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SM 319. Penn in the Alps. Reto Giere. 10 day summer program

The aim of this 10-day summer program is to introduce inquisitive students to the nature, culture, history and languages of the European Alps in Switzerland and Italy. We will be exploring the geology of the Alps and how it influences the development of wildlife, flora, history, religion, culture and of entire regions, how humans have altered the environment, and how humans respond to climate change in Alpine ecosystems. We will learn how to observe nature in a spectacular landscape, visit cultural sites off the beaten track and explore some of the well-known localities, such as Zurich, Valtellina, Bellinzona, and the Engadine.

330. (GEOL634) Chemical Oceanography: Role of the Ocean in the Global Carbon Cycle. Murray.

The field of chemical oceanography has evolved from one of discovery to an interdisciplinary science that uses chemical distributions to understand physical, biological, geological and chemical processes in the sea. The study of chemical oceanography includes much of the background required to understand the global carbon cycle on all time scales. In this course, the main unifying science Theme #1 is The Global Carbon Cycle. The syllabus is organized into three broad subthemes. Theme #2. What controls the composition of seawater and are humans changing it? Theme #3. What are the chemical constraints on biological production in the ocean? Theme #4. What is the fate of organic matter produced by biological production and what are the impacts of this organic matter on the ocean and underlying sediments?

ENVIRONMENTAL STUDIES (ENVS)-----Note: Listings for GEOL follow ENVS 999

109. Introduction to Geotechnical Science. (A) Physical World Sector. All classes. Omar.

Open to architectural and engineering majors as well as Ben Franklin Scholars. Field trips. Relations of rocks, rock structures, soils, ground water, and geologic agents to architectural, engineering, and land-use problems.

SM 096. Field Approaches to Understanding the Earth & Environmental Science. (A) Scatena. Corequisite(s): GEOL 100 or GEOL 109 highly recommended.This is a field based course. Weekend fieldtrips are required.

Understanding landscapes and the relationships between the natural world and society is fundamental to the natural sciences, architecture, medicine and public health, real estate and finance, urban studies and a range of other disciplines. The primary goal of this course is to expose students to the science of reading landscapes and disciplines that are founded in observation and hypothesis testing in the field. In addition, the course will orient incoming students to the physical environment in which they will be living while they are at Penn.

The course will be centered around lectures and discussions that are based on ten or more field trips that will take place on weekends and afternoons throughout the semester. The trips will be led by faculty members and will cover topics of plate tectonics, bedrock and surficial geology, geomorphology, hydrology, environmental geology, pollution and field ecology.

L/R 100. Introduction to Geology. (A) Physical World Sector. All classes. Omar. Field trips required.

An introduction to processes and forces that form the surface and the interior of the Earth. Topics include, changes in climate, the history of life, as well as earth resources and their uses.

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L/R 103. Natural Disturbances and Human Disasters. (A) Physical World Sector. All classes. Scatena.

Natural disturbances play a fundamental role in sculpturing landscapes and structuring natural and human-based ecosystems. This course explores the natural and social science of disturbances by analyzing their geologic causes, their ecological and social consequences, and the role of human behavior in disaster reduction and mitigation. Volcanoes, earthquakes, floods, droughts, fires, and extraterrestrial impacts are analyzed and compared.

111. Geology Laboratory. (C) Omar.Prerequisite(s): GEOL 100 preferably taken concurrently. Field trips required.

Hands-on study of earth materials and processes. Identification and interpretation of rocks, minerals and fossils. Topographic and geologic maps. Evolution of landscapes. Field trips lead to a synthesis of the geologic history of southeastern Pennsylvania.

L/R 125. Earth and Life Through Time. (C) Physical World Sector. All classes. Willingbring.

Origin of Earth, continents, and life. Continental movements, changing climates, and evolving life.

L/R 130. Oceanography. (B) Physical World Sector. All classes. Dmochowski.

The oceans cover over 2/3 of the Earth's surface. This course introduces basic oceanographic concepts such as plate tectonics, marine sediments, physical and chemical properties of seawater, ocean circulation, air-sea interactions, waves, tides, nutrient cycles in the ocean, biology of the oceans, and environmental issues related to the marine environment.

201. (GEOL521, GEOL531) Mineralogy. (A) Omar.Prerequisite(s): GEOL 100 and CHEM 001 or 101.

Crystallography, representative minerals, their chemical and physical properties. Use of petrographic microscope in identifying common rock-forming minerals in thin section.

205. (GEOL405) Paleontology. (B) Living World Sector. All classes. Pfefferkorn. Two field trips required.

