semester hours. Repeatable for credit.

**GEOL517. FIELD METHODS FOR ECONOMIC GEOLOGY. 3.0 Semester Hrs.**

(II) Methods of field practices related to mineral exploration and mining. Lithology, structural geology, alteration, and mineralization vein-type precious metal deposits. Mapping is conducted both underground at the Edgar Test Mine and above ground in the Idaho Springs area. Drill core and rock chips from different deposit types are utilized. Technical reports are prepared for each of four projects. Class is run on Saturday (9 am-4 pm) throughout the semester. Prerequisites: GEGN401. 6 hours lab and seminar; 3 semester hours. Offered alternate years when student demand is sufficient.

**GEOL518. MINERAL EXPLORATION. 3.0 Semester Hrs.**

(II) Mineral industry overview, deposit economics, target selection, deposit modeling, exploration technology, international exploration, environmental issues, program planning, proposal development. Team development and presentation of an exploration proposal. Prerequisite: GEOL515, GEOL520, or equivalent. 2 hours lecture/seminar, 3 hours lab; 3 semester hours. Offered when student demand is sufficient.

**GEOL519. ABITIBI GEOLOGY AND EXPLORATION FIELD SCHOOL. 3.0 Semester Hrs.**

(II, S) Methods of field practices related to mineral exploration and mining. Regional and deposit-scale geology of Archean mineral deposits, including lode gold deposits and volcanic-hosted massive sulfide deposits. Includes mineral prospect evaluation, structural geology, physical volcanology, deposit definition, alteration mapping, mining methods, ore processing, and metallurgy. Core logging, underground stope mapping, open pit mapping, lithogeochemical sampling, and field-analytical techniques. Course involves a seminar in the spring semester that focuses on the geology and deposit types in the area to be visited. An intense 14-day field trip is run in the summer semester. Each day includes up to 4 hours of instruction in the field and 4 hours of team-oriented field exercises. Prerequisites: none. 6 hours lab and seminar; 2 semester hours in spring, 1 semester hour in summer. Offered alternate years when student demand is sufficient.

**GEOL520. NEW DEVELOPMENTS IN THE GEOLOGY AND EXPLORATION OF ORE DEPOSITS. 2.0 Semester Hrs.**

(I, II, S) Each topic unique and focused on a specific mineral deposit type or timely aspects of economic geology. Review of the geological and geographic setting of a specific magmatic, hydrothermal, or sedimentary mineral deposit type. Detailed study of the physical and chemical characteristics of selected deposits and mining districts. Theory and application of geological field methods and geochemical investigations. Includes a discussion of genetic models, exploration strategies, and mining methods. Prerequisite: GEGN401. 2 hours lecture; 2 semester hours.

**GEOL521. FIELD AND ORE DEPOSIT GEOLOGY. 3.0 Semester Hrs.**

(I, S) Field study of major mineral deposit districts inside and outside of the USA. Examines regional and deposit-scale geology. Underground and open pit mine visits and regional traverses. Topics addressed include deposit definition, structural geology, alteration mapping, mining methods, and ore processing. Course involves a seminar in the spring semester that focuses on the geology and deposit types in the area to be visited. An intense 10-14 day field trip is run in the summer semester. Prerequisites: none. 6 hours lab and seminar; 2 semester hours in spring, 1 semester hour in summer. Offered alternate years when student demand is sufficient. Repeatable for credit.

**GEOL522. TECTONICS AND SEDIMENTATION. 3.0 Semester Hrs.**

(II) Application and integration of advanced sedimentologic and stratigraphic concepts to understand crustal deformation at a wide range of spatial- and time-scales. Key concepts include: growth-strata analysis, interpretation of detrital composition (conglomerate unroofing sequences and sandstone provenance trends), paleocurrent deflection and thinning trends, tectonic control on facies distribution and basic detrital zircon and fission track analysis. Students will read a wide range of literature to explore the utility and limitation of traditional "tectonic signatures" in stratigraphy, and will work on outcrop and subsurface datasets to master these concepts. Special attention is paid to fold-thrust belt, extensional and salt-related deformation. The course has important applications in Petroleum Geology, Geologic Hazards, and Hydrogeology. Required: 2-3 fieldtrips, class presentations, and a final paper that is written in a peer-reviewed journal format. Prerequisites: GEOL314 or equivalent, and GEOL309 or equivalent. 3 hours lecture and seminar; 3 semester hours. Offered even years.

