## Term Information

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|---|---|
| **Effective Term** | Spring 2025 |

## General Information

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|---|---|
| **Course Bulletin Listing/Subject Area** | Earth Sciences |
| **Fiscal Unit/Academic Org** | School of Earth Sciences - D0656 |
| **College/Academic Group** | Arts and Sciences |
| **Level/Career** | Graduate, Undergraduate |
| **Course Number/Catalog** | 5201 |
| **Course Title** | Introduction to Seismology |
| **Transcript Abbreviation** | Intro Seismology |
| **Course Description** | This course will provide students with the fundamentals to understand seismic theory, wave propagation, earth structure, earthquake source physics, and seismic data analysis. This is meant to be a comprehensive introduction to seismology, providing students with the requisite skills to begin research in seismology. |
| **Semester Credit Hours/Units** | Fixed: 3 |

## Offering Information

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|---|---|
| **Length Of Course** | 14 Week |
| **Flexibly Scheduled Course** | Never |
| **Does any section of this course have a distance education component?** | No |
| **Grading Basis** | Letter Grade |
| **Repeatable** | No |
| **Course Components** | Lecture |
| **Grade Roster Component** | Lecture |
| **Credit Available by Exam** | No |
| **Admission Condition Course** | No |
| **Off Campus** | Never |
| **Campus of Offering** | Columbus |

## Prerequisites and Exclusions

| | |
|---|---|
| **Prerequisites/Corequisites** | Math through Calculus III (MATH 2153) or graduate standing or permission of the instructor. Geophysical inverse theory relies heavily on linear algebra. A working knowledge of either Python or Matlab is essential for successful completion of some homework assignments. Python is preferred, with a basic understanding of I/O of data, use of Numpy/Pandas/Scipy for data manipulation, and basic plotting (e.g., matplotlib). Students wishing to form a solid base in Python should consider CSE 1224.. |
| **Exclusions** | |
| **Electronically Enforced** | No |

## Cross-Listings

**Cross-Listings**

## Subject/CIP Code

| | |
|---|---|
| **Subject/CIP Code** | 40.0601 |
| **Subsidy Level** | Doctoral Course |
| **Intended Rank** | Junior, Senior, Masters, Doctoral |

## Requirement/Elective Designation

Required for this unit's degrees, majors, and/or minors

## Course Details

**Course goals or learning objectives/outcomes**

- Basic understanding of wave propagation through Earth materials
- Understanding inverse methods for determining composition of the Earth
- Ability to download and manipulate seismic data to setup common seismology inverse problems
- Understanding of earthquake source dynamics and how events are commonly characterized with seismic data

**Content Topic List**

- seismic theory

wave propagation

earth structure

earthquake source physics

seismic data analysis

**Sought Concurrence** No

## Attachments

- EARTHSC 5201 Intro to Seismology.docx: Syllabus

*(Syllabus. Owner: Griffith,William ASHLEY)*

- CURRICULAR MAP OF COURSES BS - EARTHSC 5201 Added.docx: Curricular Map

*(Other Supporting Documentation. Owner: Griffith,William ASHLEY)*

- CEGE Concurrence.txt: Concurrence from Civil Engineering

*(Concurrence. Owner: Griffith,William ASHLEY)*

- CoverLetter_EARTHSC5201.pdf: Cover letter

*(Cover Letter. Owner: Griffith,William ASHLEY)*

## Comments

## Workflow Information

| Status | User(s) | Date/Time | Step |
|---|---|---|---|
| Submitted | Griffith,William ASHLEY | 08/08/2024 02:17 PM | Submitted for Approval |
| Approved | Griffith,William ASHLEY | 08/08/2024 02:23 PM | Unit Approval |
| Approved | Vankeerbergen,Bernadette Chantal | 08/08/2024 03:38 PM | College Approval |
| Pending Approval | Jenkins,Mary Ellen Bigler<br>Hanlin,Deborah Kay<br>Hilty,Michael<br>Neff,Jennifer<br>Vankeerbergen,Bernadette Chantal<br>Steele,Rachel Lea | 08/08/2024 03:38 PM | ASCCAO Approval |