Geologic history of invertebrates and their inferred life habits, paleoecology, and evolution. Introduction to paleobotany and vertebrate paleontology.

206. (GEOL506) Stratigraphy. (A) Jerolmack.Prerequisite(s): GEOL 100 or permission of instructor. Two field trips, field project

Introductory sedimentary concepts, stratigraphic principles, depositional environments, and interpretation of the rock record in a paleoecological setting.

208. (GEOL630) Structural Geology. (B) Phipps.Prerequisite(s): GEOL 100 and 111; PHYS 150 strongly recommended. Three field trips required

Introduction to deformation as a fundamental geologic process. Stress and strain; rock mechanics. Definition, measurement, geometrical and statistical analysis, and interpretation of structural features. Structural problems in the field. Maps, cross-sections, and three-dimensional visualization; regional structural geology.

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299. Independent Study. (C) Staff.Prerequisite(s): Permission of department. May be repeated for credit

Directed study for individuals or small groups under close supervision of a faculty member.

305. (GEOL545) Earth Surface Processes. (B) Physical World Sector. All classes. Jerolmack.Prerequisite(s): ENVS 200, GEOL 100, or permission of the instructor. This course includes two required weekend field trips, and a hands-on laboratory.

Patterns on the Earth's surface arise due to the transport of sediment by water and wind, with energy that is supplied by climate and tectonic deformation of the solid Earth. This course presents a treatment of the processes of erosion and deposition that shape landscapes. Emphasis will be placed on using simple physical principles as a tool for (a) understanding landscape patterns including drainage networks, river channels and deltas, desert dunes, and submarine channels, (b) reconstructing past environmental conditions using the sedimentary record, and (c) the management of rivers and landscapes under present and future climate scenarios. The course will conclude with a critical assessment of landscape evolution on other planets, including Mars.

317. (GEOL417) Petrology and Petrography. (B) Omar.Prerequisite(s): GEOL 201. Two field trips

Occurrences and origins of igneous and metamorphic rocks; phase equilibria in heterogeneous systems. Laboratory study of rocks and thin sections as a tool i interpretation of petrogenesis.

405. (GEOL205) Paleoecology. (A) Natural Science & Mathematics Sector. Class of 2010 and beyond. Bordeaux.Prerequisite(s): GEOL 205 or permission of instructor.

Relationship of fossil assemblages to life assemblages; structure of ancient communities, and interaction of organisms with each other and with the physica environment; evolution of communities.

318. Glaciers,Ice & Climate. Goldsby.Prerequisite(s): Students should have basic knowledge of Calculus. MATH 114 or equivalent.

All forms of frozen water at Earth's surface define the cryosphere. These icy environmnets are an integral part of the global climate system, with important linkages and feedbacks resulting from their influences on surface energy and moisture fluxes, clouds, precipitation, hydrology, and circulation in the atmosphere and oceans. This course will survey the various components of the cryosphere and their interactions with climate, with a strong emphasis on the dynamics of glaciers and ice sheets. Broad topics to be covered are 1)the rudimentary mechanics of glacier and ice sheet flow, 2)fast-flowing ice streams and factors limiting their motion, 3)ice-quakes and their origins, 4)the nature of climate data recorded in natural ice bodies, 5)the influence of climate on the stability of ice sheets and glaciers, and 6)glacier-like flow on other planetary bodies. This will be a lecture-based course with written assignmnets and problems sets.

401. Environmental Geology. (M) Willig.

The purpose of this course is to better understand the interactions of humans and the environment through an examination of geologic processes and features as they influence, and are influenced, by human activities. the ultimate goal of such study is to make better land use decisions. Following a review of some basic geologic concepts, we will study hazardous geologic processes including; volcanic eruptions, earthquakes, river flooding,coastal flooding and erosion, landslides, and subsidence. Next, we will discuss environmental impacts associated with the use of fossil fuels, water, and soils. The course will conclude with student presentations of selected topics in environmental geology.

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SM 409. (GEOL509) Intro to Remote Sensing. Dmochowski.Prerequisite(s): PHYS151 and MATH114 or equivalent are preferable, but not required. See instructor.

This course will introduce students to the principles of remote sensing, characteristics of remote sensors, and remote sensing applications. Image acquisition, data collection in the electromagnetic spectrum, and data set manipulations for earth and environmental science applications will be emphasized. We will cover fundamental knowledge of the physics of remote sensing; aerial photographic techniques; multispectral, hyperperspectral, thermal, and other image analysis. Students will pursue an independent research project using remote sensing tools, and at the end of the semester should have a good understanding and the basic skills of remote sensing.

