EARTH, ENVIRONMENTAL, AND PLANETARY SCIENCES

Contact Information
Earth, Environmental, and Planetary Sciences
https://earthscience.rice.edu/
105 Keith Wiess Geological Labs
713-348-4880

Cin-Ty Lee
Department Chair
ctlee@rice.edu

Earth, Environmental, and Planetary Sciences encompass a range of interrelated disciplines focused on understanding the origin of Earth and planetary systems, the processes that operate within them, and their evolution through time. Topics represented in our field include the physics and chemistry of the solid Earth and its planetary neighbors, the causes and consequences of plate tectonics, and the origin and importance of the oceans and atmosphere. The study of past and present-day environmental processes is integral to understanding the impacts of Earth’s climate, land surface evolution, natural resources, and natural hazards on the biosphere, including humans.

The Department of Earth, Environmental and Planetary Sciences offers undergraduate and graduate programs for a wide range of interests. All undergraduate majors take a five-course core sequence, typically in the freshman through junior years, gaining a fundamental understanding of Earth and planetary systems, processes, materials, history, and interactions. Majors also take a course in applied laboratory, field, and computational techniques, and introductory courses in mathematics, chemistry, and possibly, physics and biology. The BS degree provides three areas of specialization:

- **Geoscience** - focused on Earth systems and processes, including upper-level courses in solid Earth geophysics, geochemistry, tectonics, and a range of elective options.
- **Environmental Earth Science** - emphasizing interactions between Earth processes and Earth’s biosphere, enhanced by upper-level electives selected from BioSciences, Chemistry, Civil and Environmental Engineering, and more.
- **Planetary Science** - designed to apply our knowledge of the Earth to other planetary systems in our solar system, enhanced by upper-level electives in Physics and Astronomy and beyond.

The BS degree with a major in Earth, Environmental, and Planetary Sciences should be chosen by students planning a career or further study in Earth, Environmental, or Planetary Sciences, or a related field. The BA degree is a more flexible program that still provides a comprehensive overview of Earth, Environmental, and Planetary Sciences, but can be combined easily with other majors or professional career paths. Many undergraduate students engage in research projects during their careers, gaining the opportunity to work with complex and highly interconnected problems, gaining skills to become leaders and entrepreneurs in the real world - field and laboratory opportunities abound! Future career opportunities include academia, working in industry, business or government, or working with and for societal issues. Many students present their own research projects at national and international professional conferences.

The department also offers an undergraduate minor providing a solid introduction to the broad field of Earth, Environmental, and Planetary Sciences*, and allowing students to gain exposure to additional advanced topics, while pursuing their major in another field.

The department offers two graduate degrees, a Master of Science and Doctor of Philosophy. Students select research projects in concert with their research advisors, and have the opportunity to work on a wide-range of open-ended, complex, and highly interconnected problems.

Faculty members have joint research projects with scientists at over 100 institutions worldwide, giving an international scope to the department with research programs on all the continents, in all of the oceans, and on four planets. Faculty research interests span a wide range of topics; see https://earthscience.rice.edu for more information. Many departmental research programs involve substantial field activities, both on land and at sea. Several courses also include field trips to a variety of destinations and geologic settings.

*Students interested in an undergraduate major with an environmental emphasis have multiple options at Rice University, spanning the Schools of Natural Sciences, Engineering, Humanities, and Social Sciences, including:

- **Environmental Earth Science Area of Specialization** under the BS degree with a major in Earth, Environmental, and Planetary Sciences, described above. This major is built upon a strong foundation in Earth Science, and focuses on the interface between the Earth and life.
- **Environmental Science (BS and BA degrees)** is a broad and interdisciplinary program that incorporates humanities and social sciences perspectives of environmental issues, in addition to natural sciences. This major is jointly administered by the BioSciences and Earth, Environmental, and Planetary Sciences departments, and offers two corresponding Major Concentrations: Earth Science and Ecology and Evolutionary Biology.
  - **Environmental Engineering Area of Specialization** within the Bachelor of Science in Chemical Engineering (BSChE) degree.
  - **Environmental Engineering Major Concentration** within the BA degree with a major in Civil and Environmental Engineering.

Similarly, students interested in an undergraduate minor with an environmental emphasis have three options at Rice University:

- **Minor in Earth, Environmental and Planetary Sciences** offered by the Earth, Environmental, and Planetary Sciences department, with a strong Earth Science basis.
- **Minor in Energy and Water Sustainability** offered through the Civil and Environmental Engineering department, highlighting engineering and economic considerations.
- **Minor in Environmental Studies**, an interdisciplinary minor drawing broadly from the Schools of Natural Sciences, Engineering, Humanities, and Social Sciences.

**Bachelor’s Programs**


Minor

Master's Programs

Doctoral Program

Chair
Cin-Ty Lee

Professors
Rajdeep Dasgupta
Gerald R. Dickens
André W. Droxler
Richard G. Gordon
Cin-Ty Lee
Adrian Lenardic
Alan R. Levander
Caroline A. Masiello
Julia K. Morgan
Fenglin Niu
Dale S. Sawyer
Colin A. Zelt

Associate Professor
Helge Gonnermann

Assistant Professors
Sylvia Dee
Melodie French
Jeffrey Nittrouer
Kirsten Siebach
Mark Torres
Laurence Yeung

Professors Emeriti
John B. Anderson
Albert W. Bally
Dieter Heymann
William P. Leeman
Andreas Lüttge
Manik Talwani

Peter R. Vail

Lecturers
Kenneth Abdulah
Vitor dos Santos Abreu
Gary G. Gray
Eric Scott
Robert R. Stewart
John R. Sumner

Wiess Visiting Scholars
Francis Albarede
Yehuda Ben-Zion
Janne Blichert-Toft

Adjunct Faculty
Kevin Biddle
K. K. Bissada
Christian Davies
Jeffrey J. Dravis
Brandon Dugan
Paul M. "Mitch" Harris
N. Ross Hill
Stephen J. Mackwell
Patrick J. McGovern
Chin Man William Mok
David L. Olgaard
James Pindell
Malcolm Ross
Kurt Rudolph
Stephanie S. Shipp
Lori Summa
Robert Wegner

For Rice University degree-granting programs:
To view the list of official course offerings, please see Rice’s Course Catalog ([https://courses.rice.edu/admweb/!SWKSCAT.cat?p_action=cata](https://courses.rice.edu/admweb/!SWKSCAT.cat?p_action=cata))
To view the most recent semester’s course schedule, please see Rice’s Course Schedule ([https://courses.rice.edu/admweb/!SWKSCAT.cat](https://courses.rice.edu/admweb/!SWKSCAT.cat))

Earth Science (ESCI)

ESCI 101 - THE EARTH

Short Title: THE EARTH

Department: Earth/Environment/Planetary Sci

Grade Mode: Standard Letter

Course Type: Lecture

Distribution Group: Distribution Group III

Credit Hours: 3

Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.

Course Level: Undergraduate Lower-Level

Description: Study of the nature of the Earth and its processes. Cross-list: ENST 101. Mutually Exclusive: Cannot register for ESCI 101 if student has credit for ESCI 115/ESCI 301.
In this course students will learn about the science behind natural disasters. The topics that will be discussed include earthquakes, tsunamis, volcanic eruptions, hurricanes, and tornadoes. We will cover processes on Earth's surface, such as carbon cycling, ocean and atmospheric circulation, and climate change. Lectures will be minimal.

In this course, students will gain a better appreciation of our planet, from how it formed and evolved through millions of years to how its surface environment has been shaped by life, including by humans. These concepts will be introduced through one or more field trips in Texas. Through this course, students will become better stewards of our planet.

In this course students will learn about the science behind natural disasters. The topics that will be discussed include earthquakes, tsunamis, volcanic eruptions, hurricanes, and tornadoes. We will cover processes on Earth's surface, such as carbon cycling, ocean and atmospheric circulation, and climate change. Lectures will be minimal.

Why is Earth habitable? How do we sustain our existence on this unique planet? This course will introduce students to our species' interactions with Planet Earth. We will explore how Earth formed and what systems through time have made the planet habitable, how we use the rock record to investigate past surface environments and climate changes, and how humans are altering Earth's future. The first segment covers the building of Planet Earth and geologic factors that control habitability. The second segment covers rocks of the American Southwest as a case study for how we read the rock record to understand ancient surface environments and climate changes. The final segment of the course will focus on human impacts on our planet, environmental policy and reading the recently published National Climate Assessment.
ESCI 115 - INTRODUCTION TO THE EARTH
Short Title: INTRODUCTION TO THE EARTH
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Lower-Level
Description: This course provides a comprehensive introduction to the Earth, its origins and composition, and the processes that change it, covering rock and mineral identification, geologic maps, plate tectonics and its causes, Earth structure and geophysics, sedimentology and stratigraphy, and surface processes. Mutually Exclusive: Cannot register for ESCI 115 if student has credit for ESCI 101/ESCI 301.

ESCI 201 - THE SCIENCE OF CLIMATE CHANGE
Short Title: SCIENCE OF CLIMATE CHANGE
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Distribution Group: Distribution Group III
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Lower-Level
Description: This undergraduate course will introduce students to the fundamentals of natural and anthropogenic climate change. After briefly reviewing Earth's composition and its fluid envelopes, we will cover the basic physics of the climate system, providing tools to understand weather and climate phenomena (e.g. monsoons, El Niño), the greenhouse effect, and climate feedbacks. Building on this understanding, a succinct tour of geologic history will help us paint a more complete picture of Earth's climate variations and how they affected human evolution and history. With this context, we will be able to judge the anomalous character of recent climate change, establish its anthropogenic nature, and discuss solutions to the current climate crisis. Students from any major are encouraged to enroll and engage on important topic. Cross-list: ENST 201.

ESCI 113 - ENVIRONMENTAL CRISIS SEMINAR
Short Title: ENVIRONMENTAL CRISIS SEMINAR
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Seminar
Credit Hour: 1
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Lower-Level
Description: Discussion of environmental crises. Topics vary annually. Distribution Credit for ESCI/ENST/EBIO 113 no longer eligible beginning Fall 2019. Cross-list: ENST 113. Repeatable for Credit.

ESCI 114 - DISCOVERIES IN EARTH, ENVIRONMENTAL AND PLANETARY SCIENCES SEMINAR
Short Title: DISCOVERIES IN EEPS SEMINAR
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Seminar
Credit Hour: 1
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Lower-Level
Description: Overview of exciting discoveries, research and recent advances in Earth, Environmental, and Planetary Sciences, facilitated through discussions with graduate students and faculty, as well as laboratory visits and demonstrations. Topics may vary. Distribution Credit for ESCI/ENST 114 no longer eligible beginning Fall 2019. Cross-list: ENST 114.

ESCI 114 - DISCOVERIES IN EARTH, ENVIRONMENTAL AND PLANETARY SCIENCES
Short Title: DISCOVERIES IN EARTH, ENVIRONMENTAL AND PLANETARY SCIENCES
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Seminar
Credit Hour: 1
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Lower-Level
Description: This course provides a comprehensive introduction to the Earth, its origins and composition, and the processes that change it, covering rock and mineral identification, geologic maps, plate tectonics and its causes, Earth structure and geophysics, sedimentology and stratigraphy, and surface processes. Mutually Exclusive: Cannot register for ESCI 115 if student has credit for ESCI 101/ESCI 301.

ESCI 214 - THE PLANETS
Short Title: THE PLANETS
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Distribution Group: Distribution Group III
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Lower-Level
Description: The physical, chemical, and geological development of the solar system from 4.6 billion years ago until today. All planets, their major satellites, comets, and asteroids will be discussed.

ESCI 220 - INTRODUCTION TO COMPUTATION IN THE EARTH, ENVIRONMENT AND PLANETARY SCIENCES
Short Title: INTRO TO EEPS COMPUTATION
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Distribution Group: Distribution Group III
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Lower-Level
Prerequisite(s): MATH 101 (may be taken concurrently) or MATH 105 or MATH 111 (may be taken concurrently) or MATH 112 (may be taken concurrently)
Description: A broad introduction to solving earth, environmental, and planetary science problems using programming and basic computational methods. The course will consist of a series of two week modules using the MATLAB environment. Each module consists of lectures to present theory and labs to provide guidance with relevant programing techniques. Recommended Prerequisite(s): MATH 102 or equivalent, and PHYS 101 and 102 or equivalents. May be taken concurrently.
ESCI 238 - SPECIAL TOPICS
Short Title: SPECIAL TOPICS
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Laboratory, Lecture, Seminar, Internship/Practicum
Credit Hours: 1-4
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Lower-Level
Description: Topics and credit hours vary each semester. Contact department for current semester’s topic(s). Repeatable for Credit.

ESCI 299 - EXPERIENTIAL EDUCATION IN EARTH, ENVIRONMENTAL, AND PLANETARY SCIENCES
Short Title: EXPERIENTIAL ED IN EARTH SCI
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Internship/Practicum
Credit Hour: 1
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Lower-Level
Description: This course is designed to allow currently enrolled undergraduate students to gain experience in a department/faculty-approved internship/practicum with the goal of further developing their professional skills. Repeatable for Credit.

ESCI 307 - ENERGY AND THE ENVIRONMENT
Short Title: ENERGY AND THE ENVIRONMENT
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: This course explores the physical principles of energy use and its impact on Earth's environment and climate. Topics will include energy mechanics, climate change, and the environmental impacts and future prospects of various fossil fuel and alternative energy sources. Cross-list: CEVE 307, ENST 307.