THE OHIO STATE UNIVERSITY

College of Arts and Sciences

School of Earth Sciences

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earthsciences@osu.edu
www.earthsciences.osu.edu

August 8, 2024

Dear ASC Curriculum Committee Members,

I am submitting this proposal for EARTHSC 5201: Introduction to Seismology, on behalf of our newest Assistant Professor, Dr. Brendan Crowell. Seismology, the study of Earth's Interior via seismic waves produced by both passive (i.e., earthquakes) and active (i.e., man made) sources, is a core discipline in the field of Geophysics, and this is a course we have been sorely missing since the Geophysics concentration in the B.S. program in Earth Sciences was created. We are very excited to have Dr. Crowell to teach this course. On Bernadette Vankeerbergen's advice, I submitted a concurrence request to the Department of Civil and Geodetic Engineering, and their response was enthusiastically supportive. This course will be important to undergraduate and graduate students in Earth Sciences, graduate students in Geodetic Science, and students in Civil and Geodetic Engineering, particularly those with a concentration in Geotechnical Engineering. Thank you for your consideration.

Sincerely,

Sincerely,
Ashley

W. Ashley Griffith, PhD
Professor and Associate Director for Administration
Field Camp Director
School of Earth Sciences
The Ohio State University
275 Mendenhall Laboratory, 125 South Oval Mall, Columbus, OH 43210-1308
Office Location: ML 381
Cell: 330-285-4650
Webpage: http://u.osu.edu/griffith.233/

# Introduction to Seismology

Earth Sciences 5201 (3 Credit Hours)
Meeting Time: TBA
Meeting Location: TBA

***Instructor***
Dr. Brendan Crowell, Mendenhall Laboratory, Room 329, Phone TBD, crowell.97@osu.edu
Office Hours: TBA

***Course Objectives/Description***
This course will provide students with the fundamentals to understand seismic theory, wave propagation, earth structure, earthquake source physics, and seismic data analysis. This is meant to be a comprehensive introduction to seismology, providing students with the requisite skills to begin research in seismology. Lessons will include examples with real seismic recordings, using standardized workflows for data analysis from common archives (i.e., SAGE facility).

***Modality***
In-person

***Course Format***
In-person lecture with lecture materials provided in PPT or PDF format after classes. Homework assignments will be roughly due every other week and may include both problem sets and coding notebooks (i.e., Jupyter Notebooks). Will also include two midterm exams and one final exam.

***Prerequisites***

Math through Calculus III (MATH 2153) or graduate standing or permission of the instructor. Geophysical inverse theory relies heavily on linear algebra. A working knowledge of either Python or Matlab is essential for successful completion of some homework assignments. Python is preferred, with a basic understanding of I/O of data, use of Numpy/Pandas/Scipy for data manipulation, and basic plotting (e.g., matplotlib). Students wishing to form a solid base in Python programming should consider CSE 1224.

***Grading Breakdown (% of final grade)***
Homework assignments: 50%
Midterm 1: 15%
Midterm 2: 15%
Final Exam: 20%

***Grading Scale***

A (>= 93); A- (>= 90, < 93); B+ (>= 87, < 90); B (>= 83, < 87); B- (>= 80, < 83); C+ (>= 77, < 80); C (>= 73, < 77); C- (>= 70, < 73); D+ (>= 67, < 70); D (>= 60, < 67); E (< 60)

***Textbook***

Introduction to Seismology, Peter Shearer
https://www.cambridge.org/highereducation/books/introduction-to-seismology/C1471C1B553C05997E2BC7EB26D4C26D#overview

***Other potential useful texts (lessons will not be drawn from these texts)***

Quantitative Seismology, 2nd Edition, Aki and Richards
An Introduction to Seismology, Earthquakes, and Earth Structure, Stein and Wysession