411. Intro Soil Science. Plante.Prerequisite(s): GEOL 100 or equivalent.

Soil is considered the "skin of the Earth", with interfaces between the lithosphere, hydrosphere, atmosphere, and biosphere. It is a mixture of minerals, organic matter, gases, liquids and a myriad of organisms that can support plant life. As such, soil is a natural body that exists as part of the environment. This course will examine the nature, properties, formation and environmental functions of soil.

417. (GEOL317) Advanced Petrology. (A) Omar.Prerequisite(s): GEOL 317.

Chemistry, physics, phase equilibria, microscope study in igneous and metamorphic petrology.

418. Geochemistry. (M) Giere.

This course provides a comprehensive introduction to theory and applications of chemistry in the earth and environmental sciences. Theory covered will include atomic structure, chemical bonding, cosmic abundances, nucleosynthesis,radioactive decay, dating of geological materials, stable isotopes, acid-base equilibria, salts and solutions, and oxidation-reduction reactions. Applications will emphasize oceanography, atmospheric sciences and environmental chemistry, as well as other topics depending on the interests of the class. Although we will review the basics, this course is intended to supplement, rather than to replace, courses offered in the Department of Chemistry. It is appropriate for advanced undergraduate as well as graduate students in Geology, Environmental Science, Chemistry and other sciences, who wish to have a better understanding of these important chemical processes.

420. Introduction to Geophysics. (M) Doheny/Bechtel.Prerequisite(s): GEOL 100 or 109, two semesters Math and Physics, and/or instructor's permission.

This course will cover the application of geophysical investigation techniques to problems of the earth's plantary structure, local subsurface structure and mineral prospecting. The topics will include principles of geophysical measurements and interpretation with emphasis on gravity measurement, isostasy, geomagnitism, sesmic refraction and reflection,electrical prospecting, electromagnetics and groung radar.

421. (GEOL541) Elemental Cycling in Global Systems. (B) Plante.Prerequisite(s): ENVS 200, GEOL 100, or permission of the instructor.

Humans have an enormous impact on the global movement of chemical materials. Biogeochemistry has grown to be the principal scientific discipline to examine the flow of elements through the global earth systems and to examine human impacts on the global environment. This course will introduce and investigate processes and factor controlling the biogeochemical cycles of elements with and between the hydrosphere, lithosphere, atmosphere and biosphere. Students will apply principles learned in lectures by building simple computer-based biogeochemical models.

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477. Introduction to Vertebrate Paleontology. (M) Dodson.Prerequisite(s): GEOL 100, BIOL101, GEOL205 or similar course.

422. (GEOL622) Rates and Dates: Applications and Methods of Modern Geochronology. (C) Willenbring.Prerequisite(s): Students need GEOL100 or an equivalent course or a solid background in physical sciences, including either chemistry or physics.

This course is designed to give advanced undergraduate students and graduate students an understanding of the science behind numerical dating techniques in geological and archaeological contexts. This course will provide a background in the physics of radioactive decay and natural radiation sources. We will also cover various radiometric dating methods, and non-radiometric alternatives for younger samples. Numerous case studies involving questions of both geological and archaeological importance will be studied in this context. This class will cater to students interested applying chronologic tools to the areas of archeology, physical anthropology, soil science, tectonics, sea level change, climate change, land use change and ocean processes.

423. (GEOL623) ADVANCED METHODS IN COSMOGENIC NUCLIDES. (C) Prerequisite(s): GEOL 422/622 or by permission of the instructor. Corequisite(s): Earth is constantly bombarded with primary cosmic rays, high energy charged particles that interact with atoms in the atmosphere, producing a cascade of secondary particles. in turn, interact and reduce their energies in many reactions as they pass through the atmosphere. By the time the cosmic ray cascade reaches the surface of Earth, it is primarly composed of neutrons which produce nuclides in materials such as rocks and sediment at the Earth's surface. Most of these cosmogenic nuclides are produced by neutron spallation within the upper meter of mass. Using certain cosmogenic radionuclides, scientists can datehow long a particular surface has been exposed, how long a certain piece of material has been burried, or how quickly a location or drainage basin is eroding. The basic principle is that these radionuclides are produced at a known rate, and also decay at a known rate. In this course, students will learn the details and history of cosmic ray production rate estimates over .

