PROFESSIONAL MASTER’S IN MINERAL EXPLORATION

DEPARTMENT OF GEOLOGY & GEOLOGICAL ENGINEERING

CMRS.MINES.EDU/PROFESSIONAL-MASTER-IN-MINERAL-EXPLORATION/
INTRODUCTION

This non-thesis, master's degree program is designed for working professionals looking to increase their knowledge and skills, while gaining a thorough update of advances across the spectrum of economic geology, mineral exploration techniques and mining geosciences. Participants will receive a career-boosting education in the minerals industry and will learn to apply advanced geological thinking in a professional setting.

Emphasis is placed on teaching practical approaches to common problems and tasks that arise in minerals exploration and metal extraction. The Program can be completed as a full-time student in only one year or in the on-job mode visiting 5-12 day block courses.

The program requires a minimum of 30 credit hours. A minimum of 15 credit hours must be accumulated in five of the following core areas: (1) mineral deposits, (2) mineral exploration, (3) applied geophysics, (4) applied geochemistry, (5) applied structural geology, (6) petrology and (7) field geology. An additional 15 credit hours may be selected from the course offerings of the Department of Geology and Geological Engineering as well as certain course electives from other departments including Economics and Business, Metallurgy and Materials Science, Mining Engineering, Chemistry and Geochemistry, Geophysics, Applied Math and Statistics.

Up to 9 credit hours may be at the 400 level. All other credits toward the degree must be 500 level or above. A maximum of 3 credit hours may be independent study focusing on a topic relevant to the mineral exploration and mining industries.

Admission to the program is competitive and is generally restricted to individuals holding a 4-year undergraduate degree in earth sciences. A preference will be given to applicants with a minimum of two years of industrial or equivalent experience. Candidates must have completed the following or equivalent subjects, for which credit toward the advanced degree will not be granted. These are general geology, structural geology, field geology, mineralogy, petrology, chemistry (2 semesters), mathematics (2 semesters of calculus), physics (1 semester) and an additional science course other than geology.

This Professional Master's degree in Mineral Exploration provides a unique learning experience and successful completion of the program can be directly related to successful performance in the workforce. With a variety of courses and specializations, Colorado School of Mines offers a truly one-of-a-kind education in mineral exploration that will boost a participant's abilities early in their career. This program will prepare an individual to excel in the minerals industry with knowledge of the latest worldwide.

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EGN 401: MINERAL DEPOSITS

Credit: 4.00
Instructor: Dr. Zhaoshan Chang
Pre-requisite Knowledge: Thermodynamics, Petrology, Field Camp

EGN 401 is a senior-level course that may be taken for graduate credit. The course is designed for students who have an interest in studying mineral deposits or working in the exploration and mining business. This course is also designed for early career professionals who may have some experience in working in a particular style of ore deposit and want to broaden and deepen their knowledge base about the field of economic geology or learn more about a variety of other mineral deposits. Throughout the semester, EGN 401 students are taught the fundamental principles of economic geology that are presented with detailed descriptions of a variety of minerals deposits required for a successful career in the minerals industry.

The course provides an introduction to the science of economic geology and covers topics in: overview of mineral resources and their significance, the minerals industry, and the stages of a mineral exploration cycle including exploration, resources definition, mining, metallurgy, and mine closure/environmental reclamation; investigation methods; the common features, current understanding, and exploration of major types of mineral deposits through lectures, readings, and laboratory examination of samples; verbal and written communication skills in economic geology; and how to solve mineral exploration problems utilizing comprehensive geological knowledge and critical thinking with geologic maps and cross sections. There is a significant component of skills training. Students will learn to use hand lens and other field tools to identify minerals, interpret textures and alteration, recognize deposit type, determine the position of a hand sample in the architecture of an ore system, and use zoning patterns in exploration.

GEGN 403: MINERAL EXPLORATION DESIGN

Credit: 3.00
Instructor: Dr. M. Stephen Enders
Pre-requisite Knowledge: Satisfactory completion of mineral deposits or relevant experience

GEGN 403 is a senior-level capstone course that may be taken for graduate credit. The course is designed for students who have an interest but no experience working in the exploration business. This course is also designed for early career professionals who may have some experience in exploration or mine geology and want to broaden and deepen their knowledge base about a variety of mineral exploration tools, techniques, methods, and strategies.

The course covers topics in: ethics & responsibilities for exploration geologists; mineral exploration methods—geological, geochemical, geophysical, drilling; exploration approaches and project design; QA/QC, geological and assay database management; geometallurgy and mine planning considerations; resource modeling, and preliminary economic evaluation. Lectures and laboratory exercises are structured around a simulation of the entire exploration sequence from inception and planning through implementation to discovery, with initial resource estimations and preliminary economic evaluation. The course is led by Dr. M. Stephen Enders with lectures from subject matter experts in the Denver area and includes the study of case histories and many representative examples. The course uses current industry news feeds to help the students get a better understanding of the exploration business, and relevant examples of technical, economic, social, political, environmental and legal issues surrounding the industry. The capstone project is based on a dataset from a real-world project, where the objective is to integrate and interpret a variety of datasets ultimately leading to a 3D geological model of the deposit. The course compels students to work both individually and as a member of a team which culminates in a written project report and oral presentation of their project proposal for funding to an external board of directors.