ESCI 321 - EARTH AND PLANETARY SURFACE ENVIRONMENTS
Short Title: EARTH AND PLANETARY SURFACES
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 4
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ESCI 101 (may be taken concurrently) or ESCI 107 (may be taken concurrently) or ESCI 108 (may be taken concurrently) or ESCI 110 (may be taken concurrently) or ESCI 111 (may be taken concurrently) or ESCI 115 (may be taken concurrently) or ESCI 201 (may be taken concurrently) or ESCI 301 (may be taken concurrently)
Description: This course introduces the processes that shape Earth and other planetary surfaces as well as how records of these processes are preserved on landscapes and in sediment deposits. This course will cover a range of topics including surface hydrology, erosion, sediment transport, and chemical weathering and connect them to the development and interpretation of the stratigraphic record. All topics will be treated using descriptive (qualitative) approaches as well as a range of quantitative methods. This course requires a once-a-week 3-hour lab. Recommended Prerequisite(s): MATH 101, 102, PHYS 101 or 111, CHEM 121 or 151. Recommended Prerequisite(s): MATH 101, 102, PHYS 101 or 111, CHEM 121 or 151.

ESCI 322 - EARTH AND PLANETARY CHEMISTRY AND MATERIALS
Short Title: EARTH AND PLANETARY MATERIALS
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 4
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ESCI 101 (may be taken concurrently) or ESCI 107 (may be taken concurrently) or ESCI 108 (may be taken concurrently) or ESCI 110 (may be taken concurrently) or ESCI 111 (may be taken concurrently) or ESCI 115 (may be taken concurrently) or ESCI 201 (may be taken concurrently) or ESCI 301 (may be taken concurrently)
Description: This course introduces chemistry of the Solar System materials and geochemical cycles in Earth and rocky planets through whole planet scale cycles. Specific topics include rock-forming processes related to the chemical and physical differentiation of the solid Earth and terrestrial planets into their main reservoirs, e.g., continental crust, oceanic crust, mantle, and core. Beginning with the bulk composition of planetary bodies, and an overview of the chemical and petrologic properties of the rocks that make up each of these reservoirs, the basic principles of petrology and geochemistry will be presented in the context of the rock cycle, plate tectonics, as well as the origin of economically and societally important ore deposits. Some basic concepts as to how the whole planet scale processes influence the chemistry of surface environment of Earth will be also be introduced. A laboratory and field trip, where students will see petrologic and geochemical principles applied, will be required. Recommended prerequisite(s): MATH 101 and MATH 102, PHYS 101 or 111, and CHEM 121 or CHEM 151
ESCI 323 - EARTH AND PLANETARY STRUCTURE AND DYNAMICS
Short Title: EARTH AND PLANETARY STRUCTURE
Department: Earth/Environment/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 4
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ESCI 101 (may be taken concurrently) or ESCI 107 (may be taken concurrently) or ESCI 108 (may be taken concurrently) or ESCI 110 (may be taken concurrently) or ESCI 111 (may be taken concurrently) or ESCI 115 (may be taken concurrently) or ESCI 301 (may be taken concurrently)
Description: This course covers the formation and differentiation of Earth and planetary bodies, the resulting structure and composition of planetary interiors, and the geophysical tools that reveal these details. The mechanics and deformation of the Earth's crust and lithosphere are presented, emphasizing rock strength and rheology, earthquakes and faulting, brittle and ductile deformation mechanisms and processes, and an introduction to tectonic systems. A required 3-hour lab and field trip will further develop skills for recognition, interpretation, and analysis of Earth structures and deformation processes. Prerequisites ESCI 101 or ESCI 107 or ESCI 108 or ESCI 110 or ESCI 111 or ESCI 115 or ESCI 301 can be taken concurrently or with permission of instructor. Recommended Prerequisite(s): MATH 101 and (PHYS 101 or PHYS 111). These may be taken concurrently. Mutually Exclusive: Cannot register for ESCI 323 if student has credit for ESCI 333.

ESCI 324 - EARTH'S INTERIOR
Short Title: EARTH'S INTERIOR
Department: Earth/Environment/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 4
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ESCI 101 or ESCI 115
Description: Formation of Earth and solar system, Earth differentiation and geochronology. Structural seismology and the composition of Earth's interior. Density, Earth's gravity, and the geoid. Heat flow and Earth energetics. Earth's core and magnetic field. Mantle convection and plate tectonics. Oceanic and continental crust. Recommended Prerequisite(s): MATH 212 and (PHYS 101 or PHYS 111 or PHYS 125 or PHYS 141) or (PHYS 102 or PHYS 112 or PHYS 126 or PHYS 142).

ESCI 325 - OCEANS, ATMOSPHERES AND CLIMATE
Short Title: OCEANS, ATMOSPHERES & CLIMATE
Department: Earth/Environment/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Distribution Group: Distribution Group III
Credit Hours: 4
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ESCI 101 or ESCI 107 or ESCI 109 or ESCI 110 or ESCI 111 or ESCI 201
Description: Earth's climate system is characterized by complex interactions between the ocean, atmosphere, and land surfaces that are constantly evolving. This course will cover the physics and chemistry of the ocean and atmosphere to explore the mechanisms that control global and regional climate. Topics include: Earth's energy balance, atmosphere and ocean circulation, and biogeochemical climate feedbacks. We will also explore records of past climate (historical and pre-historical) and projections of future climate. Students will engage in lab-based activities to understand fluid flow in the atmosphere and ocean and complete problem sets including programming assignments.

ESCI 330 - GEOARCHAEOLOGY
Short Title: GEOARCHAEOLOGY
Department: Earth/Environment/Planetary Sci
Grade Mode: Standard Letter
Course Type: Seminar
Credit Hours: 3
Restrictions: Enrollment is limited to students with a major in Anthropology or Earth Science. Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Overview of the basics of the analysis of soils and sediments as related to archaeological deposits, and introducing the key concepts of surficial geology, site formation, landscape evolution, and the scope of depositional environments. Includes practical methods for describing stratigraphy, sediments and soil profiles in the field. Cross-list: ANTH 330.

ESCI 334 - THE EARTH LABORATORY
Short Title: EARTH LABORATORY
Department: Earth/Environment/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ESCI 322 and ESCI 323 (may be taken concurrently) and (ESCI 101 or ESCI 107 or ESCI 108 or ESCI 110 or ESCI 111 or ESCI 115 or ESCI 301)
Description: A capstone course aimed at the interpretation of the Earth's history through the integration of geological observations in the field. Includes the introduction to the basic methods of description, recording, and interpretation of geologic features in the field, including rock and outcrop description, geologic mapping and cross-section construction. The course includes a required seven-day excursion during Spring Break. Taught every Spring. ESCI 323 may be taken concurrently with ESCI 334.
ESCI 340 - GLOBAL BIOGEOCHEMICAL CYCLES
Short Title: GLOBAL BIOGEOCHEMICAL CYCLES
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: An experimental course combining the scientific disciplines of the earth sciences with the artistic disciplines of creative photography to study the natural landscape and related ecosystems. The course will combine classroom lectures and laboratory demonstrations in geoscience with classes in the use of digital and film-based cameras and illustrated lectures on recognized achievements in landscape photography. Extensive field trips will be scheduled. Students will travel frequently, at times in pairs, other times in larger groups and as a full class, accompanied by one or both professors. The budget for the course includes funding both for travel and for photography expenses. Instructor Permission Required. Cross-list: FOTO 390.

ESCI 380 - VISUALIZING NATURE
Short Title: VISUALIZING NATURE
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: An experimental course combining the scientific disciplines of the earth sciences with the artistic disciplines of creative photography to study the natural landscape and related ecosystems. The course will combine classroom lectures and laboratory demonstrations in geoscience with classes in the use of digital and film-based cameras and illustrated lectures on recognized achievements in landscape photography. Extensive field trips will be scheduled. Students will travel frequently, at times in pairs, other times in larger groups and as a full class, accompanied by one or both professors. The budget for the course includes funding both for travel and for photography expenses. Instructor Permission Required. Cross-list: FOTO 390.

ESCI 390 - GEOLOGY FIELD CAMP
Short Title: GEOLOGY FIELD CAMP
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Independent Study
Credit Hours: 1-6
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Field course typically involving geologic mapping in one or more of sedimentary, metamorphic, igneous rocks and structures. Not offered by Rice University. Students must take an approved field camp from another university and transfer credit to Rice University. Recommended Prerequisite(s): ESCI 334.

ESCI 391 - EARTH SCIENCE FIELD EXPERIENCE
Short Title: EARTH SCIENCE FIELD EXPERIENCE
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Independent Study
Credit Hours: 1-6
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Comprises participating in an earth science expedition or research experience, follow-up analysis of some aspect of the data acquired, and a written report. Must be approved in advance by one of the department undergraduate advisors. Instructor Permission Required.

ESCI 401 - SEMINAR: UNDERGRADUATE HONORS THESIS
Short Title: SEM: UG HONORS THESIS
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Seminar
Credit Hour: 1
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Introduction to and presentation of original undergraduate research for Earth Science Undergraduate Honors Thesis candidates. Students will be introduced to basic research protocols and approaches, and will learn how to give presentations on their research, and gain experience presenting their research. Repeatable for Credit.

ESCI 403 - SEMINAR: DEPARTMENT RESEARCH
Short Title: SEM: DEPARTMENT RESEARCH
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Seminar
Credit Hour: 1
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Introduction to current research in the Earth Science department. Students will learn how to give a presentation and will get experience presenting their research. Graduate/Undergraduate Equivalency: ESCI 603. Repeatable for Credit.

ESCI 404 - SEMINAR: DEPARTMENT RESEARCH
Short Title: SEM: DEPARTMENT RESEARCH
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Seminar
Credit Hour: 1
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Introduction to current research in the Earth Science department. Students will learn how to give a presentation and will get experience presenting their research. Graduate/Undergraduate Equivalency: ESCI 604. Repeatable for Credit.
ESCI 405 - SEMINAR: CURRENT RESEARCH IN EARTH SCIENCE
Short Title: SEM:CURR RESRCH EARTH SCIENCE
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Seminar
Credit Hour: 1
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: A series of lectures and paper discussions in various areas of Earth science. Graduate/Undergraduate Equivalency: ESCI 605. Repeatable for Credit.

ESCI 406 - SEMINAR: CURRENT RESEARCH IN EARTH SCIENCE
Short Title: SEM:CURR RESRCH EARTH SCIENCE
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Seminar
Credit Hour: 1
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: A series of lectures and paper discussions in various areas of Earth science. Graduate/Undergraduate Equivalency: ESCI 606. Repeatable for Credit.

ESCI 407 - GEOCHEMISTRY OF EARTH'S SURFACE
Short Title: GEOCHEM EARTH'S SURFACE
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: This course will cover concepts in aqueous geochemistry in the context of chemical weathering and Earth's major biogeochemical cycles. Central to this course will be weekly student-led discussions of scientific literature. Students will also learn basic numerical modeling and data analysis techniques using MATLAB, field methods, and basic analytical chemistry. Graduate/Undergraduate Equivalency: ESCI 607. Mutually Exclusive: Cannot register for ESCI 407 if student has credit for ESCI 607.

ESCI 410 - OPTICAL MINERALOGY AND PETROGRAPHY
Short Title: OPTICAL MINERALOGY & PETROGRPH
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ESCI 322
Description: This is a lab course focused on the identification of minerals with petrographic microscopy. Principles of crystallography, mineral optics, and mineral chemistry will be covered in the first third of the course. The second third of the course will focus on the identification of minerals in igneous, metamorphic, and sedimentary rocks with emphasis on petrogenetic interpretation. The last third of the course will involve each student working on specific petrologic themes in the context of regional tectonics or magmatic processes. Taught every other Fall. Graduate/Undergraduate Equivalency: ESCI 610. Mutually Exclusive: Cannot register for ESCI 410 if student has credit for ESCI 610.

ESCI 411 - ADVANCED PETROLOGY
Short Title: ADVANCED PETROLOGY II
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: This course will bring together constraints from field geology, petrography, petrology, geochemistry, and geodynamics to tackle advanced A87 research questions of whole Earth processes that are relevant in the 21st century. The topics that may be covered include, but are not limited to, interplay between magmatic and tectonic processes, magma generation, migration, extraction, and dynamic stability in various settings, magmatic differentiation, volatiles and fluids exchange between various reservoirs and effects on long-term climate, ore genesis, and formation and modification of continents. Graduate/Undergraduate Equivalency: ESCI 611. Mutually Exclusive: Cannot register for ESCI 411 if student has credit for ESCI 611.

ESCI 412 - ADVANCED PETROLOGY
Short Title: ADVANCED PETROLOGY II
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ESCI 322
Description: Evaluation of the evolution of igneous rocks in the Earth's crust and mantle. Topics will include phase equilibria, experimental studies, and geochemistry. Labs will stress thin section petrography. Graduate/Undergraduate Equivalency: ESCI 612. Mutually Exclusive: Cannot register for ESCI 412 if student has credit for ESCI 612. Repeatable for Credit.
ESCI 415 - DECISION MAKING AND ECONOMICS IN THE ENERGY INDUSTRY
Short Title: DECISION MAKING AND ECONOMICS
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: This course will provide students with an understanding of how energy projects are evaluated. Topics include resource-size determination, geologic and economic risk, discounted cash-flow economics, and other common methods used in decision making. Emphasis will be placed on working in teams to understand basic concepts and sensitivities. Graduate/Undergraduate Equivalency: ESCI 615. Recommended Prerequisite(s): ESCI 321 and ESCI 323. Mutually Exclusive: Cannot register for ESCI 415 if student has credit for ESCI 615.

