

# ES 4432A - Advanced Mineral Deposit Geochemistry

## Course Outline - Winter 2017

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**Instructor:** Robert Linnen

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### *Schedule*

**Lectures:** 3 hrs per week, Wed. 9:30-11:30 P&AB 150; Fri. 9:30-10:30 P&AB 150

**Tutorial:** 1 hr per week, Fri. 8:30-9:30 B&GS 1053

**Seminar:** 2 hrs per week, TBA

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### **Pre-requisites:**

ES2230a/b Introduction to Geochemistry;

ES3370a/b Metallogeny I: Ore Petrology

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### **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.

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### **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](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>.

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### **Course Website**

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](mailto:rlinnen@uwo.ca).

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**Lectures:** 3 hrs per week, Wed. 9:30-11:30 UCC58; Fri. 9:30-10:30 UCC58

**Tutorial:** 1 hr per week: Fri. 8:30-9:30 UCC58

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### **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.

### **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 from igneous, metamorphic and sedimentary environments.

### **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 in order to understand the

environmental impact of mining a solid understanding of mineral deposits is required.

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

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## Evaluation

<i>Component</i>	<i>Notes</i>	<i>Value</i>
Mid Term	February 15	25%
Assignments	3 problem sets	5%
Term Paper	April 1	25%
Term Paper Presentation	April 6	10%
Final Exam	Scheduled by the Registrar	35%

*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 **January 29<sup>th</sup> and an email sent to professor Linnen by that date indicating 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 April 1<sup>st</sup>**. 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> ).

*Oral Presentation* of the subject chosen for the written assignment will consist of a **10 minute talk and 2 minutes for questions**. 80% of the mark for this is based on the presentation and 20% is based on your participation of the discussion of other people’s presentations.

## **Some Potential Topics for the Written Report**

Email your topic to me by **January 27<sup>th</sup>**, the same topic will not be presented by two students so the first student to email me will be given the topic.

Magmatic deposits:

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

Hydrothermal deposits associated with igneous rocks

- skarn deposits W, Cu or Au (or other metals).
- Sn-W mineralization associated with greisen alteration.
- granite-hosted U deposits
- Mexican silver province.
- geothermal systems as a natural laboratory

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), (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).

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
- genesis of sandstone-hosted Pb deposits.
- formation of Au deposits in banded iron formations.

Ore deposits associated with surficial processes

- 'supergene' enrichment of Cu in porphyry Cu deposits.
- Au deposits of the Witwatersrand, South Africa, placer versus hydrothermal?
- 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***

- 1) Introduction
  - background on the mineral exploration industry
  - introduction on why are models in economic geology are important
- 2) Stable Isotopes
  - nomenclature, fractionation, thermodynamics
  - O and H isotopic compositions of natural waters
  - fluid-rock interactions
  - C and S isotopes
- 3) Geothermometry
  - estimation of lithostatic pressure
  - use of phase equilibria
  - thermodynamics of mineral exchange reactions
  - isotope geothermometry
- 4) Diamonds
  - igneous background
  - kimberlites
  - indicator minerals
  - geothermometry and geobarometry of kimberlites and diamonds
- 5) Nickel Deposits
  - review of deposit types
  - constraints from experimental petrology
  - sulfide-silicate melt partitioning
  - depositional model
- 6) 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
- 7) Rare Metal Deposits
  - controls of metal solubility in granitic melts
  - tin, tantalum and lithium deposits
  - REE-Nb deposits
- 8) Solubility and Mineral Deposition
  - controls on metal and gangue mineral solubility
  - causes of mineral deposition
- 9) Fluid Inclusions
  - origin and classification of fluid inclusions
  - interpretation of fluid inclusion data
  - H<sub>2</sub>O-NaCl and H<sub>2</sub>O-CO<sub>2</sub> systems

#### 10) Porphyry Copper and Molybdenum Deposits

- review of deposit types
- geochemistry of alteration and mineralization
- fluid-melt partitioning and metal solubility in porphyry systems
- similarities and differences of porphyry Cu and Mo deposits

#### 11) Gold Deposits

- IOCG, epithermal, orogenic gold deposits
- behaviour of sulphur
- transport and deposition of gold
- fluid inclusions in gold deposits

#### 12) Sedimentary Exhalative (SEDEX) Deposits

- review of SEDEX deposits
- heat flow, fluid inclusions and isotopic constraints
- role of anoxic basins and interpretation of sulfur isotopic data

#### 13) Mississippi Valley Type (MVT) Deposits

- fluid inclusion characteristic
- transport and deposition of Pb-Zn
- isotopic and heat constraints

### ***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/](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](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](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, should use the Student Medical Certificate when visiting an off-campus medical facility or request a Records Release Form (located in the Dean's Office) for visits to Student Health Services. The form can be found here:

[http://www.uwo.ca/univsec/pdf/academic\\_policies/appeals/accommodation\\_illness.pdf](http://www.uwo.ca/univsec/pdf/academic_policies/appeals/accommodation_illness.pdf)

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