

Harold Hamm School of Geology and Geological Engineering (Geol and GeoE)

<http://www.geology.und.edu/>

FACULTY: Forsman, Gerla, Gosnold, Hartman, Ho, LeFever, Mahmood, Matheny, Nordeng, Perkins, Putkonen and Wang

Degrees Granted:

The Harold Hamm School of Geology and Geological Engineering offers programs of study leading to the following graduate degrees:

- Master of Arts (M.A.) in Geology
- Master of Science (M.S.) in Geology
- Doctor of Philosophy (Ph.D.) in Geology
- Master of Science (M.S.) in Geological Engineering
- Doctor of Philosophy (Ph.D.) in Geological Engineering

The Harold Hamm School also offers programs leading to combined Bachelor of Science (B.S.) and Master of Science (M.S.) degrees in either Geology or Geological Engineering.

As part of their graduate degree requirements, students will normally conduct research and write a thesis/dissertation. Research emphasis is currently in the following areas:

1. hydrogeology and environmental geology
2. economic geology of petroleum and coal
3. sedimentology, stratigraphy, and paleontology
4. glacial geology, geomorphology, and soils
5. petrology and geochemistry
6. geophysics and tectonics
7. water quality
8. engineering geology
9. numerical reservoir simulation, enhanced hydrocarbon recovery planning and economic valuation
10. interdisciplinary geological projects involving several research areas including integrated basin analysis, ecohydrology, climate change, carbon sequestration, remote sensing, and underground coal gasification.

Details about the Master of Science and Doctor of Philosophy in Geological Engineering, or about the combined B.S./M.S. degrees in Geological Engineering, can be found in Engineering section of this catalog.

Information about the Geology degrees can be found below and by clicking on the links to the Degrees or Courses sections at the top of this page.

Master of Arts (M.A.), Master of Science (M.S.), and Doctor of Philosophy (Ph.D.) in Geology*

*For M.S. and Ph.D. in Geological Engineering, please see separate listing in the Engineering section of this catalog.

Mission Statement and Program Goals

The Geology Graduate Programs provide instruction and research opportunities for graduate students in the geological sciences, maintain and

develop geological research at UND, and serve the community, state, and region.

Goal 1: Graduate students will be able to communicate effectively in writing and through oral presentation.

Goal 2: Graduates of our program shall be employable in Earth science professions.

Goal 3: Graduate students shall be proficient in recently developed computational, laboratory, and field technology and instrumentation.

Goal 4: Graduate students shall be up-to-date concerning current trends in the geological sciences.

Goal 5: Graduate students shall have a broad knowledge of geology.

Goal 6: Graduate students shall do well in their coursework, demonstrating acquisition of knowledge and skills in the Earth sciences.

Goal 7: Graduate students shall have advanced and in-depth training in their chosen field.

Goal 8: The faculty who teach and advise geology graduate students shall be actively engaged in research and serve as excellent role models.

Master of Arts (M.A.) in Geology

Admission Requirements

The applicant must meet the School of Graduate Studies' current minimum general admission requirements as published in the graduate catalog.

1. For admission to the geology M.A. program, applicants must hold a bachelor's degree in geology from an accredited college or university or otherwise demonstrate sufficient coursework, training, or experience in geoscience.
2. Applicants may be admitted under "provisional" or "qualified" status, but to advance to "approved" status, they must have completed 5 to 6 credit hours of geology field course, or its equivalent, along with satisfactory achievement in supporting sciences and mathematics, as determined by the Harold Hamm School of Geology and Geological Engineering's Graduate Admissions Committee.
3. Applicants must have a cumulative grade point average of 3.0 or higher.
4. Applicants are encouraged to submit their GRE score to support their application, especially if they do not have an undergraduate degree in geology.
5. Applicants must satisfy the School of Graduate Studies' English Language Proficiency requirements as published in the graduate catalog.
6. For a Master of Arts degree, students must complete two or more semesters of calculus while an undergraduate or graduate student.

Students missing any of the above requirements may be admitted under provisional or qualified status, but all admission requirements must be completed, without graduate credit, within one year after beginning graduate work.

Initial decisions for admission and financial aid are made about March 1 for the fall semester and about September 1 for the spring semester.

To encourage undergraduate geology students to extend their studies to include a graduate degree, the College of Engineering and Mines has a combined program that permits students to earn both a bachelor's (B.S.) and a master's (M.A.) degree in geology. This program allows students to designate two three-credit graduate courses to count for both degrees. The selected courses must have graduate course standing and be designated when a student requests admission to the program.