**Topics:**

1) History of Seismology (Week 1)
2) Linear algebra and calculus refresher (Week 1)
3) Stress and Strain relations (Week 2)
    a) Stress tensor
    b) Principal axes of stress
    c) Deviatoric stress
    d) Strain tensor
    e) Linear stress-strain relationship
    f) Elastic moduli
4) Seismic Wave Equation (Weeks 3-4)
    a) The wave equation in 1-D
    b) The momentum equation
    c) The full seismic wave equation
    d) Plane waves
    e) P and S wave polarization
    f) Spherical waves
    g) Synthetic seismograms
5) Travel time ray theory (Week 5)
    a) Snell's law
    b) Ray paths for 1-D layered Earth
    c) Travel time curves, tau(p) function
    d) Low velocity zones
    e) Spherical Earth ray tracing
    f) 3-D ray tracing
    g) Seismic phases
6) Inversion of travel time data (Week 6)
    a) 1-D velocity inversion
    b) Layer cake model

    c) Tau(p) Inversion
    d) Linear inverse models and regularization
    e) 3-D velocity inversion, tomography
    f) Earthquake locations
    g) Relative event locations
7) Amplitude and phase ray theory (Week 7)
    a) Seismic wave energy
    b) Geometrical spreading in 1-D
    c) Reflection and transmission coefficients
    d) Turning points
    e) Modeling plane waves
    f) Attenuation
8) Reflection seismology (Weeks 8-9)
    a) Zero-offset sections
    b) Midpoint stacking
    c) Sources and deconvolution
    d) Migration
    e) Velocity analysis
    f) Receiver functions
    g) Kirchhoff theory
9) Surface waves and Normal modes (Weeks 10-11)
    a) Love waves
    b) Rayleigh waves
    c) Dispersion
    d) Global surface waves
    e) Normal modes
10) Earthquake seismology (Weeks 12-14)
    a) Green's functions and the moment tensor
    b) Earthquake faults
    c) Non double couple sources
    d) Radiation patterns
    e) Pulse shapes and directivity
    f) Source spectra
    g) Empirical Green's functions
    h) Stress drop and self-similarity
    i) Radiated energy
    j) Earthquake magnitudes
    k) Slip modeling
    l) Aftershocks
11) Network Seismology (Week 15)
    a) Local monitoring
    b) Global monitoring
    c) Analysis platforms
    d) Magnitude saturation

    e) The W Phase
    f) Early warning
12) Instrumentation (Week 16)
    a) Strong-motion sensors
    b) Broadband seismometers
    c) Historical instrumentation
    d) Standard naming conventions, SNCLs
13) Introductory seismic data analysis (lessons interspersed throughout semester pertaining to downloading specific data sets related to lectures - all Python based)

***Assignment Schedule and Format***

Homeworks with coding exercises will be 3-5 questions that require writing simple scripts, to be completed in either Jupyter notebooks with Python3 or in Matlab. Homeworks will be assigned at the first lecture of the week shown and due the last lecture of the week shown.

*Homework 1* - assigned Week 1, due Week 3. An overview of common linear algebra problems in seismology

*Homework 2* - assigned Week 3, due Week 5. Coding exercises on continuum mechanics and the seismic wave equation.

*Midterm 1* - Week 6 - material up to travel time ray theory

*Homework 3* - assigned Week 5, due Week 7. Coding exercises on travel time ray theory and inversion.

*Homework 4* - assigned Week 7, due Week 9. Coding exercises on amplitude and phase ray theory.

*Homework 5* - assigned Week 9, due Week 11. Coding exercises on reflection seismology and surface waves

*Midterm 2* - Week 12 - Material between Inversion of travel time data and normal modes.

*Homework 6* - assigned Week 12, due Week 15. Coding exercises on earthquake seismology.

*Final Exam* (Week 16) - Test on all material, with more focus on later material.

***Expected Learning Outcomes***

- Basic understanding of wave propagation through Earth materials
- Understanding inverse methods for determining composition of the Earth

- Ability to download and manipulate seismic data to setup common seismology inverse problems
- Understanding of earthquake source dynamics and how events are commonly characterized with seismic data

Measurement of these expected learning outcomes will come directly from coding exercises for the applied tasks and homework/tests for theoretical knowledge.