After completing the course, a student will:

1. Know how to develop a mineral deposit target model
2. Know how to rank prospect options based upon target model
3. Know how to apply the target model to the progressive evaluation of a single property
4. Participate in the mineral exploration process through a phased design project
5. Understand the basic principles of exploration technologies: geologic mapping, geophysics, geochemistry, remote sensing and geographic information systems (GIS) and integration of these components in the mineral exploration process
6. Learn how to use Leapfrog software program and complete a preliminary resource estimation
7. Incorporate the significant current non-technical aspects of resource development: political, legal and social issues into a framework for responsible exploration
8. Understand the ethical and regulatory requirements for exploration geologists
9. Have a basic knowledge of the structure of the mineral exploration industry
10. Understand the relationship and necessary input of other science/engineering disciplines (e.g., mine engineering, metallurgy) in the mineral exploration process
GEOL 501: APPLIED STRATIGRAPHY

Credit: 3.00
Instructor: Dr. Piret Pliink-Björklund
Pre-requisite Knowledge: Undergraduate course in sedimentology and stratigraphy

GEOL 501 offers a pragmatic approach to analyzing sediments and sedimentary rocks and provides a graduate level foundation of sedimentological concepts necessary for geologists in the minerals industry. Students learn 1) fundamental principles of sedimentology and stratigraphy, 2) pragmatic problem-solving skills, and 3) practical field skills for analyzing the sedimentary record. Focus is on lifelong learning and significance of hypothesis vs model-based research. Students are guided through a detailed synopsis of the different functions of sedimentological and stratigraphic studies in academia and industry and taught to apply fundamental principles and field practices to different businesses.

GEOL 501 provides fundamental understanding and an overview of multiple industrial applications of sedimentology and stratigraphy including petroleum and mineral exploration. Successful students gain practical field skills to assess the sedimentary record and evaluate data against different tectonic and climatic controls, compositional make up, and sedimentary environments. Sedimentary hosted mineral deposits and the recognition of chemical traps that control mineralization are notable topics in this course. Nearly 50% of GEOL 501 is spent in the field examining a variety of terrestrial and shallow marine outcrops near Golden, CO. Additionally, the class includes a field trip to the Southern Californian fore-arc basin to observe deep water sedimentary systems. This advantage allows for a student to fully absorb course material through on-location lessons and hands-on exercises. After completing this course student will be able to critically appraise data with a QA/QC mentality to assure a high level of scientific excellence. By guiding one through basin analyses, various descriptive facies, and their global distribution, GEOL 501 provides a scholar the experience to identify depositional environments and recognize paleo-environments of deposition. Students are also trained to solve interdisciplinary problems frequently encountered in industry. Example situations include: Addressing difficulties that arise from a rock wall collapse, complications due to borehole loss, formulating solutions that enhance recovery of mineral resources. GEOL 501 provides the basis for critical analysis of sedimentary rocks and enhances the skills of any person working with sedimentary materials.
GEOL 505: ADVANCED STRUCTURAL GEOLOGY

Credit: 3.00
Instructor: Dr. Yvette Kuiper
Pre-requisite Knowledge: Undergraduate courses in structural geology, petrology and field mapping skills

GEOL 505 builds on any undergraduate structural geology course you have taken and serves as a foundational basis for more advanced studies in mineral deposit geology. The course focuses on deformation at the microscopic scale, rheology, and on three dimensional geometries of complex shear zones, folds and of areas that underwent multiple generations of deformation. Class sessions are designed to guide students through field-based problems and relate concepts back to the classroom learning and discussions. Practical skills will be enhanced and employed to illustrate class concepts. In addition, the course covers stereographic projection and field data analysis/interpretations. The course provides a valuable opportunity to polish an individual’s field mapping skills and present their findings in both oral and in written formats.

Brief list of topics covered: Stress and strain, rheology, deformation mechanisms and microstructure, shear zones and shear sense indicators, transpression/transstension, vorticity, instantaneous stretching axes, flow apophyses, strain partitioning, orientated core and orientated samples, stereographic projection including orthogonal projection, and field mapping.

This course covers the processes that cause deformation in geologic materials at a graduate level. Structures at thin section scale are studied and become the basis of a semester project which includes presentation and synopsis of microstructures in a thin section of the students choosing. A major assignment includes a two-day field excursion to Golden Gate Canyon State Park to map a portion of the Idaho Springs Ralston Shear Zone. The laboratory consists of in-class problems, microscopy, and some field-based problems. Some labs are related to the lectures to either practice the skills learned in class or to illustrate concepts discussed in class.

At the conclusion of the class, students will:

1. Have a solid background in structural geology, with an emphasis on ductile deformation
2. Have a basic understanding of stress, strain, rheology and deformation mechanisms
3. Be able to recognize shear zones and analyze shear fabrics including shear sense indicators
4. Have gained experience mapping in ductilely deformed rocks (folds, shear zones)
5. Know the basic strain symmetries (pure shear/simple shear, transpression/transstension, orthorhombic, monoclinic and triclinic strain symmetries) and what fabrics result from them
6. Understand microstructures in the field and under the microscope
7. Understand strain partitioning, and implications for mineralization
8. Know how to orient core and take structural measurements from orientated core
9. Be much more comfortable conducting structural analysis using stereographic projection
10. Have improved their ability to think three-dimensionally

GEOL 513: HYDROTHERMAL GEOCHEMISTRY

Credit: 3.00
Instructor: Dr. Thomas Monecke
Pre-requisite Knowledge: Satisfactory completion of a mineral deposits course and its prerequisites or an interest in geothermal systems with adequate background knowledge

GEOL 513 is a unique modular course offered once per year during the spring semester. It is the principal aim of the course to introduce students to the behavior of hydrothermal fluids and the geochemistry of high-temperature aqueous systems through the study of natural systems. Fundamental phase relationships of aqueous fluids will be evaluated to answer the question what the physical nature of hydrothermal fluids is under different pressure and temperature conditions. The course addresses the question how fluids evolve during fluid migration in different geological environments through processes of phase separation, fluid-rock interaction, mineral precipitation, and fluid mixing. Principles of hydrothermal geochemistry will be explained using selected ore-forming hydrothermal systems as examples. Emphasis is placed on porphyry and epithermal environments associated with magmatic arcs and subaerial geothermal systems forming in extensional suprasubduction settings. The course will cover a number of practical aspects including hand specimen petrography, ore microscopy, fluid inclusion analysis, and geochemical data analysis techniques.

