

MINERAL DEPOSITS 51-322/522
FALL 2009 SYLLABUS
3 CREDITS

INSTRUCTOR:

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OFFICE HOURS

Monday 12:40 – 1:40
Wednesday 12:40 – 1:40
Friday 12:40 – 1:40

TEXTBOOKS:

Robb, L., 2005, Introduction to Ore-Forming Processes: Blackwell Publishing, Malden, MA, 373 p.

Hedenquist, J. W., Thompson, J. F. H., Goldfarb, R. J., and Richards, J. P., (eds.), 2005, Economic Geology 100th Anniversary Volume, 1905-2005: Society of Economic Geologists, Inc., Littleton, CO, 1136 p. (ISBN: 978-1-887483-01-8)

ADDITIONAL READINGS

Many additional readings will be required (some recommended) during the semester. Many of these will be available from the black binder in Harrington 216 labeled "Mineral Deposits Readings". You may temporarily take the papers out of the binder to copy them. **RETURN THEM IMMEDIATELY TO THE BINDER.** Treat the papers in the binder with care, and do not write on them. Assigned readings are listed in the "Topical Outline" below, with suggested readings according to topic listed in the "Additional Readings" (also below).

WEB RESOURCES:

There is a Desire to Learn (D2L) site set up for this course. Consult it on a daily basis for information regarding the course. An outstanding resource related to the USGS Minerals Resource Program is located at [www.http://minerals.usgs.gov/products/#fs](http://www.minerals.usgs.gov/products/#fs).

COURSE POLICIES:

Schedule:

Lecture: 1:50 – 2:50 MWF

Attendance:

Your regular attendance and note-taking will have a significant effect on your grade. It is in your best interest to attend each lecture and lab. As noted in the section titled "Total Points" below, class participation is worth 100 points (10% of your grade).

Course Summary

Mineral deposits geology (also known as Economic Geology) is one of the most fascinating fields in geology. This discipline in geology requires you to use *all* the tools you have acquired during your geological education, including mineralogy, lithology, stratigraphy, structural geology, geochemistry, geophysics, and particularly hand sample/field identification skills. Mineral deposits geology is a very process-oriented science – we will evaluate various types of data (field, chemical, mineralogical, geophysical, etc.) and incorporate our findings to develop models for how various types of mineral deposits form. One of the goals of studying mineral deposits is to determine the various field, mineralogical, petrological, structural, geochemical, and geophysical aspects of various types of ores. These detailed examinations are also essential for developing ideas and genetic models that will help us to more effectively and efficiently discover more mineral deposits, and are essential when mine engineers are developing mine plans. *The minerals industry is commonly affected by the ebbs and tides of the economic markets. Although the minerals industry has been significantly affected by the current "economic crisis", many speculators and analysts suggest that within the next year, this sector of the economy will be in recovery mode as stockpiles of natural resources are depleted. The economic up-turn, as well as increased demand for metals by rapidly developing Asian countries (e.g. China and India) will drive this recovery. In fact, the need for natural resources obtained by environmentally sustainable methodologies has never been greater. This is good for all of you, as the demand for well-trained, field-oriented exploration geologists is likely to rise in coming years.*

In recent years, the detailed evaluations of ore deposits carried out by economic geologists have also been useful in developing mining methods that are less deleterious to the environment than those employed previously. Such data have also been used to solve a number of serious environmental problems associated with old,

abandoned mines. Many environmental solutions are essentially applied economic geology, so many “economic geologists” are actually employed in environmental firms.

In this course, you will learn about a wide variety of mineral deposits types (see attached Topical Outline). You will do this through a combination of attending lectures, completing “lab-like” exercises, and by reading textbooks, journal articles, and pertinent field trip guidebook articles related to our class field trip.

Exams / Assignments: There will be two take-home exams on the lecture materials (*combined worth a total of 300 points*). Exam 1 will cover the materials associated with the tools of the economic geologist (mapping, geochemistry, geophysics, etc.), igneous ore-forming processes, magmatic deposits, diamond deposits and kimberlite-hosted base- and precious metal deposits. Exam 2 will cover hydrothermal processes, pluton-associated hydrothermal deposits, epithermal deposits, volcanic associated hydrothermal massive sulfide deposits, iron formations, and lode gold deposits. **All take home exams are to be done INDEPENDENTLY, otherwise you will not be given credit for the exam** (the rules are the same that govern the way many mining and mineral exploration companies work....if you are found to be discussing projects with people from other companies, you will be fired).

