

EAS 368: ORE DEPOSITS GEOLOGY

Winter 2012

LECTURES: EAS 368-B1, MWF, 9:00–9:50 am, ESB 2-35
PROFESSOR: Dr. Jeremy Richards (ESB 3-02; Jeremy.Richards@UAlberta.ca)
OFFICE HOURS: Mondays 13:00–14:00 or any time by appointment
REQUIRED TEXT: Evans, A.M., 1993, Ore geology and industrial minerals, an introduction, 3rd edn: Blackwell Scientific, 390 p.
LECTURE NOTES: Basic lecture notes are posted on e-Class the week prior to each class.

LAB INSTRUCTORS:

Theodore Oramah	ESB 2-04E	e-mail: oramah@ualberta.ca
Rui Wang	CCIS 3-025	e-mail: rw5@ualberta.ca
Shaunaugh Whelan	CCIS 3-037	e-mail: shaunaug@ualberta.ca

LAB COORDINATOR:

Marilyn Huff	ESB 3-04A	e-mail: huff@ualberta.ca
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CALENDAR DESCRIPTION:

Mineralogy and petrography of ore and gangue minerals under the reflected and transmitted light microscope and in hand specimen. Interpretation of ore textures and paragenetic sequences. Geological characteristics and distribution of ore deposits, including deposits of base and precious metals, diamonds, and industrial minerals. Prerequisite: EAS 331. Not available to students with credit in EAS 433.

COURSE OBJECTIVES:

To gain an awareness and appreciation of:

- The minerals industry, its economic basis, and impacts.
- The variety, form, and global distribution of a range of important metalliferous mineral deposit types;
- Their regional geological and tectonic context;
- Their geochemical and geophysical signatures, as applicable to mineral exploration;
- A basic understanding of mineral exploration practices.

To gain a practical knowledge of:

- Common ore and alteration minerals in hand specimen and polished section, and the interpretation and description of their textures;
- Suites of ore and alteration minerals associated with different mineral deposit types.

COURSE PHILOSOPHY:

Despite current popular beliefs, the maintenance of modern civilization is dependent on the affordable and plentiful supply of raw materials and energy. Banning mining is not a realistic option for the modern world. Nonetheless, many of the concerns of environmentalists are valid, and must not be ignored. Thus, one of the challenges facing the extractive minerals industry today is how to find and recover these raw materials with the least environmental and social impact. We will approach the subject of the origin of and exploration for mineral deposits with this challenge in mind.

The study of mineral deposits is a particularly satisfying one for the geologist because it draws upon all aspects of the geological sciences, and often other sciences too. Thus, you will find aspects of mineralogy and geochemistry particularly applicable, but also paleontology and sedimentology (in dealing with sediment-hosted mineral deposits), igneous and metamorphic petrology (intrusive-hosted and metamorphic deposits), and even remote sensing and physical geology (field exploration). A key characteristic of the successful exploration geologist is a lively but realistic imagination, and the ability to extrapolate useful information and make accurate predictions from limited available data. This expertise will come with experience, but the basic principles and current theories required for making informed judgements will be reviewed here.

Course Timetable and Content:

Lectures are from 9.00 to 9.50 a.m., Monday, Wednesday, and Friday, ESB 2-35.

Labs will be held in ESB 3-07 in several sections.

Day	Date	Lecture (ESB 2-35)	Lab (ESB 3-07)
Mon	9 Jan	Course introduction	No lab
Wed	11	Role of minerals in society	
Fri	13	The minerals industry	
Mon	16	Mine life cycle	Introduction to ore microscopy
Wed	18	Distribution of elements	
Fri	20	Oxides and native metals	
Mon	23	Oxides and native metals cont.	Oxides and native metals
Wed	25	Sulfides	
Fri	27	Sulfides cont.	
Mon	30	Arsenides, antimonides, sulfosalts, tellurides	Sulfide minerals I
Wed	1 Feb	Arsenides, antimonides, sulfosalts, tellurides cont.	
Fri	3	Ore textures	
Mon	6	Ore textures cont.	Sulfide minerals II
Wed	8	Alteration mineralogy	
Fri	10	Alteration mineralogy cont.	
Mon	13	Alteration mineralogy cont.	Ore textures and paragenesis Alteration minerals
Wed	15	Review class	
Fri	17	LECTURE MID-TERM EXAM	
	20–24	READING WEEK	
Mon	27	Orthomagmatic oxide/sulfide deposits	LAB MID-TERM EXAM (in your normal lab period)
Wed	29	Orthomagmatic oxide/sulfide deposits cont.	
Fri	2 Mar	Pegmatite, greisen, skarn deposits	
Mon	5	Pegmatite, greisen, skarn deposits cont.	Orthomagmatic deposits
Wed	7	Diamonds and the diamond industry	
Fri	9	Diamonds and the diamond industry cont.	
Mon	12	Porphyry deposits	Magmatic-hydrothermal deposits
Wed	14	Porphyry deposits cont.	
Fri	16	Porphyry deposits cont.	
Mon	19	Epithermal deposits	Epithermal deposits
Wed	21	Epithermal deposits cont.	
Fri	23	Epithermal deposits cont.	
Mon	26	Mesothermal deposits	Mesothermal deposits and VHMS
Wed	28	Mesothermal deposits cont.	
Fri	30	Stratiform & stratabound deposits: VHMS	
Mon	2 April	SEDEX Pb-Zn deposits	Sediment-hosted deposits
Wed	4	MVT Pb-Zn deposits	
Fri	6	GOOD FRIDAY	
Mon	9	EASTER MONDAY	LAB FINAL EXAM (in your normal lab period)
Wed	11	Sediment-hosted Cu deposits	
Fri	13	Placer deposits, residual deposits and weathering	
Wed	18 Apr	LECTURE FINAL EXAM*	