Students may be admitted to the Combined Degree program if they have:

1. Completed 95 credit hours towards the bachelor's degree.
2. Completed 30 credit hours of coursework and 8 credit hours of upper division coursework in the geological sciences, including the equivalent of physical and historical geology.

3. Maintained an overall GPA of at least 3.0 in all geological sciences they took.
4. Completed an application to the UND School of Graduate Studies and been accepted for admission.

Once admitted to the Combined Degree Program, undergraduate students are eligible to take 500-level courses for graduate credit. Students must complete the petition titled, "Graduate Credit as an Undergraduate Student" prior to registering for the courses. Such courses could be included in the 30 credit hours for the degree and could appear in the program of study.

Students in the Combined Degree Program will be admitted to the School of Graduate Studies on completion of 125 credit hours for the bachelor's degree.

The time normally needed to complete the Combined Degree Program is 1 year, plus an additional summer after admission to the Graduate School.

Degree Requirements

Students seeking the Master of Arts degree at the University of North Dakota must satisfy all general requirements set forth by the School of Graduate Studies as well as the following particular requirements set forth by the Harold Hamm School of Geology and Geological Engineering.

1. Students must complete a program of study that includes a minimum of 30 credit hours, including the credits granted for the thesis and the research leading to the thesis.
2. At least 15 credit hours must be for classes at or above the 500-level.
3. A maximum of 7 credit hours required for the degree may be transferred from another institution.
4. A minimum of 6 credit hours (undergraduate or graduate) must come from each subject area listed below:
 - a. mineralogy, petrology, geochemistry
 - b. sedimentology, stratigraphy, paleontology, geomorphology
 - c. structural geology, geophysics, hydrogeology
5. Up to 12 credit hours of 300-400 level coursework in geology may be taken for graduate credit.

The time normally needed to complete the requirements for the master's degree in geology is about two years of full-time work. Students with graduate teaching or research assistantships may need more time.

Master of Science (M.S.) in Geology

Admission Requirements

The applicant must meet the School of Graduate Studies' current minimum general admission requirement as published in the graduate catalog.

1. For admission to the geology M.S. program, applicants must hold a bachelor's degree in geology from an accredited college or university or otherwise demonstrate sufficient course work, training, or experience in geoscience.
2. Applicants may be admitted under "provisional" or "qualified" status, but to advance to "approved" status, they must have completed 5 to 6 credit hours of geology field course, or its equivalent, along with satisfactory achievement in supporting sciences and mathematics, as determined by the Harold Hamm School of Geology and Geological Engineering's Graduate Admissions Committee.
3. Applicants must have a cumulative grade point average of 3.0 or higher.
4. Applicants are encouraged to submit their GRE score to support their application, especially if they do not have an undergraduate degree in geology.
5. Applicants must satisfy the School of Graduate Studies' English Language Proficiency requirements as published in the graduate catalog.
6. For a Master of Science degree, students must complete 2 semesters of calculus, plus an additional calculus or relevant math, computer programming, or statistical class, while an undergraduate or graduate student.

Students missing any of the above requirements may be admitted under provisional or qualified status, but all admission requirements must be

completed, without graduate credit, within one year after beginning graduate work.

Initial decisions for admission and financial aid are made about March 1 for the fall semester and about September 1 for the spring semester.

To encourage undergraduate geology students to extend their studies to include a graduate degree, the College of Engineering and Mines has a Combined Program that permits students to earn both a bachelor's (B.S.) and a master's (M.S.) degree in Geological Engineering. This program allows students to designate two three-credit graduate courses to count for both degrees. The selected courses must have graduate course standing and be designated when a student requests admission to the program.

Students may be admitted to the Combined Degree Program if they have:

1. Completed 95 credit hours towards the bachelor's degree.
2. Completed 30 credit hours of coursework and 8 credit hours of upper division coursework in the geological sciences, including the equivalent of physical and historical geology.
3. Maintained an overall GPA of at least 3.0 in all geological sciences they took.
4. Completed an application to the UND Graduate School and been accepted for admission.

Once admitted to the Combined Degree Program, undergraduate students are eligible to take 500-level courses for graduate credit. Students must complete the petition titled, "Graduate Credit as an Undergraduate Student" prior to registering for the courses. Such courses could be included in the 30 credit hours for the degree and could appear in the program of study.

Students in the Combined Degree Program will be admitted to the School of Graduate Studies on completion of 125 credit hours for the bachelor's degree.

The time normally needed to complete the Combined Degree Program is 1 year, plus an additional summer after admission to the Graduate School.

