

EAS 568: GEOCHEMISTRY OF ORE DEPOSITS

Winter 2015

LECTURES: EAS 568, Tu-Th, 9:30–10:50 am, ESB 2-35
INSTRUCTOR: Dr. Jeremy Richards (ESB 3-02; Jeremy.Richards@ualberta.ca)
OFFICE HOURS: Mondays 13:00–14:00 or any time by appointment
RECOMMENDED TEXTBOOK:

Richards, J.P., and Larson, P.B., (eds.), 1998, *Techniques in Hydrothermal Ore Deposits Geology: Reviews in Economic Geology*, v. 10, 256 p. QE 390.5 T38 1998, ISBN#: 1-887483-54-3

LECTURE NOTES: Basic lecture notes are posted on e-Class the week prior to each class.

CALENDAR DESCRIPTION

Geochemical processes involved in ore formation. Introduction to aqueous thermodynamics; application of stable and radiogenic isotope, and fluid inclusion studies to interpretation of ore-forming processes. Application of geochemical and other methods to exploration for ore deposits.

COURSE OBJECTIVES

To gain a practical understanding of:

- Behavior of the elements in the natural environment;
- Basic aqueous-phase thermodynamics and the properties of aqueous solutions;
- Construction and use of activity–activity diagrams;
- Solubility and deposition of ore and gangue components;
- Systematics and use of fluid inclusions;
- Systematics and use of light stable isotopes;
- Systematics and use of radiogenic isotopes;
- Applications of these methods to the study and understanding of, and exploration for ore deposits.

In addition, the structure of the course is designed to stimulate critical and independent thought, numeracy, and basic research and communications skills.

COURSE PHILOSOPHY

Geology is an imprecise science at the best of times, but the study of ore deposits often pushes the limits because of our real need to model and understand complex processes that are either occurring out of our physical reach, or that occurred some time in the geological past. It is not sufficient merely to develop a neat academic model that theoretically satisfies our observations, because these models might actually be used in the minerals industry to guide exploration and mine development, so they need to be right in practice too. Successful investments of millions, sometimes billions, of dollars depend on the models actually working. The economic geologist must therefore be a good scientist *and* a realist, attributes that will be of value in any professional career.

The aim of this course will therefore be to lead participants to a practical understanding and appreciation of the tools and techniques currently used in the study of mineral deposits, while drawing attention to the limitations of these methods and the subjectivity of data interpretation. Opportunities will be provided, through directed reading and report writing, for participants to assess in detail the methods used and interpretations offered in literature studies, and to formulate your own interpretations where appropriate.

COURSE CONTENT AND TIMETABLE

Lectures are from 9:30 to 10.50 a.m. on Tuesdays and Thursdays, in ESB 2-35.

Day	Date	Lecture (ESB 2-35)
Tuesday	6 January	Introduction: Course philosophy; term paper
Thursday	8	Basic Thermodynamics I: Chemical reactions
Tuesday	13	Basic Thermodynamics II: Enthalpy, Entropy, Gibbs Free Energy
Thursday	15	Basic Thermodynamics III: Chemical Potentials, Activities
Tuesday	20	Basic Thermodynamics IV: Equilibrium constants; Activity-activity diagrams**
Thursday	22	Hydrothermal Fluids I: Water
Tuesday	27	Hydrothermal Fluids II: Water-NaCl; Gases in aqueous solutions
Thursday	29	Hydrothermal Fluids III: Solubility and deposition of ore and gangue components**
Tuesday	3 February	Hydrothermal Fluids IV: Alteration geochemistry
Thursday	5	Hydrothermal Fluids V: Alteration geochemistry cont.
Tuesday	16–20	READING WEEK
Tuesday	24	Fluid Inclusions I: The nature of...
Thursday	26	MID-TERM EXAM
Tuesday	3 March	Fluid Inclusions II: Petrography (lab demonstration)
Thursday	5	Fluid Inclusions III: Systematics
Tuesday	10	Fluid Inclusions IV: Systematics cont.
Thursday	12	Fluid Inclusions V: Applications
Tuesday	17	Light Stable Isotopes I: Systematics
Thursday	19	Light Stable Isotopes II: O, H, S, C
Tuesday	24	Light Stable Isotopes III: Water–rock interactions**
Thursday	26	Radiogenic Isotopes I: Systematics
Tuesday	31	Radiogenic Isotopes II: Rb-Sr, Sm-Nd, Re-Os
Thursday	2 April	Radiogenic Isotopes III: U-Pb, K-Ar, $^{40}\text{Ar}/^{39}\text{Ar}$ **
Tuesday	7	Radiogenic Isotopes IV: Source Tracing
Thursday	9	Orthomagmatic Ore Deposits: Partition coefficients; Term Papers due in class
Wednesday	22 April	FINAL EXAM in ESB 2-35, 9–11 AM*

* Final exam date is provisional: it is the student's responsibility to verify this date on BearTracks when the Final Exam Schedule is posted.

****Problem Sheets:**

Four problem sheets relating to material covered in the lectures will be issued after the lectures indicated with a double-asterisk. Answers are to be returned to the instructor by the end of the lecture one week later. They will be assessed and returned, and are worth 5% each of the total course mark. The exams will contain some problems very similar to the ones on the problem sheets (in addition to essay-type questions).