This course will be a combination of traditional lectures (generally on Mondays and Wednesdays) coupled with seminar-like days (where you run the course) and lab-like days in which we will look at minerals, rocks, or geochemical/geophysical data (both of these will generally be on Fridays). There will be several assignments associated with these “hands-on” days (things such as mineral and rock identification, logging drill core, evaluating geochemical data, and of course, looking at suites of rocks from various types of ore deposits).

Prior to the seminar days, I will assign a paper(s) or chapter(s) to read. If these days are to be successful learning experiences, you must read the paper(s) or chapter(s) prior to coming to class. *If it appears to me that the class (as a group) is not doing the assigned reading, I will assign short summary papers to be handed in at the beginning of the seminar day to make sure you have done your work.*

Expect three assignments worth 100 points each. These assignments will include exploration diamond drill core logging, mass-balance analysis of alteration and mineralization processes, and lithochemical evaluations associated with mineral exploration.

There will also be two mineral and rock identification exams (100 points each) given during the semester. The first exam (given the end of the third week of the semester) will evaluate your retention of the minerals and rocks you learned during your Mineralogy and Lithology courses. The second (final) exam will evaluate your knowledge of the rocks and minerals (and associated ore deposits) that we will be discussing in class, as well as rocks and minerals learned in your Mineralogy and Lithology courses. The dates for these exams are listed on the “Topical Outline” below.

In addition to our regularly scheduled class, we will also be taking a one-day long field trip to northern Michigan to evaluate the Back-Forty volcanogenic massive sulfide (VMS) deposit. This relatively recent discovery near Stephenson, Michigan represents another successful mineral exploration venture in rocks associated with the Wisconsin Magmatic Terrane, the world’s most prolific Proterozoic VMS belt. We will leave during at approximately 7:00 am on Friday, September 25, and spend the day looking at outcrop exposures and diamond drill core with Aquila Resources geoscientists. We should be home by no later than 7:30 pm that day. More details will be provided as we approach the date of the trip. During the field trip, you will keep a field book which will be handed in and graded (100 points). More details of the trip and its costs will be provided later in the semester.

Total Points: A summary of the total points possible in this course, based on the materials covered in the previous section of this syllabus, is summarized below:

		<u>Points</u>
Lecture Exams	2 exams (150 points each)	300
Mineral/Rock ID Exams	2 exams (100 points each)	200
“Hands-on Day” Projects	3 projects (100 points each)	300
Field Trip Notes	100 points	100
Class Participation	100 points (given at end of semester)	<u>100</u>
	<i>Total</i>	<i>1000</i>

Tray Reports: Oral tray reports can be completed during the course of the semester. Tray reports consist of individual efforts identifying unknown mineral and/or rock samples. The tray reports essentially provide you with an opportunity to obtain a limited number of additional points in the course. There will be a limit of 8 tray reports per person (160 points) during the semester, so to perform well, lab exams, lecture exams, and homework will be extremely important! There will be a sliding scale in terms of the points available for each tray report. The following sliding scale will be used:

Tray Reports 1, 2, and 3	15 points each
Tray Reports 4 and 5	20 points each
Tray Reports 6, 7, 8	25 points each

The purpose of the sliding scale is to emphasize the importance of understanding and applying the materials covered in the lecture and lab parts of this course. The more of these you complete, the more points the tray reports are worth! **You must successfully complete at least one tray report during the semester to pass the course (there will be absolutely no exceptions).**

Grades: Your grade is based on your *total points* earned in the course. As you can see from the list above, the lecture materials (lecture exams 1, 2, and 3) hold the same amount of weight as hands-on rock and mineral-associated assignments (the “hands-on day projects, the mineral/rock ID exams, and the field trip). A tentative scale for grading is listed below:

<u>Grade</u>	<u>Percentage</u>
A	95% - 100%
A-	90% - 95%
B+	87% - 90%
B	83% - 87%
B-	80% - 83%
C+	77% - 80%
C	73% - 77%
C-	70% - 73%
D+	67% - 70%
D	63% - 67%
D-	60% - 63%
F	Less than 60%