ESCI 416 - ECONOMIC GEOLOGY MINERAL DEPOSITS
Short Title: ECON GEOL MINERAL DEPOSITS
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: An overview of metallic and nonmetallic mineral deposits, theories of their origin, and classification. The impact of government regulation, economics, production practices, and exploration will be considered. Graduate/Undergraduate Equivalency: ESCI 616. Mutually Exclusive: Cannot register for ESCI 416 if student has credit for ESCI 616.

ESCI 417 - PETROLEUM INDUSTRY ECONOMICS AND MANAGEMENT
Short Title: PETROLEUM IND ECONOMICS MGMT
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Topics covered include resource size determination; geologic risk analysis; establishing minimum economic thresholds; economic chance factors; the concepts of present worth, investment efficiency, rates of return. Price forecasting, cost inflation are discussed. Graduate/Undergraduate Equivalency: ESCI 617. Recommended Prerequisite(s): ESCI 415. Mutually Exclusive: Cannot register for ESCI 417 if student has credit for ESCI 617.

ESCI 418 - QUANTITATIVE HYDROGEOLOGY
Short Title: QUANTITATIVE HYDROGEOLOGY
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Advanced course that will provide a quantitative overview of groundwater hydrology. Emphasis will be placed on mastering concepts in fluid mechanics and applying these concepts to water supply, environmental, and geological problems. Cross-list: CEVE 418. Graduate/Undergraduate Equivalency: ESCI 618. Mutually Exclusive: Cannot register for ESCI 418 if student has credit for ESCI 618.

ESCI 419 - CHARACTERIZATION OF EARTH, ENVIRONMENTAL, AND PLANETARY MATERIALS
Short Title: EARTH MATERIALS
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CHEM 111 or CHEM 121 or CHEM 151
Description: This course will provide an overview of various characterization methods used in geological, chemical, material science and other natural science and engineering research. The techniques that will be discussed include but not limited to electron beam methods (imaging and spectroscopy), X-ray methods, ion-beam analysis, vibrational spectroscopies, and Synchrotron-based techniques. Graduate/Undergraduate Equivalency: ESCI 619. Mutually Exclusive: Cannot register for ESCI 419 if student has credit for ESCI 619.

ESCI 421 - PALEOCEANOGRAPHY
Short Title: PALEOCEANOGRAPHY
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ESCI 321
Description: The evolution of the ocean, climate and the global carbon cycle over the last 100 million years as recorded by the biology, chemistry and composition of deep-sea sediment. Graduate/Undergraduate Equivalency: ESCI 621. Recommended Prerequisite(s): ESCI 109. Mutually Exclusive: Cannot register for ESCI 421 if student has credit for ESCI 621.
ESCI 422 - CLIMATE DYNAMICS
Short Title: CLIMATE DYNAMICS
Department: Earth/Environment/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ESCI 101 or ESCI 107 or ESCI 109 or ESCI 115 or ESCI 201 or ESCI 301 or ESCI 321 or ESCI 340
Description: Earth's climate is a chaotic system, characterized by nonlinear interactions between the ocean, atmosphere, and land surfaces. This course will focus on the dynamics of the ocean and atmosphere, including the drivers of large-scale circulation, heat transport, and modes of natural variability. We will also explore projections of future climate change scenarios and records of historical climate change. Students will learn to post-process climate model output, analyze, and map these data using Python. Graduate/Undergraduate Equivalency: ESCI 622. Mutually Exclusive: Cannot register for ESCI 422 if student has credit for ESCI 622.

ESCI 423 - ANTARCTIC MARINE GEOLOGY
Short Title: ANTARCTIC MARINE GEOLOGY
Department: Earth/Environment/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ESCI 321
Description: The study of marine geologic principles and processes using examples from the Southern Oceans. Graduate/Undergraduate Equivalency: ESCI 623. Recommended prerequisite(s): ESCI 321. Mutually Exclusive: Cannot register for ESCI 423 if student has credit for ESCI 623.

ESCI 424 - CLIMATE CHANGE
Short Title: CLIMATE CHANGE
Department: Earth/Environment/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ESCI 201 or ESCI 301
Description: Earth's climate is a chaotic system, characterized by nonlinear interactions between the ocean, atmosphere, and land surfaces. This course will focus on the dynamics of the ocean and atmosphere, including the drivers of large-scale circulation, heat transport, and modes of natural variability. We will also explore projections of future climate change scenarios and records of historical climate change. Students will learn to post-process climate model output, analyze, and map these data using Python. Graduate/Undergraduate Equivalency: ESCI 622. Mutually Exclusive: Cannot register for ESCI 422 if student has credit for ESCI 622.

ESCI 425 - ORGANIC GEOCHEMISTRY
Short Title: ORGANIC GEOCHEMISTRY
Department: Earth/Environment/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: This course covers the organic geochemistry of the natural environment. Topics include: production, transport, decomposition, and storage of organic matter in the marine and terrestrial environments, use of isotopes to track biogeochemical processes and natural and perturbed carbon cycle issues, including past and recent climate shifts. Cross-list: CHEM 425, ENST 425. Graduate/Undergraduate Equivalency: ESCI 625. Mutually Exclusive: Cannot register for ESCI 425 if student has credit for ESCI 625.

ESCI 426 - INTRODUCTION TO SEISMIC INTERPRETATION: STRUCTURAL STYLES AND SEISMIC STRATIGRAPHY
Short Title: 2D SEISMIC STRUCTURE AND STRAT
Department: Earth/Environment/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ESCI 442 (may be taken concurrently)
Description: This course will introduce students to analysis of sub-regional structural and stratigraphic frameworks. We will utilize the interpretation of 2D seismic profiles to reconstruct basin history and discuss implications for petroleum systems. Students will gain an understanding of a variety of structural and stratigraphic styles, as expressed on seismic data. Instructor Permission Required. Graduate/Undergraduate Equivalency: ESCI 626. Mutually Exclusive: Cannot register for ESCI 426 if student has credit for ESCI 626.

ESCI 427 - SEQUENCE STRATIGRAPHY
Short Title: SEQUENCE STRATIGRAPHY
Department: Earth/Environment/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): ESCI 321
Description: This course will introduce students to the concepts of sequence stratigraphy and the power behind this correlation technique. The course is divided between classic sequence stratigraphy using cores, well-logs, and outcrop examples and seismic sequence stratigraphy. Graduate/Undergraduate Equivalency: ESCI 627. Mutually Exclusive: Cannot register for ESCI 427 if student has credit for ESCI 627.

ESCI 429 - VOLCANOES
Short Title: VOLCANOES
Department: Earth/Environment/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Introduction to volcanoes and associated physical processes. Conceptual and quantitative discussion of topics related to magma transport, magma storage, and volcanic eruptions. The course includes a 4-6 day field trip to California and Oregon. Graduate/Undergraduate Equivalency: ESCI 629. Mutually Exclusive: Cannot register for ESCI 429 if student has credit for ESCI 629.
ESCI 430 - TRACE-ELEMENT AND ISOTOPE GEOCHEMISTRY FOR EARTH AND ENVIRONMENTAL SCIENCE  
Short Title: TRACE-ELEMENT & ISOTOPE GEOCHEM  
Department: Earth/Environment/Planetary Sci  
Grade Mode: Standard Letter  
Course Type: Lecture  
Credit Hours: 3  
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.  
Course Level: Undergraduate Upper-Level  
Description: Introduction to the principles of trace-element and isotope geochemistry and their applications to high and low temperature processes in the earth. Topics to be covered are trace-element partitioning, basic quantum physics, radiogenic isotopic systems and stable isotope fractionation. Graduate/Undergraduate Equivalency: ESCI 630. Recommended Prerequisite(s): ESCI 322. Mutually Exclusive: Cannot register for ESCI 430 if student has credit for ESCI 630.  

ESCI 431 - GEOMORPHOLOGY  
Short Title: GEOMORPHOLOGY  
Department: Earth/Environment/Planetary Sci  
Grade Mode: Standard Letter  
Course Type: Lecture/Laboratory  
Credit Hours: 3  
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.  
Course Level: Undergraduate Upper-Level  
Prerequisite(s): ESCI 321  
Description: This course will investigate physical, chemical, and biological processes that contribute to the development and shaping of Earth's surface across a continuum of subaerial and subaqueous environments. Mandatory 4-day field trip is associated with this class. Instructor Permission Required. Graduate/Undergraduate Equivalency: ESCI 631. Repeatable for Credit.  

ESCI 433 - ISOTOPE GEOCHEMISTRY  
Short Title: ISO TOPE GEOCHEMISTRY  
Department: Earth/Environment/Planetary Sci  
Grade Mode: Standard Letter  
Course Type: Lecture  
Credit Hours: 3  
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.  
Course Level: Undergraduate Upper-Level  
Description: An introduction to the principles and techniques of stable and radiogenic geochemistry in the geosciences. The course will begin by examining the fundamental physics relevant to isotope partitioning and decay, followed by a survey of different isotope systems and how they are used to study surface processes, element cycling, climate, and planetary science. Graduate/Undergraduate Equivalency: ESCI 633. Recommended Prerequisite(s): ESCI 322. Mutually Exclusive: Cannot register for ESCI 433 if student has credit for ESCI 633.  

ESCI 434 - PLANETARY SURFACE PROCESSES  
Short Title: PLANETARY SURFACE PROCESSES  
Department: Earth/Environment/Planetary Sci  
Grade Mode: Standard Letter  
Course Type: Lecture/Laboratory  
Credit Hours: 3  
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.  
Course Level: Undergraduate Upper-Level  
Description: This course is designed to expand understanding of geologic processes by considering how common or distinctive different geologic processes are on Earth compared to other bodies throughout the solar system. Students will leave the course with an appreciation for the types of surface processes that dominate different bodies throughout the solar system. How does the surface of Earth compared to the surfaces of other bodies in our solar system? How can we best extrapolate our understanding of Earth to other bodies? What do we learn about Earth from such comparisons? Graduate/Undergraduate Equivalency: ESCI 634.  

ESCI 435 - MECHANICS OF SEDIMENT TRANSPORT  
Short Title: MECHANICS-SEDIMENT TRANSPORT  
Department: Earth/Environment/Planetary Sci  
Grade Mode: Standard Letter  
Course Type: Lecture  
Credit Hours: 3  
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.  
Course Level: Undergraduate Upper-Level  
Description: Evaluation of sedimentary transport dynamics: physical interaction between fluid flow and sediment mobility, from grain to bedform scale; exploration of environments including rivers, estuaries, deltas, coastlines, and deserts. Examination of sediment transport for geology, environmental, and engineering applications; formation of diagnostic sedimentary features recognized in the stratigraphic record. Instructor Permission Required. Graduate/Undergraduate Equivalency: ESCI 635. Mutually Exclusive: Cannot register for ESCI 435 if student has credit for ESCI 635.  