Term Papers:

1. Literature Appraisal: In the first half of the term, participants will write a 3000–5000-word critical appraisal of the assumptions, scientific methodology, and interpretations presented in an individual published paper, chosen from a list provided. Other literature should be used for comparison or to support your arguments where appropriate. This assignment is designed to develop the skills of critical thinking and scientific evaluation, and hone your writing skills.

SUBMISSION DATE: By the start of the mid-term exam on **Thursday 26 February**.

2. Literature Review: Participants will undertake a 5000-word literature review of a topic in mineral deposits geology chosen from a list provided. This assignment is designed to exercise bibliographic search and review techniques, as well as writing skills.

SUBMISSION DATE: By the start of the lecture on **Thursday 9 April**.

COURSE MARK-WEIGHT DISTRIBUTION AND GRADING:

First half-term paper (literature appraisal).....	20%
Second half-term paper (literature review).....	20%
Problem sheets (4 @ 2.5% each)	10%
Midterm exam (based on lecture material, problem sheets, and readings)	20%
Final exam (based on lecture material, problem sheets, and readings)	30%

Late submissions will attract a penalty of 10% per day of the total mark available for that piece of work (to a minimum of zero), the due date and the date of actual submission each counting as one day.

Distribution of Grades and Grade Assignment: A letter grade will be assigned for your efforts and achievement in the course. Grades will be based upon your earned percentage of cumulative marks and the overall mark distribution, using natural breaks in the distribution where present as grade boundaries. Your final grade will thus reflect a combination of absolute achievement and relative standing in the class. Historically recommended grade distributions are used as a guideline only, and the actual grade distribution will vary from year to year depending on cohort performance.

NB: Grades are unofficial until approved by the Department and/or Faculty offering the course.

PAST (OR REPRESENTATIVE) EVALUATIVE MATERIAL

Example questions for the midterm and final exams will be posted on the course eClass site and will be reviewed in class in the week before the exams.

Communication Skills:

The 1999 SEG Employers' Survey rated "Oral presentation, report writing, and making diagrams to show data" as the most important non-geological skills for potential graduate employees (Dilles et al., 1999: SEG Newsletter, No. 38, p. 24–26).

Because the ability to communicate knowledge is just as important as the possession of that knowledge, a significant proportion of marks for written work will go towards presentation and correct use of the English language. Please spell-check and proof-read your work carefully. If you know your writing is not good, get a friend to proof-read your work, sign up for a writing course, or visit the [Centre for Writers](#). This really *is* important to you!

EXAMINATIONS AND SUBMISSION DEADLINES

The Midterm exam (50 minutes, in class, **Thursday 26 February**) will consist of short-answer questions and numerical problems similar to those encountered on the problem sheets, with a limited choice of questions.

The Final exam (2 hours; **provisionally scheduled for Wednesday 22 April, 9–11 AM**) will additionally contain an essay question, with a choice of topics. Information gained from suggested readings may enhance your grade by enabling you to answer questions with a broader knowledge base.

Note: Students must verify this date on BearTracks when the Final Exam Schedule is posted.

The final exam planner is found on the [Registrar's website](#).

The Literature Appraisal is due at the start of the mid-term exam on **Thursday 26 February**.

The Literature Review is due at the start of the lecture on **Thursday 9 April**.

Deferred Exams

- **Deferred Lecture Midterm:** Students who are granted permission to sit a deferred midterm exam must do that exam on: **Friday 6 March, 2015, from 10:00–10:50, in ESB 3-02.**
- **Deferred Lecture Final:** Students who are granted permission to sit a deferred final exam must do that exam on: **Wednesday 29 April, 2015, from 09:00–11:00, in ESB 3-02.**

DEFERRED EXAM POLICY (See Calendar [§23.3](#) and [§23.5.6](#) for details)

Term Exams:

A student who cannot write a term examination due to incapacitating illness, severe domestic affliction, or other compelling reasons (which exclude simple inconvenience) can apply in writing to the Instructor for a deferred midterm examination. Such an application must be made “to the instructor within two working days following the scheduled date of the term work or term exam missed, or as soon as the student is able, having regard to the circumstances underlying the absence” and must be supported by a Statutory Declaration (*in lieu* of a medical statement form) or other appropriate documentation (Calendar [§23.3.1](#)). The Instructor may decide either to allow the student to sit a deferred exam (on date shown above), or to waive the exam and adjust the weighting of the remaining work to 100%.

Note that there is no deferred midterm lab exam: students can apply to have the weight of their lab midterm transferred to the weight of the lab final exam.

Deferral of term work is a privilege and not a right; there is no guarantee that a deferral will be granted. Misrepresentation of facts to gain a deferral is a serious breach of the *Code of Student Behaviour*.

Final Exams:

A student who cannot write a final examination due to incapacitating illness, severe domestic affliction, or other compelling reasons (which exclude simple inconvenience) can apply in writing to sit a deferred final exam on date shown above. Such an application must be made to the student's Faculty office within two working days of the missed examination and must be supported by a Statutory Declaration or other appropriate documentation (Calendar [§23.3.2](#)).