**GEOL523. REFLECTED LIGHT AND ELECTRON MICROSCOPY. 2.0 Semester Hrs.**

(I) Theoretical and practical aspects of reflected light and electron microscopy. Emphasis will be placed on applications to ore deposit exploration and research. Lecture and discussion topics will highlight both standard and new techniques and instrumentation including SEM and QEMSCAN, as well as key questions in mineral deposit genesis which can be addressed using reflected light and electron microscopy. Includes detailed study of a selected suite of samples, with emphasis on mineral identification, textural relationships, paragenetic sequences, and mineral chemistry. Course culminates in a project. Prerequisites: GEGN401. 1 hour lecture; 3 hours lab; 2 semester hours.

**GEOL524. ECONOMIC GEOLOGY. 3.0 Semester Hrs.**

(I) Provides an up-to-date synopsis of the geological settings and characteristics of the major types of magmatic, hydrothermal, and sedimentary metallic ore deposits. Emphasis is placed on the discussion of the source of metals, their transport, and the physical and chemical factors controlling the deposition of metallic ores in different geological environments. Exploration strategies are discussed for each deposit type. Laboratory consists of hand specimen study of host rock and ore mineral suites, optical microscopy, interpretation of phase diagrams, drill core logging, and open pit and underground field investigations. Lectures and laboratories are accompanied by assigned reading. 2 hours lecture; 3 hours lab; 3 semester hours.

**GEOL525. PRINCIPLES OF METAMORPHIC GEOLOGY. 3.0 Semester Hrs.**

(I) Study of metamorphic processes and products that occur on Earth at the micro- to the macro-scale. Areas of focus include (a) the nature of metamorphism in subduction zones and continental interiors, (b) the mechanisms and physico-chemical effects of fluid-rock and melt-rock interactions, (c) links between metamorphism and ore-forming processes, and (d) combining metamorphism with geochemistry, isotope geochronology, and structural geology to quantify the tectonothermal evolution of the lithosphere throughout space and time. Laboratory exercises emphasize the examination, identification, and interpretation of metamorphic minerals and microstructures in hand sample and down the microscope, and the calculation and application of thermodynamically constrained phase equilibria to describe and predict the pressure-temperature evolution of rocks and terranes. Short field excursions to local sites of metamorphic interest. Offered every other year. Prerequisites: GEOL321 and GEGN307. 2 hours lecture; 3 hours lab; 3 semester hours.

**GEOL535. LITHO ORE FORMING PROCESSES. 1.0 Semester Hr.**

Litho-geochemistry is the study of fluid-rock interaction in hydrothermal systems from a mineralogical perspective. Practical 1 credit seminar course where we review mechanisms of metal complexation, transport and mineralization processes in hydrothermal fluids and how they are connected to mineral alteration textures, mineral/rock geochemistry and mineral paragenesis. Students will combine observations of mineral assemblages in rocks and thin sections, and geochemical data to link this knowledge to field observations. The tools provided by this course will enable students to recognize alteration types, establish a mineral paragenesis, and connect alteration features with geochemical changes in bulk rock and mineral chemistry in ore deposits. An extra day will be spent in the field to visit a historic mining district in Colorado. The seminar course comprise also discussions and readings of recent articles and a brief review of hydrothermal-(magmatic) ore deposits (e.g. Greisen alteration, epithermal and porphyry systems, REE and critical metal deposits in (per)alkaline systems, Pb-Zn MVT type deposits). Prerequisite: GEOL321, GEGN401.

