GEOLOGY – B.S.

Program director
Kevin E. Nick

The Department of Earth and Biological Sciences offers a program leading to the Bachelor of Science degree in geology. This program provides the student with a field-oriented education, emphasizing the application of geological principles. Sedimentary geology, paleontology, and environmental geology are areas of emphasis within the department. The curriculum is designed as a degree-completion program, which means two years of college-level course work should be completed before admission. The program aims to maintain affordability through tuition rates and scholarships. Please contact the department at <ebs@llu.edu> for any questions or comments.

Objectives
The integrated core course (major) sequence of the geology degree provides students with a general background in geology as preparation for a career or graduate studies in geology, paleontology, and environmental geology. Fieldwork is emphasized because it provides the link to basic geological data beyond the classroom and laboratory. Throughout the geology curriculum, students are taught to apply the scientific method to resolve geologic problems. Students are encouraged to consider multiple working hypotheses during this process.

Learning outcomes
1. Demonstrate knowledge of the composition and structure of the earth, its stratigraphy, geological processes, and earth and planetary models.
2. Demonstrate skill in finding reference materials and collecting and presenting field and laboratory data.
3. Demonstrate written, analytical, and oral skills with the integration of technology in communication.
4. Demonstrate ability to analyze and synthesize previous knowledge.
5. Demonstrate a professional aptitude and attitude.
6. Demonstrate critical evaluation skills in relating faith, science, and public interest issues.

Curriculum
The Bachelor of Science degree in geology requires a total of 192 quarter units. The total units are divided according to general studies requirements, major requirements, and electives.

The following summarizes the general categories and numbers of credits required for the degree and will help in planning the course schedule. All units are quarter units.

Major requirements—41 units
Major electives—20 units
Minimum general studies in the natural sciences—44 units
Minimum other general studies requirements—38 units
Other electives (this number will decrease if units in above categories are greater)—49 units
Total—192 units

Residence requirements
Minimum requirements include one year of full-time residence at Loma Linda University, completing at least 32 of the last 48 units; or a minimum of 45 total units of course work for the degree at Loma Linda University. If the student has attended an institution that does not grant bachelor's degrees, a maximum of 105 quarter units of credit can be transferred from a two-year junior or community college.

Honors program
Students may apply and be accepted into the geology honors program if they meet the following requirements: a G.P.A. of 3.0 or above, obtain guidance from a sponsoring faculty member, and submit an approved research proposal. Honor students must register for at least 2 units of undergraduate research, conduct original research under a faculty member’s direction, submit a written undergraduate thesis, and deliver a public oral presentation.

Geology careers
A baccalaureate degree in geology prepares a student to enter graduate programs in geology or paleontology, for employment in environmental and energy-related industries; or (with the necessary education courses) for teaching in secondary schools. Most employment opportunities in industry, research, or college teaching require a graduate degree.

In addition to the geology major, a student preparing to teach at the elementary or secondary level will need to complete the requirements for a teaching credential. The student should consult the Geology Program undergraduate director for further information. Education courses will count toward general studies requirements.

Scholarships and discounts for earth and biological sciences undergraduate students
Tuition rate for courses offered by the Geology Program (B.S.): $290/unit; 12-18 units—$3,480 per quarter

- Academic scholarships based on test results
  - American College Test (ACT) score of 30 or above: $1,600 (or 16 percent of tuition). For a student who maintains a cumulative G.P.A. of at least 3.5, renewable for successive years.
  - Scholastic Aptitude Test (SAT): Student must maintain a 3.5 cumulative G.P.A., renewable for successive years. If a student qualifies for both an ACT and an SAT scholarship, the scholarship with the largest dollar value will apply.

• National Merit Finalist Scholarship covers 100 percent of tuition.
• National Merit Semifinalist Scholarship covers 34 percent of tuition.
• National Merit Commended Scholarship covers 20 percent of tuition.