Deferred examinations are a privilege and not a right; there is no guarantee that a deferred examination will be granted. Misrepresentation of facts to gain a deferred examination is a serious breach of the *Code of Student Behaviour*.

Recommended Course Texts:

Richards, J.P., and Larson, P.B., (eds.), 1998, Techniques in Hydrothermal Ore Deposits Geology: Reviews in Economic Geology, v. 10, 256 p. QE 390.5 T38 1998, ISBN#: 1-887483-54-3

Additional recommended resources:

Barnes, H.L., 1997, Geochemistry of Hydrothermal Ore Deposits, 3rd edn.: Wiley, 972 p.
QE 515 B26 1997

Barnes, H.L., 1979, Geochemistry of Hydrothermal Ore Deposits, 2nd edn.: Wiley, 798 p.
QE 515 B26 1979

Berger, B.R., & Bethke, P.M., (eds.), 1985, Geology and Geochemistry of Epithermal Systems: Reviews in Economic Geology, v. 2, 298 p. QE 390.5 G345 1985

Henley et al., 1984, Fluid–Mineral Equilibria in Hydrothermal Systems: Reviews in Economic Geology, v. 1, 267 p. QE 516.3 F646 1984

Wood, B.J., & Fraser, D.G., 1978, Elementary Thermodynamics for Geologists: Oxford, 303 p.
QC 311.15 W87 1978

DISCLAIMER

Any typographical errors in this Course Outline are subject to change, and changes will be announced in class. The date of the final examination is set by the Registrar and takes precedence over the final examination date reported in this syllabus.

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FORMAL NOTICES

GFC POLICY ON COURSE OUTLINES

Policy about course outlines can be found in Section [23.4\(2\)](#) of the University Calendar. “GFC, in approving these guidelines, expected that there would be a common sense approach to their application and understood that circumstances might develop, during a term, where a change to the course outline, as set out in §23.4(2)a, made sense to all concerned. Such changes shall only occur with fair warning or general class consent.”

ACADEMIC STANDARDS

“The University of Alberta is committed to the highest standards of academic integrity and honesty. Students are expected to be familiar with these standards regarding academic honesty and to uphold the policies of the University in this respect. Students are particularly urged to familiarize themselves with the provisions of the [Code of Student Behaviour](#) and avoid any behaviour which could potentially result in suspicions of cheating, plagiarism, misrepresentation of facts and/or participation in an offence. Academic dishonesty is a serious offence and can result in suspension or expulsion from the University.”

All forms of dishonesty are unacceptable at the University. Any offence will be reported to the Associate Dean of Science who will determine the disciplinary action to be taken. Cheating, plagiarism and misrepresentation of facts are serious offences. Anyone who engages in these practices will receive at minimum a grade of zero for the exam or paper in question and no opportunity will be given to replace the grade or redistribute the weights. As well, in the Faculty of Science the sanction for cheating on any examination will include a disciplinary failing grade (no exceptions) and senior students should expect a period of suspension or expulsion from the University of Alberta.

See www.ualberta.ca/tie for more information on Academic Standards. Remember that it is the student’s responsibility to be aware of the contents of the Code of Student Behaviour. Ask the Instructor if you have questions about acceptable collaborations, cheating, etc.

COLLABORATION

Lab work commonly involves working in small teams. Be sure that you understand University policies on collaboration (see brochure at: <http://www.tie.ualberta.ca/~media/tie/Documents/Collaborating.pdf>), and specific expectations for each lab. If in doubt, ask your Instructor.

EXAMS

Your student photo I.D. is required at exams to verify your identity. Students will not be allowed to begin an examination after it has been in progress for 30 minutes. Students must remain in the exam room until at least 30 minutes has elapsed. No electronic equipment of any kind can be brought into examination rooms, and hats should not be worn.

CELL PHONES

Cell phones are to be turned off during lectures, labs, and seminars. Cell phones are not to be brought to exams.

RECORDING AND/OR DISTRIBUTION OF COURSE MATERIALS

Audio or video recording, digital or otherwise, of lectures, labs, seminars or any other teaching environment by students is allowed only with the prior written consent of the instructor or as a part of an approved accommodation plan. Student or instructor content, digital or otherwise, created and/or used within the context of the course is to be used solely for personal study, and is not to be used or distributed for any other purpose without prior written consent from the content author(s).

SPECIALIZED SUPPORT AND DISABILITY SERVICES

Students who require accommodations in this course due to a disability affecting mobility, vision, hearing, learning, or mental or physical health are advised to discuss their needs with Specialized Support and Disability Services, 2-800 Students’ Union Building, 492-3381 (phone) or 492-7269 (TTY).

Remember to provide the Instructor and Lab Coordinator with copies of your Letter of Introduction early in the term, and completed Exam Instructions & Authorization sheets at least 1 week in advance of exams, so that your exam needs can be met come exam time.

ACADEMIC SUPPORT CENTRE

Students who require additional help in developing strategies for better time management, study skills or examination skills should contact the Academic Support Centre (2-300 Students’ Union Building).