**GEOL540. ISOTOPE GEOCHEMISTRY AND GEOCHRONOLOGY. 3.0 Semester Hrs.**

(II) A study of the principles of geochronology and stable isotope distributions with an emphasis on the application of these principles to important case studies in igneous petrology and the formation of ore deposits. U, Th, and Pb isotopes, K-Ar, Rb-Sr, oxygen isotopes, hydrogen isotopes, and carbon isotopes included. Prerequisite: none. 3 hours lecture; 3 semester hours. Offered alternate years.

**GEOL550. INTEGRATED BASIN MODELING. 3.0 Semester Hrs.**

(I) This course introduces students to principal methods in computer-based basin modeling: structural modeling and tectonic restoration; thermal modeling and hydrocarbon generation; and stratigraphic modeling. Students apply techniques to real data set that includes seismic and well data and learn to integrate results from multiple approaches in interpreting a basin's history. The course is primarily a lab course. Prerequisite: none. A course background in structural geology, sedimentology/stratigraphy or organic geochemistry will be helpful. 1 hour lecture, 5 hours labs; 3 semester hours.

**GEOL551. APPLIED PETROLEUM GEOLOGY. 3.0 Semester Hrs.**

(II) Subjects to be covered include computer subsurface mapping and cross sections, petrophysical analysis of well data, digitizing well logs, analyzing production decline curves, creating hydrocarbon-porosity-thickness maps, volumetric calculations, seismic structural and stratigraphic mapping techniques, and basin modeling of hydrocarbon generation. Students are exposed to three software packages used extensively by the oil and gas industry. Prerequisite: GEGN438 or GEOL609. 3 hours lecture; 3 semester hours.

**GEOL552. UNCONVENTIONAL PETROLEUM SYSTEMS. 3.0 Semester Hrs.**

(II) Unconventional petroleum systems have emerged as a critical and indispensable part of current US production and potential future reserves. Each of the 5 unconventional oil and 4 unconventional gas systems will be discussed: what are they, world wide examples, required technology to evaluate and produce, environmental issues, and production/resource numbers. The oil part of the course will be followed by looking at cores from these systems. The gas part of the course will include a field trip to the Denver, Eagle, and Piceance Basins in Colorado to see outstanding outcrops of actual producing units. Prerequisites: GEGN438 or GEOL609, GEGN527. 3 hours lecture; 3 semester hours. Offered alternate years.

**GEOL553. GEOLOGY AND SEISMIC SIGNATURES OF RESERVOIR SYSTEMS. 3.0 Semester Hrs.**

(II) This course is a comprehensive look at the depositional models, log signatures, characteristics, and seismic signatures for all the main reservoirs we explore for and produce from in the subsurface. The first half is devoted to the clastic reservoirs (12 in all); the second part to the carbonate reservoirs (7 total). The course will utilize many hands-on exercises using actual seismic lines for the various reservoir types. Prerequisites: GEOL501 or GEOL314. 3 hours lecture; 3 semester hours. Offered alternate years.

**GEOL555. STRUCTURAL FIELD RESEARCH. 4.0 Semester Hrs.**

(I) This course focuses on geological field work along the Colorado Front Range through inquiry-based research and hypothesis-testing. The type of problems students will work on will vary from more applied problems (e.g. centered around the Edgar mine) or more academic/scientific orientated problems, depending on the student's interest. The class will be split up in groups of students with similar interests. In the first part of the course, we take an introductory two-day field trip, and students will review existing literature and maps and write a brief research proposal including hypotheses, tests and a work plan for the remainder of the course. The second part of the course will focus on field work. During the last part of the course, students prepare a geological map and appropriate cross sections, and a report presenting rock descriptions, structural analysis, a geological history, and interpretation of results in the context of the hypotheses posed. Prerequisites: (need previous field experience such as a field course, and a course in structural geology and one in earth materials). 2 hours lecture, 6 hours lab; 4 semester hours.

**GEOL557. EARTH RESOURCE DATA SCIENCE 1: FUNDAMENTALS. 3.0 Semester Hrs.**

A hands-on course intended to introduce basic concepts of data science as it pertains to managing surface and subsurface Earth resources, and give examples that can be used in daily geoscience workflows.