- Renewable G.P.A. scholarships (eligibility based on G.P.A. at the end of previous academic year): If a student is eligible for a National Merit Scholarship and/or an ACT scholarship, as well as a G.P.A. scholarship, the scholarship with the largest dollar value will apply.
  - G.P.A. between 3.75 and 4.00, $1,480 per year (or 15 percent of tuition).
  - G.P.A. between 3.50 and 3.74, $1,180 per year (or 12 percent of tuition).
  - G.P.A. between 3.25 and 3.49, $900 per year (or 9 percent of tuition).
### Additional scholarship guidelines

- The sum of scholarships and other financial awards cannot exceed cost for tuition and fees.
- If a student qualifies for more than one scholarship or reduced tuition award, the award with the largest dollar value applies.
- Scholarship or tuition reduction will be applied as a credit to the student's tuition account at the rate of one-third of the total per quarter and is available to full-time students only.
- Loss of scholarship money may result when a student does not maintain the minimum cumulative G.P.A. required by the particular scholarship.
- The last day of final tests for the first quarter that a student is enrolled at LLU is the deadline for verifying with Student Financial Services that the student qualifies for a scholarship for the academic year.
- The scholarships and reduced tuition award listed here apply only to students enrolled in undergraduate programs in the Department of Earth and Biological Sciences.

Note: Determination of the amount of scholarships and awards at Loma Linda University is influenced by FAFSA data. State and federal grants, as well as other grants and subsidies, will be applied before Loma Linda University scholarships and discounts; therefore, some students may be eligible to receive only a portion of their scholarship award.

### Admissions

#### Applications

Applications are accepted at any time. Review of applications begins in February for Autumn Quarter admission.

In addition to Loma Linda University (http://llucatalog.llu.edu/about-university/admission-policies-information/#admissionrequirementstext) admission requirements, the applicant must also complete the following requirements for admission to the Geology BS program:

- complete two years (minimum of 96 quarter units) of general education and science courses at any accredited institution. This should include the majority of the General Studies requirements. Note this would typically include a year of general chemistry and general physics with associated laboratory sections, and mathematics. Please contact the program director if you have questions about this requirement.
- achieve a minimum of 2.5 G.P.A. during the first two years of coursework.
- submit letters of recommendation from two faculty at institutions previously attended.

### General studies requirements

The information below provides a summary of the University's general education requirements for undergraduate students. For a complete description of Loma Linda University's general education requirements and criteria, the student should refer to the Division of General Studies (http://llucatalog.llu.edu/about-university/division-general-studies/#courserequirementstext) section in this CATALOG.

### Domain 1: Religion and Humanities

**Humanities (12 quarter units minimum)**

Choose courses from three of the following areas: civilization/history, fine arts (art history and music history), literature, philosophy, and performing/visual arts (not to exceed 4 quarter units).

**Religion**

An applicant who has attended an Adventist college or university is required to have taken four quarter units of religion from an Adventist institution for each year of attendance at an Adventist college or university. Up to 8 quarter credits may apply toward the 20 units needed in Domain 1. If the applicant has not attended an Adventist institution, no religion units are required. In either case, however, the applicant must have completed 20 quarter/14 semester units in Domain 1: Humanities and Religion.

### Domain 2: Scientific Inquiry and Analysis

**Natural Sciences (12 units minimum; additional units count toward Domain 5 and the total general studies requirement)**

- Mathematics, including calculus (8-12 units)
- Statistics (4 units)
- General chemistry with laboratory—one full year, complete sequence
- General physics with laboratory—one full year, complete sequence
- Courses in genetics and ecology, or general biology with laboratory (8 units)

**Social Sciences (12 units minimum)**

- One course dealing with human diversity (e.g., cultural anthropology)
- Choose remaining units from the following areas: geography, economics, political science, psychology, sociology, etc.

### Domain 3: Communication (9 units minimum)

- English composition (complete sequence)
- Elective areas may include courses in computer information systems, critical thinking, and public speaking.

### Domain 4: Health and Wellness (2-6 units)

- Two activity courses in physical education
- Personal health or nutrition

### Domain 5: Electives

Electives from the previous four domains may be selected to complete the general education minimum requirements of 68 quarter units.

Specific general studies requirements are detailed in the Division of General Studies (http://llucatalog.llu.edu/about-university/division-general-studies/#courserequirementstext) section in this CATALOG. It is recommended that applicants contact the department at <ebs@llu.edu> for a review of their academic plan as early as possible.

