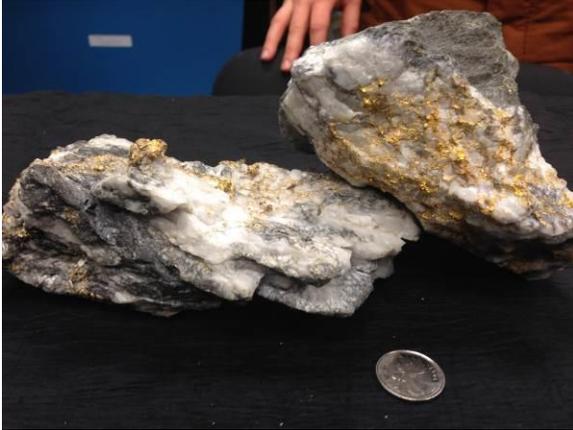


ES 4432A - Mineral Deposit Geochemistry

Course Outline - Fall 2019



Gold from the Hollinger mine, Timmins, ON



Molybdenite at the Boss Mtn mine, BC

Instructor: Robert Linnen

office B&GS 1000B **email:** rlinnen@uwo.ca **tel. ext.** 89207

Meeting hours: There are no fixed office hours, please set up an appointment when you need to meet

Teaching Assistant: none

Pre-requisites:

ES2230a/b Introduction to Geochemistry;

ES3370a/b Metallogeny I: Ore Petrology

Schedule

Lectures: 3 hrs per week: Monday 12:30-14:30 & Wednesday 12:30-13:30 MC-17

Tutorial: 1 hr per week: Wednesday 13:30-14:30 B&GS 1056 Tutorial dates are available to go over course material on request. Should any classes need to be cancelled the tutorial time slot will also be available for make-up lectures.

Important Dates

Tuesday, October 23rd – Midterm exam in class

Fall Reading Week November 4-8 – no classes

November 27th – Oral Presentations

December 4th – Term paper due

December 8-19 – Examination period. Final exam, date and location TBA.

Accessibility:

Please contact the course instructor if you require lecture or printed material in an alternate format or if any other arrangements can make this course more accessible to you. You may also wish to contact Services for Students with Disabilities (SSD) at 661-2111 ext. 82147 if you have questions regarding accommodation.

Support Services

Learning-skills counsellors at the Student Development Centre (<http://www.sdc.uwo.ca>) are ready to help you improve your learning skills. They offer presentations on strategies for improving time management, multiple-choice exam preparation/writing, textbook reading, and more. Individual support is offered throughout the Fall/Winter terms in the drop-in Learning Help Centre, and year-round through individual counselling.

Students who are in emotional/mental distress should refer to Mental Health@Western (http://www.health.uwo.ca/mental_health) for a complete list of options about how to obtain help.

Additional student-run support services are offered by the USC, <http://westernusc.ca/services>.

The website for Registrarial Services is <http://www.registrar.uwo.ca>.

Course Website and Contact Information

Students should check OWL (<http://owl.uwo.ca>) on a regular basis for news and updates. This is the primary method by which information will be disseminated to all students in the class.

Students are responsible for checking OWL on a regular basis. Additional information on the course will be disseminated through email. The uwo email address will be used by default, if students use other email addresses they must ensure that uwo mail is automatically forwarded.

For any concerns, including setting up an appointment, student should contact Robert Linnen directly at rlinnen@uwo.ca.

CALENDAR DESCRIPTION

The principals of metal concentration and deposition in magmatic and hydrothermal environments are examined. Natural and experimental data, including fluid inclusion, stable isotope, metal solubility, mineral stability and metal partition behavior are used to develop genetic models for ore deposits, which form the basis of mineral exploration strategies.

Prerequisite(s): Earth Sciences 2230A/B and 3370A/B.

WHY STUDY MINERAL DEPOSITS?

Mining is one of Canada's most important industries and mineral exploration and exploitation is one of the largest sectors that employs geologists, geological engineers and other Earth scientists and engineers. There is also an environmental cost to mining and, to understand the environmental impact of mining, a solid understanding of mineral deposits is required.

WHAT ARE THE PRINCIPAL OBJECTIVES OF THIS COURSE?

