GEOLOGY & ENVIRONMENTAL GEOSCIENCES (GEOL)

Faculty

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Geology is the natural science that involves the nature and history of Earth, including scientific analysis of environmental problems. The Bucknell geology curriculum engages students with concepts and issues related to Earth and its environments through coursework, field studies and scientific research. A geology degree equips students with analytical skills, problem-solving skills, communication skills, experience in teamwork and solid grounding in field-based science. Geoscience includes diverse subdisciplines, including geologic hazards, geochemistry, geophysics, hydrogeology, tectonics and engineering geology. At an introductory level, geology coursework provides students with basic knowledge of Earth and its systems and how that knowledge can provide an understanding of potential solutions to environmental problems. Knowledge of Earth, its processes, hazards, history, resources and limitations can be an important component of a liberal arts education and can provide a foundation for advanced work in the discipline.

An undergraduate degree provides the foundation needed for employment or graduate degree specialization. In addition to gaining acceptance to some of the most prestigious graduate programs in the country, recent graduates secured employment in environmental or engineering consulting firms, governmental agencies, oil and gas companies, and educational institutions. Students also have used our courses toward certification as teachers in Earth and space sciences.

At Bucknell University, students can major in either environmental geosciences or geology, and each of these is available in both bachelor of arts and bachelor of science degree programs. These four tracks are united in having a common core of six geology courses:

GEOL 203	Physical/Environmental Geology	1
GEOL 204	Evolution of the Earth	1
GEOL 304	Crystallography-Mineralogy	1
GEOL 309	Sedimentology and Stratigraphy	1
GEOL 314	Structural Geology	1
GEOL 316	Geomorphology	1

A bachelor of science track is appropriate for students who have decided to begin a career in geoscience or pursue a graduate degree in a geologic/environmental profession. Students who elect a bachelor of arts track have greater curricular flexibility, allowing for a second major. Recent bachelor of arts graduates have attended graduate school or secured employment in geoscience, environmental science, environmental law or policy, education, business, medicine and science writing.

Bachelor of Arts Major in Geology

Requires eight geology courses and two additional courses.

Program Requirements		
GEOL 203	Physical/Environmental Geology	1
GEOL 204	Evolution of the Earth	1
GEOL 304	Crystallography-Mineralogy	1
GEOL 309	Sedimentology and Stratigraphy	1
GEOL 314	Structural Geology	1
GEOL 316	Geomorphology	1
Two courses at the 300 level or above with the exception of GEOL 319 and GEOL 320		2
Additional requirements for the major include:		
MATH 201	Calculus I	1
or MATH 216	Statistics I	
PHYS 211	Classical and Modern Physics I	1
or CHEM 205	Principles of Chemistry	

Students are encouraged to take a summer field course in geology, to elect additional courses in science and mathematics, and to participate in independent study research opportunities through GEOL 319 Undergraduate Research and/or GEOL 320 Undergraduate Research.

Bachelor of Science Major in Geology

Requires 10 geology courses and five to six additional science/math courses:

Program Requirements		
GEOL 203	Physical/Environmental Geology	1
GEOL 204	Evolution of the Earth	1
GEOL 304	Crystallography-Mineralogy	1
GEOL 309	Sedimentology and Stratigraphy	1
GEOL 314	Structural Geology	1
GEOL 316	Geomorphology	1
GEOL 340	Igneous and Metamorphic Petrology	1
Select three of the following:		3
GEOL 317	Paleontology	
GEOL 321	Special Topics in Geology	
or GEOL 322	Special Topics in Geology	
GEOL 305	Introduction to Geochemistry	
GEOL 334	Geophysics	
GEOL 336	Hydrogeology	
GEOL 338	Applied Environmental Geomorphology	
A supervised research experience approved by the department.		
Additional requirements for the major include:		
MATH 201 & MATH 202	Calculus I and Calculus II	2
MATH 211	Calculus III	1
or MATH 216	Statistics I	
PHYS 211	Classical and Modern Physics I	1
Chemistry requirement [1]		1-2
A summer course in field geology is recommended.		

[1] CHEM 205 Principles of Chemistry and CHEM 230 Principles of Chemistry 2 or CHEM 231 Quantitative Analysis.

Below is the recommended sequence for the Bachelor of Science major.