* Provisional: It is the student's responsibility to verify this date on BearTracks when the Final Exam Schedule is posted

Examination Times

Final Exam is provisionally scheduled for **Wednesday 18 April, 2012, from 09:00–11:00, in ESB 2-35.**

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

Deferred Exams

- **Deferred Lecture Midterm:** Students who are granted permission to sit a deferred mid-term must do that exam on: **Wednesday 29 April, 2012, 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: **Tuesday 1 May, 2012, 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 an excused absence. 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 dates shown below), or to waive the exam and adjust the weighting of the remaining work to 100%.

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 exam on dates shown below. Such an application must be made to the student’s Faculty office “within two working days following the scheduled date of the 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 [§23.3.2](#)).

Deferral of final exams 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*.

Assessment

Marks and Grading:

Lecture Midterm Exam.....	20%
Laboratory Midterm Exam	20%
Laboratory Exercises	10%
Laboratory Final Exam	20%
Lecture Final Exam	30%

Note that a letter grading scheme will be used for the final evaluation of course performance, but individual pieces of work will each be marked out of 100%. Because the relationship of marks to grades is not fixed, histograms of class performance will be provided periodically so that individuals can measure their relative successes.

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- **Lecture Midterm** (50 minutes) will consist of a limited choice of short-answer questions relating to topics covered in the lectures.
- **Laboratory Midterm** (2 hours) will consist of hand samples and polished sections for identification and description.
- **Laboratory Exercises** will consist of the preparation and submission of mineral, rock, and ore suite descriptions (in hand specimen and polished section). A nominal mark of 1% (course total) per lab will be given for attendance and submission of work, and feedback will be provided.
- **Laboratory Final Exam** will consist of hand samples, polished sections, and sample suites for identification, description, and genetic interpretation.
- **Lecture Final Exam** (2 hours) will consist of short-answer questions and an essay question with a choice of topics. Questions in the Final may be asked relating to all aspects of the course, including laboratories. Information gained from suggested readings may enhance your grade.

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.

About your instructor:

Jeremy Richards (Jeremy.Richards@UAlberta.CA)

My office is at the west end of the 3rd floor of the Earth Sciences Building (room ESB 3-02) — if my door is open, feel free to stop by with any questions you may have, in or out of “office hours”; or you can make a specific appointment by phone (780-492-3430) or e-mail (Jeremy.Richards@UAlberta.ca).

Please note that I do not respond to e-mails that do not address me by name (“Dear Dr. Richards” is a customary salutation) or end with your signature (i.e., provide your name), or do not respect common norms of politeness and civility.

My research interests focus on the origin of mineral deposits, especially of metals such as copper and gold, and sustainable development of mineral resources. These interests take me and my graduate students all over the world, including various parts of Canada (Canada is one of the world’s top suppliers of minerals). On the way we see some spectacular geology and mineral deposits, and I hope to be able to impart some of the excitement of the geological and mining world to you during this course.



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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 29 SEP 2003). The General Faculties Council, in approving these guidelines, expects a common sense approach to their application and understands that circumstances might develop, during a term, where a change to the course outline as set out in Section 61.6(a) of the GFC Policy Manual, makes 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 (online at www.ualberta.ca/secretariat/appeals.htm) 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.” (Section 23.4(2) of the University Calendar; GFC 29 SEP 2003.)

All forms of dishonesty are unacceptable at the University. Any offense will be reported to the Senior Associate Dean of Science who will determine the disciplinary action to be taken. Cheating, plagiarism, and misrepresentation of facts are serious offenses. 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 or Lab Coordinator if you have questions about acceptable collaborations, cheating, etc.

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. Electronic equipment cannot be brought into examination rooms.