**MINERAL DEPOSITS 51-322/522
Topical Outline 2009**

<u>Week of</u>	<u>Lecture Topics</u>	<u>Seminar/"Lab" Topics</u>
Sept. 7	Introduction; The Tools of the Economic Geologist (Mapping/Petrography/Geochemistry/Geophysics/ Phase Diagrams)	Mineral ID Lab
Sept. 14	Magmatic Processes/ Magmatic Deposits (Magmatic Cr, Ti, Cu, Ni, PGE)	Rock ID Lab
Sept. 21	Magmatic Deposits / Diamonds (Magmatic Cu, Ni, PGE/ Kimberlite & Lamprophyres)	Back-Forty Field Trip
Sept. 28	Volcanic-Hosted Cu-Ni-PGE (Komatiite-hosted Deposits)	<u>Mineral/Rock ID Exam</u>
Oct. 5	Pluton-Associated Hydrothermal Deposits (Porphyry Copper, Gold, Molybdenum, Epithermal Systems)	Core Logging
Oct. 12	Volcanic Associated Hydrothermal Deposits (Epithermal Systems)	Porphyry & Epithermal Deposits
FIRST MID-SEMESTER EXAM, DUE FRIDAY, OCTOBER 16		
Oct. 19	Geological Society of America Meeting, Portland, Oregon	
Oct. 26	Volcanic-Associated Hydrothermal Deposits (Epithermal / VMS Deposits)	<u>Isocon Evaluation</u>
Nov. 2	Volcanic-Associated Hydrothermal Deposits (VMS Deposits)	VMS Chemical Model
Nov. 9	Volcanic-Associated Hydrothermal Deposits (VMS and Gold-rich VMS Deposits)	<u>VMS Core/ Box Plot</u>
Nov. 16	Volcanic-Sedimentary Associated Hydrothermal Deposits (Iron Formations/SEDEX)	Iron Formation
Nov. 23	Structurally Controlled Precious Metal Deposits (Shear Zone (Lode) Gold)	Lode Gold
Nov. 25 – Nov. 29: Thanksgiving Break		
Nov. 30	Structurally Controlled Precious Metal Deposits (Shear Zone (Lode) Gold - continued)	Lode Gold
Dec. 7	Carbonate-Associated Disseminated Gold Deposits (Carlin-type Gold)	<u>Mineral/Rock ID Final Exam</u>
Dec. 14	Review day (Monday)	

SECOND MID-SEMESTER EXAM, DUE WEDNESDAY, DECEMBER 16

Required* and Optional Readings**

Introduction: Tools of the Economic Geologist

Robb, L., 2005. Introduction to Ore-Forming Processes: Introduction, pages 1-15*.

Robb, L., 2005. Introduction to Ore-Forming Processes: Ore Deposits in a Global Tectonic Setting, p. 311-344.**

Moon, C. J., Whateley, M. K. G., and Evans, A. M., 2006, Chapters 1**, 2**, 7** (Chapter 7 will be discussed on Friday, February 8)

Magmatic Processes

Raymond, L. A., 2002. Petrology: The Study of Igneous, Sedimentary, & Metamorphic Rocks: McGraw Hill, p. 161-192*.

Robb, L., 2005. Introduction to Ore-Forming Processes: Igneous Ore-forming Processes, p. 19-74*.

Magmatic Deposits

Barnes, S. J., and Lightfoot, P. C., 2005. Formation of magmatic nickel sulfide ore deposits and processes affecting their copper and platinum group element contents: Economic Geology 100th Anniversary Volume, p. 179-213*.

Cawthorn, R. G., Barnes, S. J., Ballhous, C., and Malitch, K. N., 2005. Platinum group element, chromium, and vanadium deposits in mafic and ultramafic rocks: Economic Geology 100th Anniversary Volume, p. 215-249.*

Eckstrand, O. R., 1996, 27.1 Nickel-copper sulfide: *in* Geology of Canadian Mineral Deposit Types, (ed.) O. R. Eckstrand, W. D. Sinclair, and R. I. Thorpe: Geological Survey of Canada, Geology of Canada, no. 8, p. 584-605**.

Duke, J. M., 1996, 28. Mafic-ultramafic hosted chromite: *in* Geology of Canadian Mineral Deposit Types, (ed.) O. R. Eckstrand, W. D. Sinclair, and R. I. Thorpe: Geological Survey of Canada, Geology of Canada, no. 8, p. 615-624**.