First Year			
First Semester	**Credits**	**Second Semester**	**Credits**
MATH 201	1	MATH 202	1
GEOL 203 or 204[2]	1	GEOL 204 or 203[2]	1
	2		**2**
Sophomore			
First Semester	**Credits**	**Second Semester**	**Credits**
CHEM 205	1	MATH 211 or 216	1
GEOL 304	1	GEOL 340	1
GEOL 316	1		
	3		**2**
Junior			
First Semester	**Credits**	**Second Semester**	**Credits**
PHYS 211	1	GEOL 309	1
Elective in geology[3]			
GEOL 314	1		
	2		**1**

Senior			
First Semester	**Credits**	**Second Semester**	**Credits**
Elective in geology[3]		Elective in geology[3]	
	0		**0**

Total Credits: 12

[2] GEOL 250 Geology for Engineers may be substituted for GEOL 203 Physical/Environmental Geology by consultation with the department.

[3] Three courses chosen from GEOL 305 Introduction to Geochemistry, GEOL 317 Paleontology, GEOL 334 Geophysics, GEOL 321 Special Topics in Geology or GEOL 322 Special Topics in Geology and GEOL 336 Hydrogeology.

Bachelor of Arts Major in Environmental Geosciences

Requires eight geology courses and two additional courses:

Program Requirements		
GEOL 203	Physical/Environmental Geology	1
GEOL 204	Evolution of the Earth	1
GEOL 304	Crystallography-Mineralogy	1
GEOL 309	Sedimentology and Stratigraphy	1
GEOL 314	Structural Geology	1
GEOL 316	Geomorphology	1
GEOL 305	Introduction to Geochemistry	1
Select one of the following:		1
GEOL 334	Geophysics	
GEOL 336	Hydrogeology	
GEOL 338	Applied Environmental Geomorphology	
Additional requirements for the major include:		
MATH 201	Calculus I	1
or MATH 216	Statistics I	
PHYS 211	Classical and Modern Physics I	1
or CHEM 205	Principles of Chemistry	

Students are encouraged to take a summer field geology course and to participate in independent study research opportunities through GEOL 319 Undergraduate Research and GEOL 320 Undergraduate Research.

Electives are recommended in science and mathematics, as well as from other departments offering environmental sciences and engineering courses.

Bachelor of Science Major in Environmental Geosciences

Requires 10 geology courses and six additional science/math courses:

Program Requirements		
GEOL 203	Physical/Environmental Geology	1
GEOL 204	Evolution of the Earth	1
GEOL 304	Crystallography-Mineralogy	1
GEOL 305	Introduction to Geochemistry	1
GEOL 309	Sedimentology and Stratigraphy	1
GEOL 314	Structural Geology	1
GEOL 316	Geomorphology	1
GEOL 334	Geophysics	1
GEOL 336	Hydrogeology	1
Select one of the following:		1
GEOL 317	Paleontology	
GEOL 321	Special Topics in Geology	
or GEOL 322	Special Topics in Geology	
GEOL 338	Applied Environmental Geomorphology	

GEOL 340	Igneous and Metamorphic Petrology	
A supervised research experience approved by the department.		
Additional requirements for the major include:		
MATH 201 & MATH 202	Calculus I and Calculus II	2
MATH 211	Calculus III	1
or MATH 216	Statistics I	
PHYS 211	Classical and Modern Physics I	1
Two courses from approved list of courses from either biology, chemistry or civil engineering: [4]		2
OPTION 1:		
BIOL 203	Integrated Concepts in Biology Fall	
BIOL 204	Integrated Concepts in Biology Spring	
OPTION 2: Select two courses in chemistry:		
CHEM 205 & CHEM 230	Principles of Chemistry and Principles of Chemistry 2	
Or		
CHEM 211 & CHEM 212	Organic Chemistry I and Organic Chemistry II	
OPTION 3: Select two courses in engineering:		
CEEG 320	Water Resources Engineering	
CEEG 340	Environmental Engineering	
CEEG 350	Geotechnical Engineering I	
CEEG 421	Hydrology	
CEEG 425	Groundwater	
CEEG 444	Hazardous Waste Management	
CEEG 451	Environmental Geotechnology	
ENGR 222	Civil Engineering Fluid Mechanics	
ENGR 229	Solid Mechanics I	
Additional recommended courses:		
Environmental policy course (e.g. ENST 211, ENST 221, ENST 245)		
A summer course in field geology is strongly recommended.		
Additional courses in statistics and advanced mathematics.		