GEOL 513 builds on basic knowledge learned in geology- and geochemistry-themed undergraduate courses. Students will be exposed to fluid sampling techniques during a one-day field trip to Steamboat Springs, Colorado. Samples will be collected from active geothermal systems and transported back to the Colorado School of Mines campus for major and trace element analysis. In addition, in-situ chemical parameters will be measured and recorded in the field. This course is intended to build a fundamental understanding of ore-forming processes that can be applied in industry settings.
GEOL 514: THE BUSINESS OF ECONOMIC GEOLOGY

Credit: 3.00
Instructor: Dr. M. Stephen Enders
Pre-requisite Knowledge: Satisfactory completion of a mineral deposits course or relevant experience

GEOL 514 is a "seminar style" graduate course designed for students who have an interest but no experience working in the exploration business as well as for students and early career professionals who may have some experience in exploration, mining, or economic geology and want to broaden and deepen their knowledge base about the business of exploration and the economic and financial aspects of the industry.

The course covers topics in: 1) overall structure and organization of the industry, 2) reserves, resources, and regulatory requirements, 3) exploration portfolio management and decision making, 4) case histories and current studies of major, mid-tier and junior companies, 5) mine and exploration finance, equity markets and funding, 6) royalties and royalty companies, 7) private equity companies, 8) the CEO, CFO and VP Exploration offices, 9) investor relations and business development functions, 9) financial, environmental and social aspects of sustainable mineral development, and 10) deal types and negotiations.

The course is led by Dr. Enders with lectures from CEO’s, CFO’s and other subject matter experts from the Denver area and includes the study and analysis of case histories and current situations. Current industry news feeds are used to to help the students get a better understanding of the exploration business, and relevant examples of technical, economic, social, political, environmental and legal issues surrounding the industry. Each student will select a commodity and a company who specializes in that commodity to follow through the course resulting in an analyst-like final written report and oral presentation. The capstone experience is based on a required class trip to Toronto, Canada for the annual Prospectors and Developers Association of Canada (PDAC) conference in early March where the students get to hone their networking and interviewing skills and get the most up-to-date information and perspective on the industry. The PDAC trip also includes informal meetings with 6-10 companies who present their story directly to the class, typically with C-suite executives and vice presidents of exploration.

GEOL 514 has a professional development focus and covers topics traditionally taught in a business school to students that are specifically interested in a career in mining or mineral exploration. After completing the course, a student will understand company structure, exploration finance, portfolio management, the regulatory environment, and sustainable development aspects related to the minerals industry. Most importantly, the student will get a keen understanding of the role of various technical experts, managers, and executives and how they need to work together in a variety of settings to make any minerals business successful. The student will conclude the course with a much better perspective on how they can make a positive impact wherever they work.

GEOL 519: ABITIBI GEOLOGY AND FIELD SCHOOL

Credit: 3.00
Instructor: Dr. Thomas Monecke
Pre-requisite Knowledge: Satisfactory completion of a mineral deposits course and its prerequisites, undergraduate field camp, and prior reading on volcanology

GEOL 519 is an intense 12-day field course offered in the first two weeks of summer session. The course takes place in the Archean Abitibi greenstone belt of Ontario and Quebec in Canada and exposes students to the single most highly endowed region of the crust in terms of gold and base metals. Course topics cover Archean greenstone architecture, Archean tectonic processes, and Archean metamorphogenesis. Particular emphasis will be placed on the characteristics of volcanogenic massive sulfide and orogenic gold deposits and exploration strategies used to find these deposits under cover. The course offers an exclusive opportunity to get a student trained in geology field skills that can be immediately applied to industry upon graduation such as mapping and core logging. In addition, students will be trained in physical volcanology, structural geology, geochemistry, and metamorphic petrology.

GEOL 519 emphasizes student discovery and field skills development. Lectures are given in the field followed by outcrop inspections. Each day’s worth of learning material is accompanied by one or two exercises to help put concepts into practical use. Course assignments encourage students to map geologic features at different scale (including underground and open pit), measure stratigraphic sections, log drill core, make structural measurements, and create exploration plans in the field. Because of the remote location, there will be an added course fee for travel, transportation, room and board.
GEOL 523: REFLECTED LIGHT AND ELECTRON MICROSCOPY

Credit: 3.00
Instructor: Dr. Katharina Pfaff
Prerequisite Knowledge: Basic levels of transmitted light microscopy and mineral deposits knowledge

GEOL 523 serves as the counterpart course to optical mineralogy in transmitted light and teaches theoretical and practical aspects of reflected light and electron microscopy. This hands-on course teaches skills necessary for individuals in greenfield/brownfield exploration, mine planning, and environmental science surrounding mining operations and reclamation. Emphasis is placed on applications to ore deposit exploration and research and how field observations and observations made under the electron microscope relate. The student will learn how to approach unknown materials using reflected light microscopy and subsequently examine ore mineral and gangue relationships in real world examples given through class assignments.

Lecture, discussion and hands-on labs will highlight various electron beam techniques such as traditional SEM (the most widely used technique in industry today), automated mineralogy, cathodoluminescence (CL), electron probe microanalysis and transmitted electron microscopy (TEM). The course culminates in a project, during which students will utilize the methods and techniques learned in class. Emphasis is placed on the proper presentation of data and understanding of each techniques' strengths and limitations.

GEOL 525: PRINCIPLES OF METAMORPHIC GEOLOGY

Credit: 3.00
Instructor: Dr. Richard Palin
Prerequisite Knowledge: Basic petrology, optical mineralogy and structural geology

GEOL 525 covers the causes and effects of metamorphism in the earth through a comprehensive series of 28 lectures and 10 labs, all of which involve significant student participation. This course aims to build a foundation of graduate-level knowledge of metamorphic geology and familiarize students with examining, describing, and interpreting the significance of metamorphic rocks in various tectonic environments. Notable topics relevant to economic geology include metasomatism, the behavior of sulfur in the metamorphic environment, and the formation of organic gold, diamonds, and banded iron formations.