Ore deposit models are the foundation on which mineral exploration and exploitation are based on. This course first develops the geochemical tools that are used to study mineral deposits and interpret how deposits form and what controls metal distribution. A variety of ore-forming processes are examined by using a variety of mineral deposit types. Many of the sedimentary ore environments were covered in ES3370, consequently 4432 focuses more on igneous and metamorphic host rocks.

LEARNING OUTCOMES

Upon successful completion of this course students will be able to:

- Apply the geological and geochemical tools that are used to develop ore deposit models
- Apply geological and geochemical tools to critically evaluate ore deposit models that have been published in the literature
- Use geochemistry to understanding ore-forming processes in magmatic, metamorphic, sedimentary and hydrothermal environments.
- Develop critical thought, writing and oral presentation skills through the term paper and associated oral presentation.
- Apply the scientific approach evaluating models of ore deposit types not covered in this course.
- Evaluate new ore deposit models as practicing professional geologists

RESOURCES

There is no formal text. **Notes will be posted on the ES 4432 OWL website.** There are several useful mineral deposits textbooks in the library. These include:

Moon, C.J., Whateley, M.K.G. and Evans, A.M., 2006, Introduction to mineral exploration.

Robb, L.J., 2005, Introduction to ore-forming processes

The USGS also has a number of mineral deposit models on their website

<http://minerals.usgs.gov/products/depmod.html>

MARKING SCHEME

<i>Component</i>	<i>Notes</i>	<i>Value</i>
Mid Term	October 23	20%
Assignments	4 problem sets	10%
Oral Presentation	November 27	5%
Term Paper	December 4	25%
Final Exam	Scheduled by the Registrar	40%

For the Mid Term and Final Exam students should bring a calculator and a ruler. Both will consist of a mixture of multiple choice, short answer questions and possibly a problem. No electronic devices may be in your possession during tests and exams.

Term Paper: This is to be written as a journal paper. **Follow the format of the journal Economic Geology** (marks will be deducted if this format, including references, is not adhered to). The theme of the assignment is 'Genetic Modeling in Economic Geology'. Subject material could be an analysis of a single ore deposit or mining camp, a comparison of different styles of mineralization, evaluation of a general type of mineralization, geochemistry of a particular element (solubility, transport and deposition), or any other topic that would be suitable for publication in the journal Economic Geology. **You are encouraged to come up with your own topic.** However, a list of potential topics is also provided below. Topics must be selected by **October 1st and an email sent to professor Linnen by that date indicating the topic** (the same topic will not be presented by two students so the first student to email me will be given the topic). You should use the **Georef** program in the library to get up-to-date references and request interlibrary loans if necessary (I will use this program to see what references are available).

The report should consist of a Title, Abstract and Introduction, followed by the main body of the text (including figures), Conclusions and References. The written assignment is **due December 4th**. The length of the text and figures should be 10-15 pages, using a 12 pt. font, (Times Roman, Helvetica or Courier), double spacing and "normal" margins.

There should be some figures (with figure captions) containing geochemical data or phase equilibria etc., and the figures should be properly explained in the text. A model for the genesis of mineralization should be proposed and evaluated in light of alternative models. All material must be properly referenced and the list of references should reflect the fact that your knowledge of the presented material is up to date. The marks will be based on originality, the depth of understanding, logic of arguments etc., as well as presentation and writing style.

The term papers may be subject to submission for textual similarity review to the commercial plagiarism detection software under license to the University for the detection of plagiarism. All papers submitted for such checking will be included as source documents in the reference database for the purpose of detecting plagiarism of papers subsequently submitted to the system. Use of the service is subject to the licensing agreement, currently between The University of Western Ontario and Turnitin.com (<http://www.turnitin.com>).

Rubric for 4432 Term Paper

The marking rubric for the term paper is Presentation (10%), Abstract (10%), Introduction (10%), Main Body, (40%), Conclusions (10%), Overall Writing (10%), References (10%).

When you are reading journal articles pay attention to how other people write. What do you think makes a good abstract, Introduction etc.

Format: All papers should have a title page with title and the author, student and course numbers. Papers must use Economic Geology format, including references. See <http://www.segweb.org/pdf/publications/economic-geology/Instructions-to-Authors.pdf>

Abstract: Should summarize the key findings, generally some data is included and why this data is important

Introduction: Identify what the main problem is, why this problem is important, then outline how you will address this problem in the paper

Main Body: Think about the order of presentation of data and ideas. If methods need describing (for a term paper this normally is not the case), this should come first. Present all of the data first, these are the observations and facts. Then interpret and integrate the data. The interpretation should be consistent with the problem that is identified in the Introduction.