***Academic Misconduct***

Students may collaborate on homework assignments, however, each student must turn in their own copy of the work. I do not discourage the use of AI resources for your homework, but these resources will often give you the incorrect answer, so be forewarned that you will probably receive a lower grade.

It is the responsibility of the Committee on Academic Misconduct to investigate or establish procedures for the investigation of all reported cases of student academic misconduct. The term "academic misconduct" includes all forms of student academic misconduct wherever committed; illustrated by, but not limited to, cases of plagiarism and dishonest practices in connection with examinations. Instructors shall report all instances of alleged academic misconduct to the committee (Faculty Rule 3335-5-487). For additional information, see the Code of Student Conduct http://studentlife.osu.edu/csc/.

***Disability Services***

The university strives to maintain a healthy and accessible environment to support student learning in and out of the classroom. If you anticipate or experience academic barriers based on your disability (including mental health, chronic, or temporary medical conditions), please let me know immediately so that we can privately discuss options. To establish reasonable accommodations, I may request that you register with Student Life Disability Services. After registration, make arrangements with me as soon as possible to discuss your accommodations so that they may be implemented in a timely fashion.

If you are isolating while waiting for a COVID-19 test result, please let me know immediately. Those testing positive for COVID-19 should refer to the Safe and Healthy Buckeyes site for resources. Beyond five days of the required COVID-19 isolation period, I may rely on Student Life Disability Services to establish further reasonable accommodations. You can connect with them at slds@osu.edu; 614-292-3307; or slds.osu.edu.

***Religious Accommodations***

Ohio State has had a longstanding practice of making reasonable academic accommodations for students' religious beliefs and practices in accordance with applicable law. In 2023, Ohio State updated its practice to align with new state legislation. Under this new provision, students

must be in early communication with their instructors regarding any known accommodation requests for religious beliefs and practices, providing notice of specific dates for which they request alternative accommodations within 14 days after the first instructional day of the course. Instructors in turn shall not question the sincerity of a student's religious or spiritual belief system in reviewing such requests and shall keep requests for accommodations confidential.

With sufficient notice, instructors will provide students with reasonable alternative accommodations with regard to examinations and other academic requirements with respect to students' sincerely held religious beliefs and practices by allowing up to three absences each semester for the student to attend or participate in religious activities. Examples of religious accommodations can include, but are not limited to, rescheduling an exam, altering the time of a student's presentation, allowing make-up assignments to substitute for missed class work, or flexibility in due dates or research responsibilities. If concerns arise about a requested accommodation, instructors are to consult their tenure initiating unit head for assistance.

A student's request for time off shall be provided if the student's sincerely held religious belief or practice severely affects the student's ability to take an exam or meet an academic requirement and the student has notified their instructor, in writing during the first 14 days after the course begins, of the date of each absence. Although students are required to provide notice within the first 14 days after a course begins, instructors are strongly encouraged to work with the student to provide reasonable accommodation if a request is made outside the notice period. A student may not be penalized for an absence approved under this policy.

If students have questions or disputes related to academic accommodations, they should contact their course instructor, and then their department or college office. For questions or to report discrimination or harassment based on religion, individuals should contact the Office of Institutional Equity. (Policy: Religious Holidays, Holy Days and Observances)

From: Lenhart, John
Sent: Wednesday, August 7, 2024 12:17 PM
To: MacKay, Allison A.; Griffith, W. Ashley
Cc: Howat, Ian; Sawyer, Derek
Subject: RE: Concurrence requested for Introduction to Seismology

Hello Ashley,

I passed the proposed syllabus around the geotechnical faculty in CEGE and they are supportive of the new course and would likely direct some of their students to take it.

Thus, we are happy to provide concurrence.

Thanks!