Areas of focus include (a) the nature of metamorphism in subduction zones and continental interiors, (b) the mechanisms and physico-chemical effects of fluid-rock and melt-rock interactions, (c) links between metamorphism and ore-forming processes, and (d) combining metamorphism with geochemistry, isotope geochronology, and structural geology to quantify the tectonothermal evolution of the lithosphere throughout space and time.

Laboratory exercises emphasize the examination, identification, and interpretation of metamorphic minerals and microstructures at all scales. Labs 1-5 involve optical microscopy, and allow students to use transmitted light microscopes to analyze and interpret metamorphic rocks in thin section. Subsequent labs involve using a range of geophysical, geochemical, geochronological, and petrological data to qualitatively and quantitatively constrain large-scale tectonometamorphic processes that take place in the Earth (e.g. rates of heat flow).

Additionally, a 1-day field trip to the Front Range of the Rocky Mountains allows students to visit local metamorphic rocks with a range of mineralizations, including topaz-bearing deposits and skarn deposits. Upon completion of this course, students will be able to analyze metamorphic terrains and apply that knowledge in an industry setting with confidence and accuracy.
GEOL 520: New Developments in the Geology and Exploration of Ore Deposits

Credit: 3.00
Coordinator: Dr. Thomas Monecke and Zhaoshan Chang
Pre-requisite Knowledge: Satisfactory completion of mineral deposits or relevant experience

GEOL 520 is a graduate-level course. The course instructors will be invited world experts of each major type of mineral deposit. The deposit types covered in this course may vary slightly at the time offering but will always cover porphyry, skarn, epithermal, VHMS, orogenic, and sedimentary rock-hosted base metal deposits. Students will be updated with the latest development in deposit characterization, understanding of the formation processes, controlling factors on the location of the orebodies, and exploration methods. Students will also be refreshed with the fundamentals with expert insights. The course has a lab component with representative samples from all over the world.

Sillitoe (2010)

GEOL 598: Skarns and Related Deposits

Credit: 3.00
Instructor: Dr. Zhaoshan Chang
Pre-requisite Knowledge: Introduction to mineral deposits; Igneous petrology; Field camp

GEOL 598 is a graduate-level course specifically tailored to expanding a student’s knowledge, field and research skills, and understanding of skarns, skarn deposits, and their transition to and relationship with other types of deposits including porphyry-, epithermal-, carbonate replacement deposits (CRD), IOCG, and Carlin-type or Carlin-like deposits.

The course will improve the students’ exploration capability for this group of deposits. The course will cover the following topics: Skarn definition, mineralogy, classification, evolution, zoning patterns, factors affecting skarn formation and zoning patterns, metal association and zoning, skarns replacing igneous rocks, geochemistry, features of Au, Cu, Fe, Sn, W, Zn-Pb-Ag-Mn, and Mn skarns, magma fertility, fluid sources/composition/evolution, metal sources/transportation/deposition, sulfur source, relationship with various types of deposits, tectonic settings, formation/preservation, and exploration methods. The course includes labs involving hand samples, calculations, exploration exercise, and a field trip to a major skarn-porphyry deposit and other prospects in Utah, Arizona, or New Mexico.

Hannington et al. (1998)
GEOL 535: LITHOGEOCHEMISTRY OF ORE-FORMING PROCESSES

Credit: 3.00  
Instructor: Dr. Alexander Gysi  
Pre-requisite Knowledge: Satisfactory completion of a mineral deposits course, optical mineralogy, along with a basic understanding of petrology and mineralogy

GEOL 535 is a practical 1 credit seminar course where we review mechanisms of metal complexation, transport and mineralization processes in hydrothermal fluids and how they are connected to mineral alteration textures, mineral/rock geochemistry and mineral paragenesis. Students will combine observations of mineral assemblages in rocks and thin sections, and geochemical data to link this knowledge to field observations. The tools provided by this course will enable students to recognize alteration types, establish a mineral paragenesis, and connect alteration features with geochemical changes in bulk rock and mineral chemistry in ore deposits. An extra day will be spent in the field to visit a historic mining district in Colorado. The seminar course comprises also discussions and readings of recent articles and a brief review of hydrothermal-(magmatic) ore deposits (e.g. Greisen alteration, epithermal and porphyry systems, REE and critical metal deposits in (per)alkaline systems, Pb-Zn MVT type deposits).

Course objectives
1. Recognize alteration types and establish a mineral paragenesis  
2. Connect alteration features with geochemical changes in bulk rock and mineral chemistry  
3. Calculate stability of minerals and solubility of metals in fluids  
4. Interpret and recognize the genesis of different hydrothermal ore deposits

GEOL 628: ADVANCED IGNEOUS PETROLOGY

Credit: 3.00  
Instructor: TBD  
Pre-requisite Knowledge: Basic levels of mineralogy and optical mineralogy

GEOL 628 is a graduate-level course specifically tailored to expanding a student’s understanding of igneous rocks and processes. This is classical igneous geology instruction that builds on the basis knowledge for applications that will support a career in minerals.

Course topics include: (1) Chemical properties of igneous rocks (2) Igneous processes and their quantification (3) Classification of igneous rocks (4) Phase equilibria in igneous systems and (5) Chemical parameters characterizing igneous rocks.

Lab assignments urge the application of class concepts in a practical manner with themes in layered mafic intrusions, volcanioclastics, carbonatites, kimberlites and REE deposits. Students characterize mineralogical, compositional, and textural properties of rocks from a variety of eruptive and tectonic settings to gain a full understanding of igneous processes and the tectonic associations that can be interpreted.

Class exercises introduce numerical approaches to igneous petrology and emphasize the use of phase diagrams, thermodynamic data, and chemical information to interpret petrogenesis. There is a presentation assignment, where a student is encouraged to become an expert on a particular subject and lead a class discussion that inspires critical thought.