Diamonds

Gurney, J. J., Helmstaedt, H. H., le Roex, A. P., Nowicki, T. E., Richardson, S. H., and Westerlund, K. J., 2005, Diamonds: crustal distribution and formation processes in time and space and an integrated deposit model: Economic Geology 100th Anniversary Volume, p. 143-178.*

Moon, C. J., Whateley, M. K. G., and Evans, A. M., 2006, Chapter 17.**

Kjarstrand, B. A., 25. Primary Diamond Deposits: *in* Geology of Canadian Mineral Deposit Types, (ed.) O. R. Eckstrand, W. D. Sinclair, and R. I. Thorpe: Geological Survey of Canada, Geology of Canada, no. 8, p. 559-572**.

Pluton-Associated Hydrothermal Deposits (Porphyry Systems)

Seedorf, E., Dilles, J. H., Proffett, J. M., Einaudi, M. T., Zurcher, L., Stavast, W. J. A., Johnson, D. A., and Barton, M. D., 2005. Porphyry deposits: characteristics and origin of hypogene features: Economic Geology 100th Anniversary Volume, p. 251-298*.

Gammons, C. H., and Williams-Jones, A. E., 1997. Chemical mobility of gold in the porphyry-epithermal environment: Economic Geology, v. 92, p. 45-59*. (To be discussed on Friday, March 7)

Robb, L., 2005. Introduction to Ore-Forming Processes: Magmatic-Hydrothermal Ore-Forming Processes, p. 75-126*.

Kirkham, R. V., and Sinclair, W. D., 1996. 19. Porphyry copper, gold, molybdenum, tungsten, tin, silver: *in* Geology of Canadian Mineral Deposit Types, (ed.) O. R. Eckstrand, W. D. Sinclair, and R. I. Thorpe: Geological Survey of Canada, Geology of Canada, no. 8, p. 421-446**.

Subaerial Volcanic-Associated Hydrothermal Deposits (Epithermal Systems)

Simmons, S. F., White, N. C., John, D. A., 2005. Geological characteristics of epithermal precious and base metal deposits: Economic Geology 100th Anniversary Volume, p. 485-522.*

White, N. C., and Hedenquist, J. W., 1995. Epithermal Gold Deposits: Styles, characteristics, and exploration: SEG Newsletter, Number 23, p. 1-13.*

Dube, B., Dunning, G., and Laziere, K., 1998. Geology of the Hope Brook mine, Newfoundland, Canada: A preserved late Proterozoic high-sulfidation epithermal gold deposit and its implications for exploration: Economic Geology, v. 93, p. 405-436.* (This will be the basis of the Isocon Exercise)

Robb, L., 2005. Introduction to Ore-Forming Processes: Hydrothermal Ore-forming Processes, p. 129-215.*

Taylor, B. E., 1996. 15.1 Epithermal gold deposits: *in* Geology of Canadian Mineral Deposit Types, (ed.) O. R. Eckstrand, W. D. Sinclair, and R. I. Thorpe: Geological Survey of Canada, Geology of Canada, no. 8, p. 329-350.**

White, N. C., and Hedenquist, J. W., 1990. Epithermal Environments and styles of mineralization: variations and their causes, and guidelines for exploration: Journal of Geochemical Exploration, v. 36, no. 1-3, p. 445-474.**

Submarine Volcanic-Associated Hydrothermal Deposits (VMS) and Gold-Rich VMS

Franklin, J. M., Gibson, H. L., Jonasson, I. R., and Galley, A. G., 2005. Volcanogenic massive sulfide deposits: Economic Geology 100th Anniversary Volume, p. 523-560.*

Gibson, H. L., Morton, R. L., and Hudak, G. J., 1999. Submarine volcanic processes, deposits, and environments favorable for the location of volcanic-associated massive sulfide deposits: *in* Barrie, C. T., and Hannington, M. D., 1999, Volcanic-Associated Massive Sulfide Deposits: Processes and Examples in Modern and Ancient Settings, Reviews in Economic Geology, v. 8, p. 13-51.*

Hannington, M. D., Poulsen, K. H., Thompson, J. F. H., and Sillitoe, R. H., 1999. Volcanogenic gold in the massive sulfide environment: Reviews in Economic Geology, v. 8, p. 325-356.*

Hudak, G. J., Morton, R. L., Franklin, J. M., and Peterson, D. M., 2003. Morphology, distribution, and estimated eruption volumes for intracaldera tuffs associated with volcanic-hosted massive sulfide deposits in the Archean Sturgeon Lake Caldera Complex, NW Ontario: American Geophysical Union Monograph 40, Explosive Subaqueous Volcanism, p. 345-360.*

Hathway, B., Hudak, G., and Hamilton, M., 2008, Geologic setting of volcanic-associated massive sulfide deposits in the Kamiskotia Area, Abitibi Subprovince, Canada: Economic Geology, v. 103, p. 1185-1202.