John

John J. Lenhart, Ph.D.
Professor and Associate Chair
Co-Director, Ohio Water Resources Center
Department of Civil, Environmental and Geodetic Engineering
The Ohio State University
470 Hitchcock Hall, 2070 Neil Avenue, Columbus, OH 43210

Phone: 614/688-8157
Email: lenhart.49@osu.edu
Web: https://envsurfchem.engineering.osu.edu/
and http://wrc.osu.edu/

From: MacKay, Allison A. <mackay.49@osu.edu>
Sent: Monday, August 5, 2024 6:54 PM
To: Griffith, W. Ashley <griffith.233@osu.edu>
Cc: Lenhart, John <lenhart.49@osu.edu>
Subject: RE: Concurrence requested for Introduction to Seismology

Hello Ashley,

Thank you for sending the information for your SES concurrence request. I have CC'd John Lenhart, who oversees our Undergraduate Studies Committee. John will be in touch with the formal CEGE response.

Thank you,
Allison

Allison MacKay, PhD, BCEEM
Professor and Chair
Chair, ASCE Department Heads Coordinating Council
Past-President, Association of Environmental Engineering and Science Professors

College of Engineering Department of Civil, Environmental and Geodetic Engineering
470C Hitchcock Hall, 2070 Neil Ave, Columbus, OH 43210
614-247-7652 Office
mackay.49@osu.edu
Pronouns: she/her/hers / Honorific: Prof.

My working day may not be your working day, so feel free to respond on your schedule.

From: Griffith, W. Ashley <griffith.233@osu.edu>
Sent: Sunday, August 4, 2024 10:42 PM
To: MacKay, Allison A. <mackay.49@osu.edu>
Cc: Howat, Ian <howat.4@osu.edu>; Sawyer, Derek <sawyer.144@osu.edu>
Subject: Concurrence requested for Introduction to Seismology

Dear Dr. MacKay,

The School of Earth Sciences is seeking concurrence with the Department of Civil, Environmental, and Geodetic Engineering for the proposed course EARTHSC 5201 Introduction to Seismology (syllabus attached). We are proposing this as a 3-credit course to be taught by our newest Assistant Professor, Brendan Crowell, and it will fit in as an elective for our Geophysics majors. My hope is that any overlap between this course and those in CEGE will be complementary.

Please email your responses/concurrences to me (griffith.233@osu.edu) and our chair copied to this email, howat.4@osu.edu. Concurrence will be assumed if no response is received within two weeks (Aug 19). Thank you very much for this help for your help.

Sincerely,
Ashley

W. Ashley Griffith, PhD
Professor
Associate Director for Administration
Field Camp Director
School of Earth Sciences
The Ohio State University
275 Mendenhall Laboratory, 125 South Oval Mall, Columbus, OH 43210-1308
Office Location: ML 381
Cell: 330-285-4650
Webpage: http://u.osu.edu/griffith.233/

**CURRICULAR MAP OF COURSES AVAILABLE IN EARTH SCIENCES B.S.**

| Course Number | Course Title | PLO A: Read/ evaluate Earth Sci literature | PLO B: Present Earth Sci info | PLO C: Apply Earth Sci data | PLO D: Apply appropriate techniques/ methods | PLO E: Identify Earth Sci problems, develop solutions | PLO F: Apply other sciences | BS program required /elective |
|---|---|---|---|---|---|---|---|---|
| Earth Sciences 1100 | Planet Earth: How it works | B | B | B | B | B | B | O-prep |
| Earth Sciences 1105 | Geology of the National Parks | B | B | B | | B | B | O-prep |
| Earth Sciences 1108 | Gemstones | B | B | B | | B | B | O-prep |
| Earth Sciences 1121 | The Dynamic Earth | B | B | B | B | B | B | O-prep |
| Earth Sciences 1151 | Natural Hazards | B | B | B | B | B | B | O-prep |
| Earth Sciences 2203 | Environmental Geoscience | B | B | B | | B | B | O-prep |
| Earth Sciences 2205 | The Planets | B | B | B | | B | B | O-prep<br>O-PS |
| Earth Sciences 2206(&S) | Principles of Oceanography | B | B | B | | B | B | O-prep<br>O-SS |
| Earth Sciences 1200 | Introductory Earth Science Lab | | B | B | B | B | B | O-prep |
| Earth Sciences 2000 | Preparation for Thesis and Careers in the Earth Sciences | B-I | B-I | B-I | | B-I | | R-GS<br>R-GP<br>R-CWE |
| Earth Sciences 2122 | Climate and Life over Billions of years on Earth | B-I | B-I | B-I | B-I | B-I | | O-SS<br>R-GS |
| Earth Sciences 2155 | Energy and Environment | B-I | B-I | B-I | B-I | B-I | | O-SS |
| Earth Sciences 2203 | Environmental Geoscience | B-I | B-I | B-I | B-I | B-I | | O-SS |
| Earth Sciences 2204 | Exploring Water Issues | B-I | B-I | B-I | B-I | B-I | | O-SS |
| Earth Sciences 2210 | Energy, Mineral Resources, and Society | B-I | B-I | B-I | B-I | B-I | | O-SS |
| Earth Sciences 2212 | Intro to Earth Materials | B-I | B-I | B-I | B-I | B-I | | O-CWE |
| Earth Sciences 3411 | Water Security for the 21st Century | I | I | I | I | I | | O-SS |