[4] Additional courses from biology, chemistry or civil engineering may be substituted with the approval of the department.

The recommended sequence for the Bachelor of Science major in Environmental Geosciences is as follows. (The sequence may be altered in consultation with adviser.)

First Year

First Semester	Credits	Second Semester	Credits
MATH 201	1	MATH 202	1
GEOL 203 or 204[5]	1	GEOL 204 or 203[5]	1
	2		**2**

Sophomore

First Semester	Credits	Second Semester	Credits
GEOL 314	1	GEOL 305	1
GEOL 316	1	GEOL 309	1
MATH 211 or 216	1		
	3		**2**

Junior

First Semester	Credits	Second Semester	Credits
PHYS 211	1	Science/engineering elective (see Electives table below)	1
GEOL 304	1	GEOL 336	1

Science/engineering elective (see Electives table below)		1	
		3	**2**

Senior

First Semester	Credits	Second Semester	Credits
GEOL 334		1 Elective in geology[6]	1
		1	**1**

Total Credits: 16

5 GEOL 250 Geology for Engineers may be substituted for GEOL 203 Physical/Environmental Geology by consultation with the department.

6 One 300-level or above geology course chosen from GEOL 317 Paleontology, GEOL 321 Special Topics in Geology or GEOL 322 Special Topics in Geology, GEOL 338 Applied Environmental Geomorphology, or GEOL 340 Igneous and Metamorphic Petrology.

Independent supervised research experiences are strongly encouraged by the department and research opportunities are available through GEOL 319 or GEOL 320 Undergraduate Research.

The department encourages majors who are completing independent research experiences and who meet requirements to become candidates for Honors in geology.

The department attempts to make it possible for students to enroll in study abroad programs. At times this involves changing sequences of recommended courses. Consultation with major adviser is essential.

Courses in all of our degree programs are designed to provide students with many opportunities to practice and develop their writing, speaking, and information literacy skills, consistent with the learning objectives of the College of Arts & Sciences Core Curriculum (CASCC).

Culminating Experience Within the Major

The Culminating Experience for BA students is designed to provide more flexibility to allow for students to better tailor this experience to their broad interests. All BA geology majors will meet the Culminating Experience through one of four options:

- Successful completion of the Supervised Research Experience for BA majors (described below).
- Successful completion of one semester of GEOL 319 Undergraduate Research/GEOL 320 Undergraduate Research or a summer research experience in collaboration with a supervising faculty member.
- Successful completion of a summer field course, subject to approval by the department.
- Successful completion of an internship, subject to approval by the department.

By the end of fall semester junior year, BA students submit a written proposal to their academic adviser describing which of the above options they have chosen to satisfy the Culminating Experience. The academic and/or research advisors vet proposals and set criteria for successful completion of the research experience. A grade of C- or above is expected for successful completion of summer field camp or GEOL 319/GEOL 320. A positive support letter from the primary supervisor is expected for successful completion of an internship.

BS students satisfy the Culminating Experience within the major by completing the Supervised Research Experience (described below).

Supervised Research Experience

BA Geology and Environmental Geosciences Majors

BA students must complete all of the following requirements to successfully complete the Supervised Research Experience:

1. Consult with multiple, potential faculty research advisers during the fall semester of their junior year and select a project in collaboration with at least one member of the department faculty preferably by the end of the fall semester, and no later than the last day of class of the spring semester, junior year.
2. In consultation with their research adviser, students will develop a written proposal summarizing the research objective, work plan and significance. The research proposal must be completed at a time agreed upon by the student and their research adviser, but no later than the fourth week of classes in the fall semester, senior year. The proposal is reviewed by both the academic and research advisers for approval.
3. Research projects are one-semester minimum duration during the academic year or eight weeks minimum duration during the summer. Research may be conducted off-campus under the supervision of an off-campus co-adviser. If the research takes place during the academic year, students must successfully complete GEOL 319 Undergraduate Research and/or GEOL 320 Undergraduate Research.
4. BA students in consultation with their research adviser will give either an oral presentation of the results of their research or submit a written report of their findings to successfully complete the Research Experience.

BS Geology and Environmental Geosciences Majors

To satisfy the Supervised Research Experience, BS students plan and execute a research project supervised by a faculty member during their junior and/or senior year. All BS majors must complete this requirement for their Culminating Experience.