ESCI 436 - WELL LOGGING AND PETROPHYSICS  
Short Title: WELL LOGGING AND PETROPHYSICS  
Department: Earth/Environment/Planetary Sci  
Grade Mode: Standard Letter  
Course Type: Lecture  
Credit Hours: 3  
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.  
Course Level: Undergraduate Upper-Level  
Description: Basics of wireline logging and logging while drilling including borehole environment, resistivity, radiation, thermal, and elastic wave measurements and measuring tools. Building from this introduction, basic interpretation of logging data and formation evaluation will be studied. Graduate/Undergraduate Equivalency: ESCI 636. Mutually Exclusive: Cannot register for ESCI 436 if student has credit for ESCI 636.
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<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Short Title</th>
<th>Department</th>
<th>Grade Mode</th>
<th>Course Type</th>
<th>Credit Hours</th>
<th>Restrictions</th>
<th>Course Level</th>
<th>Prerequisite(s)</th>
<th>Description</th>
<th>Department</th>
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<tbody>
<tr>
<td>ESCI 440</td>
<td>GEOPHYSICAL DATA ANALYSIS: DIGITAL SIGNAL PROCESSING</td>
<td>GEOPHYSICAL DATA ANALYSIS</td>
<td>Earth/Environmnt/Planetary Sci</td>
<td>Standard Letter</td>
<td>Lecture/Laboratory</td>
<td>3</td>
<td>Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.</td>
<td>Undergraduate Upper-Level</td>
<td>MATH 101 and MATH 102</td>
<td>Data sampling, aliasing, discrete Fourier transform, digital filter design techniques, z-transform, and discrete Hilbert transform are introduced. Deconvolution, velocity filters, polarization filter, stacking, beam forming and migration techniques will be taught together with their application in geophysical studies. Graduate/Undergraduate Equivalency: ESCI 640. Mutually Exclusive: Cannot register for ESCI 440 if student has credit for ESCI 640.</td>
<td>Earth/Environmnt/Planetary Sci</td>
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<tr>
<td>ESCI 441</td>
<td>GEOPHYSICAL DATA ANALYSIS: INVERSE METHODS</td>
<td>GEOPHYSICAL DATA ANALYSIS</td>
<td>Earth/Environmnt/Planetary Sci</td>
<td>Standard Letter</td>
<td>Lecture</td>
<td>3</td>
<td>Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.</td>
<td>Undergraduate Upper-Level</td>
<td>MATH 211</td>
<td>Review of linear algebra and probability. Data fitting, model parameter estimation, inverse theory, linear and nonlinear methods, and global optimization. Graduate/Undergraduate Equivalency: ESCI 641. Mutually Exclusive: Cannot register for ESCI 441 if student has credit for ESCI 641.</td>
<td>Earth/Environmnt/Planetary Sci</td>
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<td>ESCI 442</td>
<td>EXPLORATION GEOPHYSICS</td>
<td>EXPLORATION GEOPHYSICS</td>
<td>Earth/Environmnt/Planetary Sci</td>
<td>Standard Letter</td>
<td>Lecture/Laboratory</td>
<td>4</td>
<td>Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.</td>
<td>Undergraduate Upper-Level</td>
<td>MATH 101 and (PHYS 101 or PHYS 102 or PHYS 111 or PHYS 112)</td>
<td>Study of the principles and procedures involved in geophysical exploration. Includes acquisition, processing, and interpretation of seismic, ground-penetrating radar, gravity, magnetic, and electrical data. Graduate/Undergraduate Equivalency: ESCI 642. Mutually Exclusive: Cannot register for ESCI 442 if student has credit for ESCI 642.</td>
<td>Earth/Environmnt/Planetary Sci</td>
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<td>ESCI 444</td>
<td>REFLECTION SEISMIC DATA PROCESSING</td>
<td>REFLEC SEISMIC DATA PROCESSING</td>
<td>Earth/Environmnt/Planetary Sci</td>
<td>Standard Letter</td>
<td>Lecture</td>
<td>3</td>
<td>Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.</td>
<td>Undergraduate Upper-Level</td>
<td>ESCI 442</td>
<td>Experience with processing reflection seismic data. Includes seismic data organization, velocity analysis, stacking, filtering, deconvolution, migration, and display, using the Center for Computational Geophysics facility's seismic processing system(s). Recommended Prerequisite(s): ESCI 442. Mutually Exclusive: Cannot register for ESCI 444 if student has credit for ESCI 564.</td>
<td>Earth/Environmnt/Planetary Sci</td>
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<tr>
<td>ESCI 450</td>
<td>REMOTE SENSING</td>
<td>REMOTE SENSING</td>
<td>Earth/Environmnt/Planetary Sci</td>
<td>Standard Letter</td>
<td>Lecture/Laboratory</td>
<td>3</td>
<td>Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.</td>
<td>Undergraduate Upper-Level</td>
<td></td>
<td>Introduction to electromagnetic remote sensing of the earth and other planets using passive and active methods. The course includes a computer lab component involving processing and interpretation of remote sensing imagery, and an individual project. Cross-list: CEVE 450. Graduate/Undergraduate Equivalency: ESCI 650. Mutually Exclusive: Cannot register for ESCI 450 if student has credit for ESCI 650.</td>
<td>Earth/Environmnt/Planetary Sci</td>
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<tr>
<td>ESCI 452</td>
<td>GIS FOR SCIENTISTS AND ENGINEERS</td>
<td>GIS FOR SCIENTISTS</td>
<td>Earth/Environmnt/Planetary Sci</td>
<td>Standard Letter</td>
<td>Lecture</td>
<td>3</td>
<td>Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.</td>
<td>Undergraduate Upper-Level</td>
<td></td>
<td>Basic principles of Geographic Information Systems, with a focus on effectively applying the technology to the geosciences. Main platform of the class will be ESRI's ArcGIS, but a wide array of other tools will also be introduced. Material will be delivered via a blend of lecture and hands-on exercises. Graduate/Undergraduate Equivalency: ESCI 652. Mutually Exclusive: Cannot register for ESCI 452 if student has credit for ESCI 652.</td>
<td>Earth/Environmnt/Planetary Sci</td>
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</tbody>
</table>
**ESCI 454 - EARTH AND PLANETARY INTERIORS**  
**Short Title:** EARTH AND PLANETARY INTERIORS  
**Department:** Earth/Environmnt/Planetary Sci  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3  
**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.  
**Course Level:** Undergraduate Upper-Level  
**Prerequisite(s):** (ESCI 101 or ESCI 107 or ESCI 108 or ESCI 110 or ESCI 111 or ESCI 115 or ESCI 301) and ESCI 323 and MATH 211 and (PHYS 101 or PHYS 111 or PHYS 102 or PHYS 112)  
Mutually Exclusive: Cannot register for ESCI 454 if student has credit for ESCI 654.

**ESCI 456 - PLANETARY VOLCANISM**  
**Short Title:** PLANETARY VOLCANISM  
**Department:** Earth/Environmnt/Planetary Sci  
**Grade Mode:** Satisfactory/Unsatisfactory  
**Course Type:** Seminar  
**Credit Hours:** 2  
**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.  
**Course Level:** Undergraduate Upper-Level  
**Description:** This seminar will cover the broad range of volcanic phenomena in the solar system, via weekly readings of, and student presentations on, classic and recent papers. Topics include: Composition (basaltic, silicic, unusual, carbonatite), cryovolcanism, structure (caldera, rift zones, volcanic spreading radiating dike systems, magma chambers, and sill complexes), and dynamics (eruption mechanism, effusive vs. explosive, volatiles and atmospheres/oceans). The planetary settings to be considered include Earth, Venu, Mars, Mercury, Moon, large asteroids and outer planet satellites. Graduate/Undergraduate Equivalency: ESCI 656. Mutually Exclusive: Cannot register for ESCI 456 if student has credit for ESCI 656.

**ESCI 460 - GEOLOGICAL AND GEOPHYSICAL FLUID DYNAMICS**  
**Short Title:** GEOL & GEOPHYS FLUID DYNAMICS  
**Department:** Earth/Environmnt/Planetary Sci  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3  
**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.  
**Course Level:** Undergraduate Upper-Level  
**Prerequisite(s):** MATH 211 and MATH 212  
**Description:** Advanced course in the foundations of fluid mechanics and its application to Earth science. Aspects of continuum physics, heat and mass transfer, and the rheologic behavior of materials will be covered in developing the fundamental laws that describe fluid motion. Applications include atmospheric dynamics, mantle and lithospheric dynamics, and hydrogeology. Graduate/Undergraduate Equivalency: ESCI 660. Mutually Exclusive: Cannot register for ESCI 460 if student has credit for ESCI 660.

**ESCI 461 - SEISMOLOGY I**  
**Short Title:** SEISMOLOGY I  
**Department:** Earth/Environmnt/Planetary Sci  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3  
**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.  
**Course Level:** Undergraduate Upper-Level  
**Prerequisite(s):** MATH 102 or MATH 106 or PHYS 102 or PHYS 112  
**Description:** Principles of elastic wave propagation, the determination of Earth structure, and the understanding of earthquake physics. Graduate/Undergraduate Equivalency: ESCI 661. Mutually Exclusive: Cannot register for ESCI 461 if student has credit for ESCI 661.

**ESCI 462 - TECTONOPHYSICS**  
**Short Title:** TECTONOPHYSICS  
**Department:** Earth/Environmnt/Planetary Sci  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture/Laboratory  
**Credit Hours:** 3  
**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.  
**Course Level:** Undergraduate Upper-Level  
**Prerequisite(s):** MATH 102 or MATH 106 or PHYS 102 or PHYS 112  
**Description:** Applications of continuum physics to the deformation, flexure, heat transfer, and gravity field of the lithosphere. Graduate/Undergraduate Equivalency: ESCI 662. Recommended Prerequisite(s): MATH 212. Mutually Exclusive: Cannot register for ESCI 462 if student has credit for ESCI 662.

**ESCI 463 - STRUCTURE AND EVOLUTION OF TECTONIC SYSTEMS**  
**Short Title:** TECTONIC SYSTEMS  
**Department:** Earth/Environmnt/Planetary Sci  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3  
**Restrictions:** Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.  
**Course Level:** Undergraduate Upper-Level  
**Prerequisite(s):** ESCI 323  
**Description:** The distribution, origin, and evolution of various tectonic systems, and characterization of their structural and geophysical signatures, emphasizing crustal and lithospheric processes associated with tectonic deformation. Review of representative global examples of convergent and collisional margins, divergent and passive margins, and transform margins. Graduate/Undergraduate Equivalency: ESCI 663. Mutually Exclusive: Cannot register for ESCI 463 if student has credit for ESCI 663.
ESCI 464 - GLOBAL TECTONICS
Short Title: GLOBAL TECTONICS
Department: Earth/Environmt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Geometrical aspects of plate tectonics, the 3 traditional types of plate boundaries, instantaneous plate motions, earthquakes and faulting, space geodesy, geomagnetic reversals, paleomagnetic poles, hotspots, "absolute" plate motion, true polar wander, driving forces, diffuse plate boundaries, plate nonrigidity, and rheology of the lithosphere. Graduate/Undergraduate Equivalency: ESCI 664. Mutually Exclusive: Cannot register for ESCI 464 if student has credit for ESCI 664.

ESCI 465 - ENVIRONMENTAL & APPLIED ROCK PHYSICS
Short Title: APPLIED ROCK PHYSICS
Department: Earth/Environmt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): (MATH 101 or MATH 102) and (PHYS 101 or PHYS 102 or PHYS 111) and CAAM 210
Description: Rock physics, the study of the impact of rock microstructure, mineralogy, fluids, stress state, and diagenetic features on wave propagation in porous media. Understanding the use of such relationships for quantitative analysis of seismic datasets. Applications to geologic carbon storage, permafrost characterization, geothermal systems, and hydrogeology. Graduate/Undergraduate Equivalency: ESCI 665. Recommended Prerequisite(s): Knowledge of applied geophysics, seismology, continuum mechanics, differential equations, and petrology will expand the value of the material. Mutually Exclusive: Cannot register for ESCI 465 if student has credit for ESCI 665.

ESCI 467 - GEOMECHANICS
Short Title: GEOMECHANICS
Department: Earth/Environmt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: An examination of deformation and failure processes within the Earth's shallow crust, with a focus on rock and sediment mechanics, and associated fluid processes. Emphasis will be on geologic applications, including sediment consolidation, slope stability, fault mechanics, and earthquake nucleation and rupture. Graduate/Undergraduate Equivalency: ESCI 667. Mutually Exclusive: Cannot register for ESCI 467 if student has credit for ESCI 667.

ESCI 471 - EARTH SYSTEMS MODELING I: PHILOSOPHY AND FUNDAMENTALS
Short Title: EARTH SYSTEMS MODELING I
Department: Earth/Environmt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CHEM 111 or CHEM 121 or PHYS 101 or PHYS 102
Description: A model is a simplified representation of something. Scientific models range from conceptual to physical to mathematical. In Earth and planetary science, one is often concerned with modeling interactions between physical, chemical, and biological components, i.e., with modeling systems. This class will cover the fundamentals of scientific modeling with a focus on Earth systems. Graduate/Undergraduate Equivalency: ESCI 671. Recommended Prerequisite(s): MATH 211. Mutually Exclusive: Cannot register for ESCI 471 if student has credit for ESCI 671. Repeatable for Credit.

ESCI 472 - EARTH SYSTEMS MODELING: NUMERICAL TECHNIQUES AND APPLICATIONS
Short Title: NUMERICAL METHODS EARTH SYSTEM
Department: Earth/Environmt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CHEM 111 or CHEM 121 or PHYS 101 or PHYS 102
Description: Introduction to numerical methods with applications in Earth Science using Matlab and COMSOL. Much of the class is spent in the computer lab learning Matlab and COMSOL, followed by hands-on exercises. Graduate/Undergraduate Equivalency: ESCI 672. Recommended Prerequisite(s): MATH 211.

ESCI 477 - SPECIAL TOPICS
Short Title: SPECIAL TOPICS
Department: Earth/Environmt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Internship/Practicum, Seminar, Laboratory, Lecture, Lecture/Laboratory
Credit Hours: 1-4
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Topics and credit hours vary each semester. Contact department for current semester's topic(s). Repeatable for Credit.

ESCI 481 - UNDERGRADUATE RESEARCH IN EARTH SCIENCE
Short Title: UNDERGR RESEARCH EARTH SCIENCE
Department: Earth/Environmt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Research
Credit Hours: 1-6
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Advanced work adapted to the needs of the individual undergraduate student reading. Instructor Permission Required. Repeatable for Credit.
ESCI 491 - SPECIAL STUDIES FOR UNDERGRADUATES
Short Title: SPECIAL STUDY FOR UNDERGRADS
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Research
Credit Hours: 1-6
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Work in Earth Science adapted to the needs of individual undergraduate research. Instructor Permission Required. Repeatable for Credit.

ESCI 495 - SEMINAR: TOPICS IN ENVIRONMENTAL SCIENCE
Short Title: TOPICS: ENVIRONMENTAL SCIENCE
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Seminar
Credit Hours: 3
Restrictions: Enrollment limited to students with a class of Senior. Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: This course provides an integration of interdisciplinary topics that span environmental sciences. Topics will vary depending upon the interests and needs of both students and faculty. Only Seniors may register for this course without instructor permission. Cross-list: BIOS 495.

ESCI 499 - GRAPHIC AND VISUAL DESIGN FOR SCIENTISTS
Short Title: VISUAL DESIGN FOR SCIENTISTS
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Seminar
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: A significant portion of a scientists time is spent solving visual design problems (graphics for papers, visual layouts for seminars, posters, teaching). Effective communication of scientific information is part of a scientists skill set. This class is designed to enhance that skill set in terms of presenting visual information clearly, simply, and effectively. Graduate/Undergraduate Equivalency: ESCI 699. Mutually Exclusive: Cannot register for ESCI 499 if student has credit for ESCI 699. Repeatable for Credit.