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| Earth Sciences 2245 | Introductory Data Analysis for Earth and Environmental Sciences | B-I | B-I | B-I | B-I | B-I | | R-GS<br>R-CWE<br>R-GP |
| Earth Sciences 4194 | Group Studies | I | I | I | I | I | I | |
| Earth Sciences 4194H | Honors Group Studies | I | I | I | I | I | I | |
| Earth Sciences 5310 | Remote Sensing in the Earth Sciences | A | A | A | A | | A | O-GP<br>O-PS<br>O-MS |
| Earth Sciences 4421 | Earth Materials | I | I | I | I | I | I | R-GS<br>O-CWE<br>O-CWE<br>O-MC |
| Earth Sciences 4423 | Introductory Petrology | I | I | I | I | I | I | R-GS<br>O-MC |
| Earth Sciences 4425 | Energy Resources and Sustainability | I | I | I | I | I | I | O-SS |
| Earth Sciences 4450 | Water, Ice, and Energy in the Earth System | I | I | I | I | I | I | R-CWE<br>O-MS<br>O-HG |
| Earth Sciences 4501 | Paleontology | I | I | I | I | I | I | O-MC |
| Earth Sciences 4502 | Stratigraphy and Sedimentation | I | I | I | I | I | I | R-GS<br>O-CWE<br>O-MC |
| Earth Sciences 4530 | Structural Geology | I | I | I | I | I | I | R-GS<br>R-GP |
| Earth Sciences 4560 | Applied Geophysics | I | I | I | I | I | I | R-GP<br>O-PS<br>O-PG |
| Earth Sciences 4880 | Seminar in Geophysics | I | I | I | I | I | I | |
| Earth Sciences 4998 | Undergraduate Research in Earth Sciences | I - A | I - A | I - A | I - A | I - A | I - A | |
| Earth Sciences 4998H | Honors Undergraduate Research in Earth Sciences | A | A | A | A | A | A | |
| Earth Sciences 4999.01 | Undergraduate Thesis in Earth Sciences | I - A | I - A | I - A | I - A | I - A | I - A | R-GS<br>R-CWE<br>R-GP |
| Earth Sciences 4999.01H | Honors Undergraduate Thesis in Earth Sciences | A | A | A | A | A | A | |
| Earth Sciences 5160 | Geomicrobiology | A | A | A | A | A | A | O-CWE |