Earth is constantly bombarded with primary cosmic rays, high energy charged particles that interact with atoms in the atmosphere, producing a cascade of secondary particles. These particles, in turn, interact and reduce their energies in many reactions as they pass through the atmosphere. By the time the cosmic ray cascade reaches the surface of the Earth, it is primarily composed of neutrons which produce nuclides in materials such as rocks and sediment at the Earth's surface. Most of these cosmogenic nuclides are produced by neutron spallation within the upper meter of mass. Using certain cosmogenic radionuclides, scientists can date how long a particular surface has been exposed, how long a certain piece of material has been buried, or how quickly a location or drainage basin is eroding. The basic principle is that these radionuclides are produced at a known rate, and also decay at a known rate. In this course, students will learn the details and history of cosmic ray production rate estimates over the globe and through geologic time. A primer to the various accepted scaling methods will be discussed as well as age and erosion rate calculations and advanced and new applications.

428. Introduction to Isotope Geochemistry. (A) Giere.

498. (ENVS498) Senior Thesis. (F) Giegengack.Prerequisite(s): GEOL400-level and declaration of the EASC major. The Earth Science major, as of the fall of 2008, requires 1 semester of GEOL399 and two semesters of GEOL498.

The culmination of the Earth Science major. Students, while working with an advisor in their concentration, conduct research and write a thesis.

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501. Pleistocene Geology. (M) Giegengack.Prerequisite(s): GEOL 100 or equivalent.

Origin, extent in space and time, and effect on geologic processes of Late Cenozoic climatic change; Pleistocene stratigraphy in different parts of the world.

503. Earth Systems and Earth Hazards. (B) Phipps.Prerequisite(s): Geology 100 (introductory physical geology,) or permission of the instructor. The course is intended for Masters' students in Environmental Studies and Applied Geology, as well as upperclass geology majors.

This course will examine the hazards that arise from living on an active planet from a large-scale systems standpoint. We will briefly survey the Earth's major systems, emphasizing energy generation, storage, and flow within the Earth, and then proceed to an examination of the hazards that result. This will include earthquakes and tsunamis, volcanic eruptions, river and coastal flooding, and hurricanes, tornadoes, and other major storms. We will touch briefly on global warming and other current topics.

SM 508. The Geology and Geography of Energy Resources. (M) Phipps.Prerequisite(s): Geol100 or equivalent is preferred. Possible field trips.

This course will survey the way geology controls the formation and location of energy resources. Questions we'll address include, "How are oil and gas fields formed?", "Why does the Middle East have so much oil?", "What are the best locations in the US for wind and solar energy generation, and why?". We will discuss hydrocarbon, nuclear, solar, wind, and tidal energy sources.

SM 509. (GEOL409) Intro to Remote Sensing. Dmochowski.Prerequisite(s): PHYS151 and MATH114 or equivalent are preferable, but not required. See instructor.

This course will introduce graduate students to the principles of remote sensing, characteristics of remote sensors, and remote sensing applications. Image acquisition, data collection in the electromagnetic spectrum, and data set manipulations for earth and environmental science applications will be emphasized. We will cover fundamental knowledge of the physics of remote sensing; aerial photographic techniques; multispectral, hyperspectral, thermal, and other image analysis. Students will pursue an independent research project using remote sensing tols, and at the end of the semester should have a good understanding and the basic skills of remote sensing. Expectations for the graduate student independent research projects will be at the graduate level and can relate to their capstone or Ph.D. thesis research topics.

521. (GEOL201, GEOL531) Mineralogy of Rock Preservation. (A) Omar. Graduate School of Fine Arts students only.

Advanced crystallography, representative minerals, their chemical and physical properties, with emphasis on building stone preservation. Use of petrographic microscope in identifying common rock-forming minerals in thin section.

510. Geophysical Fluid Dynamics. Nathan Paldor.Prerequisite(s): Math 114 or equivalent or permission by the instructor.

This class will discuss physical principles fundamental to the theoretical,observational, and experimental study of geophysical fluids, the equations of motion for rotating fluids; hydrostatic and Boussinesq approximations; circulation theorem; conservation of potential vorticity; scale analysis, geostrophic wind, quasigeostrophic system; wave theory and applications, flow instabilities, geophysical boundary layers. Depending on student interest, the class will be adapted to include applications from Oceanography, Meteorology, Geophysics or Engineering.

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511. Soil Science w Lab. (A) Plante.Prerequisite(s): GEOL 100 or equivalent. Field trips

Soil is considered the "skin of the earth", with interfaces between the lithosphere, hydrosphere, atmosphere, and biosphere. It is the mixture of minerals, organic matter, gases, liquids and a myriad of organisms that can support plant life. As such, soil is a natural body that exists as part of the environment. This course will examine the nature, properties, formation and environmental functions of soil. In addition to lectures, the course includes biweekly labs or field trips, and a multi-day field trip to held during Spring Break.