ESCI 501 - SPECIAL STUDIES FOR GRADUATE STUDENTS
Short Title: SPECIAL STUDIES GRAD STUDENTS
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Independent Study
Credit Hours: 1-15
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Advanced work in Earth science adapted to the needs of individual graduate students. Instructor Permission Required. Repeatable for Credit.

ESCI 502 - FIELD TRIP FOR ADVANCED GEOLOGY AND PETROLOGY
Short Title: FIELD TRIP-ADV GEOL & PETROL
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Prerequisite(s): ESCI 322 and ESCI 334
Description: A field trip course centered on weekly readings and several mapping projects carried out over the course of 1 week. The course will focus on western North American geology with emphasis on igneous and metamorphic petrology and structural geology in the context of regional tectonics. Field studies will be accompanied by quantitative data collection and analysis. Each student will be responsible for a small field-based project. Instructor Permission Required. Repeatable for Credit.

ESCI 503 - CRYOSPHERE
Short Title: CRYOSPHERE
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Prerequisite(s): ESCI 321
Description: The growth and decay of glaciers play a large role in modulating Earth’s climate system. This course focuses on physical glaciology, glacial geomorphology, the geologic record of glaciation, and glacier-climate interactions in the past, present, and future.

ESCI 504 - SILICICLASTIC DEPOSITIONAL SYSTEMS
Short Title: SILICICLASTIC DEPOSITION SYST
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Study of modern and ancient sedimentary environments with emphasis on field work. Depositional models examined in relation to climatic, oceanographic, and tectonic influences.

ESCI 506 - CARBONATE DEPOSITIONAL SYSTEMS
Short Title: CARBONATE DEPOSITIONAL SYSTEMS
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Prerequisite(s): ESCI 321
Description: Characterization of modern and ancient, shallow and deep sedimentary environments and facies. Includes examination of different depositional models in relation both to climate and to hydrographic and geographic settings, as well as three field trips. Meeting times will be determined after registration.
ESCI 507 - APPLIED SEDIMENTOLOGY II
Short Title: APPLIED SEDIMENTOLOGY II
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Prerequisite(s): ESCI 505
Description: Advanced field studies in sedimentary geology. This course is intended to provide graduate students with experience working in sedimentary rocks by working on projects of their own design.

ESCI 508 - SEMINAR: GLOBAL SEISMOLOGY
Short Title: SEM:GLOBAL SEISMOLOGY
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Seminar
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Seminar topics may vary. Repeatable for Credit.

ESCI 509 - SEMINAR: DEPARTMENT TYPE-LOCALE FIELD TRIPS
Short Title: SEM:DEPT-LOCATE-FIELD TRIPS
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Seminar
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Seminar topics may vary. Repeatable for Credit.

ESCI 511 - PUTTING EARTH SCIENCE INTO ACTION
Short Title: SEM: EARTH SCIENCE INTO ACTION
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Seminar
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Seminar topics may vary. Repeatable for Credit.

ESCI 512 - SEMINAR: CARIBBEAN
Short Title: SEM: CARIBBEAN
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Seminar
Credit Hour: 1
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Seminar topics may vary. Repeatable for Credit.

ESCI 514 - ADVANCED BIOGEOCHEMISTRY
Short Title: ADVANCED BIOGEOCHEMISTRY
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 1-4
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course will explore carbon, nitrogen, and water cycling at the advanced level. Instructor Permission Required. Repeatable for Credit.

ESCI 515 - GEOPHYSICAL FIELD WORK FOR EDUCATORS
Short Title: GEOPHYS FLD WK FOR EDUCATORS
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course consists of 2 weeks of geophysical field work and is designated for in-service K-12 teachers. Instructor Permission Required. Repeatable for Credit.

ESCI 516 - TOPICS ON CARBONATES
Short Title: TOPICS ON CARBONATES
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Seminar
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Seminar topics may vary. 7-day field trip to Belize is required. Recommended Prerequisite(s): MATH 211. Repeatable for Credit.

ESCI 519 - SEMINAR: SEISMOLOGY
Short Title: SEM: SEISMOLOGY
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Seminar
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Seminar topics may vary. Repeatable for Credit.

ESCI 520 - SEMINAR: SEISMOLOGY
Short Title: SEM: SEISMOLOGY
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Seminar
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Seminar topics may vary. Repeatable for Credit.

ESCI 521 - SEMINAR: TECTONICS OF CONTINENTAL MARGINS
Short Title: SEM:TECTONICS-CONTINEN-MARGINS
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Seminar
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Seminar topics may vary. Repeatable for Credit.

ESCI 522 - SEMINAR: ADVANCED TOPICS IN GEOFLUIDS, GEOTHERMICS, AND PLANETARY EVOLUTION
Short Title: SEM:GEOFLUIDS/ThERMICS, PLANET
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Seminar
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Seminar topics may vary.
ESCI 523 - SEMINAR: SEISMIC MODELING AND INVERSE METHODS
Short Title: SEM:SEISMICMODEL&INVERSEMETHOD
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Seminar
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Seminar topics may vary. Repeatable for Credit.

ESCI 524 - SEMINAR: ADVANCED TOPICS IN EARTH STRUCTURE AND DEFORMATION
Short Title: SEM:ADV TOPICS EARTH STRUCTURE
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Seminar
Credit Hours: 1-4
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Seminar topics may vary. Please contact the department for more details. Repeatable for Credit.

ESCI 526 - SEMINAR: DEVELOPMENTS IN STRUCTURAL GEOLOGY
Short Title: SEM:DEVELOPSTRUCTURALGEOLOGY
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Seminar
Credit Hours: 2
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Seminar topics may vary. Repeatable for Credit.

ESCI 527 - SEMINAR: QUANTITATIVE PETROLEUM SYSTEMS ANALYSIS
Short Title: QUANT PETROLEUM SYS ANALYSIS
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Seminar
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Seminar topics may vary. Course taught at the University of Houston. Repeatable for Credit.

ESCI 528 - SEMINAR: ADVANCED TOPICS IN HYDROGEOLOGY
Short Title: SEM:ADV TOPICS HYDROGEOLOGY
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Seminar
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Seminar topics may vary. Repeatable for Credit.

ESCI 529 - THE MOON: ORIGIN AND EVOLUTION OF EARTH'S COMPANION
Short Title: THE MOON: ORIGIN & EVOLUTION
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Seminar
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This seminar course addresses fundamental issues in the origin and evolution of the Moon, spanning the disciplines of geology, geophysics, geochemistry and petrology. Sources range from classic studies to recent results from orbiting spacecraft and laboratory analysis. Readings will be supplemented by guest presentations from active researchers in the field. Repeatable for Credit.

ESCI 530 - DATA SCIENCE ENVIRONMENTAL AND GEOSCIENCES
Short Title: DATA SCIENCE GEO-HYDRO-ENV APP
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course focuses on practical applications of common data science techniques to extract information from environmental, hydrologic and geological data. Lectures cover theories and examples with biweekly course work assignments. Students are required to complete a group project and presentation at the end of the course.

ESCI 531 - ADVANCED TECTONOPHYSICS/GLOBAL TECTONICS
Short Title: ADV TECTONOPHY/GLOBL TECTONICS
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Seminar
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Seminar topics may vary. Repeatable for Credit.

ESCI 532 - SEMINAR: TOPICS IN SEDIMENTOLOGY
Short Title: SEM:TOPICS-SEDIMENTOLOGY
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Seminar
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Seminar topics may vary. Repeatable for Credit.
ESCI 534 - CLASTIC DEPOSITIONAL SYSTEMS FIELD TRIP  
Short Title: FIELD TRIP CLASTIC DEP SYSTEMS  
Department: Earth/Environmnt/Planetary Sci  
Grade Mode: Standard Letter  
Course Type: Seminar  
Credit Hours: 1  
Restrictions: Enrollment is limited to Graduate level students.  
Course Level: Graduate  
Prerequisite(s): ESCI 504  
Description: This is a five day trip that takes place in northwestern New Mexico. The trip is intended for students with strong interests in sedimentology and stratigraphy and focuses on field methods in interpretation of clastic sedimentary deposits in terms of their depositional environment, sequence stratigraphic occurrence and reservoir and source rock potential. The field area includes four different basins, which provides further opportunity for discussion of sedimentary basin evolution. The course also includes reading assignments and class presentations on topics related to the trip. Repeatable for Credit.

ESCI 536 - SEMINAR: DEPARTMENT TYPE - LOCALE FIELD TRIP  
Short Title: SEM: LOCALSE FIELD TRIP  
Department: Earth/Environmnt/Planetary Sci  
Grade Mode: Standard Letter  
Course Type: Seminar  
Credit Hours: 2-4  
Restrictions: Enrollment is limited to Graduate level students.  
Course Level: Graduate  
Prerequisite(s): ESCI 321 (may be taken concurrently) and ESCI 322 (may be taken concurrently) and ESCI 323 (may be taken concurrently) and ESCI 324 (may be taken concurrently))  
Description: Seminar topics vary depending on location of field trip. This is a Seminar/Trip type course combination. Undergraduates are required to take prerequisites to register for this course. Prerequisites do not apply for graduate students. Prerequisites may be taken concurrently. Additional fee may be required for this course. Instructor Permission Required. Repeatable for Credit.

ESCI 537 - ADVANCED TOPICS IN THE SOLID EARTH I  
Short Title: ADV TOPICS - SOLID EARTH I  
Department: Earth/Environmnt/Planetary Sci  
Grade Mode: Standard Letter  
Course Type: Seminar  
Credit Hours: 2  
Restrictions: Enrollment is limited to Graduate level students.  
Course Level: Graduate  
Description: Seminar topics may vary.

ESCI 538 - ADVANCED TOPICS IN THE SOLID EARTH II  
Short Title: ADV TOPICS - SOLID EARTH II  
Department: Earth/Environmnt/Planetary Sci  
Grade Mode: Standard Letter  
Course Type: Seminar  
Credit Hours: 2  
Restrictions: Enrollment is limited to Graduate level students.  
Course Level: Graduate  
Description: Seminar topics may vary. Repeatable for Credit.

ESCI 539 - SEMINAR: TOPICS IN VOLCANOLOGY, MAGMATIC, AND HYDROTHERMAL PROCESSES  
Short Title: SEM: PHYSICAL VOLCANOLOGY  
Department: Earth/Environmnt/Planetary Sci  
Grade Mode: Satisfactory/Unsatisfactory  
Course Type: Seminar  
Credit Hour: 1  
Restrictions: Enrollment is limited to Graduate level students.  
Course Level: Graduate  
Description: Seminar topics may vary. Reading and discussions about current topics related to magma generation, migration, accumulation and eruption, as well as hydrothermal systems. Repeatable for Credit.

ESCI 540 - EARTH'S ATMOSPHERE  
Short Title: EARTH'S ATMOSPHERE  
Department: Earth/Environmnt/Planetary Sci  
Grade Mode: Standard Letter  
Course Type: Lecture  
Credit Hours: 3  
Restrictions: Enrollment is limited to Graduate level students.  
Course Level: Graduate  
Description: How and why has Earth's atmosphere evolved over time? We will begin with an understanding of the atmosphere today - its physics, chemistry, and dynamics - work backwards in time to frontiers that are comparatively data-poor. We focus on empirical/observational constraints that drive theories of atmospheric evolution on Earth and other planets. Recommended Prerequisite(s): MATH 211 Mutually Exclusive: Cannot register for ESCI 540 if student has credit for ESCI 414. Repeatable for Credit.

ESCI 541 - THE PLANET MARS: FORMATION, DIFFERENTIATION, STRUCTURE AND EVOLUTION  
Short Title: PLANET MARS: FORM, STRUCT, EVO  
Department: Earth/Environmnt/Planetary Sci  
Grade Mode: Satisfactory/Unsatisfactory  
Course Type: Seminar  
Credit Hours: 3  
Restrictions: Enrollment is limited to Graduate level students.  
Course Level: Graduate  
Description: This seminar addresses fundamental issues in Mars science, spanning the disciplines of geology, geophysics, geochemistry and petrology. Sources range over six decades of data from flybys and orbiting spacecraft, landed stations and rovers, and laboratory analysis of meteorites and experiments. Readings will be supplemented by presentations from active Mars researchers. Instructor Permission Required.

ESCI 542 - SEISMOLOGY II  
Short Title: SEISMOLOGY II  
Department: Earth/Environmnt/Planetary Sci  
Grade Mode: Standard Letter  
Course Type: Lecture  
Credit Hours: 3  
Restrictions: Enrollment is limited to Graduate level students.  
Course Level: Graduate  
ESCI 543 - INTRODUCTION TO THE DYNAMICS AND PHYSICAL PROPERTIES OF THE EARTH’S INTERIOR  
**Short Title:** DYNAMICS OF EARTH’S INTERIOR  
**Department:** Earth/Environmnt/Planetary Sci  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3  
**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** Overview of the Earth’s deep interior with an emphasis on dynamical processes and physical properties of the Earth’s mantle. Topics include: global energy budget; convective heat transfer; thermal evolution of the Earth; constitutive laws; rheology; seismic velocities; composition, density structure; thermal expansion; thermal conductivity. Taught every other Fall.