To successfully complete the Supervised Research Experience BS students must complete the following requirements:

1. Consult with multiple, potential faculty research advisers during the fall semester of their junior year and select a project in collaboration with at least one member of the department faculty preferably by the end of the fall semester, junior year and no later than the last day of class of the spring semester, junior year.
2. In consultation with their research adviser, students will develop a written proposal summarizing the research objective, work plan and significance. The research proposal must be completed at a time agreed upon by the student and their research adviser, but no later than the fourth week of classes in the fall semester, senior year. The proposal is reviewed by both the academic advisor or department chair and the research adviser for approval.
3. Research projects are one-semester minimum duration during the academic year or eight weeks minimum duration during the summer. Research may be conducted off-campus under the supervision of an off-campus co-adviser. If the research takes place during the academic year, students must successfully complete GEOL 319 Undergraduate Research Undergraduate Research and/or GEOL 320 Undergraduate Research.
4. BS students must complete a written thesis or scientific report that is approved by their research adviser and the department chair and give an oral presentation of the results of their research to successfully complete the Research Experience.

Students may choose from three **minors** in the area of geology:

Geology Minor

Requires four courses.

GEOL 203	Physical/Environmental Geology	1
or GEOL 250	Geology for Engineers	
GEOL 204	Evolution of the Earth	1
Select two 300-level geology courses except: GEOL 319, GEOL 320		2

Engineering Geology Minor

Requires four courses.

GEOL 250	Geology for Engineers	1
GEOL 314	Structural Geology	1
Select two 300-level geology courses except: GEOL 319, GEOL 320		2

Environmental Geology Minor

Requires four courses.

Select one of the following:		
GEOL 203	Physical/Environmental Geology	1
or GEOL 250	Geology for Engineers	
Select two of the following:		2
GEOL 305	Introduction to Geochemistry	
GEOL 316	Geomorphology	
GEOL 334	Geophysics	
GEOL 336	Hydrogeology	
GEOL 338	Applied Environmental Geomorphology	
Select one 200-level or 300-level geology course except: GEOL 319 or GEOL 320		1

Majors in Geology will be able to:

Meet all of the expectations of students in introductory courses, plus:

Understand core areas of geology and environmental geology, and interpret a wide range of earth processes on different temporal and spatial scales.

Demonstrate competence in collecting scientific data, including field observation and field and analytical measurements.

Demonstrate the skills of interpretive analysis and critical thinking with respect to geological problems involving temporal and spatial relationships.

Make informed decisions on issues of local and global environmental significance based on an understanding of:

The interconnectedness of the natural sciences;
The linkages of processes and systems that characterize Earth systems;
The interrelationships between humans and natural Earth systems.

Conduct effective independent and collaborative investigations.

Execute a formal research project, including the use of primary literature, development of a scientific proposal, collection of new primary data, interpretation of new data and dissemination of results, both orally and in a written thesis (B.S. majors only).

All students who have taken an introductory geology course will have a basic understanding of the following: how science works (the scientific method); human interaction with the environment; deep geologic time, including relative and absolute dating approaches; tectonics, the rock cycle, basic Earth structure and how we understand it; and topographic and geologic map reading.

Courses

GEOL 107. Global Change - Past and Present. 1 Credit.
Offered Either Fall or Spring; Lecture hours:3
Introduction to major transformations of the physical, biological, and chemical components of Earth systems from a geological perspective including climate, tectonics, biodiversity, sea-level, and ocean circulation. Not open to students who have taken GEOL 204. Preference given to first-years and sophomores.

GEOL 108. When Rocks Attack. 1 Credit.
Offered Either Fall or Spring; Lecture hours:3
Students explore popular depictions of natural disasters to assess their geologic plausibility. Not open to students who have taken GEOL 117 or GEOL 203 or GEOL 250. Preference given to first-years and sophomores.

GEOL 109. Energy and Natural Resources. 1 Credit.
Offered Either Fall or Spring; Lecture hours:3
Origin, development, and use of natural resources for energy production with an emphasis on petroleum, natural gas, and nuclear energy and their impact on the environment. Not open to students who have taken GEOL 117, GEOL 203, or GEOL 250. Only open to first-years and sophomores.