SM 515. Evolution/Revolution of Land Ecosystems. (M) PFEFFERKORN.

Origin and diversification of land ecosystems. Interaction between plants and animals. Effects of past climatic change and other external factors. The importance of past changes in land ecosystems to our understanding of current global change.

SM 527. Applied Techniques in Paleontology. (B) Manning.Prerequisite(s): Geol205 or equivalent is suggested.

The development of surveying, imaging, and analytical techniques has facilitated many advances in the field of paleontology in recent years. This course will review the application of new and existing technologies to the analysis and interpretation of fossil remains. The research areas to be reviewed include: Light Detection and Range (LiDAR) applications to trackway and body mass estimates in dinosaurs; soft tissue preservation in the fossil record and the techniques to recognize and identify biomarkers; dinosaur locomotor reconstruction (using Gaitsym); geochemical and elemental analysis (particularly specializing in synchotron based techniques); application of high-performance computing; mechanical analysis of biomaterials (both extant and extinct); finite element analysis and the application of high resolution X-ray tomography. Given the fluid nature of developing applications, the course will include additional techniques which are a function of the research program evolving between the Universities of Manchester and Pennsylvania.

528. Aqueous Geochemistry. (M) Andrews.Prerequisite(s): GEOL 100 Intro to Geology or permission of instructor.

Chemical composition and interactions of soils and soil water with applications to current problems.

531. (GEOL201, GEOL521) Advanced Mineralogy. (A) Omar.

Advanced crystallography, representative minerals, their chemical and physical properties. Use of petrographic microscope in identifying common rock-forming minerals in thin section.

540. Geotectonics. (M) Phipps.Prerequisite(s): GEOL 205, 206, 208, 317 and 420, or permission of instructor. Field trip

Bulk structure of the Earth. Plate tectonics and plate boundaries. Plumes, rifting, and intraplate tectonics. Geotectonics and seismicity.

541. (GEOL421) Elem Cycling in Global. (B)

SM 546. Basin Analysis. (M) Phipps.

599. Independent Study. (C) Staff.

Directed study for individuals or small groups under supervision of a faculty member.

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602. Geotechnics: Introduction to Geotechnical Engineering. (B) Doheny.

The course begins with a study of the Earth's composition, the formation of soil materials by the weathering process (Physical and Chemical), and a discussion of soil mineralogy, with particular emphasis on the clay minerals. Following this introduction, soil classification systems and physical properties of soils will be presented, as well as the State of Stress in a Soil Mass together with Seepage Theory and Groundwater Flow. The technical portion of the course will conclude with the development of Consolidation Theory and Analyses, Shear Strength Theory, Lateral Earth Pressure Theory and Application, and Slope Stability Analysis.

The course will conclude with the presentation of two Case History Sessions, presenting applications of Geotechnical Engineereing Practice and the influence of the Geologic setting.

SM 603. Luquillo Critical Zone Research Seminar. (M) Scatena.Prerequisite(s): This course is designed for PhD and MS students working on their Luquillo projects.

Classic primary readings on the geology and ecology of the Luquillo mountains and surrounding regions will be read and discussed in sessions led by EES Faculty and graduate students who are involved in Luquillo CZ research.

604. Geostatistical Analysis. (A) Vann.Prerequisite(s): STAT 101 or equivalent statistics course; BioL 556 suggested or other Inferential Statistics courses, covering uni- and multi-variate techniques.

Univariate and multivariate approaches to the analysis of spatial correlation and variability. Many disciplines, including geology, ecology and the environmental sciences regularly need to analyze and make predictions from data that is spatially autocorrelated. Mine reserve estimation, pollutant dispersal and the use of randomization tests in ecology are examples of where spatial statistics may be applied.

SM 606. Topics in Sedimentary Petrology and Stratigraphy. (M) Pfefferkorn.Prerequisite(s): GEOL 205, 206, 706 or permission of instructor.

Analysis of selected paleoenvironmental, stratigraphic, and sedimentological problems in the field and laboratory.

ADVANCED STRATIGRAPHY: In-depth study of sedimentology, stratigraphic principles, and paleoecological interpretation based on the rock record.

SEDIMENTARY PETROLOGY: Interpretation of rocks using microscopic techniques. Students will make thin-sections of various sedimentary rock types collected from regional depositional basins (Geol 706). Diagenetic, syn- and post-depositional processes will be investigated.