The class concludes with an open-ended term project that encourages the student to present work that demonstrates their understanding of the breadth and depth of concepts taught in the course. In the past, the students have visited the Stillwater Complex, the San Juan volcanic field and other relevant locations to experience the concepts being taught in GEOL 628 firsthand. GEOL 628 is an appropriate foundational course for any graduate student entering the Professional Master’s Program.
GEOL 645: VOLCANOLOGY

Credit: 3.00
Instructor: Dr. Wendy Bohrson
Pre-requisite Knowledge: Basic levels of mineralogy and optical mineralogy and a first course in igneous petrology

GEOL 645 is a graduate-level volcanology course that emphasizes fluid and volatile component effects on igneous eruptions. This course is appropriate for graduate students who wish to build on their previous igneous petrology education. Course topics include: (1) An introduction to volcano-tectonic settings (2) Volatiles and physical properties of magmas (3) Physical volcanology (4) Volcanic processes and (5) Tectonic controls that give rise to volcanic terranes. Laboratory assignments start with igneous mineralogy, mineral nucleation and growth and progress into instruction on specific suites of samples that follow along with lecture topics. The course takes a deep dive into volcanic rock characterization, tectonic controls on eruptions and the properties of magma, particularly as these properties influence volcanic eruptions. There is an explicit focus on volatiles: Fluid and gas sampling, chemical composition and distribution, effects of volatiles on rheology, vesiculation, and analytical methods are all detailed in depth. Students will gain an appreciation of the textural relationships observed in volcanic rocks with the specific intent of optimizing the use of chemical information to interpret the rocks. GEOL 645 serves an enhancement course for anyone looking to gain expertise in the mineralization processes of hydrothermal systems and high temperature fluid-rock interaction.

At the conclusion of the class, students will:

1. Know how water and other volatiles affect the physical aspects of magma, host rocks, and eruptions
2. Know how volatiles and tectonics affect the chemical characteristics of volcanic rocks
3. Be able to identify textural relationships and interpret their meaning

MNGN 528: MINING GEOLOGY

Credit: 3.00
Instructor: Dr. Elizabeth Holley
Pre-requisite Knowledge: A course in mineral deposits and its prerequisites (or professor's consent)

MNGN 528 is taught as a field-based course in odd years and a modeling-based course in even years. The field-based course teaches geologists and engineers how to investigate geological factors that affect the mining life cycle. The project-based modeling course enhances student understanding of geological uncertainty in mining, using state-of-the-art software. Each version of this course is designed to help students leverage geoscience skills to create successful industry products and bridge the gap between geological science and mining business operations.

The field-based course is taught in a seminar-style setting, wherein teams of students lead discussions on a reading list topical to the field trip. Class lessons guide a student to think about how geological factors influence activities at all stages of the mining life cycle. These concepts are then explored further during field trips to active mines where a student will gain firsthand experience through interactions with scientists and professionals that have direct knowledge of the subject matter. Additionally, there is a 10-day field trip to northern Nevada to observe world-class Carlin-type, epithermal, and porphyry-style mineralization. Students conduct open pit and underground mapping exercises, log core, and attend operations and processing tours. After completing this course, a student will be able to recognize the important field characteristics of each deposit style and translate that knowledge to decision-making in mining operations.

The modeling-focused version of this course gives students hands-on exposure to the ways in which geological uncertainty affects mining activities. Datasets donated by industry entities are used as teaching tools to demonstrate real-world situations that are commonly encountered at a mine. Class projects are driven by students and are customized to ensure that information applicable to specific student interests is covered. Top tier modeling software packages are available for class use to assist students in assessing geological uncertainties associated with their project and investigating how those uncertainties might propagate to affect the block model. After completing this course, a student will have experienced a practical decision-making process to assess project feasibility and logistics. Moreover, the multi-disciplinary approach allows for geologists, mining engineers, metallurgists and economists to effectively work together in a collaborative environment and critically evaluate the impact of geological variables on the many aspects of mining.
INTERDISCIPLINARY COURSES AVAILABLE TO PM MINERAL EXPLORATION STUDENTS

GEOLOGY
- GEOL NEW: Exploration Geochemistry
- GEOL 502: Structural Methods for Seismic Interpretation
- GEOL 555: Structural Geology Field Research
- GEOL 624: Carbonate Sedimentology and Petrology

GEOCHEMISTRY
- CHGC 503: Introduction to Geochemistry
- CHGC 504: Methods in Geochemistry
- CHGC 509: Introduction to Aqueous Geochemistry
- CHGC NEW: Analytical Techniques

GEOLOGICAL ENGINEERING
- GEGN 432: Geological Data Management
- GEGN 432: Geological Data Analysis
- GEGN 475: Applications of Geographic Information Systems (GIS)
- GEGN 586: Numerical Modelling of Geochemical Systems

GEOPHYSICS
- GPGN 404: Digital Signal Processing
- GPGN 411: Gravity and Magnetics
- GPGN 420: Electrical and Electromagnetic Methods
- GPGN 461: Seismic Data Processing
- GPGN NEW: Geophysics for Geologists

MINING ENGINEERING
- MNGN 427: Mine Valuation
- MNGN 438: Geostatistics
- MNGN 508: Advanced Rock Mechanics
- MNGN 510: Fundamentals of Mining and Mineral Resource Development
- MNGN 560: Industrial Minerals Production
- MNGN 565: Mine Risk

SOCIETY OF ECONOMIC GEOLOGISTS (SEG) CHAPTER AT MINES

Mines maintains an active and exciting SEG student chapter, established in February of 1987 as the first student chapter in the world. All students are encouraged to join SEG to maximize their learning experience while attending the Professional Master’s in Mineral Exploration program. This organization’s mission is to encourage its members to pursue an increasing knowledge of geology and its application to minerals exploration and mining. To achieve these goals, the chapter sponsors field trips, short courses, guest lectures, social events and a biannual student conference that highlights student research in economic geology and related fields at Mines.

