MINERAL DEPOSITS 51-322/522
SPRING 2006 SYLLABUS
3 CREDITS

INSTRUCTOR: Dr. George J. Hudak
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OFFICE HOURS

Monday	1:50 - 4:00
Tuesday	12:40 - 4:00
Friday	12:40 - 2:50

TEXTBOOK: Robb, L., 2005, Introduction to Ore-Forming Processes: Blackwell Publishing Co., 373 p. (ISBN 0-632-06378-5).

SOFTWARE: Dyar, M. D., 2005, Hands on Mineral Identification: TASA Graphic Arts Inc., version 1.1.

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 read them. Please treat the papers in the binder with care, and do not write on them. It may be necessary to use GEOREF to obtain the other readings. 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.

COURSE POLICIES:

Schedule: Lecture: 10:20 – 11:20 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 about

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 into developing 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. *At the present time, the minerals industry is in a "boom" period, largely due to the increased demand for metals by rapidly developing Asian countries (in particular, China and India). In fact, the need for natural resources has never been greater. This is good for all of you, as the demand for well-trained, field-oriented exploration geologists is also increasing.*

In recent years, the detailed evaluations of ore deposits carried out by economic geologists have also been useful in developing mining methods that have considerably less effect on the environment than those employed previously. These data have also been used to solve a number of serious environmental problems associated with old, abandoned mines. Many environmental solutions are applied economic geology.

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 "hands-on" exercises, reading textbooks, journal articles, and field trip guidebooks, and attending a two-and-one-half day-long field trip to see precious metal and base metal prospects in northeastern Minnesota.

Exams / Assignments: There will be *three take-home exams* on the lecture materials *(combined worth a total of 450 points).* *Exam 1* will cover the materials associated with the tools of the economic geologist (mapping, geochemistry, geophysics, etc.), igneous ore-forming processes, and magmatic deposits. *Exam 2* will cover hydrothermal processes, pluton-associated hydrothermal deposits, epithermal deposits, and volcanic associated hydrothermal massive sulfide deposits. The Exam 3 will cover materials associated with iron formations, sedimentary exhalative (SEDEX) and Mississippi Valley Type (MVT) base metal deposits, and shear zone-associated (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).

It is impossible to gain a thorough understanding of ore deposits without looking at rocks (ore samples, host rock samples, hydrothermally altered rocks, etc.), maps (geological, alteration, geochemical, geophysical, etc), and data sets (particularly geochemistry). Although there is no assigned laboratory for this course, most Fridays will be "hands-on" days in which we will look at minerals, rocks, or geochemical/geophysical data. There will 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). *Expect four assignments worth 50 points each*. Additionally, all of you will have a larger exploration-oriented project (the Prospect X Project, worth 100 points) to complete during the semester. The project will require you to map a field area (samples will be set up in the "sandbox" in the Sed Lab), do hand sample and petrographic evaluations and descriptions, evaluate geochemical (and possibly geophysical) data, and write a short (8-10 page) report in a style similar to that used by highly paid mineral industry consultants. Appendices with data will also be required. More details on this project will be given during the semester.

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 second 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, and will include 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 two-and-one-half day-long field trip between April 28 and April 30*. We will leave during the early afternoon of Friday, April 29, and drive to Bearhead Lake State Park (about a seven hour drive), which is located between Soudan and Ely, Minnesota. On Saturday day we will wake up early (e.g. on the road by 7:00 am), and look at Archean iron formations, synvolcanic intrusions, submarine mafic and felsic metavolcanic rocks, and associated alteration zones and base metal mineralization within the Lower Member of the Ely Greenstone Formation. After lunch on a spectacular outcrop that illustrates three nearly perfectly preserved basalt sheet/pillow lava flows, we head over to the Mud Creek Road, and look at felsic volcaniclastic rocks and shear-zone type (lode) gold mineralization. On Sunday we will break camp early and drive back to Oshkosh via Ely, Minnesota, and the western shoreline of Lake Superior, where we will investigate disseminated Cu-Ni-PGE mineralization in the Proterozioc Duluth Gabbro. *During the field trip, you will keep a field book which will be handed in and graded (50 points).* More details of the trip 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:

		Points
Lecture Exams	3 exams (150 points each)	450
Mineral/Rock ID Exams	2 exams (100 points each)	200
"Hands-on Day" Projects	4 projects (50 points each)	200
Prospect X Project	Consultant-style Report	100
Class Participation	50 points (given at end of semester)	50
Field Trip	Lab Notebook	50
	Total	*1050*

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 and lecture exams 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:

Grade	Percentage
A	90% - 100%
AB	85% – 89.9%
B	80% - 84.9%
BC	75% - 79.9%
C	70% - 74.9%
CD	65% – 69.9%
D	60% – 64.9%
F	<60%