Degree Requirements

Students seeking the Master of Science degree at the University of North Dakota must satisfy all general requirements set forth by the School of Graduate Studies, as well as the following particular requirements set forth by the Harold Hamm School of Geology and Geological Engineering:

1. Students must complete a program of study that includes a minimum of 30 credit hours, including the credits granted for the thesis and the research leading to the thesis.
2. At least 15 credit hours must be for classes at or above the 500-level.
3. A maximum of 7 of the credit hours required for the degree may be transferred from another institution.
4. A minimum of 6 credit hours (undergraduate or graduate) must come from each subject area listed below:
 - a. Mineralogy, petrology, geochemistry
 - b. Sedimentology, stratigraphy, paleontology, geomorphology
 - c. Structural geology, geophysics, hydrogeology
5. Up to 12 credit hours of 300-400 level coursework in geology may be taken for graduate credit.

The time normally needed to complete the requirements for the master's degree in geology is about two years of full-time work. Students with graduate teaching or research assistantships may need more time.

Doctor of Philosophy (Ph.D.) in Geology

Admission Requirements

The applicant must meet the School of Graduate Studies' current minimum general admission requirements as published in the graduate catalog.

1. For admission to the geology Ph.D. program, applicants must hold a bachelor's degree in geology from an accredited college or university or otherwise demonstrate sufficient coursework, training, or experience in geoscience.

- For "approved" status, students must have completed a 5-6 credit hour geology field course, along with satisfactory achievement in supporting science and mathematics, as determined by the department graduate admissions committee.
- For all graduate programs in the Department of Geology and Geological Engineering, a cumulative 3.0 or higher grade point average is required.
- Submission of a Graduate Record Examination (GRE) general test score is strongly recommended if you do not have a degree in geology. Applicants are encouraged to submit their GRE score to support their application.
- Satisfy the School of Graduate Studies' English Language Proficiency requirements as published in the graduate catalog.

Students missing any of the above requirements may be admitted under provisional or qualified status, but all admission requirements must be completed, without graduate credit, within one year after beginning graduate work.

Initial decisions for admission and financial aid are made about March 1 for the fall semester and about September 1 for the spring semester.

Degree Requirements

Students seeking the Doctor of Philosophy degree at the University of North Dakota must satisfy all general requirements set forth by the School of Graduate Studies as well as particular requirements set forth by the Geology and Geological Engineering Department.

Students normally take the equivalent of three years of full-time work beyond the master's degree for the doctorate.

- Completion of 90 semester credits beyond the baccalaureate degree.
- Maintenance of at least a 3.0 GPA for all classes completed as a graduate student.
- With approval of a student's Faculty Advisory Committee, up to one-half of the work beyond a master's degree (maximum of 30 semester credit hours) may be transferred from another institution that offers post-master's degrees in the discipline.
- A qualifying examination may be required before the end of the student's first year in a doctoral program.
- Demonstration of:
 - proficiency in two foreign languages, or
 - proficiency in one foreign language and two scholarly tools courses, or
 - proficiency in four scholarly tools courses (scholarly tools courses typically are advanced undergraduate courses in related fields in mathematics, science, or engineering).
- Completion of a dissertation, which incorporates independent work that is an original contribution to knowledge.

Master of Science (M.S.) in Geological Engineering

Admission Requirements

The applicant must meet the School of Graduate Studies' current minimum general admission requirements as published in the graduate catalog. Additionally:

- To be admitted under "approved" status, the applicant must hold a Bachelor of Science degree in Geological Engineering from an ABET accredited or equivalent program. A bachelor's degree in another engineering discipline or in a science field, qualifies a student to be admitted to "qualified status" with an obligation to acquire background undergraduate engineering and geology knowledge.
- Applicants must submit a Graduate Record Examination General Test score if their B.S. degree is from a non-ABET accredited program. Other applicants are encouraged to submit GRE scores to support their application.
- Applicants must have a cumulative Grade Point Average (GPA) of 3.0 or higher.
- Applicants must satisfy the School of Graduate Studies' English Language Proficiency requirements as published in the graduate catalog.

To encourage undergraduate geological engineering students to extend their studies to include a graduate degree, the College of Engineering and Mines has a Combined Program that permits students to earn both a bachelor's (B.S.) and a master's (M.S.) degree in Geological Engineering. This program allows students to designate two three-credit graduate courses to count for both degrees. The selected courses must have graduate course standing and be designated when a student requests admission to the program.