The SEG student chapter provides one-of-a-kind opportunities to students, including weekly lunch and learn meetings lead by industry representatives and monthly joint meetings and presentations with the Denver Regional Exploration Geologists’ Society (DREGS). Off-campus activities have included domestic and international field trips to active mine sites accompanied by industry experts and Mines geology faculty. In past years, the chapter visited mines and world-class deposits in Nevada, Arizona, Montana, Peru, New Zealand, Columbia and Namibia, among many others. The SEG student chapter offers opportunities for any enthusiastic geology student at Mines. This student chapter continues to offer a wealth of extracurricular opportunities to the student membership by providing a basis linking interested students with professional geoscientists in industry, academia and government.
ABOUT THE INSTRUCTORS

Dr. Zhao Shan Chang (PhD, Peking University, PhD, Washington State University) has previously worked at Peking University as an Assistant Professor (1997-2000); at Washington State University as a Research Associate (2004), at CCGES, University of Tasmania, as a Research Fellow/Senior Research Fellow (2004-2011), and at James Cook University (JCU), as a Senior Lecturer/Associate Professor (2011-2013). He was also the Director of EGRU (Economic Geology Research Centre) at JCU from 2012 to 2018. Currently, Dr. Chang is the Chair Professor and Chair Chairperson Chairperson of Economic Geology at Colorado School of Mines. He works closely with the mineral industry on exploration-oriented research projects, looking for far field signals, and zoning goals. He has been directly employed in exploration projects.

Dr. Chang studies a wide spectrum of mineral systems, including porphyry-, skarn-, epithermal-, IOCG-, W-Sn, and sediment-hosted gold deposits. He also works on ore-forming processes and ore controlling factors, magma fertility, and regional metallogenic. His research mainly involves field investigation and drill core logging, petrography, SWIR spectral techniques, whole rock and mineral chemistry, textural imaging using various techniques including CL, BSE, microprobe, geochronology, PXE, fluid inclusion thermometry and composition, various isotope systems (O-H-S-C, Co-Zn-Fe-Sr, HS, and LA-ICP-MS techniques).

While studying at the University of California at Los Angeles, she received her BS degree from Stanford University, worked for the US Geological Survey for several years, and received her PhD from UCLA. She spent several years at UC Santa Barbara as a researcher/postdoctoral student. She was on the faculty at Central Washington University for 20 years before joining the faculty at Colorado School of Mines. Currently, Dr. Bohrson is the department head for the Department of Geology and Geological Engineering.

Bohrson's research interest includes physical and chemical changes in magma as they ascend through the crust and the development and application of energy and mass transport in the Earth system. Bohrson's work focuses on compositional, dynamical and phase equilibria changes in evolving crustal magmas. Her research focuses on active volcanoes, exploring the relationship between magmatic processes and geophysical signals prior to eruption.

Dr. Yvette Kuiper (PhD, University of New Brunswick) has authored 43 peer-reviewed publications, field guides and published government reports and maps. She has taught 22 unique classes at four different universities throughout her academic career. Dr. Kuiper serves as a peer reviewer for 14 different academic journals and four different national research funding sources. She frequently advises students on projects with controlled ore deposits. Her research is supported by the National Science Foundation, geological surveys and the mining industry.

Kuiper's research focuses generally on the following: structural analysis and geochronology of complexly deformed metamorphosed regions; tectonic evolution of mountain belts; the structural setting of ore deposits; and comparison of field structural data with numerical models that predict the formation and development of structures. Dr. Kuiper's research on evolution of mountain belts, with an emphasis on shear zones and fold belts, is currently carried out in the southeastern New England Appalachian and Morocco, the southern Abitibi Greenstone Belt of Ontario and Quebec, and the Idaho Tectonomorphic Zone in Idaho. Recent work includes the Rankin Gold Belt in Yukon, Canada; the Foix Fold Belt in Nunavut, Canada; the Monashee Complex in British Columbia, Canada; the Hudson Valley fold-belt belt in New York; and the Superior Boundary Zone in Manitoba, Canada.

Dr. Piret Plink-Björklund (PhD, Göteborg University) has worked on projects ranging from loose modern sediments to Precambrian sedimentary rocks with considerable metamorphic overprint. She has frequently advised students with sedimentary-hosted copper PhD projects. Her research is of both fundamental and applied nature and she has had projects that have benefited mineral, petroleum and dimension stone businesses. Her belief that understanding the stratigraphic record, combined with other fundamental pillars of geology, creates a more robust program for understanding rocks at the outcrop and beyond scale.

Plinl-Kjorklund's research interests include: outcrop studies in Precambrian to Quaternary sediments; the record of climate, sea-level and tectonic changes in the sediments and sedimentary rocks; and the linkage of depositional systems from source to sink.

Dr. Piret Plink-Björklund

Dr. Thomas Moncke (PhD, TU Bergakademie Freiberg, Germany) is an economic geologist specializing in the formation of base and precious metal deposits in modern and ancient volcanic arcs. He has more than 20 years of experience in exploration and mining geology and has authored or co-authored approximately 80 journal papers, book chapters, government publications and field guides during that period. Dr. Moncke's doctoral thesis focuses on the analysis of a volcanic-hosted massive sulfide deposit in northern Australia. Dr. Moncke has conducted post-doctoral research on modern and ancient gold-rich volcanogenic-hydrothermal systems at the Institute of Marine Sciences in Kiel, Germany, the University of Ottawa and the Geological Survey of Canada. He runs a large research group and supervises graduate student working on a diverse range of hydrothermal ore deposits around the world.

Moncke's research interests include: metallogeny of modern and ancient volcanic arcs; economic geology of hydrothermal ore deposits; fluid-fluid, fluid-mineral and fluid-rock interactions as tools to reconstruct fluid characteristics; physical volcanology; archean geology and metallogeny; and hydrothermal geochemistry.

Dr. Katharina Pfaff (PhD, University Tübingen, Germany) is a mineralogist by training who runs the SEM lab in the Department for Geology and Geological Engineering at Mines. Her lab is entitled "industrial funded" and, as a result, her work is focused primarily on industrial consortia. This unique situation allows Dr. Pfaff to instruct through assignments that closely relate to what industry issues are relevant at the present time. Her students and advisors often participate on projects that she pursues with industry partners.