GEOL 117. Environmental Geohazards. 1 Credit.
Offered Either Fall or Spring; Lecture hours:3
Geologic environmental hazards. Emphasis on hazards recognition and assessment in seminars, and field applications. Topics include: soils, slopes, floods, fans, earthquakes, land use, coastal, and groundwater hazards. Preference given to first-years and sophomores. Not open to Geology majors, except by permission of instructor, or students who have taken GEOL 108 or GEOL 316.

GEOL 201. Earth and the Environment. 1 Credit.
Offered Summer Session Only; Lecture hours:3,Other:2
Earth and the Environment examines the fundamental geological processes that govern how the earth works. The topics include plate tectonics, types of rocks and minerals, the rock cycle, volcanism, seismicity, surface processes and introduction to geologic mapping. Finally, it examines the human impact on the geological environment.

GEOL 203. Physical/Environmental Geology. 1 Credit.
Offered Both Fall and Spring; Lecture hours:3,Lab:4
Introduction to Earth's dynamic systems, plate tectonic processes that make Earth a unique planet, and human interaction with Earth. Geologic factors and limitations that affect use or management of the environment. Not open to students who have taken GEOL 250. Prerequisite: first- or second-year status, others by permission.

GEOL 204. Evolution of the Earth. 1 Credit.
Offered Either Fall or Spring; Lecture hours:3,Lab:4
Introduction to the evolution of life, climate, plate tectonics, and catastrophes through time provides perspective for making decisions about ongoing and future environmental change. Preference given to first-years and sophomores.

GEOL 208. Surface Mapping & Subsurface Imaging. 1 Credit.
Offered Either Fall or Spring; Lecture hours:3,Lab:2
Course is designed for students without prior exposure to geoscience, to learn how to detect subsurface features (walls, roads, groundwater, bedrock). Students learn how to collect geospatial data over the earth's surface, present/analyze data in a GIS environment. Not open to students who have taken GEOL 230 or GEOL 334.

GEOL 230. Environmental GIS. 1 Credit.
Offered Either Fall or Spring; Lecture hours:4
Geographic Information Systems (GIS) in geologic mapping, environmental monitoring, and hydrologic modeling. Introduction to global positioning, (GPS), environmental databases, spatial analyses, and terrain modeling.

GEOL 250. Geology for Engineers. 1 Credit.
Offered Spring Semester Only; Lecture hours:3,Lab:4
Basic principles, including properties of rocks and soils, hydrology, surface processes, rock mechanics, environmental parameters, geological hazards, and engineering case histories. Not open to students who have taken GEOL 203. GEOL 250 is restricted to first- and second-year civil and environmental engineering students and others by permission.

GEOL 304. Crystallography-Mineralogy. 1 Credit.
Offered Either Fall or Spring; Lecture hours:3,Lab:3
Principles of crystallography and mineralogy; crystal morphology, structure, chemistry, physical properties, genesis, occurrence, and identification of important minerals by various techniques including chemical analysis. Prerequisite: GEOL 203 or GEOL 204 or GEOL 250 or permission of the instructor.

GEOL 305. Introduction to Geochemistry. 1 Credit.
Offered Either Fall or Spring; Lecture hours:3,Lab:4
Composition of natural waters and sediments, basic thermodynamics and kinetics, acid-base and oxidation-reduction reactions, chemical weathering, stable and radioactive isotopes, carbon and nutrient cycles, anthropogenic impacts on geochemical cycles. Prerequisites: CHEM 203 or CHEM 205 or CHEM 207 or permission of the instructor. Crosslisted as GEOL 605.

GEOL 309. Sedimentology and Stratigraphy. 1 Credit.
Offered Spring Semester Only; Lecture hours:3,Lab:4
Principles and techniques of the study of depositional processes and environments. Emphasis on semester-long sedimentary basin analysis project including analysis of Paleozoic outcrops near campus. Prerequisite: GEOL 204.

GEOL 314. Structural Geology. 1 Credit.
Offered Fall Semester Only; Lecture hours:3,Lab:4
Orientation and geometric analyses of rock structures, kinematics and mechanics of rock deformation at all scales. Prerequisite: GEOL 203 or GEOL 250 or permission of the instructor. Crosslisted as GEOL 614.