Students may be admitted to the Combined Degree Program if they have:

- Completed 95 credit hours towards the bachelor's degree.
- Completed 30 credit hours of coursework and 8 credit hours of upper division coursework in the geological sciences, including the equivalent of physical and historical geology.
- Maintained an overall GPA of at least 3.0 in all geological sciences they took.
- Completed an application to the UND Graduate School and been accepted for admission.

Once admitted to the Combined Degree Program, undergraduate students are eligible to take 500-level courses for graduate credit. Students must complete the petition titled, "Graduate Credit as an Undergraduate Student" prior to registering for the courses. Such courses could be included in the 30 credit hours for the degree and could appear in the program of study.

Students in the Combined Degree Program will be admitted to the School of Graduate Studies on completion of 125 credit hours for the bachelor's degree.

The time normally needed to complete the Combined Degree Program is 1 year, plus an additional summer after admission to the Graduate School.

Degree Requirements

Students seeking the Master of Science degree at the University of North Dakota must satisfy all general requirements set forth by the School of Graduate Studies' as well as particular requirements set forth by the Harold Hamm School of Geology and Geological Engineering.

Thesis Option:

- A minimum of 30 credit hours in a major field, including the credits granted for the thesis and the research leading to the thesis.

Geology/Geological Engineering coursework	12
Other Engineering and Science coursework	12
Thesis	6
Total Credits	30
- At least one-half of the credit hours must be at or above the 500-level.
- A maximum of one-fourth of the credit hours required for the degree may be transferred from another institution.
- Completion of the thesis.

Non-Thesis Option (Independent Study):

- Thirty-four (34) credit hours including credits required for the major.

Geology/Geological Engineering coursework	15
Research Project/Independent Study	3
Electives	16
Total Credits	34
- At least one-half of the credit hours must be at or above the 500-level.
- A maximum of one-fourth of the credit hours required for the degree may be transferred from another institution.
- Preparation of a written independent study approved by the faculty advisor.
- Comprehensive final examination.

Admission Requirements

- A baccalaureate degree in an engineering discipline with a GPA of 3.3 or higher or a Master of Science degree in an engineering discipline with a GPA of 3.0.
- Satisfy the Graduate School's English Language Proficiency requirements as published in the Graduate Catalog.

3. In addition to meeting the general provisions in the UND graduate catalog and the minimum requirements in items 1-2 above, candidates are assessed using a holistic process that considers Student's Record of Publications, GRE test scores (for students who are applying with a B.S. engineering degree from a non-ABET accredited program), transcripts of previous college work, relevant research and work experience, letters of recommendation, research interests, and English language skills. Students must specify a track on their admission form to facilitate this evaluation.
4. A student holding a non-engineering degree or who does not meet the minimum requirements in items 1-2 above may apply to one of the Master of Science degree programs in the College of Engineering and Mines. Students successfully completing a UND M.S. engineering degree will be considered to satisfy the requirements of items 1-2 above; however, these students shall still be subject to the holistic evaluation process described in item 3 with the exception that new GRE test scores will not be required.
5. Students admitted to an engineering M.S.E.E. program but meeting the minimum requirements in items 1-2 above, may after one calendar year, and upon the recommendation of his/her advisory committee, request to by-pass the master's degree and work directly toward the Ph.D. degree. The recommendation of the advisory committee shall be brought to a vote by the program graduate committee relevant to the degree track requested by the student. A minimum of one week before such a meeting, the program graduate committee shall be notified and provided with the student's updated file which shall consist of the materials used for application into the M.S.E.E. program, a transcript of all academic work completed at UND, and any additional materials the student wishes to have considered. If the recommendation is approved by the relevant graduate committee, the student will be given the qualifying exam. Passing this exam will advance the student to Approved Status in the Doctoral Program in Geological Engineering.

Residence Requirements

The purpose of residence requirements is to provide an opportunity for a sustained and concentrated intellectual effort, to provide for immersion in an academic research environment, and to permit extensive interaction with fellow students and faculty of the Geological Engineering Department. Within the first two years of graduate work at UND, at least two consecutive semesters must be completed in residence. During residency, a student must be registered for at least nine credits in a semester, or be a graduate research or teaching assistant taking the appropriate credits to qualify as a full-time student. The remainder of the credits required for a degree can be completed in a manner to accommodate the student's fiscal, family, job related, and other constraints with the consent of the student's adviser. The program of study must be completed within the seven-year period normally allowed for graduate programs.

Under special circumstances, the student in conjunction with his/her advisory committee and the Geological Engineering Graduate Committee, can petition the Dean of the Graduate School for variances in this policy.