**GEOL558. EARTH RESOURCE DATA SCIENCE 2: APPLICATIONS AND MACHINE-LEARNING. 3.0 Semester Hrs.**

Introduction to specific applications (use cases) for Earth resource data science, with examples from the petroleum and minerals industries as well as water resource monitoring and remote-sensing of Earth change. Students are encouraged to provide their own datasets to enable real-world application of the concepts discussed.

**GEOL560. IMPERIAL BARREL AAPG COMPETITION CLASS. 3.0 Semester Hrs.**

(II) The course is designed for geoscience students to evaluate as a team a geophysical and geological dataset. The data set consists of seismic, well data, geochemical information, and geophysical logs. The class provides students with an insight into the hydrocarbon exploration business. A petroleum geology background is useful but not required. A team will compete at the Rocky Mountain Section competition and go onto the Annual American Association of Petroleum Geologist (AAPG) meeting competition if they win the section competition. The class is intended for graduate students only. 3 hours lecture; 3 semester hours.

**GEOL565. RISKS AND VOLUMES ASSESSMENT FOR CONVENTIONAL AND UNCONVENTIONAL PROSPECTS AND PLAYS. 3.0 Semester Hrs.**

(II) Students learn to translate geological knowledge into sound and realistic numbers and ranges for consistent risk and volume assessment of exploration prospects. Prerequisite: GEGN438. 3 hours lecture; 3 semester hours.

**GEOL570. APPLICATIONS OF SATELLITE REMOTE SENSING. 3.0 Semester Hrs.**

(II) An introduction to geoscience applications of satellite remote sensing of the Earth and planets. The lectures provide background on satellites, sensors, methodology, and diverse applications. Topics include visible, near infrared, and thermal infrared passive sensing, active microwave and radio sensing, and geodetic remote sensing. Lectures and labs involve use of data from a variety of instruments, as several applications to problems in the Earth and planetary sciences are presented. Students will complete independent term projects that are presented both written and orally at the end of the term. Prerequisites: PHGN200 and MATH225. 2 hours lecture, 2 hours lab; 3 semester hours.

**GEOL575. PETROLEUM SYSTEMS ANALYSIS. 3.0 Semester Hrs.**

(I, II, S) The goal is to learn how to analyze petroleum systems and use tools of petroleum geochemistry and basin modeling to find, appraise and produce oil and gas. Prerequisites: GEGN438. 3 hours lecture; 3 semester hours.

**GEOL585. APPLICATION OF SEISMIC GEOMORPHOLOGY. 3.0 Semester Hrs.**

(I) Seismic Geomorphology is the study of landforms imaged in 3-D seismic data, for the purpose of understanding the history, processes and fill architecture of a basin. This course will review both qualitative and quantitative approaches to interpreting and applying seismic geomorphologic observations in basin exploration and development. Examples from Gulf of Mexico, Indonesia, Trinidad, Morocco, New Zealand and other basins of the world will be used to illustrate the techniques for interpreting the depositional elements of fluvial, deltaic, shoreline, shelf, deep water clastic systems, as well as delineating geohazards, and for quantifying and using those data to predict reservoir distribution and architecture, body geometries, planning field developments and assessing uncertainty. This introductory look at the tool of seismic geomorphology is suitable for any geoscientists or engineers looking to enhance their understanding of ancient depositional systems imaged in seismic data. 3 hours lecture; 3 semester hours.

**GEOL598. SEMINAR IN GEOLOGY OR GEOLOGICAL ENGINEERING. 3.0 Semester Hrs.**

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

**GEOL599. INDEPENDENT STUDY IN GEOLOGY. 0.5-6 Semester Hr.**

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree.

**GEOL601. CORE TO OUTCROP STRATIGRAPHY. 2.0 Semester Hrs.**

(II) A seminar series integrating core and outcrop observations with class discussions. Topics range from global to regional scale tectono-stratigraphy to process sedimentology. Discussions are based on reading journal papers combined with core observations. Field trip encompasses a series of outcrop-based projects/exercises. Prerequisite: GEOL501. 2 hours seminar; 2 semester hours.