SM 611. Field Study of Soils. (B) Johnson.Prerequisite(s): GEOL 511 or permission of instructor. All day field trips

Processes of soil development in a variety of temperate environments. Effects of lithology and climate on soil properties.

SM 614. Regional Geology and Ecology of North America. (A) Phipps.

SM 615. Advanced Vertebrate Paleontology Seminar. (C) Dodson. May be repeated for credit

Topics in vertebrate paleontology and paleoecology.

616. Geology of the Carboniferous Period. (M) Pfefferkorn.

Paleogeography, biogeography, stratigraphy, paleoclimatology, flora, and fauna of the Carboniferous Period.

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SM 617. Topics in Sedimentology. (M) Prerequisite(s): GEOL 206 or permission of instructor.

CLIMATE CHANGES THRU TIME: Issues of anthropologenically-induced climate changes are hotly debated. However, it is not possible to make meaningful predictions of future climates without understanding the forces that have controlled past climates. This course will review the geologic evidence for past climate changes and discuss processes that affect global climate changes. It will involve analysis and modeling of various sedimentary environments, systems, and processes.

ANCIENT TERRESTRIAL ENVIRONMENTS: Multi-disciplinary approaches and techniques that enable the extraction of comprehensive information (weathering, deposition, diagenisis, tectonics) from ancient continental deposits. The goal is the reconstruction of integrated environmental, geographic, and climatic conditions for selected time slices.

SM 618. Geochemistry Seminar. (C) Staff.

Topics in geochemistry.

619. Instrumentation for the Geosciences. (B) Vann.

An introduction to the theory, operation and application of modern analytical instrumentation used in geo- and environmental sciences. Primarily focused on laboratory instrumentation such as mass spectroscopy, elemental analyses and x-ray techniques. Some field instruments will be introduced as well. Students will be expected to develop projects utilizing the various instruments.

SM 620. Geophysics Seminar. (M) Staff.

Topics in solid Earth geophysics.

SM 621. Advanced Biogeochemistry. (M) Plante.Prerequisite(s): Geol421 or permission from instructor.

Through close readings from the primary literature, students will undertake an in-depth study of biogeochemical cycling and human disturbance of biogeochemical cycles. Special emphasis will be on carbon and nitrogen cycling in terrestrial ecosystems, but may include other topics based on the interests of enrolled students.

623. (GEOL423) ADV COSMOGENIC NUCLIDES. (C)

SM 625. Advanced Paleobotany Seminar. (M) Pfefferkorn. May be repeated for credit

Topics in paleobotany, paleoecology and evolution.

627. SPEC TOPIC PALEONTOLOGY.

SM 628. Seminar in Isotope Geochemistry. (M) Staff.Prerequisite(s): Intermediate background in chemistry, physics, biology, or geology.

This course is for advanced undergraduates and graduate students interested in learning about or pursuing applications of isotope geochemistry, with an emphasis on biological and climatic processes (e.g. plant physiology, soils, nutrient cycling, and atmospheric chemistry).We will meet to discuss readings both from the literature and textbook chapters where necessary for backround. Grading will be on the basis of class participation and short weekly writing assignments. The latter will be completed prior to the class by both students and professor to ensure thorough discussion of each topic.

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SM 630. (GEOL208) Advanced Structural Geology Seminar. (M) Phipps. May be repeated for credit. Four-day field trip

Topics in tectonophysics and/or regional structural geology.

SM 631. Reconstructing Former Sea Levels. (B) Horton. Course includes a mandatory several day-long field trip.

The significance of relative sea level since the last glacial maximum is recognized by disciplines across the Earth sciences. Relative sea-level histories are important for calibrating and constraining geophysical models of Earth's rheology and the isostatic adjustment of Earth to ice and water loads. Sea level is crucial to any study of coastal evolution as it serves as the ultimate baseline for continental denudation. The stability of sea level in recent past has been an important factor in sustaining coastal communities and may have profoundly influenced the very initiation of human civilization. The Intergovernmental Panel on Climate Change (IPCC) recently re-emphasized the importance of sea level as a barometer of climate and drew attention to the potentially devastating consequences of future climate change. However, the IPCC also highlighted the uncertainty with which the driving mechanisms of recent sea-level change are understood and the disconnect between long-term geological and recent observational trends. In this course we will begin to fill this important knowledge gap.

SM 646. First Billion Years: The Early History of Earth and Life. (A) Phipps.