Please note: Grades of C- and below are not accepted for credit toward the degree.

### Program requirements

#### Major

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
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<tbody>
<tr>
<td>GEOL 204</td>
<td>Physical Geology</td>
<td>4</td>
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<tr>
<td>GEOL 316</td>
<td>Mineralogy</td>
<td>4</td>
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<tr>
<td>GEOL 317</td>
<td>Igneous and Metamorphic Petrology</td>
<td>4</td>
</tr>
<tr>
<td>GEOL 416</td>
<td>Sedimentology and Stratigraphy</td>
<td>6</td>
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<tr>
<td>GEOL 424</td>
<td>Structural Geology</td>
<td>4</td>
</tr>
<tr>
<td>GEOL 431</td>
<td>Geochemistry</td>
<td>4</td>
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</tbody>
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GEOL 443 Historical Geology 4
GEOL 456 Field Methods of Geologic Mapping 4
GEOL 475 Philosophy of Science and Origins 4
GEOL 485 Seminar in Geology 3

Religion
Select at least one course from each prefix: 6
- RELE 4__ Upper-division ethics
- RELR 4__ Upper-division relational
Select one of the following: 2
- RELT 406 Adventist Beliefs and Life
- RELT 423 Loma Linda Perspectives
- RELT 436 Adventist Heritage and Health
- RELT 437 Current Issues in Adventism

Geology electives
Select at least one course from the following: 4
- GEOL 426 Invertebrate Paleontology
- GEOL 427 Vertebrate Paleontology
- GEOL 444 Paleobotany
Select 16 units from the following or from the unused elective courses above: 16
- BIOL 406 Marine Biology
- BIOL 407 Herpetology
- BIOL 409 Mammalogy
- BIOL 412 Biology of Marine Invertebrates
- BIOL 413 Ecology
- BIOL 444 Biodiversity and Conservation
- GEOL 431 Geochemistry 4 Units.
- GEOL 434 Introduction to GIS for the Natural Sciences 2 Units.
- GEOL 444 Paleobotany 4 Units.
- GEOL 446 Hydrogeology
- GEOL 447 Research and Experimental Design
- GEOL 448 Field Geology Studies
- GEOL 449 Special Projects in Geology
- GEOL 450 Undergraduate Research
- HGIS 422 Principles of Geographic Information Systems
- HGIS 424 Desktop GIS Software Applications
- HGIS 434 Advanced GIS Software Applications

General electives 27
Total Units 96

Seminar attendance requirements
All students must register for and attend GEOL 485 Seminar in Geology for each quarter of residence at this University.

Normal time to complete the program
4 years — 2 years (6 quarters) at LLU based on full-time enrollment; part-time permitted

Courses
GEOL 204. Physical Geology. 4 Units.
Introductory geology course that provides the student with a broad picture of geological processes operating on and within the earth. Introduction to minerals, sedimentary and igneous rocks, and fossils. Weathering, earthquakes, volcanism, erosion and sedimentation, and plate tectonics. Three class hours, one three-hour laboratory or field trip per week.

GEOL 316. Mineralogy. 4 Units.
Studies minerals, including: crystallography and crystal chemistry, phase diagrams, and systematic classification. Mineral identification based on hand sample, optical, and other analytical techniques. Three class hours and one three-hour laboratory or field trip per week.

GEOL 317. Igneous and Metamorphic Petrology. 4 Units.
Systematically studies igneous and metamorphic rocks, including: classification by petrography and geochemical methods; application of one-, two-, and three-component phase diagrams; and models of petrogenesis. Three class hours and one three-hour laboratory or field trip per week.

GEOL 416. Sedimentology and Stratigraphy. 6 Units.
Interprets the sedimentary rock record through a study of rock types, depositional processes, and models. Studies stratigraphic nomenclature and approaches to correlation on local, regional, and/or global scales. Laboratory analysis of primary and diagenetic mineralogy, textures, and sedimentary structures in clastic and carbonate rocks. Field descriptions of sedimentary rocks, structures, and sequences; and field experience in interpreting depositional processes and stratigraphic relationships.