Pfaff's research interests include: mineral chemistry and mineralogy; geochemistry of hydrothermal ore deposits; economic geology of hydrothermal ore deposits; thermodynamic modeling of element solubilities, transportation and precipitation mechanisms and fluid/rock interaction; igneous petrology in peralkaline systems, magmatic layering; rare earth element systematics in igneous and hydrothermal systems; and radiogenic and stable isotope geochemistry.

Dr. Stephen Enders (PhD, University of Arizona) has worked in the mining and mineral exploration business for 43 years. Dr. Enders went on to become the President of Phelps Dodge Exploration Corporation in 2000. He left Phelps Dodge to join Newmont Mining Company as their Senior Vice President of Worldwide Exploration in 2003 to 2009 before moving on to become the Director and Chief Operating Officer of EMX Royalty Corporation from 2009-2015, where he is a senior advisor to date. In addition, he is a co-founder and a technical advisor for Cupric Canyon Capital LLC.

Enders is the Director of Subsurface Frontiers in the Office of Research and Technology Transfer at Mines after a three-year assignment as the Department Head for Geology and Geological Engineering. Previously, he was a Research Professor in the Mining Engineering Department and the Director of the Center for Innovation in Earth Resources Science & Engineering at Mines from 2009-2015. He is an Honorary Lecturer at the Chinese University of Geosciences, and received the Distinguished Achievement Medal from the Colorado School of Mines in 2009, the Ben F. Dickerson Award from the Society for Mining, Metallurgy & Exploration in 2014, and the Ralph W. Marsden Award from the Society of Economic Geologists in 2016.

Dr. Alexander Gysi (PhD, University of Iceland) conducts research and experiments in order to understand the geochemistry of REE in crustal and mantle environments. Dr. Gysi has a strong interdisciplinary background covering aqueous geochemistry, mineralogy and petrology and has worked internationally with several industrial partners over his academic career. He has collaborated with the industry for the exploration of the world-class REE deposit in Strange Lake, Canada, and participated in the Caribfix Project in Iceland, which aimed at injecting CO2 from a geothermal powerplant into basaltic rock formations. Dr. Gysi's work is focused on the formation of critical metal deposits.

Dr. Gysi's research at Mines is currently funded by government grants (e.g., National Science Foundation) and aims at linking fundamental and applied research to advance the field of economic geology of critical metal resources. Dr. Gysi's research interests include the following: lithogeochemistry of hydrothermal ore deposits; thermodynamics of rare earths and exsolution processes; experiments on rare earths and secondary phases; fluid/rock interaction; geochemistry of rare earth elements and other critical metals; evolution of pegmatites and alkaline/peralkaline magmatic/hydrothermal systems; and CO2 sequestration in geological rock formations.
1. PAY ATTENTION TO DEADLINES

There are several deadlines that must be met for your application to be given full consideration. These deadlines are by far the most important thing to keep in mind when applying to Mines. For specific information about deadlines, visit: mines.edu/graduate-admissions/fall-deadline-process

2. WHAT MATERIALS ARE NECESSARY?

- Application fee: There is a non-refundable application fee of either $60 USD or $75 USD depending on when you submit your application. The fee for international students is $80 USD.
- Transcripts: Transcripts are the best indicator of your ability to succeed academically. You must submit all transcripts from all previously attended institutions so the department’s admissions committee can view your academic history and how your GPA was calculated.
- Resume/CV: Your resume should contain a comprehensive list of your education, and professional experience.
- Important: Special training, publications, projects, internships, etc. should be included in your resume. Certificates (athletic, special trainings, internships etc.), published papers, etc. should not be submitted with your application packet. A current resume gives a prospective advisor a good understanding of what work you have engaged in and of your exposure to the minerals industry.
- Statement of Goals: The statement of goals is typically one to two pages in length. The purpose of this is to introduce you to the Graduate Admissions Review Committee. Your essay must cover the details of your background and who you are. In the statement, you should address professional and personal goals, as well as why Mines would be the best place for you to achieve those goals. Why are you applying to Mines? What is your passion for geology? Why have you decided to leave your career and go back to school? What are you hoping to gain out of this program? Where do your ambitions lie? Why do you feel as though you will succeed? What are some professional challenges you have overcome to get where you are today?

The application Review Committee will then determine who you are and why you are applying to the Professional Master’s in Mineral Exploration program at Mines. Please also explain your level of experience.
- Three letters of recommendation: Letters from past professors and employers are preferred. Anyone who directly supervised your work and can attest to your professional or academic profile is best. Please do not have family members or personal references write letters of recommendation for your application. Family members usually cannot speak to your professional caliber in an unbiased manner. Mines never accepts letters of recommendation directly from the applicant. Letters must be submitted by your professional reference to the Mines Graduate School. The letters will be forwarded to the department after you have completed and submitted your application.

For more information about the application process, visit: mines.edu/graduate-admissions/faq

3. WHAT PROFICIENCY TESTS SHOULD I TAKE?

- The Geology and Geological Engineering Department only accepts the GRE test. The GRE test is offered in both computer and hand written sections. The test consists of four sections: quantitative reasoning, analytical writing, verbal reasoning, and research sections. The test is aimed at evaluating all disciplines and is used as a tool to evaluate many types of students applying for master’s graduate degree.
- What scores are needed? There is no minimum score that qualifies an applicant for acceptance. The applicant will need to demonstrate proficiency in the math, verbal, and writing sections of the GRE. The proficiency exams become more important the longer an applicant has been out of school. It is recommended that the applicant take the exams sooner rather than later. The material may be increasingly difficult to recollect as time passes. The Graduate Admissions Review Committee will take the GRE into account when evaluating the application as a whole.

- What level of English is required to apply (for international applicants)? The department accepts and TOEFL or IELTS scores. Mines applicants must be able to pass either the TOEFL or IELTS exam to prove proficiency in English. This basic level of English proficiency is important because there is no communication barrier does not exist between professors, staff and students. It is important that all applicants at Mines to have a strong grasp on the English language to ensure academic success. All classes are taught in English. A minimum level of communication skill in English is essential to transfer ideas and complete assignments at Mines.