Conclusions: This should summarize the interpretations from the main body of the paper. A minimal amount of data should be repeated here. Conclusions are different from the abstract, the latter summarizes the entire paper, including data, whereas the former only summarizes the interpretations, but can also extend those interpretations to broader implications for other studies.

Some Potential Topics for the Term Paper

Email your topic to me by **October 1st**

Magmatic deposits:

- V-Ti deposits.
- podiform chromite deposits.
- Komatiite-hosted (Kambalda-type) Ni sulphide deposits

Hydrothermal deposits associated with igneous rocks

- IOCG
- Co deposits, e.g., Cobalt Ontario, NICO, NWT
- skarn deposits W, Zn, Cu or Au (or other metals).
- granite-hosted U deposits
- Mexican silver province.
- Bayan Obo REE, China

Hydrothermal deposits associated with metamorphic rocks.

- origin of the specific Au deposits or camps, e.g., Hemlo or Red Lake (Ontario), Val d'Or (Quebec), Eleonore (Quebec), (structural controls, alteration, fluid inclusions).
- genesis of metamorphosed, sedimentary-hosted Pb-Zn-Ag deposits, e.g., Broken Hill or Mt Isa (Australia).
- Au-rich volcanogenic massive sulphide deposits, e.g., Bousquet (Quebec)
- West African (e.g., Obuasi, Ghana) gold deposits

Hydrothermal deposits associated with volcanic and sedimentary rocks

- Origin or aspect of a specific VMS deposit, e.g., Kidd Creek
- the role of organic material in ore-forming processes.
- Roll front U deposits
- Unconformity-related U deposits
- Au deposits of the Witwatersrand, South Africa, placer versus hydrothermal?
- Sukhoi Log Au deposit (black shale-hosted), Russia
- formation of Au deposits in banded iron formations.

Ore deposits associated with surficial processes

- 'supergene' enrichment of Cu in porphyry Cu deposits.
- genesis of the Elliot Lake (Ontario) paleoplacer U deposits.
- formation of Ni laterite deposits.
- Mn nodules on the seafloor: their origin and significance.

Industrial Minerals

- gem deposits (emeralds, sapphire, ruby),
graphite, wollastonite, talc

SYLLABUS

Introduction

- background on the mineral exploration industry
- introduction on why are models in economic geology are important

1) Stable Isotopes

- nomenclature, fractionation, thermodynamics
- O and H isotopic compositions of natural waters
- fluid-rock interactions
- C and S isotopes

2) Geothermometry

- estimation of lithostatic pressure
- use of phase equilibria
- thermodynamics of mineral exchange reactions
- isotope geothermometry

3) Diamonds

- igneous background
- kimberlites
- indicator minerals
- geothermometry and geobarometry of kimberlites and diamonds

4) Magmatic Sulfide Cu-Ni Deposits

- review of deposit types
- constraints from experimental petrology
- sulfide-silicate melt partitioning
- depositional model

5) Platinum Group Element (PGE) and Chromium Deposits

- review of the Bushveld and Stillwater complexes
- constraints from phase equilibria
- sulfur solubility in silicate melts
- comparison of the origin of PGE and Ni deposits

6) Rare Metal Deposits

- controls of metal solubility in granitic melts
- tantalum and lithium deposits
- REE-Nb deposits

7) Fluid Inclusions

- origin and classification of fluid inclusions
- interpretation of fluid inclusion data
- H₂O-NaCl and H₂O-CO₂ systems

8) Porphyry Deposits

- review of deposit types

- geochemistry of alteration and mineralization
 - fluid-melt partitioning and metal solubility in porphyry systems
 - granite series, porphyry Mo & porphyry Sn deposits
- 9) Solubility and Mineral Deposition
- controls on metal and gangue mineral solubility
 - fluid inclusion and stable isotopes
 - causes of mineral deposition
- 10) Hydrothermal Alteration
- metamorphism versus metasomatism
 - Gresens equations for gains and losses of elements
 - MacLean method of mass balance
 - Pearce Element Ratios applied to metasomatism
- 11) Epithermal Gold Deposits
- classification of gold deposits
 - behavior of sulfur
- 12) Orogenic Gold Deposits
- structural and metamorphic setting
 - fluid inclusion and stable isotopes
 - alteration and mass balance
 - transport and deposition of gold