**GEOL608. HISTORY OF GEOLOGICAL CONCEPTS. 3.0 Semester Hrs.**

(I) Lectures and seminars concerning the history and philosophy of the science of geology; emphasis on the historical development of basic geologic concepts. Course is an elective for doctoral candidates in department. 3 hours lecture; 3 semester hours.

**GEOL609. ADVANCED PETROLEUM GEOLOGY. 3.0 Semester Hrs.**

(I) Subjects to be covered involve consideration of basic chemical, physical, biological and geological processes and their relation to modern concepts of oil/gas generation (including source rock deposition and maturation), and migration/accumulation (including that occurring under hydrodynamic conditions). Concepts will be applied to the historic and predictive occurrence of oil/gas to specific Rocky Mountain areas. In addition to lecture attendance, course work involves review of topical papers and solution of typical problems. 3 hours lecture; 3 semester hours. Prerequisite: GEGN438.

**GEOL610. ADVANCED SEDIMENTOLOGY. 3.0 Semester Hrs.**

(I) Keynote lectures, mixed with discussions, in-class exercises, core and field observations in a seminar series on sedimentology. Introduction to current hot topics in sedimentology, and discussions on fundamental principles. Specific topics vary yearly depending on most recent advancements and course participant's interests. Quantitative sedimentology. Applications of sedimentology. All seminars are based on reading and discussing journal papers. Field trip to a modern environment. Essays and presentations required. Prerequisite: GEOL501. Acceptable to take GEOL610 at the same time, as GEOL501. 3 hours lecture and seminar; 3 semester hours. Offered alternate years.

**GEOL611. SEQUENCE STRATIGRAPHY IN SEISMIC, WELL LOGS, AND OUTCROP. 3.0 Semester Hrs.**

(I) Keynote lectures and a seminar series on the sequence stratigraphy of depositional systems, including both siliciclastics and carbonates and how they behave in changing sea-level, tectonic subsidence, and sediment supply conditions. Application of sequence stratigraphy concepts to reflection seismic, well-log, and outcrop datasets. Field trip and report required. Prerequisite: GEOL501. 3 hours lecture and seminar; 3 semester hours.

**GEOL613. GEOLOGIC RESERVOIR CHARACTERIZATION. 3.0 Semester Hrs.**

(I) Principles and practice of characterizing petroleum reservoirs using geologic and engineering data, including well logs, sample descriptions, routine and special core analysis and well tests. Emphasis is placed on practical analysis of such data sets from a variety of clastic petroleum reservoirs worldwide. These data sets are integrated into detailed characterizations, which then are used to solve practical oil and gas field problems. 3 hours lecture; 3 semester hours. Prerequisite: GEGN438, GEOL501, GEOL505 or equivalents.

**GEOL617. THERMODYNAMICS AND MINERAL PHASE EQUILIBRIA. 3.0 Semester Hrs.**

(I) Basic thermodynamics applied to natural geologic systems. Evaluation of mineral-vapor mineral solution, mineral-melt, and solid solution equilibria with special emphasis on oxide, sulfide, and silicate systems. Experimental and theoretical derivation, use, and application of phase diagrams relevant to natural rock systems. An emphasis will be placed on problem solving rather than basic theory. Prerequisite: DCGN209 or equivalent. 3 hours lecture; 3 semester hours. Offered alternate years.

**GEOL621. PETROLOGY OF DETRITAL ROCKS. 3.0 Semester Hrs.**

(II) Compositions and textures of sandstones, siltstones, and mudrocks. Relationship of compositions and textures of provenance, environment of deposition, and burial history. Development of porosity and permeability. Laboratory exercises emphasize use of petrographic thin sections, x-ray diffraction analysis, and scanning electron microscopy to examine detrital rocks. A term project is required, involving petrographic analysis of samples selected by student. Pre-requisites: GEGN206, GEOL321 or equivalent. 2 hours lecture and seminar, 3 hours lab; 3 semester hours. Offered on demand.