CELL PHONES

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

RECORDING

Recording is not permitted except as part of an approved accommodation plan, which requires the prior written consent of the Instructor.

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 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 (2-703 Students’ Union Building).

DISCLAIMER

Any typographical errors in this Course Outline are subject to change and 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.

EAS 368: Bibliography

Course Texts

Required:

Evans, A.M., 1993, Ore geology and industrial minerals, an introduction, 3rd edn: Blackwell Scientific, 390 p. [QE 390 E92]

Recommended:

Marshall, D., Anglin, C.D., and Mumin, H., 2004, Ore mineral atlas: GAC, Mineral Deposits Division, 112 p.

Spry, P.G., and Gedlinske, B.L., 1997, Tables for the determination of common opaque minerals: Economic Geology Special Publication, 52 p. [QE 369 O6 S7715]

Taylor, R., 2009, Ore textures: recognition and interpretation: Springer. Download from <http://www.springerlink.com/content/v13117/-section=679213&page=1>

Web Sites

Rob Ixer's Virtual Atlas of Opaque and Ore Minerals: <http://www.smenet.org/opaque-ore/>

General Mineralogy: <http://webmineral.com/>

Mineral and Gemstone Kingdom: <http://www.minerals.net/>

INFOMINE: <http://www.info-mine.com/>

Society of Economic Geologists: <http://www.segweb.org/>

Society for Geology Applied to Mineral Deposits (SGA): <http://e-sga.org/>

Geological Assoc. Canada, Mineral Deposits Division: <http://www.sfu.ca/mdd/>

Additional Ore Microscopy and Alteration References

Craig, J.R., and Vaughan, D.J., 1994, Ore Microscopy and Ore Petrography: J. Wiley Intersci., 434 p. [QE 390 C886]

Glass, H.J., and Voncken, J.H.L., 2010, An easy-to-use program for the determination of common opaque minerals: Computers & Geosciences, v. 36, p. 1532–1534.

Thompson, A.J.B., and Thompson, J.F.H., 1996, Atlas of alteration: Geol. Assoc. Canada. [QE 390.5 A65]

General References

Barnes, H.L., 1979, Solubilities of ore minerals, in Barnes, H.L., ed., Geochemistry of hydrothermal ore deposits, Second Edition: New York, J. Wiley Intersci., p. 404-460.

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

Bekker, A., Slack, J.F., Planavsky, N., Krapez, B., Hofmann, A., Konhauser, K.O., and Rouxel, O.J., 2010, Iron formation: The sedimentary product of a complex interplay among mantle, tectonic, oceanic, and biospheric processes: Economic Geology, v.105, p. 467–508.

Berger, B.R., and Bethke, P.M., eds., 1995, Geology and Geochemistry of Epithermal Systems: Soc. Econ. Geol., Reviews in Economic Geology, v. 2. [QE 390.5 G345]

Boyle, R.W., ed., 1999, Sediment-hosted stratiform copper deposits: Geol. Assoc. Canada, Spec. Paper 36, 710 p. [TN 441 S448]

Crowson, P., 1998, Inside mining : the economics of the supply and demand of minerals and metals: Mining Journal Books, 230 p. [TN 145 C76]

Crowson, P., 2008, Mining Unearthed: The definitive book on how economic and political influences shape the global mining industry: Aspermont UK, London, 423 p. [HD 9506 A2 C76]

Eckstrand, O.R., Sinclair, W.D., and Thorpe, R.I., eds., 1995, Geology of Canadian mineral deposit types: Geological Survey of Canada, Geology of Canada no. 8, 640 p. [QE 375 G46]

Evans, A.M., ed., 1995, Introduction to mineral exploration: Blackwell Scientific, 396 p. [TN 270 I58]

Goodfellow, W.D., ed., 2007, Mineral Deposits of Canada: Geological Association of Canada, Mineral Deposits Division, Special Publication No. 5, 1061 p.

Groves, D.I., Bierlein, F.P., Meinert, L.D., and Hitzman, M.W., 2010, Iron oxide copper-gold (IOCG) deposits through earth history: Implications for origin, lithospheric setting, and distinction from other epigenetic iron oxide deposits: Economic Geology, v. 105, p. 641–654.

Guilbert, J.M., and Park, C.F., 1996, The geology of ore deposits: Freeman & Co. [QE 390 G95]

Hedenquist, J.W., Thompson, J.F.H., Goldfarb, R.J., and Richards, J.P., editors, 2005, Economic Geology 100th Anniversary Volume: Society of Economic Geologists, 1136 p.

Hitzman, M.W., Selley, D., and Bull, S., 2010, Formation of sedimentary rock-hosted stratiform copper deposits through earth history: Economic Geology, v. 105, p. 627–639.