General Information

General information is available at <http://www.registrar.uwo.ca/>. For scholastic offenses, University of Western Ontario policies are listed http://www.uwo.ca/univsec/academic_policies/. Scholastic offences are taken seriously and graduate students are directed to read the policy, specifically, the definition of what constitutes a Scholastic Offence, at the following Web site:

http://www.uwo.ca/univsec/pdf/academic_policies/appeals/scholastic_discipline_undergrad.pdf

Information for accommodation for religious holidays can be found at

http://www.uwo.ca/univsec/pdf/academic_policies/appeals/accommodation_religious.pdf

The link to learning skills services at the Student Development Centre is <http://www.sdc.uwo.ca/> and services provided by the University Students' Council is <http://westernusc.ca/services/>

Accommodation for Illness

A student requiring academic accommodation due to illness or other serious circumstances, you must provide valid medical or supporting documentation to the Academic Counselling Office of your home faculty as soon as possible. Any student looking to book an appointment with a physician, a counsellor, psychologist, psychiatrist, in search of group care options, or any other service provided through Student Health Services and Psychological Services must book an initial appointment in Student Health Services, UCC 11 (Lower Level of the University Community Centre).

For further information, please consult the university's medical illness policy at http://www.uwo.ca/univsec/pdf/academic_policies/appeals/accommodation_medical.pdf

For non-medical absences, where the student has received academic accommodation the student should contact the course instructor and the nature of the accommodation will be discussed and agreed upon, depending on the nature of the absence.

Mental Wellbeing

Crisis supports will continue to be offered in both Student Health Services (UCC 11) and Psychological Services (WSSB 4100) during operating hours. Please call 911 if your safety, or the safety of others is a concern. Additional crisis supports can be found at www.uwo.ca/health/crisis.html.

Students can book an appointment with Student Health Services or Psychological Services in-person in UCC 11 (Monday-Friday 9:00a.m.-4:00p.m.), or by telephone at 519-661-3030.

If you require any further clarification, please email health@uwo.ca.

Accessibility Statement

Please contact the course instructor if you require material in an alternate format or if you require any other arrangements to make this course more accessible to you. You may also wish to contact Services for Students with Disabilities (SSD) at 661-2111 x.82147 for any specific question regarding an accommodation. Students are not required to sit for more than one hour at a time. For additional information please see www.uwo.ca/univsec/pdf/academic_policies/appeals/accommodation_disabilities.pdf

Academic Policies

The website for Registrarial Services is <http://www.registrar.uwo.ca>.

In accordance with policy, <http://www.uwo.ca/its/identity/activatenonstudent.html>, the centrally administered e-mail account provided to students will be considered the individual's official university e-mail address. It is the responsibility of the account holder to ensure that e-mail received from the University at his/her official university address is attended to in a timely manner.

Scholastic offences are taken seriously and students are directed to read the appropriate policy, specifically, the definition of what constitutes a Scholastic Offence, at the following Web site: http://www.uwo.ca/univsec/pdf/academic_policies/appeals/scholastic_discipline_undergrad.pdf.

Support Services

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format or if any other arrangements can make this course more accessible to you. You may also wish to contact Student Accessibility Services (SAS) at 661-2147 if you have any questions regarding accommodations.

The policy on Accommodation for Students with Disabilities can be found here:

http://www.uwo.ca/univsec/pdf/academic_policies/appeals/accommodation_disabilities.pdf

The policy on Accommodation for Religious Holidays can be found here:

http://www.uwo.ca/univsec/pdf/academic_policies/appeals/accommodation_religious.pdf

Learning-skills counsellors at the Student Development Centre (<http://www.sdc.uwo.ca>) are ready to help you improve your learning skills. They offer presentations on strategies for improving time management, multiple-choice exam preparation/writing, textbook reading, and more. Individual support is offered throughout the Fall/Winter terms in the drop-in Learning Help Centre, and year-round through individual counselling.

If you are a Science student, the Academic Counselling Office of the Faculty of Science is located in NCB 280, and can be contacted at scibmsac@uwo.ca.