The course will cover the origin of the Earth. Topics will range constituent atoms to planetesimals; the formation of the Earth including its accretion and differentiation; the early bombardment history of the earth and the formation of the Moon; the cooling of the Earth and the origins of continents and oceans. additionally variour theries for origin of life will be covered including the Archean world, tectonics, the evolution of the atmosphere and oceans, and early life.

636. Quantitative Paleoclimatology. (M) Staff.

This course provides a comprehensive, rigorous survey of our knowledge of the Earth's climate system from ancient to modern.Topics to be covered will include geological evidence for past climate changes, with an emphasis on quantitative methods using geochemistry and geophysics; the basis of earth system modeling; statistical climatology; climate change detection; time-series analysis in climatology.

SM 637. Recent Climate Change. (A) Staff.

Increases in "greenhouse gases" produced through human activity appear to be affecting the Earth's climate. This course will examine climate change over the last 500 years. We will examine the available instrumental records over this time period as well as proxy climate records such as ice core, tree ring, sediment cores, coral cores and others. Students will research individual topics and present them regularly, review published articles, and attend some seminars.

SM 639. Isotopes in Paleoclimatology. (A) Staff.

Isotope records in tree rings, ice cores, corals, and sediments can be used to reconstruct past climate variables such as temperature, salinity, atmospheric CO2, El Nino events, cloud cover and precipitation. This course focuses on isotope techniques and applications in paleoclimatology. Special emphasis will be placed on stable carbon, stable oxygen and radiocarbon. This course is suitable for upper level undergraduates and graduate students.

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651. Geocomputations I. (M) Mastropaolo. Offered through LPS - See current timetable

Review and applications of selected methods from differential equations, advanced engineering mathematics and geostatistics to problems encountered in geology, engineering geology, geophysics and hydrology.

652. Physical Geology for Environmental Professionals. (A) Doheny. Offered through LPS - See current timetable

Study of the genesis and properties of earth materials (minerals,rocks,soil, water); consideration of volcanic,erosional, glacial, and earthquake processes along with the characterization of the earth's deep interior crustal and near-surface structure.Classroom study of minerals, crystals, fossils, and rocks as time permits.

653. Introduction to Hydrology. (A) Sauder. Offered through LPS - See current timetable

Introcudction to the basic principles of the hydrologic cycle and water budgets, precipitation and infiltration, evaporation and transpiration, stream flow, hydrograph analysis (floods), subsurface and groundwater flow, well hydraulics, water quality, and frequency analysis.

SM 654. Geomechanics I: Solids. (A) Duda.

Mechanical properties of solid and fluid earth materials, stress and strain, earth pressures in soil and rock, tunnels, piles, and piers; flow through gates, wiers, spillways and culverts, hydraulics, seepage and Darcy's law as applied to the hydrologic sciences.

655. CRITICAL ZONE SCIENCE: Baselines for Industry Applications. (B) Jimenez.Prerequisite(s): Physical Geology, Calculus , Hydrology and Aqueous Geochemistry.

What is Critical Zone Science? Why does it matter to Industry? Why does it matter to you and me? This course will introduce students to Critical Zone science research and its application to diverse fields of the environmental and geoscience industries. This is an advanced multidisciplinary problem solving course exploring the underlying critical zone processes of hydrology, biogeochemistry and geomorphology and their application to multi-faceted industry related problems. Emphasis will be placed on completion of quantitative problem sets and related written reports that require a multidisciplinary understanding of real world problems. Lectures by guest speakers from the worlds of Critical Zone science research and the consulting industry will aid students in the solving of complex problems.

656. Fate and Transport of Pollutants. (A) Mastropaolo.

This course covers basic groundwater flow and solute transport modeling in one-,two- and three-dimensions. After first reviewing the principles of modeling, the student will gain hands-on experience by conducting simulations on the computer. The modeling programs used in the course are MODFLOW (USGS), MT3D, and the US Army Corps of Engineers GMS (Groundwater Modeling System).

657. Field Geophysics. (B) Doheny.Prerequisite(s): GEOL 420: Introduction to Geophysics.

Use of geophysics field equipment (gravity, magnetic, seismic, electrical,electromagnetic, and radar) to collect geologic site investigation data. Theoretical analysis of collected geophysical and geological data to interpret subsurface conditions.

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SM 658. Geostatistics. (C) Mastropaolo.

Statistical analysis of data from geological, geotechnical, and geohydrologic sources.

659. Surface Water Hydrology. (B) Bellini.

This course will focus on various aspects of surface water hydrology. Topics covered include: study of all aspects of precipitation and runoff; study of the natural occurrences of floods and droughts; the establishment of design floods; methods of preventing or alleviating damages due to floods; water losses through evaporation, transpiration, and infiltration; storm water management; and hydrologic considerations in environmental issues.