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Topical Outline 2006

Week of	***Lecture Topics***	***" Hands-on" Topics***
Jan. 30	Introduction; The Tools of the Economic Geologist (Mapping/Petrography/Geochemistry/Geophysics/ Phase Diagrams)	Phase Diagrams
Feb. 6	Magmatic Processes/ Magmatic Deposits (Magmatic Cr, Ti)	***Mineral/Rock ID Exam/***IGPET
	FIRST LAB EXAM FRIDAY, FEBRUARY 10 (100 POINTS)	
Feb. 13	Magmatic Deposits (Magmatic Cu, Ni, PGE)	Magmatic Deposits
Feb. 20	Diamonds (Porphyry Copper, Gold, Molybdenum)	Core Logging
	FIRST MID-SEMESTER EXAM, DUE WEDNESDAY, MARCH 10	
Feb. 27	Pluton-Associated Hydrothermal Deposits (Porphyry Copper, Gold, Molybdenum)	Porphyry Deposits
March 6	Pluton- and Volcanic Associated Hydrothermal Deposits Ch. 6; (Porphyry and Epithermal Systems)	Epithermal Deposits
March 13	Spring Break	
March 20	Volcanic-Associated Hydrothermal Deposits (Epithermal / VMS Deposits)	Isocon/ Prospect X
March 27	Volcanic-Associated Hydrothermal Deposits (VMS Deposits)	VMS Deposits
April 3	Volcanic-Associated Hydrothermal Deposits (VMS and Gold-rich VMS Deposits)	VMS Core/ Box Plot
	SECOND MID-SEMESTER EXAM, DUE WEDNESDAY, MARCH 10	
April 10	Volcanic-Sedimentary Associated Hydrothermal Deposits (Iron Formations)	Iron Formation
April 17	Sediment-Associated Hydrothermal Deposits (SEDEX AND MVT)	SEDEX/ MVT
April 24	Structurally Controlled Precious Metal Deposits (Shear Zone (Lode) Gold)	Lode Gold
	Field Trip To Northeastern Minnesota, April 28 – April 30 (more details later)	
May 1	Carbonate-Associated Disseminated Gold Deposits (Carlin-type Gold)	Project X
	Project X Due Friday May 5	
May 8	ILSG 52nd Annual Meeting (Sault Ste. Marie, Ontario) (Study for Final Lab Exam/Complete Final Exam)	***MINERAL/ROCK ID EXAM***
	THIRD MID-SEMESTER EXAM, DUE AT NOON, FRIDAY MAY 12	

Required* 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

Magmatic Processes

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

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

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.

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)

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.

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.

Subaerial Volcanic-Associated Hydrothermal Deposits (Epithermal Systems)

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

Volcanic/Sedimentary Associated Hydrothermal Deposits - Iron Formations

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

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.

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.

Sediment-Associated Hydrothermal Deposits (Sedex/Mississippi Valley-Type)

Leach, D. L., Sangster, D. F., Kelley, K. D., Large,R. R., Garven, G., Allen, C. R., Gutzmer, J., and Walters, S., 2005. Sediment-hosted lead-zinc deposits: a global perspective: Economic Geology 100th Anniversary Volume, p. 561-607.

Hitzman, M., Kirkam, R., Broughton, D., Thorson, J., and Selley, D., 2005. The sediment-hosted stratiform copper ore system: Economic Geology 100th Anniversary Volume, p. 609-642.

Lydon, J. W., 1996. 6.1. Sedimentary exhalative sulphides (SEDEX): *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. 130-152.

Sangster, D. F., 1996. 10. Mississippi valley-type lead-zinc: *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. 253-261.

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: Economic Geology 100th Anniversary Volume, p. 407-450.

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.

Minnesota Field Trip

Hudak, G. J., Heine, J., Jirsa, M., and Peterson, D. M., 2004. Field Trip 1: Volcanic stratigraphy, hydrothermal alteration, and VMS potential of the Lower Ely Greenstone, Fivemile Lake to Sixmile Lake area: in Severson, M. J. and Heinz, J., 2004, Institute on Lake Superior Geology, Proceedings Volume 50, Part 2 – Field Trip Guidebook, p. 1-44.

Peterson, D. M., Jirsa, M. A., and Hudak, G. J., 2005. Field Trip 9: Architecture of an Archean greenstone belt: stratigraphy, structure, and mineralization: *in* Robinson, L., Minnesota Geological Survey Guidebook 21: Field Trip Guidebook for Selected Geology in Minnesota and Wisconsin: 2005 North Central GSA Meeting, p. 154-180.

Carbonate-Associated Disseminated Gold Deposits (Carlin-Type Gold)

Cline, J. S., Hofstra, A. H., Muntean, J. L., Tosdal, 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.

* I will indicate in class which of these readings (or which sections of these readings) you will need to study in 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 Metamophic 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 Techical, 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 Techical, 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

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

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 Norli'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

Cas, R. A. F., 1992. Submarine volcanism: eruption styles, products, and relevance to understanding the host-rock successions to volcanic-hosted massive sulfide deposits: Economic Geology, v. 87, p. 511-541.

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