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|---|---|---|---|---|---|---|---|---|
| Earth Sciences 5189.01 | Field Geology I | I - A | I - A | I - A | I - A | I - A | I - A | R-GS R-PG O-MC |
| Earth Sciences 5189.02 | Field Geology II | A | A | A | A | A | A | R-GS O-PG |
| Earth Sciences 5191 | Internship in the Earth Sciences | I - A | I - A | I - A | I - A | I - A | I - A | |
| Earth Sciences 5191.01 | Museum Internship | A | A | A | A | A | A | |
| Earth Sciences 5193.xx | Individual Studies | I - A | I - A | I - A | I - A | I - A | I - A | |
| Earth Sciences 5194 | Group Studies | I - A | I - A | I - A | I - A | I - A | I - A | |
| Earth Sciences 5201 | Introduction to Seismology | A | A | A | A | A | A | O-GP |
| Earth Sciences 5203 | Geo-environment and Human Health | A | A | A | A | A | A | O-CWE O-HG |
| Earth Sciences 5205 | Planetary Science | A | A | A | A | A | A | R-PS |
| Earth Sciences 5206 | Advanced Oceanography | A | A | A | A | A | A | R-MS O-CWE |
| Earth Sciences 5242 | Nat. Hist. Bahamas | I-A | I-A | I-A | I-A | I-A | I-A | O-MS O-CWE |
| Earth Sciences 5268 | Soils and Climate Change | A | A | A | A | A | A | O-CWE O-HG |
| Earth Sciences 5501 | Museum Databases | A | A | A | A | A | A | O-MC |
| Earth Sciences 5550 | Geomorphology | I-A | I-A | I-A | I-A | I-A | I-A | O-PS O-HG |
| Earth Sciences 5600 | Siliciclastic Depositional Systems | A | A | A | A | A | A | |
| Earth Sciences 5601.01 | Sedimentary Petrology: Sandstones | A | A | A | A | A | A | |
| Earth Sciences 5601.02 | Sedimentary Petrology: Carbonate Rocks and Shales | A | A | A | A | A | A | |
| Earth Sciences 5602.01 | Carbonate Depositional Systems I | A | A | A | A | A | A | |
| Earth Sciences 5602.02 | Carbonate Depositional Systems II | A | A | A | A | A | A | O-MS |
| Earth Sciences 5603 | Stratigraphy | A | A | A | A | A | A | |
| Earth Sciences 5604 | Sequence Stratigraphy | A | A | A | A | A | A | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Earth Sciences 5605 | Paleoceano graphy | A | A | A | A | A | A | |
| Earth Sciences 5613 | Micropaleon tology | A | A | A | A | A | A | |
| Earth Sciences 5614 | Paleobiology | A | A | A | A | A | A | |
| Earth Sciences 5615 | Paleoecology | A | A | A | A | A | A | |
| Earth Sciences 5617 | Petrology of Earth and Planets | A | A | A | A | A | A | |
| Earth Sciences 5618 | Advanced Historical Geology | A | A | A | A | A | A | |
| Earth Sciences 5621 | Introduction to Geochemistry | A | A | A | A | A | A | O-CWE O-HG |
| Earth Sciences 5622 | Stable Isotope Biogeo chemistry | A | A | A | A | A | A | O-MS |
| Earth Sciences 5625 | Igneous Petrology | A | A | A | A | A | A | |
| Earth Sciences 5627 | Global Biogeochemical Cycles | A | A | A | A | A | A | |
| Earth Sciences 5628 | Environmental Isotope Geochemistry | A | A | A | A | A | A | |
| Earth Sciences 5629 | Principles of Petrology | A | A | A | A | A | A | |
| Earth Sciences 5636 | Advanced Topics in Mineralogy and Crystallography | A | A | A | A | A | A | |
| Earth Sciences 5641 | Geostatistics | A | A | A | A | A | A | O-GP |
| Earth Sciences 5642 | Geomathe matical Analysis | A | A | A | A | A | A | |
| Earth Sciences 5644 | Tectonic Evolution of Continents | A | A | A | A | A | A | |
| Earth Sciences 5645 | Advanced Structural Geology | A | A | A | A | A | A | O-GP |
| Earth Sciences 5646 | Geodynamics | A | A | A | A | A | A | O-GP O-PS |
| Earth Sciences 5650 | Glaciology | A | A | A | A | A | A | O-CWE |
| Earth Sciences 5651 | Hydrogeology | A | A | A | A | A | A | O-CWE O-GP R-HG |
| Earth Sciences 5655 | Land Surface Hydrology | A | A | A | A | A | A | O-CWE O-HG |