Degree Requirements

Students seeking the Doctor of Philosophy degree at the University of North Dakota must satisfy all general requirements set forth by the Graduate School as well as particular requirements set forth by the Geological Engineering Doctoral Program.

The following requirements are in addition to the UND graduate school general requirements for the Ph.D.:

1. Completion of 90 semester credits beyond the baccalaureate degree
2. Maintenance of at least a 3.0 GPA for all classes completed as a graduate student.
3. Scholarly Tools: Proficiency in mathematics demonstrated by completing nine approved credits of mathematics intensive coursework (equivalent to UND 400-level or higher courses) with a grade of B or better which must include at least one course in numerical analysis. Scholarly tools courses taken for graduate credit after a student has enrolled in a graduate program at UND may be counted to fulfill requirements listed in Item 5 below.
4. A maximum of 30 credit hours can be transferred from a master's program.
5. A minimum of 30 credit hours must be doctoral research and dissertation.
6. Exactly 3 credit hours of the GEOE 493-selected topics in geological engineering.
7. A minimum of 39 credit hours of coursework are required (up to 21 credit hours of coursework may be transferred from a master's program in fulfilling this requirement subject to the credit transfer limits described in the general section of this graduate catalog). The coursework shall include a minimum of 27 credit hours of Geological Engineering (or relevance courses with the consent of advisor) coursework selected from the approved list of courses. Equivalent graduate level coursework may be transferred from a master's program.
8. Successful completion of a qualifying examination, taken no earlier than the end of their first year in residence and no later than the end of their second year of residence. The qualifying examination includes the following three sections.

Section I

It will cover four general areas of their selected engineering track. Selection of the four general areas for this examination shall require the approval of the candidate's faculty adviser and the track-specific Ph.D. Graduate Director. Three results for each of the four sections of the examination can be obtained: 1) pass; 2) provisional pass; and 3) fail. Candidates obtaining a result of "provisional pass" for any section of the exam will be required to remediate the topical area in which the provisional pass was received in accordance to stipulations specified by the examiner, with approval of the track-specific Graduate Director. Candidates who fail one or more sections of the exam will be allowed one opportunity to repeat that section of the exam. The reexamination must take place no later than 13 months after the initial examination attempt. A direct admit student who fails an exam a second time may request to be reclassified as a master's student and complete a track-appropriate Master of Science degree and then reapply to the Doctoral program.

Section II

A detailed written doctoral research proposal must be submitted to the committee. The proposal should cover:

1. a literature review of the relevant field of research related to the project
2. proposed methods
3. preliminary results (simulation or experiment)
4. the objectives of the proposed project, and
5. tasks and the timeline of the proposed research in a Gantt chart.

The report should be reviewed and approved by the student advisor. Then, at least three weeks prior to the next step, the report should be distributed to the student committee members for their review and grading.

Each of the above (A-E) components will be evaluated and graded (0 to 20). To pass the written exam, student should earn a minimum of 16/20 in each category. All grades from student committee members will be averaged to determine a grade in each category.

If the report earns a passing grade a date can be scheduled for an oral presentation (i.e., Section III). If failed, student has the opportunity to revise and resubmit the report to the committee for re-evaluation.

Section III

An oral comprehensive examination should be presented to the committee on the research topics described in the above section (II-A to II-E). Three results for the **oral exam** can be obtained: 1) pass; 2) provisional pass; and 3) fail. Candidates obtaining a result of "provisional pass" will be allowed to Advance to Candidacy status after completion of stipulations specified by the examining committee plus obtaining a passing result on a retest for the portion of the exam covered by the stipulations. Candidates who fail the exam will be allowed one opportunity to repeat the exam in less than 6 months as specified by the student committee. Student who fails an exam a second time may request to be reclassified as a master's student and complete a track-appropriate Master of Science degree and then reapply to the Doctoral program.

1. After successful completion of the written research proposal and oral presentation, an annual oral progress report should be presented to the committee. A part of these presentations will include details on the dissertation research progress and plan. Any deviation from the approved research objectives as stated and documented in the research proposal must be approved and justified by the committee.
2. A candidate for the degree must complete the original basic research investigation as documented in the research proposal. Each candidate

will complete the research investigation to the satisfaction of the research adviser and the advisory committee and will prepare a written dissertation covering the research. The project must represent an original and independent investigation by the student. It is expected that the results of the research will be submitted for publication in refereed research journals. The candidate will submit the dissertation to the examining committee at least four weeks prior to defense date. The examining committee consists of the PhD committee and an external examiner from outside the University. The external examiner is selected by the department's graduate committee from a list of three candidates proposed by the advisor. The external examiner should not have any common publication with the student's advisor or student and can be from academia or industry with a expertise relevant to the student's research. The student and advisor should not contact the external examiner directly before or after.