Franklin, J. M., 1996. 6.3 Volcanic-associated massive sulphide base metals: *in* Geology of Canadian Mineral Deposit Types, (ed.) O. R. Eckstrand, W. D. Sinclair, and R. I. Thorpe: Geological Survey of Canada, Geology of Canada, no. 8, p. 158-183.**

Poulsen, K. H., and Hannington, M. D., 1996. 6.4 Volcanic-associated massive sulphide gold: *in* Geology of Canadian Mineral Deposit Types, (ed.) O. R. Eckstrand, W. D. Sinclair, and R. I. Thorpe: Geological Survey of Canada, Geology of Canada, no. 8, p. 183-196.**

Moon, C. J., Whateley, M. K. G., and Evans, A. M., 2006, Chapter 17.**

Volcanic/Sedimentary Associated Hydrothermal Deposits - Iron Formations

Clout, J. M. F., and Simonson, B. M., 2005. Precambrian iron formation and iron formation-hosted ore deposits: Economic Geology 100th Anniversary Volume, p. 643-679.*

Robb, L., 2005. Introduction to Ore-Forming Processes: Sedimentary Ore-Forming Processes, p. 246-287.*

Gross, G. A., 1996. 3. Stratiform Iron: *in* Geology of Canadian Mineral Deposit Types, (ed.) O. R. Eckstrand, W. D. Sinclair, and R. I. Thorpe: Geological Survey of Canada, Geology of Canada, no. 8, p. 41-73.**

Structurally-Controlled Precious Metal Deposits (Shear Zone (Lode) Gold)

Goldfarb, R. J., Baker, T., Dube, B., Groves, D. I., Hart, C. J. R., and Gosselin, P., 2005. Distribution, character, and genesis of gold deposits in metamorphic terranes:

Kerswell, J. A., 1996. 15.3 Iron-formation-hosted stratabound gold: *in* Geology of Canadian Mineral Deposit Types, (ed.) O. R. Eckstrand, W. D. Sinclair, and R. I. Thorpe: Geological Survey of Canada, Geology of Canada, no. 8, p. 367-382.**

Poulsen, K. H., 1996a. 15. Lode Gold: *in* Geology of Canadian Mineral Deposit Types, (ed.) O. R. Eckstrand, W. D. Sinclair, and R. I. Thorpe: Geological Survey of Canada, Geology of Canada, no. 8, p. 323-328.**

Poulsen, K. H., 1996b. 15.4 Disseminated and replacement gold: *in* Geology of Canadian Mineral Deposit Types, (ed.) O. R. Eckstrand, W. D. Sinclair, and R. I. Thorpe: Geological Survey of Canada, Geology of Canada, no. 8, p. 383-392.**

Robert, F., 1996. 15.2 Quartz-carbonate vein gold: *in* Geology of Canadian Mineral Deposit Types, (ed.) O. R. Eckstrand, W. D. Sinclair, and R. I. Thorpe: Geological Survey of Canada, Geology of Canada, no. 8, p. 350-366.**

Carbonate-Associated Disseminated Gold Deposits

Cline, J. S., Hofstra, A. H., Muntean, J. L., Tosdale, R. M., and Hickey, K. A., 2005. Carlin-type gold deposits in Nevada: critical geological characteristics and viable models: Economic Geology 100th Anniversary Volume, p. 451-484.*

Moon, C. J., Whateley, M. K. G., and Evans, A. M., 2006, Chapter 16.**

Michigan Field Trip

Quigley, T., and Mahin, B., 2008, Field Trip 3: Back Forty Geology and Mineralization: *in* Bornhorst, T. J. and Klasner, J. S., Institute on Lake Superior Geology, 54th Annual Meeting, Proceedings Volume 54, Part 2 – Field Trip Guidebook, p. 66-85.