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|---|---|---|---|---|---|---|---|---|
| Earth Sciences 5656 | Ecohydrology in a Changing Climate | A | A | A | A | A | A | O-CWE O-HG |
| Earth Sciences 5660 | Geology of Metallic Deposits | A | A | A | A | A | A | |
| Earth Sciences 5661 | Petroleum Geology | A | A | A | A | A | A | O-PG |
| Earth Sciences 5663 | Global Change and Sustainability in the Earth System | A | A | A | A | A | A | O-SS |
| Earth Sciences 5670 | General and Economic Geology of Selected Areas | A | A | A | A | A | A | |
| Earth Sciences 5676 | Elemental Chemical Analysis using Inductively Coupled Plasma Optical Emission and Mass Spectrometry | A | A | A | A | A | A | |
| Earth Sciences 5680 | Deep Earth Geophysics | A | A | A | A | A | A | O-GP O-PS |
| Earth Sciences 5687 | Borehole Geophysics | A | A | A | A | A | A | O-GP O-PG |
| Earth Sciences 5703 | Principles of Biostratigraphy | A | A | A | A | A | A | |
| Earth Sciences 5713 | Taxonomy and Phylogeny in the Fossil Record | A | A | A | A | A | A | |
| Earth Sciences 5714 | Biometry | A | A | A | A | A | A | |
| Earth Sciences 5717 | Critical Issues in World Freshwater Resources | A | A | A | A | A | A | |
| Earth Sciences 5718 | Aquatic Geochemistry | A | A | A | A | A | A | |
| Earth Sciences 5719 | Environmental Organic Geochemistry | A | A | A | A | A | A | |
| Earth Sciences 5746 | Seminar in Rheological Properties of Solids | A | A | A | A | A | A | |
| Earth Sciences 5751 | Quantitative Ground-Water Flow Modeling | A | A | A | A | A | A | O-PG O-HG |
| Earth Sciences 5752 | Contaminants in Aqueous Systems | A | A | A | A | A | A | |
| Earth Sciences 5754 | Risk Assessment and Management in Earth Systems | A | A | A | A | A | A | |

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|---|---|---|---|---|---|---|---|---|
| Earth Sciences 5757 | Artificial Intelligence in Earth Sciences | A | A | A | A | A | A | O-GP |
| Earth Sciences 5779 | Seminar in Physical Properties of Minerals and Rocks | A | A | A | A | A | A | |
| Earth Sciences 5780 | Reflection Seismology | A | A | A | A | A | A | O-MS<br>O-PG |
| Earth Sciences 5781 | Gravity Exploration | A | A | A | A | A | A | O-GP |
| Earth Sciences 5782 | Magnetic Exploration | A | A | A | A | A | A | O-GP |
| Geod Sci 5781 | Geodesy and Geodynamics | A | A | A | A | A | A | O-GP<br>O-PS |
| Electives from other departments (Geog, AtmosSC, EEOB, ENR, Chem, Math, etc.) | | | | | | | I-A | |

Program Learning Goals:
A) Students critically read and evaluate Earth Science literature

B) Students present Earth Science information in a clear and logical manner, both orally and in writing.

C) Students apply knowledge of Earth Science data to understand the dynamic physical, chemical, and biological processes of the Earth and its history.

D) Students apply knowledge of appropriate techniques, field methods, field mapping, and numerical methods to measure, portray, analyze, and interpret Earth Science data in specific subdisciplines.

E) Students identify Earth Science problems and develop solutions.

F) Students apply knowledge of modern applications from chemistry, physics, biology, mathematics, statistics, and computing to the solution of Earth Science problems.

Key: B = Beginning level; I = Intermediate level; A = Advanced level

Program Course Listing:
R- Required
O - one of multiple option
prep - preparation (all BS programs)
SS – science of sustainability (all BS programs)
GS – Geological Sciences subprogram
CWE- Climate Water Environment subprogram
GP- Geophysics subprogram
MS – Marine Science certificate
PS- Planetary Science certificate
HG- Hydrogeology certificate
MC – Museum Curation certificate
PG- Petroleum Geology certificate