3. The candidate must present and successfully defend the dissertation at the final examination (see School of Graduate Studies requirements (<http://und-public.courseleaf.com/graduatestudies>)). Four results of the examination can be obtained: 1) pass; 2) minor revision 3) major revision and 4) fail. For minor revisions there is no need for another defense session and upon revising the dissertation the examining committee can pass the student. For major revisions the student is asked to fundamentally revise the methodologies and schedule another defense session. If failed, the student will not be able to obtain a PhD degree and may request to be reclassified as a master's student and complete a Master of Science degree.
4. At least two peer reviewed ISI (Institute for Scientific Information) journals (as the first author) and two peer reviewed conference papers (as the first author) submitted with the consent of advisor.

GEOE Courses

GEOE 555. Advanced Rock Mechanics. 3 Credits.

Fundamentals of rock mechanics, elasticity theory of rock, failure criterion of rocks, laboratory and field testing methods, field instrumentation, the applications of rock mechanics in mining, tunneling and rock slopes engineering, and the applications of numerical methods in rock mechanics. Prerequisites: GEOE 323 and ENGR 203. F.

GEOE 591. Advanced Hydrocarbon Extraction in Engineering. 3 Credits.

This course describes technologies that can be applied to further recover underground energy resource - oil/gas, for example, that cannot be produced by primary or second extraction. Development of these processes requires significant technological advances in our understanding of underground mining from hydrocarbon reservoirs and may be the stimulus for future technological development. Prerequisites: GEOE 301, MATH 166, MATH 266, CHEM 122, and CHEM 122L. F.

GEOE 599. Doctoral Research. 1-15 Credits.

Research contributing to the discovery and dissemination of knowledge and/or technology in Geological Engineering and contributing to the student's doctoral dissertation. Prerequisite: Admission to the PhD program in Geological Engineering. Repeatable to 15 credits. F,S,SS.

GEOE 996. Continuing Enrollment. 1-12 Credits.

Repeatable. S/U grading.

GEOE 998. Thesis. 1-9 Credits.

GEOE 999. Dissertation. 1-18 Credits.

PhD student doctoral dissertation. Prerequisite: Admission to the PhD program in Geological Engineering. Repeatable to 18 credits. S/U grading. F,S,SS.

Undergraduate Courses for Graduate Credit

GEOE 323. Engineering Geology. 3 Credits.

This course is to introduce the application of geological, hydrological and environmental principles to geotechnical/geological engineering design, construction and operation as well as various geohazards. Prerequisites: One introductory geology course and MATH 165. S.

GEOE 417. Hydrogeology. 3 Credits.

Physical and chemical aspects of groundwater movement, supply, and contamination. Prerequisites: CHEM 121 or CHEM 221; MATH 166 or consent of instructor. F.

GEOE 418. Hydrogeological Methods. 2 Credits.

Field and laboratory methods used in hydrogeology; techniques of drilling, well and piezometer installation, determination of aquifer parameters, geophysical exploration, soil classification and analysis, ground water sampling and analysis. Includes field trip. Prerequisite: GEOE 417. F.

GEOE 419. Groundwater Monitoring and Remediation. 3 Credits.

Statistical methods for groundwater sampling and monitoring network design. Groundwater remediation and design; including strategies that remove contaminants for external treatment and strategies for in-situ contaminant treatment. Prerequisites: MATH 166, GEOE 417 and a statistics course (ECON 210, PSYC 241, MATH 321 or MATH 353) or consent of instructor. S.

GEOE 425. Design Hydrology for Wetlands. 3 Credits.

Principles of chemistry, geology, hydraulics, and hydrology applied to natural and constructed wetlands and other small catchments. Prerequisites: CHEM 121 and either CE 306/ME 306 or GEOE 417. S.

GEOE 427. Groundwater Modeling. 3 Credits.

Fundamentals of numerical modeling applied to groundwater flow. Spreadsheet calculations will be used to demonstrate the finite difference method applied to groundwater movement and storage. Simulation of practical groundwater problems will be performed with the U.S. Geological Survey's MODFLOW code. Prerequisites: GEOE 417 and MATH 265; some programming experience is recommended. On demand.

GEOE 455. Geomechanics II. 2 Credits.