**GEOL624. CARBONATE SEDIMENTOLOGY AND PETROLOGY. 3.0 Semester Hrs.**

(I) Processes involved in the deposition of carbonate sediments with an emphasis on Recent environments as analogs for ancient carbonate sequences. Carbonate facies recognition through bio- and lithofacies analysis, three-dimensional geometries, sedimentary dynamics, sedimentary structures, and facies associations. Laboratory stresses identification of Recent carbonate sediments and thin section analysis of carbonate classification, textures, non-skeletal and biogenic constituents, diagenesis, and porosity evolution. 2 hours lecture/seminar, 2 hours lab; 3 semester hours. Prerequisite: GEOL321 and GEOL314.

**GEOL628. ADVANCED IGNEOUS PETROLOGY. 3.0 Semester Hrs.**

(I) Igneous processes and concepts, emphasizing the genesis, evolution, and emplacement of tectonically and geochemically diverse volcanic and plutonic occurrences. Tectonic controls on igneous activity and petrochemistry. Petrographic study of igneous suites, mineralized and non-mineralized, from diverse tectonic settings. Prerequisites: GEOL321, GEGN206. 2 hours lecture, 3 hours lab; 3 semester hours. Offered alternate years.

**GEOL642. FIELD GEOLOGY. 1-3 Semester Hr.**

(S) Field program operated concurrently with GEGN316 field camp to familiarize the student with basic field technique, geologic principles, and regional geology of Rocky Mountains. Prerequisite: Undergraduate degree in geology and GEGN316 or equivalent. During summer field session; 1 to 3 semester hours.

**GEOL643. GRADUATE FIELD SEMINARS. 1-3 Semester Hr.**

(I, II, S) Special advanced field programs emphasizing detailed study of some aspects of geology. Normally conducted away from the Golden campus. Prerequisite: Restricted to Ph.D. or advanced M.S. candidates. Usually taken after at least one year of graduate residence. Background requirements vary according to nature of field study. Fees are assessed for field and living expenses and transportation. 1 to 3 semester hours; may be repeated for credit.

**GEOL645. VOLCANOLOGY. 3.0 Semester Hrs.**

(I, II, S) Assigned readings and seminar discussions on volcanic processes and products. Principal topics include pyroclastic rocks, craters and calderas, caldron subsidence, diatremes, volcanic domes, origin and evolution of volcanic magmas, and relation of volcanism to alteration and mineralization. Petrographic study of selected suites of lava and pyroclastic rocks in the laboratory. 1 hour seminar, 6 hours lab; 3 semester hours. Prerequisite: none.

**GEOL653. CARBONATE DIAGENESIS AND GEOCHEMISTRY. 3.0 Semester Hrs.**

(II) Petrologic, geochemical, and isotopic approaches to the study of diagenetic changes in carbonate sediments and rocks. Topics covered include major near-surface diagenetic environments, subaerial exposure, dolomitization, burial diagenesis, carbonate aqueous equilibria, and the carbonate geochemistry of trace elements and stable isotopes. Laboratory stresses thin section recognition of diagenetic textures and fabrics, x-ray diffraction, and geochemical/isotopic approaches to diagenetic problems. Prerequisites: GEOL624. 2 hours lecture; 3 hours lab; 3 semester hours.

**GEOL660. CARBONATE RESERVOIRS - EXPLORATION TO PRODUCTION ENGINEERING. 3.0 Semester Hrs.**

Equivalent with PEGN660,

(II) An introduction to the reservoir characterization of carbonate rocks, including geologic description, petrophysics, and production engineering. Develops an understanding of the integration of geology, rock physics, and engineering to improve reservoir performance. Application of reservoir concepts in hands-on exercises that include reflection seismic, well-log, and core data. 3 hours lecture; 3 semester hours.

**GEOL698. SPECIAL TOPICS. 6.0 Semester Hrs.**

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

**GEOL699. INDEPENDENT STUDY IN GEOLOGY. 0.5-6 Semester Hr.**

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

**GEOL707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.**

(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.