GEOL 424. Structural Geology. 4 Units.
Theory of stress and strain, and examination of rock deformation in a framework of plate tectonics. Includes problems and applications. Three class hours—with required full-day and half-day field trips—and one three-hour laboratory or field trip per week.

GEOL 426. Invertebrate Paleontology. 4 Units.
Structure, classification, ecology, and distribution of selected fossil invertebrate groups. Principles and methods involved in the study and analysis of invertebrate fossils. Three class hours and one three-hour laboratory per week.

GEOL 427. Vertebrate Paleontology. 4 Units.
Systematics, biology, stratigraphic distribution, and biogeography of fossil vertebrates.

GEOL 431. Geochemistry. 4 Units.
Chemical concepts and their geochemical applications in areas of interest in elementary geology. Prerequisite: College chemistry; or consent of instructor.

GEOL 434. Introduction to GIS for the Natural Sciences. 2 Units.
Principles and practice of GIS data acquisition, data editing, map making, and geodatabase management. Recommended for students beginning a research project.

GEOL 435. GIS Spatial Analysis for the Natural Sciences. 3 Units.
Advanced analysis of GIS data; statistical analysis, geographic analysis of spatial data, and methods of displaying, editing, and modeling spatial data using ArcGIS and related GIS tools. Recommended for students who have research data in hand to analyze.
GEOL 436. Low Temperature Geochemistry. 4 Units.
Principles of the chemistry of systems that pertain to surface geological and environmental settings. Major topics include: water quality, mineral solubility, natural systems represented by chemical equations, carbonate equilibrium systems, mineral stability plots, and oxidation-reduction systems. Prerequisite: College chemistry; consent of instructor.

GEOL 443. Historical Geology. 4 Units.
Introduces earth history with in-depth examination of the stratigraphic record of rocks and fossils. Three class hours and one three-hour laboratory per week.

GEOL 444. Paleobotany. 4 Units.
Fossil plants; their morphology, paleoecology, taphonomy, classification, and stratigraphic distribution. Analyzes floral trends in the fossil record. Three class hours and one three-hour laboratory or field trip per week.

GEOL 455. Modern Carbonate Depositional Systems. 3 Units.
Examines modern and Pleistocene carbonate systems in the field, using these environments as models for understanding sediment production, facies development, and early diagenesis for many ancient carbonates. Presentations and readings on specific environments combined with field descriptions, mapping, analysis, and reports. Requires rigorous hiking and snorkeling in shallow water.

GEOL 456. Field Methods of Geologic Mapping. 4 Units.
Advanced geologic mapping of complex areas, with interpretation of their history; includes mapping of igneous, metamorphic, and sedimentary rocks. Experience in preparation of geologic reports of each mapped locality.

GEOL 457. Hydrogeology. 4 Units.
Theory and geology of groundwater occurrence and flow, the relation of ground water to surface water, and the potential distribution of ground water by graphical and analytical methods. Three class hours and one three-hour laboratory per week.

GEOL 475. Philosophy of Science and Origins. 4 Units.
Concepts in the history and philosophy of science, and application of these principles in analyzing current scientific trends.

GEOL 484. Readings in Geology. 1-4 Units.
Reviews literature in a specific area of geology. Students make presentations from the literature and submit current papers dealing with the assigned topic.

GEOL 485. Seminar in Geology. 0.5 Units.
Selected topics dealing with recent developments.

GEOL 486. Research and Experimental Design. 2 Units.
Concepts, methods, and tools of research—including experimental design and data analysis.

GEOL 487. Field Geology Studies. 1-6 Units.
Special field study trips lasting one or more weeks. Student involvement required, including field presentations and fieldwork assignments, such as the measurement and analysis of sedimentary sections, facies profiling, paleontologic excavation, mapping, or other geological or paleontology field activity. One unit of credit per week. May be repeated for additional credit.

GEOL 488. Topics in Geology. 1-4 Units.
Reviews current knowledge in specified areas of the earth sciences. Registration should indicate the specific topic to be studied. May be repeated for additional credit. Offered on demand.