ESCI 544 - HYDROCARBON EXPLORATION  
**Short Title:** HYDROCARBON EXPLORATION  
**Department:** Earth/Environmnt/Planetary Sci  
**Grade Mode:** Standard Letter  
**Course Type:** Seminar  
**Credit Hours:** 3  
**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** A student team will analyze and assess petroleum prospects in a sedimentary basin. Using a dataset of industry well/seismic data, the team will analyze data, identify/prioritize exploration targets, and prepare a formal presentation. Team will review their findings to industry judges for AAPG Imperial Barrel Award competition. Instructor Permission Required.

ESCI 545 - HYDROCARBON SYSTEMS ANALYSIS  
**Short Title:** HYDROCARBON SYSTEMS ANALYSIS  
**Department:** Earth/Environmnt/Planetary Sci  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture/Laboratory  
**Credit Hours:** 4  
**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** This course has lecture, lab, and field components. Students will learn about the components of the hydrocarbon system and how to rank areas of a basin for prospectively. Activities will be organized on a class and small group basis. Recommended Prerequisite(s): ESCI 323 or ESCI 427/627.

ESCI 546 - ADVANCED TOPICS IN BASIN SEDIMENTOLOGY AND STRATIGRAPHY  
**Short Title:** ADV TOPICS:BASIN SEDIM & STRAT  
**Department:** Earth/Environmnt/Planetary Sci  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3  
**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** This course will investigate the processes that lead to the development of sedimentary stratigraphy across a continuum of depositional environments, including: fluvial, deltaic, coastal near-shore, continental shelf and slope and abyssal settings. Material will include transport linkages based on studies from modern settings, and will also cover the unique stratigraphic signatures preserved in ancient depositional systems. Instructor Permission Required.

ESCI 547 - INTRODUCTION TO SCIENCE COMMUNICATION  
**Short Title:** INTRO TO SCIENCE COMMUNICATION  
**Department:** Earth/Environmnt/Planetary Sci  
**Grade Mode:** Satisfactory/Unsatisfactory  
**Course Type:** Seminar  
**Credit Hour:** 1  
**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** This course will introduce students to the methods of communicating science to the public, by exposing them to professionals and researchers from various communication careers. It will teach students to convey science to the lay audience through several methods, such as media reporting, museum programming, and general public outreach.

ESCI 548 - ADVANCED TOPICS IN FLUVIAL-DELTAIC SEDIMENTOLOGY AND STRATIGRAPHY  
**Short Title:** ADV TOPICS FLUVIAL-DELTAIC  
**Department:** Earth/Environmnt/Planetary Sci  
**Grade Mode:** Standard Letter  
**Course Type:** Seminar  
**Credit Hours:** 3  
**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** This course will investigate physical and biological processes that contribute to the development of fluvial-deltaic environments. Materials will include deriving physical erosion, transport, and deposition laws, in order to evaluate modern processes that shape deltas and coastlines. The course will also focus on sedimentary deposits of fluvial-deltaic systems and preservation potential of the stratigraphy, by examining ancient depositional systems that are preserved in the rock record. The course will explore these topics by reviewing science literature that utilizes numerical, experimental, and field studies, to further theory on the development of fluvial-deltaic systems. Instructor Permission Required. Repeatable for Credit.

ESCI 549 - DATA MANAGEMENT AND DATA GOVERNANCE  
**Short Title:** DATA MANAGEMENT  
**Department:** Earth/Environmnt/Planetary Sci  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3  
**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** This course will introduce students to the methods of data management and data governance to ensure such high quality data.
ESCI 557 - SPECIAL TOPICS IN EARTH SCIENCE
Short Title: SPECIAL TOPICS - EARTH SCIENCE
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Seminar
Credit Hours: 1-3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Topics will vary. Repeatable for Credit.

ESCI 555 - MOUNTAINS, CLIMATE AND GLOBAL CARBON CYCLING
Short Title: CARBON CYCLE
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Seminar
Credit Hours: 2
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: The purpose of this course is to discuss the origins of high elevations, such as mountains and epeirogenic uplifts, and their impacts of climate, global carbon cycling, and sedimentary processes. We will discuss the physics and chemistry of building mountains by magmatism and tectonic thickening as well as destroying them by erosion, chemical weathering, and delamination. We will explore perspectives from the deep Earth to the atmosphere. The seminar will meet once a week for two hours with the first hour being a thematic overview given by faculty or students and the second hour devoted to discussion of assigned papers. Recommended Prerequisite(s): ESCI 321 and ESCI 322. Repeatable for Credit.

ESCI 559 - SPECIAL TOPICS IN EARTH, ENVIRONMENTAL & PLANETARY SCIENCES
Short Title: SPECIAL TOPICS IN EEPs
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Seminar
Credit Hour: 1
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course deals with miscellaneous special topics not covered in other courses. Please contact the Earth Science department for the specific topics. Topics change each semester. Repeatable for Credit.

ESCI 562 - ADVANCED TOPICS IN GEOPHYSICS
Short Title: ADV TOPICS IN GEOPHYSICS
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Seminar
Credit Hour: 1
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Seminar topics may vary. Repeatable for Credit.

ESCI 564 - SEISMIC REFLECTION DATA PROCESS
Short Title: SEISMIC REFLECTN DATA PROCESS
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Prerequisite(s): ESCI 442 or ESCI 642 (may be taken concurrently)
Description: Workstation-based geologic interpretation of 3D seismic reflection data. The course will focus on interpreting horizons and faults tying interpretation to well data, analyzing seismic attributes, and other relevant topics. Emphasis will be placed on workflows utilized in hydrocarbon exploration. Mutually Exclusive: Cannot register for ESCI 558 if student has credit for ESCI 428.

ESCI 568 - 3D SEISMIC REFLECTION DATA INTERPRETATION
Short Title: 3D SEISMIC REFLECTION DATA
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Prerequisite(s): ESCI 442 or ESCI 642 (may be taken concurrently)
Description: Workstation-based geologic interpretation of 3D seismic reflection data. The course will focus on interpreting horizons and faults tying interpretation to well data, analyzing seismic attributes, and other relevant topics. Emphasis will be placed on workflows utilized in hydrocarbon exploration. Mutually Exclusive: Cannot register for ESCI 558 if student has credit for ESCI 428.

ESCI 564 - SEISMIC REFLECTION DATA PROCESS
Short Title: SEISMIC REFLECTN DATA PROCESS
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Prerequisite(s): ESCI 442 or ESCI 642 (may be taken concurrently)
Description: Workstation-based geologic interpretation of 3D seismic reflection data. The course will focus on interpreting horizons and faults tying interpretation to well data, analyzing seismic attributes, and other relevant topics. Emphasis will be placed on workflows utilized in hydrocarbon exploration. Mutually Exclusive: Cannot register for ESCI 558 if student has credit for ESCI 428.
ESCI 565 - JOINT INVERSION OF EXPLORATION GEOPHYSICAL DATA
Short Title: JNT INVERSN OF EXPLOR GEO DATA
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
description: By jointly inverting several different kinds of exploration geophysical measurements at a site we avoid some of the ambiguity inherent in the individual methods. *Students review papers (one-half of course) Recommended Prerequisite(s): ESCI 442 and (ESCI 444 or 564) and ESCI 436. Mutually Exclusive: Cannot register for ESCI 565 if student has credit for ESCI 445.

ESCI 566 - ROCK DEFORMATION AND RHEOLOGY
Short Title: ROCK DEFORMATION AND RHEOLOGY
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
description: The mechanisms of deformation and rheology of Earth's crust and mantle. Mutually Exclusive: Cannot register for ESCI 566 if student has credit for ESCI 466.

ESCI 567 - UNCONVENTIONAL ENERGY EXPLORATION
Short Title: UNCONV ENERGY EXPLORATION
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
description: Topical presentations on the exploration and production of unconventional energy resources, including sources, techniques, and prospects. Intent is to cover all non-traditional energy targets, including shale oil/gas, oil sands/heavy oil, geothermal, coalbed methane, methane clathrates (seafloor hydrates) and more. Instructor Permission Required. Mutually Exclusive: Cannot register for ESCI 567 if student has credit for ESCI 447.

ESCI 568 - THEORETICAL GLOBAL SEISMOLOGY I
Short Title: THEORETICAL GLBL SEISMOLOGY I
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
description: The course provides a path through theoretical seismology from a comprehensive analysis perspective. It consists of five parts: (i) The introduction of Earth's elastic-gravitational deformations through the calculus of variations, and the introduction of fluid-solid boundaries involving Earth's core using an action integral. (ii) The variational linearized or weak formulation of Earth's elastic-gravitational deformations. (iii) Energy estimates and well-posedness under appropriate conditions (that, for example, constrain the shapes of the major boundaries) of the system of elastic-gravitational equations describing the oscillations of the earth, and a Volterra equation justifying the extraction of the system describing acousto-elastic waves. (iv) The characterization of the spectrum of the earth, seismic normal modes and the essential spectrum associated with internal or gravity modes and embedded eigenfrequencies. The "asymptotic" resolution of the identity or seismic normal mode summation. In radial models such as PREM, a discussion of the Einstein-Brioullin-Keller quantization, trace formula and length spectrum. (v) Incorporation of dynamic ruptures, using rate- and state-dependent friction laws, generating seismic waves through an iterative coupling scheme and viscosity solutions. All parts will be illustrated with computational simulations using numerical formulations closely related to the analysis.
ESCI 570 - COMPUTATIONAL AND DATA SCIENCE IN THE ENERGY INDUSTRY
Short Title: COMP&DATA SCI ENERGY INDUSTRY
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course will be dedicated to problems and topics occurring in the energy industry, both in R&D and in operations. It has three main components: 1. Computational Geophysics 2. Reservoir Simulation Fundamentals 3. Machine Learning The first two components will be taught together in the first 10 weeks by dedicating half of the class-time to each subject. The Machine Learning component will, in part, build on the first two fundamental components and will be taught using the full class time. Computational Geophysics The participants in this geophysics part of the course are expected to be interested into learning how to use modern seismic data to image the subsurface with awareness of the computational costs of the techniques involved. The main focus will be given to current seismic imaging tools including cutting-edge Machine Learning (ML) applications. As the result of the successful completion of this course part, the course participants should be able to: (1) Understand the context and value of imaging tools for the hydrocarbon exploration business. (2) Relate the imaging tools with their computational costs for modern computer resources. (3) Properly use wave-based geophysical imaging and ML-based tools and (4) Understand main seismic processing and interpretation decisions. Applied Reservoir Simulation This component of the course will introduce participants to the practice of reservoir simulation. This class will be an applied course on reservoir simulation. Theoretical descriptions will be provided as warranted but will be kept to minimum. Class participants will learn about the fundamentals of applied reservoir simulation, use of a reservoir simulator, and how to select the proper model for a simulation study. This course will also cover data preparation, grid design, calibration of the reservoir model, forecasting of future performance, and interpretation of simulation results. Participants will also be introduced to the role of simulation in reservoir management, limitations of reservoir simulation, and the structural aspects of the models. Upscaling and recent advances simulation techniques will also be discussed. A realistic open-source reservoir simulation software will be used during the tutorials and computer projects. Machine Learning for Oil & Gas This part of the course will introduce the fundamentals of statistical learning, present a few of the popular learning paradigms and algorithms, and culminate in a small student project applying them to an oil reservoir data set using the R programming language (solutions to class problems will be accepted in any programming language or system). Much of the material presented here is also known under the names “Big Data”, “Data Analytics”, “Artificial Intelligence”, “Data Mining”, “Petroleum Data Driven Analytics” and other terms. Weeks 11 and 12 are theory only, weeks 13-15 will have small hands-on exercises incorporated and week 16 and 17 are dedicated to solving a simple oil reservoir problem using machine learning.

ESCI 571 - DATA SCIENCE METHODS AND DATA MANAGEMENT
Short Title: METHODS DATA SCIENCE/ MGMT
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Data has become a critical asset for enabling organizations to be competitive, make better decisions and support diverse stakeholders. In recent years, new methods, tools and techniques for data management and processing have been developed. In this vein, ensuring that users have the knowledge and skills to profit from this wealth of information is critical. In this course, participants will learn a holistic overview about infrastructure, data life cycles, metadata standards, policies and techniques for successfully managing and using data for decision-making. The emphasis of the course will be from the perspective of the Oil & Gas and Energy Industries. Recommended Prerequisite(s): Basic programming, introductory statistics

ESCI 580 - PITCHING YOUR SCIENCE
Short Title: PITCHING YOUR SCIENCE
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 2
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course is designed for senior level graduate students who will be facing high-stakes professional speaking opportunities, such as impromptu job conversations, formal academic and professional presentations, conversations with journalists, and/or industrial job interviews. Students will construct and practice 90-second, 5-minute, and 15-minute presentations. Most assignments will take place in-class, with limited work occurring outside of the classroom. Requirement: Participation in the Rice University 90-second thesis competition. Instructor Permission Required.

ESCI 581 - TOPICS IN PLANETARY DYNAMICS AND MAGMATIC PROCESSES
Short Title: TOPICS IN PLANETARY DYNAMICS
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Seminar
Credit Hours: 2
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Seminar topics may vary. Instructor Permission Required. Repeatable for Credit.
ESCI 590 - FIELD COURSE: APPLIED STRATIGRAPHY AND STRUCTURAL GEOLOGY
Short Title: FIELD COURSE: APPLIED STRAT
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Focus on how to interpret stratigraphy and structure from outcrop and subsurface data using a field transect from the orogenic belt to the foreland basin. By the end of the class, students should be able to measure/describe stratigraphic sections, construct a structural-stratigraphic framework, interpret structural profiles and integrate paleontology.