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- Keays, R.R., Ramsay, W.R.H., and Groves, D.I., eds., 1989, *The Geology of Gold Deposits: The Perspective in 1998*: Econ. Geol. Mon. 6, 667 p. [QE 390.2 G65 G346]
- Kerrich, R., and Cassidy, K.F., 1994, Temporal relationships of lode gold mineralization to accretion, magmatism, metamorphism and deformation—Archean to present: *Ore Geology Reviews*, v. 9, p. 263–310.
- Kirkham, R.V., et al., (eds.), 1993, *Mineral deposit modeling*: GAC Special Paper 40, 770 p. [TN 263 M55]
- Kirkham, R.V., and Sinclair, W.D., 1996, Porphyry copper, gold, molybdenum, tungsten, tin, silver, *in* Eckstrand, O.R., Sinclair, W.D., and Thorpe, R.I., eds., *Geology of Canadian mineral deposits*: Geological Survey of Canada, *Geology of Canada*, no. 8, p. 421–446.
- Marjoribanks, R., 1997, *Geological methods in mineral exploration and mining*: Chapman & Hall, 115 p. [online access]
- Meinert, L.D., 1993, Skarns and skarn deposits, *in* Sheahan, P.A., and Cherry, M.E., eds., *Ore deposit models, Volume II: Geoscience Canada Reprint Series 6*, Geol. Assoc. Canada, 154 p. [TN 263 O3]
- Mitchell, A.H.G., and Garson, M.S., 1991, *Mineral deposits and global tectonic settings*: Academic Press, 405 p. [QE 601 M68]
- Naldrett, A.J., 1989, Sulfide melts—crystallization temperatures, solubilities in silicate melts, and Fe, Ni, and Cu partitioning between basaltic magmas, and olivine, *in* Whitney, J.A., and Naldrett, A.J., *Ore deposition associated with magmas*: Society of Economic Geologists, *Reviews in Economic Geology*, v. 4, ch. 2, p. 5–20.
- Naldrett, A.J., 1999, *Magmatic sulfide deposits*: Oxford University Press, *Oxford Monographs on Geology and Geophysics* No. 14, 186 p. [QE 389.2 N168]
- Panteleyev, A., 1988, A Canadian Cordilleran model for epithermal gold-silver deposits, *in* Roberts, R.G., and Sheahan, P.A., eds., 1988, *Ore deposit models: Geoscience Canada Reprint Series 3*, Geol. Assoc. Canada, p.31–43. [QE 364.2 S7 O662]
- Peters, W.C., 1997, *Exploration and mining geology*, 2nd edition: John Wiley & Sons, 685 p. [TN 260 P48]
- Ribbe, P.H., ed., 1976, *Sulfide mineralogy*: Mineralogical Society of America, *Reviews in Mineralogy*, v. 1.
- Roberts, R.G., and Sheahan, P.A., eds., 1988, *Ore deposit models: Geoscience Canada Reprint Series 3*, Geol. Assoc. Canada, 194 p. [QE 364.2 S7 O662]
- Sawkins, F.J., 1994, *Metal deposits in relation to plate tectonics*: Berlin, Springer-Verlag, 325 p. [TN 263 S27]
- Sheahan, P.A., and Cherry, M.E., eds., 1993, *Ore deposit models, Volume II: Geoscience Canada Reprint Series 6*, Geol. Assoc. Canada, 154 p. [TN 263 O3]
- Sinclair, W.D., 1996, Granitic pegmatites, *in* *Geology of Canadian mineral deposit types*, GSC, p. 503–512. [QE 375 G46]
- Sillitoe, R.H., 2010, Porphyry copper systems: *Economic Geology*, v. 105, p. 3–41.
- Skinner, B.J., ed., 1991, *Econ. Geol. 75th Anniversary Volume*. [QE 1 E1912]
- Sverjensky, D.A., 1986, Genesis of Mississippi Valley-type lead-zinc deposits: *Annual Review of Earth and Planetary Sciences*, v. 14, p. 177–199.
- Titley, S.R., 1993, Characteristics of porphyry copper occurrence in the American Southwest, *in* Kirkham, R.V., Sinclair, W.D., Thorpe, R.I., and Duke, J.M., eds., *Mineral deposit modeling: Geological Association of Canada Special Paper 40*, p. 433–464.
- Vaughan, D.J., ed., 2006, *Sulfide mineralogy and geochemistry*: Mineralogical Society of America, *Reviews in Mineralogy*, v. 61, 714 p.

Journals

- Economic Geology* [QE 1 E19] [Online]
- Exploration and Mining Geology* [TN 26 E96] [Online]
- Mineralium Deposita* [QE 351 M664] [Online]
- Mining Magazine* [TN 1 M66]
- Northern Miner* [Shelved by title in Cameron]
- Ore Geology Reviews* [QE 390 O67] [Online]