GEOL 489. Readings in Paleontology. 1-4 Units.
GEOL 495. Special Projects in Geology. 1-4 Units.
Special project in the field, laboratory, museum, or library under the direction of a faculty member. Registration indicates the specific field of the project.

GEOL 497. Undergraduate Research. 1-4 Units.
Original investigation and/or literature study pursued under the direction of a faculty member. May be repeated for additional credit.

GEOL 512. Invertebrate Paleontology. 4 Units.
Structure, classification, ecology, and distribution of selected fossil invertebrate groups. Considers principles and methods involved in the study and analysis of invertebrate fossils. Per week: Class three hours, plus one three-hour laboratory. Additional work required beyond GEOL 426.

GEOL 513. Vertebrate Paleontology. 4 Units.
Fossil vertebrates, with emphasis on the origins of major groups. Systematics, biology, and biogeography of ancient vertebrates. Per week: class three hours, plus one three-hour laboratory. Additional work required beyond GEOL 427.

GEOL 514. Paleobotany. 4 Units.
Fossil plants, their morphology, paleoecology, taphonomy, classification, and stratigraphic distribution. Analyzes floral trends in the fossil record. Per week: three class hours and one three-hour laboratory or field trip. Additional work required beyond GEOL 444.

GEOL 516. Sedimentology and Stratigraphy. 6 Units.
Examines modern and Pleistocene carbonate systems in the field, using these environments as models for understanding sediment production, facies development, and early diagenesis for many ancient carbonates. Presentations and readings on specific environments combined with field descriptions, mapping, analysis, and reports. Requires rigorous hiking and snorkeling in shallow water.

GEOL 517. Modern Carbonate Depositional Systems. 3 Units.
Examines modern and Pleistocene carbonate systems in the field, using these environments as models for understanding sediment production, facies development, and early diagenesis for many ancient carbonates. Presentations and readings on specific environments combined with field descriptions, mapping, analysis, and reports. Requires rigorous hiking and snorkeling in shallow water. Additional work required beyond GEOL 416.

GEOL 518. Earth Structure, Process, and History. 4 Units.
Study of geological processes and the resulting geological record. Introduces minerals and rocks, sedimentary and igneous processes, fossils, plate tectonics, geological history, and models of earth history. Student prepares a teaching module on the topic. Open only to students in the M.S. degree program in natural sciences. Per week: class three class hours, one three-hour laboratory or field trip.

GEOL 526. Introduction to GIS for the Natural Sciences. 2 Units.
Principles and practice of GIS data acquisition, data editing, map making, and geodatabase management. Recommended for students beginning a research project.

GEOL 535. GIS Spatial Analysis for the Natural Sciences. 3 Units.
Advanced analysis of GIS data; statistical analysis, geographic analysis of spatial data, and methods of displaying, editing, and modeling spatial data using ArcGIS and related GIS tools. Recommended for students who have research data in hand to analyze.
GEOL 545. Taphonomy. 4 Units.
Processes that affect an organism from death until its final burial and fossilization, and utilization of this information in reconstructing ancient assemblages of organisms. Three class hours per week. One laboratory per week to study, describe, and interpret fossil assemblages of vertebrates, invertebrates, and microfossils.

GEOL 554. Limnogeology. 4 Units.
Ancient lake deposits, including their sedimentologic, paleontologic, mineralogic, geochemical, and stratigraphic characteristics. Investigates as analogs the depositional processes occurring in modern lakes. Laboratory and several extended field trips.

GEOL 555. Carbonate Geology. 4 Units.
Advanced look at the geology of carbonate rocks, including petrology; depositional environments; and overview of current topics of research. Laboratory experience in the analysis of carbonate rocks and rock sequences. Field trip to an ancient carbonate sequence.

GEOL 556. Paleoenvironments. 3 Units.
Applies paleontologic, sedimentologic, and geochemical data and methods to interpretation of past sedimentary environments, with emphasis on organism-sediment relationships. Investigates as analogs processes, sediments, and organisms in modern depositional environments.