I will also indicate in class which of these readings (or which sections of these readings) you will need to study in more detail.

Additional Readings Sources

General Sources

- Bucher, K., and Frey, M., 1994. Petrogenesis of Metamorphic Rocks: Springer – Verlag, Berlin, 318 pages.
- Evans, A. M., 1997. An Introduction to Economic Geology and its Environmental Impact: Blackwell Science, 364 pages
- Guilbert, J. M., and Parks, C. F., 1986. The Geology of Ore Deposits: W. H. Freeman and Co., New York, 985 pages.
- Kirkham, R. V. et al. 1995. Mineral Deposit Modeling: Geological Association of Canada Special Paper 40, 770 pages.
- Lord, D., Etheridge, M., Willson, M., Hall, G., and Uttley, P., 2001. Measuring exploration success: an alternative to the discovery-cost-per-ounce method of quantifying exploration effectiveness: SEG Newsletter, no. 45, p. 1-16.
- Misra, K. C., 2000. Understanding Mineral Deposits: Kluwer Academic Publishers, Dordrecht, 845 pages.
- Miyashiro, A., 1994. Metamorphic Petrology: Oxford University Press, New York, 404 pages (specifically see Appendix 3 – Glossary of Metamorphic Petrogenesis.
- Phillips, G. N., Law, J. D. M., and Myers, R. E., 2001. Is the redox state of the Archean atmosphere constrained?: SEG Newsletter, no. 47, p. 1-18.
- Richards, J. P., 2002. Sustainable development and the minerals industry: SEG Newsletter, no. 48, p. 1-12.
- Rollinson, H., 1993. Using Geochemical Data: Evaluation, Presentation, Interpretation: Longman Scientific and Technical, New York, Chapter 7 “Using Stable Isotope Data”, pages 266-316.
- Raymond, L. A., 1995. Petrology – The Study of Igneous, Sedimentary, and Metamorphic Rocks: Wm. C. Brown Publishing, Dubuque, IA, 742 pages.
- Robert, R. G., and Sheahan, P. A., 1988. Ore Deposits Models: Geological Association of Canada Geoscience Canada Reprint Series 3, 200 pages.

Introduction: Tools of the Economic Geologist

- Campbell, A. R., and Larson, P. B., 1998. Chapter 8 – Introduction to Stable Isotope Applications in Hydrothermal Systems: in Richards, J. P., and Larson, P. B., 1998, Techniques in Hydrothermal Ore Deposits Geology, Reviews in Economic Geology, v. 10, p. 173-194.
- Hoover, D. B., Heran, W. D., and Hill, P. L., 1992. The Geophysical Expression of Selected Mineral Deposits Models: United States Department of the Interior, Geological Survey Open-File Report 92-557, 129 p.
- Kyser, T. K. (ed.), 1987. Short Course in Stable Isotope Geochemistry of Low Temperature Fluids: Mineralogical Association of Canada Short Course Volume 13, 452 pages.
- Lowe, C., Thomas, M. D., and Morris, W. A., 1999. Geophysics in Mineral Exploration - Fundamentals and Case Histories: Geological Association of Canada Short Course Notes Volume 14, 175 pages.
- Richards, J. P., 2000. Lineaments revisited: SEG Newsletter, no. 42, p. 1-20.
- Rollinson, H., 1993. Using Geochemical Data: Evaluation, Presentation, Interpretation: Longman Scientific and Technical, New York, 352 pages.

Thompson, A. J. B., Hauff, P. L., and Robitaille, A. J., 1999. Alteration mapping in exploration; application of short-wave infrared (SWIR) spectroscopy: SEG Newsletter, no. 39, p. 1-27.

Valley, J. W., Taylor, H. P., and O'Neil, J. R. (eds), 1986. Stable Isotopes in High Temperature Geological Processes: Reviews in Mineralogy Volume 16, 570 pages.

Wyman, D. A. (ed.), 1996. Trace Element Geochemistry of Volcanic Rocks - Applications for Massive Sulfide Exploration: Geological Association of Canada Short Course Notes Volume 12, 402 pages.

Magmatic Processes

Carroll, M. R., and Holloway, J. R. (eds), 1994. Volatiles in Magmas: Reviews in Mineralogy Volume 30, 517 pages.