The objective of this course is to train the students to use fundamental principles and field and lab techniques of Rock Mechanics to analyze real-world problems, identify the optimal methods, and solve the practical geological engineering problems with the combination of field and laboratory, analytical and experimental means. Emphases will be on the fundamental principles and their application to practical engineering problems, both surface and underground. Prerequisites: GEOE 323 or consent of instructor. Prerequisite or Corequisite: GEOE 355. F.

GEOE 493. Selected Topics in Geological Engineering. 1-3 Credits.

Detailed study of selected topics in Geological Engineering. Includes laboratory if applicable. Repeatable. Repeatable. On demand.

GEOL Courses

GEOL 500. Sedimentary Geology. 1-4 Credits.

Selected topics in sedimentary geology, such as sedimentary processes, carbonate petrology, clastic petrology, and basin analysis. May be repeated up to 12 credits. Prerequisite: Consent of instructor. Repeatable to 12 credits. F.

GEOL 505. Isotope Geochemistry. 3 Credits.

Geochemistry and cosmochemistry of radioactive and stable isotopes; isotope equilibria; applications in paleoclimatology, environmental isotope geochemistry, igneous, metamorphic, and sedimentary petrology. Prerequisite: GEOL 321 or permission of instructor.

GEOL 506. Glacial Geology. 4 Credits.

Origin, growth, and movement of glaciers; landforms and deposits incident to glaciation. 3 hours lecture, 2 hours laboratory time per week. Prerequisite: GEOL 311.

GEOL 509. Advanced Mineralogy. 1-4 Credits.

Advanced study of specific mineral groups or selected topics in mineralogy. Prerequisite: GEOL 320; recommended prerequisite GEOL 321.

GEOL 511. Advanced Structural Geology. 4 Credits.

Reading and research in special topics in structural geology and geotectonics.

GEOL 512. Advanced Petrology. 1-4 Credits.

Selected topics in petrology taught using conventional lecture and laboratory/field approach. Prerequisite: GEOL 320.

GEOL 515. Advanced Paleontology. 3 Credits.

Selected topics include (but not limited to): Invertebrate paleontology; vertebrate paleontology; paleoecology; taxonomy; museum studies; western continental stratigraphy; critical boundaries. May be repeated. Prerequisites: GEOL 415, BIOL 150, or consent of instructor. Repeatable to 40 credits. On demand.

GEOL 518. Topics in Advanced Stratigraphy. 2-4 Credits.

Selected topics in lithostratigraphy and biostratigraphy. Prerequisites: GEOL 411, GEOL 415. Repeatable to 4 credits.

GEOL 520. Statistical Applications in Geology. 3 Credits.

The application of statistical techniques to geologic data and problems, with emphasis on analysis of geologic sequences, map analysis, and multivariate analysis of geologic data. Prerequisites: An introductory statistics course, such as CTL 515 or PSYC 241, and consent of instructor.

GEOL 522. History and Philosophy of Geology. 3 Credits.

Historical and philosophical development of the science of geology. Prerequisite: Permission of instructor.

GEOL 523. Topics in Advanced Geomorphology. 1-4 Credits.

Selected topics in geomorphic processes and landforms. Prerequisite: GEOL 311. Repeatable to 4 credits.

GEOL 525. Weathering and Soils. 3 Credits.

Properties and classification of soils; the factors and processes of weathering and soil formation. Prerequisite: GEOL 311 and GEOL 411, or consent of instructor.

GEOL 530. Topics in Physical Hydrogeology. 2 Credits.

Selected topics in groundwater, vadose-zone hydrology, fracture flow, analytical/numerical modeling, GIS and hydrology, and wetland soils/hydrology. Repeatable when topics vary. Prerequisite: Consent of instructor. Repeatable to 8 credits. F,S.

GEOL 531. Hydrogeochemistry. 3 Credits.

The origin, characteristics and modeling of surface and ground water geochemistry. Prerequisites: GEOL 321 and, MATH 166, or permission of instructor.

GEOL 532. Contaminant Hydrogeology. 3 Credits.

Chemical and physical processes affecting contaminant behavior in groundwater with analytical/numerical modeling and case studies. Prerequisites: GEOE 417 and GEOE 427 and MATH 265, or consent of instructor.

GEOL 540. Water Sampling and Analysis. 3 Credits.

Techniques of water and sediment sampling and analysis using equipment in the UND Water Quality Laboratory. Results are interpreted in the context of the natural systems from which the samples are taken. Enrollment is limited to eight students per section. A laboratory fee is required. Prerequisite: CHEM 121.

GEOL 551. Heat Flow. 3 Credits.