GEOL 557. Paleoenvironments Field Trip. 1 Unit.
Field experience intended as a follow up to GEOL 556 Paleoenvironments. Consists a ten-day field trip to selected locations representing a broad spectrum of sedimentary environments.

GEOL 558. Philosophy of Science. 4 Units.
Selected topics in the history and philosophy of science, and application of these principles in analyzing contemporary scientific trends.

GEOL 559. Philosophy of Science and Origins. 1 Unit.
Studies selected topics in the history and philosophy of science, and applies these principles in analyzing current scientific trends. Provides an advanced update in the topic for students who have had a similar course at the undergraduate level.

GEOL 565. Analysis of Sedimentary Rocks. 4 Units.
Provides exposure to a range of analytical tools used to answer questions in sedimentary geology. Emphasizes three instruments —optical microscope, x-ray diffractometer, and scanning electron microscope—and introduces other analytical approaches. Participants will use case studies to develop skills in project design, collection of quantitative data, and evaluating existing datasets.

GEOL 566. Sedimentary Processes. 4 Units.
Advanced methods and principles of sedimentology, with emphasis on analysis and interpretation of sedimentary structures and the processes that produced them. Discusses in detail sedimentary facies, depositional environments, chemogenic and biogenic sedimentation, and postdepositional diagenetic processes. Research or project paper required. Three class hours and one three-hour laboratory or field trip per week, and several extended field trips.

GEOL 567. Stratigraphy and Basin Analysis. 4 Units.
Advanced methods of stratigraphy and basin analysis, including facies analysis, depositional systems, sequence stratigraphy, paleogeography, and basin modeling. Research or project paper required. Three class hours and one laboratory or field trip per week, and two extended field trips.

GEOL 575. Hydrogeology. 4 Units.
Theory and geology of groundwater occurrence and flow, the relation of groundwater to surface water, and the potential distribution of groundwater by graphical and analytical methods. Three class hours and one three-hour laboratory per week.

GEOL 588. Topics in Geology. 1-4 Units.
Reviews current knowledge in specified areas of the earth sciences. When registering, the student must indicate specific topic to be studied. May be repeated for additional credit. Offered on demand.

GEOL 594. Readings in Geology. 1-4 Units.
Reviews the literature in a specific area of geology. Students make presentations from the literature and submit current papers dealing with the assigned topic.

GEOL 595. Readings in Limnogeology. 1 Unit.
Readings and analysis of current and classic scientific literature dealing with modern and ancient lake environments—including geochemistry, sedimentology, biology and paleontology, and related subjects. Activities include student presentations of papers, discussion, and research proposals and reports. One extended, multiday field trip required.

GEOL 607. Seminar in Geology. 0.5 Units.
Selected topics dealing with recent developments.

GEOL 616. Research and Experimental Design. 2 Units.
Concepts, methods, and tools of research—including experimental design and data analysis.

GEOL 617. Proposal Writing and Grantsmanship. 2 Units.
Skills and practice of effective proposal writing, and strategies for locating and obtaining research grants.

GEOL 618. Writing for Publication. 1 Unit.
Explores the mechanics and processes of preparing, submitting, revising, and resubmitting a manuscript for publication in a peer-reviewed journal. Designed for students who are well along in the process of writing their first manuscript for publication. Prepares students to handle the manuscript revision process when the manuscript is returned from reviewers, as well as the final stage of resubmission to the journal.

GEOL 658. Advanced Philosophy of Science readings (2). 2 Units.
Reading and discussion of selected references in the philosophy of science, and the application of these concepts in the practice of scientific research and interpretation, including their influence on scientific study of origins. Best taken near the end of a student's graduate program. Two-hour class session per week.

GEOL 695. Special Projects in Geology. 1-4 Units.
Special project in the field, laboratory, museum, or library under the direction of a faculty member. Registration indicates the specific field of the project.

GEOL 697. Research. 1-8 Units.

GEOL 698. Thesis Research. 1-8 Units.
Credit for research and for writing the master's thesis. Grade received does not indicate whether thesis is completed and approved.

GEOL 699. Dissertation Research. 1-8 Units.
Credit for research and for writing the doctoral dissertation. Grade received does not indicate whether dissertation is completed and approved.