SM 660. Department of Earth and Environmental Science Seminar.

661. Environmental Groundwater Hydrology. (B) Mastropaolo.

This course is designed to introduce the major definitions and concepts regarding groundwater flow and contaminant transport. The theory underlying concepts, including mathematical derivations of governing equations used to model groundwater flow and contaminant transport, will be discussed and applications to environmental problems addressed.

663. GROUNDWATER FLOW AND TRANSPORT MODELING II. (B) Mastropaolo.

This course is designed to introduce the major concepts regarding geochemistry and geochemical modeling. The course introduces two United States Geological Survey (USGS) computer models, PHREEQC, a geochemical speciation model, and PHAST, a transport module which is coupled with PHREEQC output. These are highly respected, world-renowned models that are free-ware via the USGS, complete with documentation. Once familiar with the models, the student can continue to work with them beyond the course experience.

PHREEQC is designed to perform a wide variety of aqueous geochemical calculations and can be used to simulate chemical reactions and transport processes in natural or polluted waters. PHREEQC is capable of modeling both equilibrium and kinetic reactions. Some of the simulations pursued during the course include: Speciation of precipitation water; Iron speciation; Zinc sorption onto hydrous ferric oxide; Oxidation of organic carbon and the sequence of electron donors in natural waters; Benzene advective transport in g

665. Engineering Geology & Geotechnics. (A) Freed.

Based on numerous case histories, the theme of this course is characterization of the geologic environment for engineering and environmental investigations. Covered are the various exploration tools and methods, including interpretation of remotely sensed imagery; field and laboratory measurments of material properties; and instrumentation monitoring. Rock masses and the significance of discontinuities are discussed as are soil formations in terms of occurrence and mode of deposition, and their typical physical properties. The latter half of the course is dedicated to the geologic hazards; i.e. ground subsidence and collapse, landslides and earthquakes, with emphasis on prediction, prevention and damage control.

666. Geology Field Work. (C) Giegengack. 4-8 weeks during the summer.

667. Landfill Design. (C) Calabria.

Topics for this course include: landfill regulations (Federal/State); permitting; siting considerations; environmental assessment; geotechnical issues; hydrogeologic investigations; landfill component design (QA/QC); linear systems; leachate collection; final cover; gas control; monitoring; surface water management; and operational, closure, post-closure considerations.

GEOLOGY
(AS) {GEOL}

668. Geomechanics II: Fluids. (B) Duda.

Static and Dynamic mechanical properties of fluid in earth materials, as applied to the Hydrologic Sciences; Principles of Fluid Mechanics and Hydraulics applied to open channel flow in earth materials; flow through gates, weirs, spillways, and culverts; Applications of Darcy's Law to subsurface flow and seepage.

SM 677. Seminar in Environmental Geology. (M) Giegengack.

706. Topics in Regional Geology. (M) Phipps.Prerequisite(s): GEOL 208 &/or 206, preferably both; GEOL 390. Field Trips required

Topics in sedimentology, stratigraphy, petrology, and/or structural geology of selected regions. Regional geologic synthesis and tectonics.

FORELAND BASINS: Structure, sedimentology, and biology/paleobiology of forelandbasins, based on the study of modern and ancient examples. These will include the modern Persian Gulf region, and the ancient Carboniferous Appalachian basin. There will be at least one field trip.

DEPOSITIONAL BASINS: Investigation and interpretation of a number of different tectonically-controlled basins throughout the region. Field work essential. All-day and weekend field trips required. Students will integrate stratigraphic, sedimentological, structural, and tectonic principles within various basinal settings.

SM 750. Topics in earth Science. Jane Willenbring. Open only to PhD students

This course will use the weekly EES seminar series to survey historic breakthrogh papers or topics in the earth sciences, as well as modern papers - written by the seminar speakers - that often put the classics in perspective. Graduate students (Ph.D. only) in the Department of Earth and Environmental Science will engage in the material through reading, presentation, and discussion. The course has several goals. (1.) To engender an understanding and appreciation of major breakthroughs in our field. (2.) To develop skills in presenting and discussing scientific results. And (3.) to refine students' understanding of what constitutes great science.

SM 777. Seminar in Quaternary Environments. (M) Giegengack.

Interdisciplinary approach to selected environmental problems of the Pleistocene.

999. Independent Study and Research. (C) Staff.Prerequisite(s): Permission of departmental committee. Hours and credits to be arranged.

Directed study for individuals or small groups under supervision of a faculty member.