ESCI 603 - SEMINAR: DEPARTMENT RESEARCH
Short Title: SEMINAR: DEPARTMENT RESEARCH
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Seminar
Credit Hour: 1
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Introduction to current research in the Earth Science department. Students will learn how to give a presentation and will get experience presenting their research. Graduate/Undergraduate Equivalency: ESCI 403. Repeatable for Credit.

ESCI 604 - SEMINAR: DEPARTMENT RESEARCH
Short Title: SEM: DEPARTMENT RESEARCH
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Seminar
Credit Hour: 1
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Introduction to current research in the Earth Science department. Students will learn how to give a presentation and will get experience presenting their research. Graduate/Undergraduate Equivalency: ESCI 404. Repeatable for Credit.

ESCI 605 - SEMINAR: CURRENT RESEARCH IN EARTH SCIENCE
Short Title: SEM:CURR RESRCH EARTH SCIENCE
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Seminar
Credit Hour: 1
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: A series of lectures and paper discussions in various areas of Earth science. Graduate/Undergraduate Equivalency: ESCI 405. Repeatable for Credit.

ESCI 606 - SEMINAR: CURRENT RESEARCH IN EARTH SCIENCE
Short Title: SEM:CURR RESRCH EARTH SCIENCE
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Seminar
Credit Hour: 1
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: A series of lectures and paper discussions in various areas of Earth science. Graduate/Undergraduate Equivalency: ESCI 406. Repeatable for Credit.

ESCI 607 - GEOCHEMISTRY OF EARTH'S SURFACE
Short Title: GEOCHEM EARTH'S SURFACE
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course will cover concepts in aqueous geochemistry in the context of chemical weathering and Earth's major biogeochemical cycles. Central to this course will be weekly student-led discussions of scientific literature. Students will also learn basic numerical modeling and data analysis techniques using MATLAB, field methods, and basic analytical chemistry. Graduate/Undergraduate Equivalency: ESCI 407. Mutually Exclusive: Cannot register for ESCI 607 if student has credit for ESCI 407.

ESCI 610 - OPTICAL MINERALOGY AND PETROGRAPHY
Short Title: OPTICAL MINERALOGY & PETROGRPH
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This is a lab course focused on the identification of minerals with petrographic microscopy. Principles of crystallography, mineral optics, and mineral chemistry will be covered in the first third of the course. The second third of the course will focus on the identification of minerals in igneous, metamorphic, and sedimentary rocks with emphasis on petrogenetic interpretation. The last third of the course will involve each student working on specific petrologic themes in the context of regional tectonics or magmatic processes. Taught every other Fall. Graduate/Undergraduate Equivalency: ESCI 410. Mutually Exclusive: Cannot register for ESCI 610 if student has credit for ESCI 410.
ESCI 611 - ADVANCED PETROLOGY II
Short Title: ADVANCED PETROLOGY II
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course will bring together constraints from field geology, petrography, petrology, geochemistry, and geodynamics to tackle advanced A87 research questions of whole Earth processes that are relevant in the 21st century. The topics that may be covered include, but are not limited to, interplay between magmatic and tectonic processes, magma generation, migration, extraction, and dynamic stability in various settings, magmatic differentiation, volatiles and fluids exchange between various reservoirs and effects on long-term climate, ore genesis, and formation and modification of continents. Graduate/Undergraduate Equivalency: ESCI 411. Mutually Exclusive: Cannot register for ESCI 611 if student has credit for ESCI 411.

ESCI 612 - ADVANCED PETROLOGY
Short Title: ADVANCED PETROLOGY
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Evaluation of the evolution of igneous rocks in the Earth's crust and mantle. Topics will include phase equilibria, experimental studies, and geochemistry. Labs will stress thin section petrography. Graduate/Undergraduate Equivalency: ESCI 412. Mutually Exclusive: Cannot register for ESCI 612 if student has credit for ESCI 412. Repeatable for Credit.

ESCI 613 - INTRODUCTION TO THE HEAT AND MASS TRANSPORT PROCESSES OF PLANETARY INTERIORS
Short Title: GEODYNAMICS
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Introduction to the use of continuum mechanics to solve fundamental problems related to mass and energy transport problems arising in the study of solid Earth, planets and moons. Topics include; heat conduction, convective heat transfer, planetary thermal evolution, geological fluid dynamics, flow through porous media, rheology of planetary materials.

ESCI 615 - DECISION MAKING AND ECONOMICS IN THE ENERGY INDUSTRY
Short Title: DECISION MAKING AND ECONOMICS
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course will provide students with an understanding of how energy projects are evaluated. Topics include resource-size determination, geologic and economic risk, discounted cash-flow economics, and other common methods used in decision making. Emphasis will be placed on working in teams to understand basic concepts and sensitivities. Graduate/Undergraduate Equivalency: ESCI 415. Recommended Prerequisite(s): ESCI 321 and ESCI 323. Mutually Exclusive: Cannot register for ESCI 615 if student has credit for ESCI 415.

ESCI 616 - ECONOMIC GEOLOGY MINERAL DEPOSITS
Short Title: ECON GEOL MINERAL DEPOSITS
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: An overview of metallic and nonmetallic mineral deposits, theories of their origin, and classification. The impact of government regulation, economics, production practices, and exploration will be considered. Graduate/Undergraduate Equivalency: ESCI 416. Mutually Exclusive: Cannot register for ESCI 616 if student has credit for ESCI 416.

ESCI 617 - PETROLEUM INDUSTRY ECONOMICS AND MANAGEMENT
Short Title: PETROLEUM IND ECONOMICS MGMT
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: An overview of metallic and nonmetallic mineral deposits, theories of their origin, and classification. The impact of government regulation, economics, production practices, and exploration will be considered. Graduate/Undergraduate Equivalency: ESCI 417. Mutually Exclusive: Cannot register for ESCI 617 if student has credit for ESCI 417.

ESCI 618 - QUANTITATIVE HYDROGEOLOGY
Short Title: QUANTITATIVE HYDROGEOLOGY
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Advanced course that will provide a quantitative overview of groundwater hydrology. Emphasis will be placed on mastering concepts in fluid mechanics and applying these concepts to water supply, environmental, and geological problems. Graduate/Undergraduate Equivalency: ESCI 418. Mutually Exclusive: Cannot register for ESCI 618 if student has credit for ESCI 418.
### ESCI 619 - MATERIALS CHARACTERIZATION
**Short Title:** MATERIALS CHARACTERIZATION  
**Department:** Earth/Environment/Planetary Sci  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3  
**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** This course will provide an overview of various characterization methods used in geological, chemical, material science and other natural science and engineering research. The techniques that will be discussed include but not limited to electron beam methods (imaging and spectroscopy), X-ray methods, ion-beam analysis, vibrational spectroscopies, and Synchrotron-based techniques. Graduate/Undergraduate Equivalency: ESCI 419. Mutually Exclusive: Cannot register for ESCI 619 if student has credit for ESCI 419.

### ESCI 621 - PALEOCEANOGRAPHY
**Short Title:** PALEOCEANOGRAPHY  
**Department:** Earth/Environment/Planetary Sci  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3  
**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** The evolution of the ocean, climate and the global carbon cycle over the last 100 million years as recorded by the biology, chemistry and composition of deep-sea sediment. Graduate/Undergraduate Equivalency: ESCI 421. Mutually Exclusive: Cannot register for ESCI 621 if student has credit for ESCI 421.

### ESCI 622 - CLIMATE DYNAMICS
**Short Title:** CLIMATE DYNAMICS  
**Department:** Earth/Environment/Planetary Sci  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3  
**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** Earth's climate is a chaotic system, characterized by nonlinear interactions between the ocean, atmosphere, and land surfaces. This course will focus on the dynamics of the ocean and atmosphere, including the drivers of large-scale circulation, heat transport, and modes of natural variability. We will also explore projections of future climate change scenarios and records of historical climate change. Students will learn to post-process climate model output, analyze, and map these data using Python. Graduate/Undergraduate Equivalency: ESCI 422. Mutually Exclusive: Cannot register for ESCI 622 if student has credit for ESCI 422.

### ESCI 623 - ANTARCTIC MARINE GEOLOGY
**Short Title:** ANTARCTIC MARINE GEOLOGY  
**Department:** Earth/Environment/Planetary Sci  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3  
**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** The study of marine geologic principles and processes using examples from the Southern Oceans. Graduate/Undergraduate Equivalency: ESCI 423. Mutually Exclusive: Cannot register for ESCI 623 if student has credit for ESCI 423.

### ESCI 625 - ORGANIC GEOCHEMISTRY
**Short Title:** ORGANIC GEOCHEMISTRY  
**Department:** Earth/Environment/Planetary Sci  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3  
**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** This course covers the organic geochemistry of the natural environment. Topics include: production, transport, decomposition, and storage of organic matter in the marine and terrestrial environments, use of isotopes to track biogeochemical processes and natural and perturbed carbon cycle issues, including past and recent climate shifts. Graduate/Undergraduate Equivalency: ESCI 425. Mutually Exclusive: Cannot register for ESCI 625 if student has credit for ESCI 425.

### ESCI 626 - INTRODUCTION TO SEISMIC INTERPRETATION: STRUCTURAL STYLES AND SEISMIC STRATIGRAPHY
**Short Title:** 2D SEISMIC STRUCTURE AND STRAT  
**Department:** Earth/Environment/Planetary Sci  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture/Laboratory  
**Credit Hours:** 3  
**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Prerequisite(s):** ESCI 642 (may be taken concurrently)  
**Description:** This course will introduce students to analysis of sub-regional structural and stratigraphic frameworks. We will utilize the interpretation of 2D seismic profiles to reconstruct basin history and discuss implications for petroleum systems. Students will gain an understanding of a variety of structural and stratigraphic styles, as expressed on seismic data. Instructor Permission Required. Graduate/Undergraduate Equivalency: ESCI 426. Mutually Exclusive: Cannot register for ESCI 626 if student has credit for ESCI 426.

### ESCI 627 - SEQUENCE STRATIGRAPHY
**Short Title:** SEQUENCE STRATIGRAPHY  
**Department:** Earth/Environment/Planetary Sci  
**Grade Mode:** Standard Letter  
**Course Type:** Lecture  
**Credit Hours:** 3  
**Restrictions:** Enrollment is limited to Graduate level students.  
**Course Level:** Graduate  
**Description:** This course will introduce students to the concepts of sequence stratigraphy and the power behind this correlation technique. The course is divided between classic sequence stratigraphy using cores, well-logs, and outcrop examples and seismic sequence stratigraphy. Graduate/Undergraduate Equivalency: ESCI 427. Mutually Exclusive: Cannot register for ESCI 627 if student has credit for ESCI 427.
ESCI 629 - VOLCANOES
Short Title: VOLCANOES
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: An introduction to volcanoes and associated physical processes. Conceptual and quantitative discussion of topics related to magma transport, magma storage, and volcanic eruptions. The course includes a 4-6 day field trip to California and Oregon. Graduate/Undergraduate Equivalency: ESCI 429. Mutually Exclusive: Cannot register for ESCI 629 if student has credit for ESCI 429.

ESCI 630 - TRACE-ELEMENT AND ISOTOPE GEOCHEMISTRY FOR EARTH AND ENVIRONMENTAL SCIENCE
Short Title: TRACE-ELEMENT& ISOTOPE GEOCHEM
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Introduction to volcanoes and associated physical processes. Conceptual and quantitative discussion of topics related to magma transport, magma storage, and volcanic eruptions. The course includes a 4-6 day field trip to California and Oregon. Graduate/Undergraduate Equivalency: ESCI 429. Mutually Exclusive: Cannot register for ESCI 629 if student has credit for ESCI 429.

ESCI 631 - GEOMORPHOLOGY
Short Title: GEOMORPHOLOGY
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course will investigate physical, chemical, and biological processes that contribute to the development and shaping of Earth's surface across a continuum of subaerial and subaqueous environments. Mandatory 4-day field trip is associated with this class. Graduate students will be assigned exercises more challenging than those assigned to undergraduate students. Instructor Permission Required. Graduate/Undergraduate Equivalency: ESCI 431. Repeatable for Credit.

ESCI 633 - ISOTOPE GEOCHEMISTRY
Short Title: ISOTOPE GEOCHEMISTRY
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: An introduction to the principles and techniques of stable and radiogenic geochemistry in the geosciences. The course will begin by examining the fundamental physics relevant to isotope partitioning and decay, followed by a survey of different isotope systems and how they are used to study surface processes, element cycling, climate, and planetary science. Graduate/Undergraduate Equivalency: ESCI 433. Recommended Prerequisite(s): ESCI 322 Mutually Exclusive: Cannot register for ESCI 633 if student has credit for ESCI 433.

ESCI 634 - PLANETARY SURFACE PROCESSES
Short Title: PLANETARY SURFACE PROCESSES
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course is designed to expand understanding of geologic processes by considering how common or distinctive different geologic processes are on Earth compared to other bodies throughout the solar system. Students will leave the course with an appreciation for the types of surface processes that dominate different bodies throughout the solar system. How does the surface of Earth compare to the surfaces of other bodies in our solar system? How can we best extrapolate our understanding of Earth to other bodies? What do we learn about Earth from such comparisons? Graduate/Undergraduate Equivalency: ESCI 434.