Marsh, B. D., 2002. On bimodal differentiation by solidification front instability in basaltic magmas, part 1: basic mechanics: *Geochimica et Cosmochimica Acta*, v. 66, no. 12, p. 2211-2229.

Marsh, B. D., 2004. A magmatic mush column Rosetta Stone: The McMurdo Dry Valleys of Antarctica: *EOS*, v. 85, no. 47, p. 497-502.

Marsh, B. D., 2006. Dynamics of magmatic systems: *Elements*, v. 2, p. 287-292.

Hersum, T. G. and Marsh, B. D., 2006. Igneous microstructures from kinetic models of crystallization: *Journal of Volcanology and Geothermal Research*, v. 154, p. 34-47.

Marsh, B. D., 2007. Crystallization of silicate magmas deciphered using crystal size distributions: *Journal of the American Ceramic Society*, v. 90, no. 3, p. 746-757.

Thomson, J. F. H., 1995. Magmas, Fluids, and Ore Deposits: Mineralogical Association of Canada Short Course Volume 23, 525 pages.

Magmatic Deposits

Arndt, N. T., Czamanske, G. K., Walker, R. J., Chauvel, C., and Fedorenko, V. A., 2003. Geochemistry and origin of the intrusive hosts of the Noril'sk-Talnakh Cu-Ni-PGE sulfide deposits: *Economic Geology*, v. 98, p. 495-515.

Naldrett, A. J. and Li, C. (eds.), 2000. A special issue on Voisey's Bay Ni-Co-Cu Deposit: *Economic Geology*, v. 95, no. 4, p. 673-928.

Theriault, R. D., Barnes, S. J., and Severson, M. J., 2000. Origin of Cu-Ni-PGE sulfide mineralization in the Partridge River Intrusion, Duluth Complex, Minnesota: *Economic Geology*, v. 95, no. 5, p. 929-943.

Wilde, A., Edwards, A., and Yakubchuk, A., 2003. Unconventional deposits of Pt and Pd: a review with implications for exploration: SEG Newsletter, no. 52, p. 1-18.

Diamonds

Bulanova, G. P., 1995. The formation of diamonds: *Journal of Geochemical Exploration*, v. 53, p. 1-24.

Pluton-Associated Hydrothermal Deposits (Porphyry Systems)

Barnes, H. L., 1975. Chapter 5 – "Hydrothermal Alteration" (pages 173-235), *in* Barnes, H. L., 1975, Geochemistry of Hydrothermal Ore Deposits: John Wiley and Sons, New York, 798 pages.

Barnes, H. L., 1997. Chapter 1 – Hydrothermal Ore Deposits – What We Do and Don't Know (pages 1-30), *in* Barnes, H. L., 1997, Geochemistry of Hydrothermal Ore Deposits, 3rd Edition: John Wiley and Sons, New York, 972 pages.

Chavez, W. X., 2000. Supergene oxidation of copper deposits: zoning and distribution of copper oxide minerals: SEG Newsletter, no. 41, p. 1-21.

Lang, J. R., Baker, T., Hart, C. J. R., and Mortenson, J. K., 2000. An exploration model for intrusion-related gold systems: SEG Newsletter, no. 40, p. 1-15.

Phillips, N., and Zhou, T., 1999. Gold-only deposits and Archean granite: SEG Newsletter, no. 37, p. 1-13.

Subaerial Volcanic-Associated Hydrothermal Deposits (Epithermal Systems)

Campbell, W. R., 1993. Research drilling into the "fluid reservoir" of the Creede epithermal vein system, San Juan Mountains, Colorado; a preliminary report: SEG Newsletter, no. 13, p. 1-16.

Elston, W. E., 1994. Siliceous volcanic centers as guides to mineral exploration; review and summary: Economic Geology, v. 89, p. 1662-1686.

Henly, R. W., and Hughes, G. O., 2000. Underground fumaroles: excess heat effects in vein formation: Economic Geology, v. 95, no. 3, p. 453-466.

Masterman, G. J., White, N. C., Wilson, C. J. L., and Pape, D., 2002. High sulfidation gold deposits in ancient volcanic terranes: insights from the mid-Paleozoic Peak Hill Deposit, NSW: SEG Newsletter, no. 51, p. 1-16.

Submarine Volcanic-Associated Hydrothermal Deposits (VMS) and Gold-Rich VMS

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