- Where can I take proficiency exams? It is important to note that some countries do not (or seldom) administer proficiency exams. If an applicant cannot find a testing location near or inside their home country, special arrangements are possible to satisfy the requirements. Any special arrangements must be approved by the department. Contact the program manager at graduate-admissions@mines.edu for further details. An applicant may provide credible references or letters of reference that confirm his/her understanding of material covered in the GRE. TOEFL or IELTS must be taken before admission is granted. There are no exceptions for this requirement.

- How can applicants prepare for exams? There are many online- and classroom-based prep courses that can be helpful to applicants. However, Mines does not offer programs to prepare students for the TOEFL, IELTS and GRE. If a student chooses to enroll in preparatory course, they should do so at their own expense.

4. ARE THERE RESOURCES TO HELP ASSIST IN THE APPLICATION PROCESS?

- The Graduate School’s website contains an abundance of information on this topic. To get an idea of what the application process requires from an administrative perspective, visit: mines.edu/graduate-admissions/apply.
- For information about International Student and Scholar Services, visit: mines.edu/issss.

5. WHAT SHOULD I EXPECT TO INVEST FINANCIALLY?

- For information about estimated costs of attendance for international, out-of-state and in-state students, visit the graduate school’s web page: mines.edu/graduate-admissions/costs. This link has additional information regarding financial aid and estimated cost of attendance. Estimates should be viewed as minimum cost of attendance and should be evaluated as such. Although Golden is a small city, cost of living is fairly high compared to other parts of the country. We encourage you to do your own research on what your expected costs of living will be.

- The school will not typically provide funding for incoming students in the Professional Master’s in Mineral Exploration program. It is the applicant’s responsibility to secure funding for tuition, room and board, meals and recreation for the duration of the program. The sources of funding can vary, but usually come from either personal capital, student loans, scholarships or employer-funded tuition.

- i. If the student’s tuition is funded by an employer, it is an agreement between student and employer that does not involve Mines. Hence, if the employer rescinds funding it will be the student’s responsibility to provide funds through different means to finish the program.

- ii. Fellowships, scholarships and grants are an excellent way to fund your education. The links below provide information on some opportunities available to students in the program.

Possible grants: finaid.mines.edu/grants
Fellowships by the Society of Economic Geologists: segweb.org/SEG/Students/Graduate_Student_Fellowship_Program/SEG_/Students/Graduate_Student_Fellowship_Program.aspx
Scholarships by the Society for Mining, Metallurgy & Exploration: smet.net/otd/gs/grads-scholarships

6. ABOUT THE PROFESSIONAL MASTER’S IN MINERAL EXPLORATION PROGRAM

- General information: Admission to this program is generally restricted to individuals holding a four-year undergraduate degree in earth sciences. Candidates for the Professional Master’s degree in Mineral Exploration must have completed the following or equivalent subjects, for which credit toward the advanced degree will not be granted. These are general geology, structural geology, field geology, mineralogy, petrology, chemistry (2 semesters), mathematics (2 semesters of calculus), physics (1 semester) and an additional science course other than geology.

- Industry experience: Please note that admission to the program is competitive. Preference will be given to applicants with a minimum of two years of industrial or equivalent experience. This program is intended to bolster a student’s industry knowledge and education. The applicant will complete a non-thesis, master’s degree that is designed for working professionals who want to increase their knowledge and skills, while gaining a thorough update of advances across the spectrum of economic geology, mineral exploration techniques and mining geosciences.

- How long does the Professional Master’s degree program take to complete? The program requires a minimum of 30 credit hours. A minimum of 15 credit hours must be accumulated in five of the following core areas: mineral deposits, mineral exploration, applied geophysics, applied geochemistry, applied geology, petrology, field geology, and economic evaluation. An additional 15 credit hours may be selected from the course offerings of the Department of Geology and Geological Engineering and allied departments including Mining Engineering, Economics and Business, Geophysics, Chemistry and Geochemistry, Metallurgy and Materials Science and Environmental Sciences.

The program is self-paced and can be completed while the student works part-time. The degree is designed to be completed in two semesters with a full course load. Selection of courses will be undertaken in consultation with an academic advisor. Up to 9 credit hours may be at the 400-level. All other credits toward the degree must be 500-level or above. A maximum of 9 credit hours may be independent study focusing on a topic relevant to the mineral exploration and mining industries.
A TRANSFORMATIVE UNIVERSITY IN AN OUTSTANDING LOCATION

COLORADO SCHOOL OF MINES is a public university focused on science and engineering, dedicated to educating and inspiring students, advancing knowledge, and innovating to address the great challenges society faces today—particularly those related to the earth, energy and the environment. Founded in 1874 with specialties in mining and metallurgy, Mines scope and mission has expanded to meet the needs of industry and society, producing distinctive graduates and revolutionary innovations, and becoming a world leader in advancing sustainable use of the Earth’s resources.

Colorado is a high-altitude arid state that goes through all four seasons. There are many outdoor recreational activities including hiking, mountain biking and skiing nearby. The weather is variable, but we enjoy, on average, 300 sunny days per year. It is cold in the winter months and we often see large snowstorms each year. It is suggested that all applicants visit the campus to ensure that they will be comfortable in this type of climate.

THE CITY OF GOLDEN is located on the Front Range at the base of the Rocky Mountains. It is an ideal terrain to study geology. There are many outstanding examples of concepts students will learn through their course of study right in Mines’ back yard. Field trips are taken frequently in many classes and the coursework takes full advantage of the school’s proximity to a variety of geological environments. Golden is a 20-minute drive from downtown Denver. Many students live in Denver and the surrounding areas and commute to Golden. There is bus and light rail transit that can transport students between Denver and Golden. Students may purchase a transit pass for cheap and effective transportation services.

To plan your campus visit accordingly, please visit: MINES.EDU/GRADUATE-ADMISSIONS/VISIT