ESCI 635 - MECHANICS OF SEDIMENT TRANSPORT
Short Title: MECHANICS-SEDIMENT TRANSPORT
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Evaluation of sedimentary transport dynamics: physical interaction between fluid flow and sediment mobility, from grain to bedform scale; exploration of environments including rivers, estuaries, deltas, coastlines, and deserts. Examination of sediment transport for geology, environmental, and engineering applications; formation of diagnostic sedimentary features recognized in the stratigraphic record. Instructor Permission Required. Graduate/Undergraduate Equivalency: ESCI 435. Mutually Exclusive: Cannot register for ESCI 635 if student has credit for ESCI 435.

ESCI 636 - WELL LOGGING AND PETROPHYSICS
Short Title: WELL LOGGING AND PETROPHYSICS
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Basics of wireline logging and logging while drilling including borehole environment, resistivity, radiation, thermal, and elastic wave measurements and measuring tools. Building from this introduction, basic interpretation of logging data and formation evaluation will be studied. Graduate/Undergraduate Equivalency: ESCI 436. Mutually Exclusive: Cannot register for ESCI 636 if student has credit for ESCI 436.
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Short Title</th>
<th>Department</th>
<th>Grade Mode</th>
<th>Course Type</th>
<th>Credit Hours</th>
<th>Restrictions</th>
<th>Course Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESCI 640</td>
<td>GEOPHYSICAL DATA ANALYSIS: DIGITAL SIGNAL</td>
<td>GEOPHYSICAL DATA ANALYSIS</td>
<td>Earth/Environmnt/Planetary Sci</td>
<td>Standard Letter</td>
<td>Lecture</td>
<td>3</td>
<td>Enrollment is limited to Graduate level students.</td>
<td>Graduate</td>
<td>Data sampling, aliasing, discrete Fourier transform, digital filter design techniques, z-transform, and discrete Hilbert transform are introduced. Deconvolution, velocity filters, polarization filter, stacking, beam forming and migration techniques will be taught together with their application in geophysical studies. Graduate/Undergraduate Equivalency: ESCI 440. Mutually Exclusive: Cannot register for ESCI 640 if student has credit for ESCI 440.</td>
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<tr>
<td>ESCI 642</td>
<td>EXPLORATION GEOPHYSICS</td>
<td>EXPLORATION GEOPHYSICS</td>
<td>Earth/Environmnt/Planetary Sci</td>
<td>Standard Letter</td>
<td>Lecture/Laboratory</td>
<td>4</td>
<td>Enrollment is limited to Graduate level students.</td>
<td>Graduate</td>
<td>Study of the principles and procedures involved in geophysical exploration. Includes acquisition, processing, and interpretation of seismic, ground-penetrating radar, gravity, magnetic, and electrical data. Graduate/Undergraduate Equivalency: ESCI 442. Mutually Exclusive: Cannot register for ESCI 642 if student has credit for ESCI 442.</td>
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<tr>
<td>ESCI 643</td>
<td>TOPICS IN GEOMATHEMATICS</td>
<td>TOPICS IN GEOMATHEMATICS</td>
<td>Earth/Environmnt/Planetary Sci</td>
<td>Standard Letter</td>
<td>Lecture</td>
<td>1-3</td>
<td>Enrollment is limited to Graduate level students.</td>
<td>Graduate</td>
<td>Content varies from year to year. Instructor Permission Required. Cross-list: CAAM 643. Recommended Prerequisite(s): CAAM 335 and CAAM 336 Repeatable for Credit.</td>
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<tr>
<td>ESCI 650</td>
<td>REMOTE SENSING</td>
<td>REMOTE SENSING</td>
<td>Earth/Environmnt/Planetary Sci</td>
<td>Standard Letter</td>
<td>Lecture</td>
<td>3</td>
<td>Enrollment is limited to Graduate level students.</td>
<td>Graduate</td>
<td>Introduction to electromagnetic remote sensing of the Earth and other planets using passive and active methods. The course includes a computer lab component involving processing and interpretation of remote sensing imagery, and an individual project. Graduate/Undergraduate Equivalency: ESCI 450. Mutually Exclusive: Cannot register for ESCI 650 if student has credit for ESCI 450.</td>
</tr>
<tr>
<td>ESCI 650</td>
<td>GIS FOR SCIENTISTS AND ENGINEERS</td>
<td>GIS FOR SCIENTISTS</td>
<td>Earth/Environmnt/Planetary Sci</td>
<td>Standard Letter</td>
<td>Lecture</td>
<td>3</td>
<td>Enrollment is limited to Graduate level students.</td>
<td>Graduate</td>
<td>Basic principles of Geographic Information Systems, with a focus on effectively applying the technology to the geosciences. Main platform of the class will be ESRI's ArcGIS, but a wide array of other tools will also be introduced. Material will be delivered via a blend of lecture and hands-on exercises. Instructor Permission Required. Graduate/Undergraduate Equivalency: ESCI 452. Mutually Exclusive: Cannot register for ESCI 652 if student has credit for ESCI 452.</td>
</tr>
</tbody>
</table>

**Department:** Earth/Environmnt/Planetary Sci

**Grade Mode:** Standard Letter

**Course Type:** Lecture

**Credit Hours:** 3

**Restrictions:** Enrollment is limited to Graduate level students.

**Course Level:** Graduate

**Description:** Study of the principles and procedures involved in geophysical exploration. Includes acquisition, processing, and interpretation of seismic, ground-penetrating radar, gravity, magnetic, and electrical data. Graduate/Undergraduate Equivalency: ESCI 442. Mutually Exclusive: Cannot register for ESCI 642 if student has credit for ESCI 442.
ESCI 656 - PLANETARY VOLCANISM
Short Title: PLANETARY VOLCANISM
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Seminar
Credit Hours: 2
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This seminar will cover the broad range of volcanic phenomena in the solar system, via weekly readings of, and student presentations on, classic and recent papers. Topics include: Composition (basaltic, silicic, unusual, carbonatite), cryovolcanism, structure (caldera, rift zones, volcanic spreading radiating dike systems, magma chambers, and sill complexes), and dynamics (eruption mechanism, effusive vs. explosive, volatiles and atmospheres/oceans). The planetary settings to be considered include Earth, Venu, Mars, Mercury, Moon, large asteroids and outer planet satellites. Graduate/Undergraduate Equivalency: ESCI 456. Mutually Exclusive: Cannot register for ESCI 656 if student has credit for ESCI 456.

ESCI 660 - GEOLOGICAL AND GEOPHYSICAL FLUID DYNAMICS
Short Title: GEOL & GEOPHYS FLUID DYNAMICS
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Advanced course in the foundations of fluid mechanics and its application to Earth science. Aspects of continuum mechanics, heat and mass transfer, and the rheologic behavior of materials will be covered in developing the fundamental laws that describe fluid motion. Applications include atmospheric dynamics, mantle and lithospheric dynamics, and hydrogeology. Graduate/Undergraduate Equivalency: ESCI 460. Mutually Exclusive: Cannot register for ESCI 660 if student has credit for ESCI 460.

ESCI 661 - SEISMOLOGY I
Short Title: SEISMOLOGY I
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Principles of elastic wave propagation, the determination of Earth structure, and the understanding of earthquake physics. Graduate/Undergraduate Equivalency: ESCI 461. Mutually Exclusive: Cannot register for ESCI 661 if student has credit for ESCI 461.

ESCI 662 - TECTONOPHYSICS
Short Title: TECTONOPHYSICS
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Applications of continuum physics to the deformation, flexure, heat transfer, and gravity field of the lithosphere. Graduate/Undergraduate Equivalency: ESCI 462. Mutually Exclusive: Cannot register for ESCI 662 if student has credit for ESCI 462.

ESCI 663 - STRUCTURE AND EVOLUTION OF TECTONIC SYSTEMS
Short Title: TECTONIC SYSTEMS
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: The distribution, origin, and evolution of various tectonic systems, and characterization of their structural and geophysical signatures, emphasizing crustal and lithospheric processes associated with tectonic deformation. Review of representative global examples of convergent and collisional margins, divergent and passive margins, and transform margins. Graduate/Undergraduate Equivalency: ESCI 463. Mutually Exclusive: Cannot register for ESCI 663 if student has credit for ESCI 463.

ESCI 664 - GLOBAL TECTONICS
Short Title: GLOBAL TECTONICS
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Geometrical aspects of plate tectonics, the 3 traditional types of plate boundaries, instantaneous plate motions, earthquakes and faulting, space geodesy, geomagnetic reversals, paleomagnetic poles, "absolute" plate motion, true polar wander, driving forces, diffuse plate boundaries, plate nonrigidity, and rheology of the lithosphere. Instructor Permission Required. Graduate/Undergraduate Equivalency: ESCI 464. Mutually Exclusive: Cannot register for ESCI 664 if student has credit for ESCI 464.

ESCI 665 - ENVIRONMENTAL & APPLIED ROCK PHYSICS
Short Title: APPLIED ROCK PHYSICS
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Rock physics, the study of the impact of rock microstructure, mineralogy, fluids, stress state, and diagenetic features on wave propagation in porous media. Understanding the use of such relationships for quantitative analysis of seismic datasets. Applications to geologic carbon storage, permafrost characterization, geothermal systems, and hydrogeology. Graduate/Undergraduate Equivalency: ESCI 465. Mutually Exclusive: Cannot register for ESCI 665 if student has credit for ESCI 465.
ESCI 677 - SPECIAL TOPICS
Short Title: SPECIAL TOPICS
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Laboratory, Lecture, Seminar, Internship/Practicum, Lecture/Laboratory
Credit Hours: 1-4
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Topics and credit hours vary each semester. Contact department for current semester's topic(s). Repeatable for Credit.

ESCI 672 - EARTH SYSTEMS MODELING II: APPLICATIONS
Short Title: APPLICATIONS
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Research
Credit Hours: 1-15
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: A significant portion of a scientist's time is spent solving visual design problems (graphics for papers, visual layouts for seminars, posters, teaching). Effective communication of scientific information is part of a scientist's skill set. This class is designed to enhance that skill set in terms of presenting visual information clearly, simply, and effectively. Graduate/Undergraduate Equivalency: ESCI 499. Mutually Exclusive: Cannot register for ESCI 699 if student has credit for ESCI 499. Repeatable for Credit.

ESCI 671 - EARTH SYSTEMS MODELING I: PHILOSOPHY AND FUNDAMENTALS
Short Title: PHILOSOPHY AND FUNDAMENTALS
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Lecture
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: In Earth and planetary science, one is often concerned with modeling interactions between physical, chemical, and biological components, i.e., with modeling systems. This class will cover the fundamentals of scientific modeling with a focus on Earth systems. Graduate/Undergraduate Equivalency: ESCI 471. Mutually Exclusive: Cannot register for ESCI 671 if student has credit for ESCI 471. Repeatable for Credit.

ESCI 667 - GEOMECHANICS
Short Title: GEOMECHANICS
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: An examination of deformation and failure processes within the Earth's shallow crust, with a focus on rock and sediment mechanics, and associated fluid processes. Emphasis will be on geologic applications, including sediment consolidation, slope stability, fault mechanics, and earthquake nucleation and rupture. Graduate/Undergraduate Equivalency: ESCI 467. Mutually Exclusive: Cannot register for ESCI 667 if student has credit for ESCI 467.

ESCI 699 - GRAPHIC AND VISUAL DESIGN FOR SCIENTISTS
Short Title: VISUAL DESIGN FOR SCIENTISTS
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: A significant portion of a scientist's time is spent solving visual design problems (graphics for papers, visual layouts for seminars, posters, teaching). Effective communication of scientific information is part of a scientist's skill set. This class is designed to enhance that skill set in terms of presenting visual information clearly, simply, and effectively. Graduate/Undergraduate Equivalency: ESCI 499. Mutually Exclusive: Cannot register for ESCI 699 if student has credit for ESCI 499. Repeatable for Credit.

ESCI 800 - THESIS RESEARCH
Short Title: THESIS RESEARCH
Department: Earth/Environmnt/Planetary Sci
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Research
Credit Hours: 1-15
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Recommended Prerequisite(s): Students must pass the preliminary exam before taking this course. Repeatable for Credit.

**Description and Code Legend**

*Note: Internally, the university uses the following descriptions, codes, and abbreviations for this academic program. The following is a quick reference:*

**Course Catalog/Schedule**
- Course offerings/subject code: ESCI
- Department Description and Code
  - Earth, Environmental, and Planetary Sciences: EEPS
- Undergraduate Degree Description and Code
  - Bachelor of Arts degree: BA
  - Bachelor of Science degree: BS
- Undergraduate Major Description and Code
  - Major in Earth, Environmental, and Planetary Sciences (for both the BA and BS degrees): EEPS
- Undergraduate Minor Description and Code
  - Minor in Earth, Environmental, and Planetary Sciences: EEPM
- Graduate Degree Descriptions and Codes
  - Master of Science degree: MS
  - Doctor of Philosophy degree: PhD
- Graduate Degree Program Description and Code
  - Degree Program in Earth Science: ESCI
- CIP Code and Description
  - EEPS Major/Program: CIP Code/Title: 40.0601 - Geology/Earth Science, General
Earth, Environmental, and Planetary Sciences

- **ESCI** Major/Program: CIP Code/Title: 40.0601 - Geology/Earth Science, General
- **EEP M** Minor: CIP Code/Title: 40.0601 - Geology/Earth Science, General

\(^1\) Classification of Instructional Programs (CIP) 2020 Codes and Descriptions from the National Center for Education Statistics: [https://nces.ed.gov/ipeds/cipcode/]