GEOL 316. Geomorphology. 1 Credit.
Offered Either Fall or Spring; Lecture hours:3,Lab:4
Physical processes shaping the Earth's surface and evolution of resulting landforms. Emphasis on linkages between landscape components and understanding complex relationships between process and form. Prerequisite: GEOL 203 or GEOL 204 or GEOL 250 or permission of the instructor. Crosslisted as GEOL 616.

GEOL 317. Paleontology. 1 Credit.
Offered Alternate Fall or Spring; Lecture hours:3,Lab:4
Principles of evolution and ecology applied to investigation of ancient life. Emphasis on analysis of field collections of marine invertebrate fossils from Paleozoic outcrops near campus. Prerequisites: (BIOL 203 or BIOL 204) or (GEOL 203 or GEOL 204) and permission of the instructor.

GEOL 318. Undergraduate Research. .5-1 Credits.
Offered Summer Session Only; Lecture hours:Varies; Repeatable
Research course for qualified students in any branch of geology. Prerequisite: permission of the instructor.

GEOL 319. Undergraduate Research. .5-1 Credits.
Offered Fall Semester Only; Lecture hours:Varies; Repeatable
Research course for qualified students in any branch of geology. Prerequisite: permission of the instructor.

GEOL 320. Undergraduate Research. .5-1 Credits.
Offered Spring Semester Only; Lecture hours:Varies; Repeatable
Research course for qualified students in any branch of geology. Prerequisite: permission of the instructor.

GEOL 321. Special Topics in Geology. .5-1 Credits.
Offered Fall Semester Only; Lecture hours:Varies,Lab:Varies; Repeatable
Investigation, report, or discussion on currently significant topics in geology. Prerequisite: permission of the instructor.

GEOL 322. Special Topics in Geology. .5-1 Credits.
Offered Spring Semester Only; Lecture hours:Varies; Repeatable
Investigation, report, or discussion on currently significant topics in geology. Prerequisite: permission of the instructor. Crosslisted as GEOL 622.

GEOL 325. Independent Study. .25-1 Credits.
Offered Both Fall and Spring; Lecture hours:Varies,Other:Varies; Repeatable
Independent study course for qualified students in any branch of geology. Prerequisite: permission of the instructor.

GEOL 334. Geophysics. 1 Credit.
Offered Either Fall or Spring; Lecture hours:3,Lab:4
Introduction to geophysical principles and methods (seismic, gravity, magnetic, electrical, electromagnetic and GPR) applied to both near-surface and solid earth studies. Emphasis placed on active learning by hands-on geophysical data collection focused on environmental and engineering applications. Prerequisites: (One 200-level geology course and MATH 201) or PHYS 211P. Crosslisted as GEOL 634.

GEOL 336. Hydrogeology. 1 Credit.
Offered Either Fall or Spring; Lecture hours:3,Lab:4
Water properties, fundamental flow equations, surface and subsurface flow, well hydraulics, regional flow, and contamination. Prerequisites: GEOL 203 or GEOL 250 and MATH 192 or MATH 201, or permission of the instructor.

GEOL 338. Applied Environmental Geomorphology. 1 Credit.
Offered Alternating Spring Semester; Lecture hours:3,Lab:4
Surviving on a complex and dynamic earth surface. Understanding environmental problems and geologic hazards with geologic principles set in a multidisciplinary framework. Prerequisites: GEOL 316 and permission of the instructor.

GEOL 340. Igneous and Metamorphic Petrology. 1 Credit.
Offered Spring Semester Only; Lecture hours:3,Lab:4
This class examines the mineralogy, petrography, geochemistry, origin and tectonic significance of igneous and metamorphic rocks. Prerequisite: GEOL 304.

GEOL 342. Caves and Karst. 1 Credit.
Offered Either Fall or Spring; Lecture hours:3,Lab:4
Students will learn how karst systems and associated landforms, like caves, form. We will explore the geochemistry and hydrogeology of karst aquifers and other topics using collected data, computer modeling, peer-reviewed literature and group projects. Students will be required to attend at least one of two weekend field trips.

GEOL 344. Paleoclimatology. 1 Credit.
Offered Either Fall or Spring; Lecture hours:3,Lab:4
Course will focus on current questions in paleoclimatology and local paleoclimate history through the production of novel paleoclimate records. Survey of paleoclimate archives and proxies, geological controls on climate, Quaternary glacial cycles, warm periods as analogs for modern climate change, millennial-scale climate oscillations, Holocene and Common Era climate.