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. 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.

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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GEGN 401: MINERAL DEPOSITS
Credit: 4.00
Instructor: Dr. Zhaoshan Chang
Pre-requisite Knowledge: Thermodynamics, Petrology, Field Camp

GEGN 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, GEGN 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 exploitation 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 Plink-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 competence, complications due to borehole collapse, 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.

GECL 530: CLAY CHARACTERIZATION
Credit: 3.00
Instructor: Dr. Wendy Harrison
Pre-requisite Knowledge: A first course in igneous petrology and basic optical mineralogy skills

GEGL 530 offers a unique learning experience not offered in other mining and minerals focused programs. Clays have a very diverse suite of properties and as a result, a great deal of information can be communicated through the study of clays and their textural relationships. Students will work directly with X-ray Diffraction (XRD) instrumentation and learn analytical techniques to examine clays from a variety of geological environments. A fundamental understanding of Clay minerals, clay properties and distributions, along with their physical and chemical behavior are key concepts communicated through instrument based assignments. Knowing how clays behave in different mineral assemblages allows you to take the next step in understanding how clays affect different geological systems which, in turn, allows you to more thoroughly examine the geology of a clay-rich terrain. Skills learned in this class are commonly applied in industry to characterize the mineralogy of ore deposits. In addition, lessons from this class can also be applied in the petroleum industry and in geotechnical roles.

At the conclusion of the class, students will:
1. Operate an XRD instrument
2. Present XRD based work
3. Inform decision making in the laboratory, mine, or exploration environment
4. Perform QAQC on 3rd party analyses and work products
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 orthographic 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, 8) 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 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 formal meetings with 6-10 companies who present their story directly to the class, typically with C-suite executives and vice presidents of exploration.

GEGN 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 metallogeny. 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 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 serves as the counterpart course to optical mineralogy in transmitted light and teaches the 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 work (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
Pre-requisite 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 orogenic 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 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. 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.

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.

Hannington et al. (1998)

Sillitoe (2010)
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 PETOLOGY
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
4. Know the proper sampling protocol to study fluids and gases involved in volcanic rocks
5. Be prepared to participate in thorough study of fluid-rock interactions

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 30-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 532: Geological Data Analysis
- GEGN 575: Applications of Geographic Information Systems (GIS)
- GEGN 586: Numerical Modeling 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

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**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. Zhoshaon 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 (2000-2003), at Taif University as a Research Fellow/Senior Research Fellow (2004-2011), and at James Cook University (JCU), as a Senior Lecturer/Associate Professor (2013-2018). He was also the Director of EGRU (Economic Geology Research Unit) at JCU from 2012 to 2015. Currently, Dr. Chang is the Rangaswami Goldow Chair in Economic Geology at Colorado School of Mines. He works closely with the mineral industry on exploration-oriented research projects, looking for far field trends, and mining companies on how they can be directly used in exploration.

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 metallogeny. 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 isotopic systems (O-H-S-C, Cu-Zn-Fe-Sr, Er, Ho), and LA ICP MS techniques.

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Dr. Wendy Bohrson (PhD, University of California, Los Angeles) received her BS degree from Stanford University, and finished her MSc and PhD work at the Colorado School of Mines. Her area of expertise is Precambrian to Neogene mineral deposits, including porphyry, skarn, and IOCG systems. She will be attending conferences on Precambrian geology in Canada and China in 2023.

Dr. Bohrson's research interests include: field geology, exploration, and mining company; system thermodynamic computational tools that track compositional, dynamical and phase equilibria changes in evolving crustal magmas. Her research focuses on active volcanoes, exploring the relationship between petrogenetic records and the geometry of gas fields.

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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 35 different academic journals and four different national research funding sources. She frequently advises graduate students with projects on structurally-controlled ore deposits. Kuiper's research has been supported by the National Science Foundation, geological surveys, and the mining industry.

Dr. 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 the formation of the structural framework that supports mineral deposits. She is currently conducting research on the geology of Precambrian sediments in Newfoundland and Labrador. Her current research interests include: Precambrian tectonics, sedimentary rocks, mineral exploration, and economic geology.

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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 Ph.D. projects. Her research interests include fundamental nature and she has had projects that have benefited mineral, petroleum, and mineralization businesses. Her research on the metamorphic stratigraphy, combined with other fundamental pillars of geology, creates a more robust program for understanding rocks at the outcrop scale.

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Dr. Thomas Monecke (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 researching the geology of metallogenesis and has authored or co-authored approximately 80 journal papers, book chapters, government publications and field guides during that period. Dr. Monecke's doctoral thesis focuses on the anatomy of a volcanic-hosted massive sulfide deposit in northern Australia. Dr. Monecke has conducted post-doctoral research on modern and ancient gold-rich, volcanic-hosted hydrothermal systems at the Institute of Marine Sciences in Kiev, the University of Ottawa and the Geological Survey of Canada. He runs a research group and supervises graduate student working on a diverse range of hydrothermal ore deposits around the world.

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

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Dr. Katharina Pfaff (PhD, University Tübingen, Germany) is a mineralogist by training who runs the SEM lab in the Department for Geology and Geotechnical Engineering at Mines. Her lab is entirely industry funded and, as a result, her work is focused primarily on industry projects. 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 advisees often participate on projects that she pursues with industry partners.

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Dr. Alexander Gysi (PhD, University of Iceland) conducts research and experiments in order to understand the geochemistry of REE in crustal fluids and ore-forming processes. Dr. Gysi's work builds on an 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-Zn deposits in Strange Lake, Canada, and participated in the CaribFk 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.

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Dr. M. 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 Director and Chief Operating Officer of EMX Royalty Corporation from 2009 to 2015. He is a co-founder and a technical advisor for Cupric Canyon Capital LLC.

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Dr. Katharina Pfaff also works as 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 Geotechnical 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 2000 to 2003. He is an Honorary Lecturer in the University of New South Wales, Australia, and the School of Economic Geologists, 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. Mendenhall Award from the Society of Economic Geologists in 2020.

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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-deadlines

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 location has advanced.
- Resume/CV: Your resume should contain a comprehensive list of your education, and professional experience.
- Important: Special trainings, 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.

3. 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 should cover the basics 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 your ambitions? 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 essay is to give the Graduate Admissions Review Committee a clear view of 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.

4. 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 Geological and Geophysical Engineering Department only accepts the GRE test: The GRE test is offered in both computer and paper copy versions. It covers 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 degree. If your 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 TOEFL or IELTS scores. Mines applicants must be able to pass either the TOEFL or IELTS exam to prove proficiency in English. A minimum level of communication skill in English is essential to transfer ideas and complete assignments in 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 mines.edu/graduate-admissions/fall-deadlines. 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授予。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 courses, they do must 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/application-process.
- For information about International Student and Scholar Services, visit: mines.edu/isss

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: mines.edu/graduate-admissions/fall-deadlines. This link has additional information regarding financing your education and estimating your 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.

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 of 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), geophysics (2 semesters), geomatics (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, 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