An exploration of Earth's thermal structure, thermal history and heat sources. The course begins with the theory of heat transfer within and through the surface of terrestrial planets. Methods of observation and modeling provide hands-on experience in field and laboratory activities. Applications of heat flow in tectonics, petrology, thermal maturity of kerogen, hydrogeology, geothermics and climate change are presented with current examples. Prerequisite: Graduate standing. Corequisite: Permission of instructor. On demand.

GEOL 560. Geothermics I. 3 Credits.

A survey of the methods of geothermal exploration, assessment and production. The course covers the various methods for discovery and characterization of geothermal resources. Methods for assessment of energy in place and determination of recoverable energy are covered in depth. Current technologies for energy extraction and power production are presented with current examples. Prerequisite: Graduate standing. Corequisite: Permission of instructor. On demand.

GEOL 561. Geothermics II. 3 Credits.

The course covers the historical development of geothermal policies, regulations and practices globally and in different states within the US. Matters of water usage, contamination and disposal are covered extensively. Current issues such as induced seismicity, hydrofracture, power plant size and location, electrical grid access and land use are critically examined. Prerequisite: Senior or Graduate Standing. Corequisite: Permission of Instructor. On demand.

GEOL 590. Research. 1-4 Credits.

Laboratory, field, or library research on problems of interest (may be repeated). Repeatable.

GEOL 591. Directed Studies. 1-4 Credits.

Directed advanced research in a specialized field of geologic study (may be repeated). Repeatable.

GEOL 996. Continuing Enrollment. 1-12 Credits.

Repeatable. S/U grading.

GEOL 997. Independent Study. 2 Credits.**GEOL 998. Thesis. 1-9 Credits.**

Repeatable to 9 credits.

GEOL 999. Dissertation. 2-12 Credits.

May be repeated up to 24 credits. Repeatable to 24 credits.

Undergraduate Courses for Graduate Credit

GEOL 311. Geomorphology. 4 Credits.

Dynamics of weathering, mass movement, running water, groundwater, waves, wind and ice in the production of landforms. Includes field trips and laboratory. Prerequisites: GEOL 101 or GEOE 203; MATH 165, PHYS 211, CHEM 121 or consent of instructor. F.

GEOL 320. Petrology. 3 Credits.

Description, classification and origin of igneous, metamorphic, and sedimentary rocks. Field and laboratory study of rocks. Engineering properties of earth materials. Advanced aspects of optical mineralogy. Includes laboratory. Prerequisite: GEOL 318. F.

GEOL 321. Geochemistry. 3 Credits.

Application of the principles of chemistry to geologic and hydrogeologic problems. Origin and distribution of the chemical elements. Introduction to radiochemistry, isotopic geochronology, and stable-isotope geochemistry. Prerequisites: GEOL 318, CHEM 122, and MATH 165 or consent of instructor. S.

GEOL 340. Digital Mapping Methods. 3 Credits.

This course integrates "hands-on" data acquisitions and map generation with an overview of the technology (GPS, lasers, and data management). Field projects focus on mapping methodology and laboratory projects focus on analysis and presentation. It is assumed that students have an undergraduate geology background and a basic knowledge of computer applications. Prerequisite: Junior Standing in geology.

GEOL 407. Petroleum Geology. 3 Credits.

Origin, accumulation and geologic occurrence of petroleum and gas. Prerequisites: GEOL 101 or GEOE 203, and GEOL 102. F, odd years.

GEOL 411. Sedimentology and Stratigraphy. 5 Credits.

Origin, transportation, deposition, and diagenesis of sediments; principles and applications of stratigraphy. Includes field trip and laboratory. Prerequisite: GEOL 320. S.

GEOL 414. Applied Geophysics. 3 Credits.

Principles of various geophysical methods and their application to geologic problems. Prerequisites: GEOL 101 or GEOE 203; MATH 165; and PHYS 211 or 251. F.

GEOL 415. Introduction to Paleontology. 4 Credits.

The principles of paleontology/paleobiology are presented using fossils to document the evolutionary, stratigraphic, and paleoecologic history of animal and plant life on Earth. Includes field trip and laboratory. Prerequisites: GEOL 102; BIOL 150 and BIOL 151 are recommended prerequisites. F, even years.

GEOL 422. Seminar II. 1 Credit.

Continuation of GEOL 421 experience. Preparation and delivery of oral presentations in science and engineering, culminating in oral presentation of senior thesis (Geol 490) or Engineering Design (485). Includes critical review of student presentations and departmental guest lectures. Prerequisites: GEOL 421, senior or graduate status in departmental major. F,S.