**Exploration, Ore Petrology, and Geochemistry**

**Earth and Planetary Science 210**  
Professor George Brimhall

**Required Texts Books:**


**Recommended Texts Books:**

Ore Geology and Industrial Minerals by A. M. Evans, Blackwell, Third Ed., 1993 *(E)*

**Recommended Summary Volumes:**


**Lecture Routine:** Each lecture period will include the topics listed below and will also include brief summaries of recurrent themes including global current events and mining sector investments and economics.

**Needed for each Lab:** Hand lens, digital camera, pocket knife, work clothes, laptop, USB jump drive

**Week 1**

**Topics**

Weds. Sept. 7  **L-1**  
Course overview, origin and fractionation of metals in earth history, ore forming systems, Classification and evolution of ore deposits over geologic time, phase equilibria and geochemistry, types of transport fluids, supergene processes, bio-utilization and toxicity, mining claims, land status maps and resource issues, mine cycle, recycling, productive versus unproductive management leadership models, metals for alternative energy, and mining sector investment, internet links.

**Reading: Journal Papers** (Reading List is at end of Syllabus). Click on CTRL button and the underlined hyperlink to read the papers on line: Brimhall *(1987A)*, Meyer *(1988)*.  
**Textbooks:** GP: (295-306), MWA: (19-32; 444-446), E: (313-344)

**Lab 1:** 345 McConne Hall: Ore microscopy, identification of common ore minerals in reflected light. Determinative tables.
Week 2:
Weds. Sept. 14 **L-2**  Plate tectonic controls on ore deposit distribution, metallogenic provinces of California, atmospheric controls on ore deposition and enrichment; ore deposits related to mafic igneous rocks (layered mafic intrusions, podiform chromite deposits, Kamblada type Ni deposits, kimberlite diamonds; regional geophysical correlations with ore deposits.

**Reading:** Papers: Albers (1981), Hildenbrand (2000).
**Textbooks:** GP: (25-169), E: (345-346)

**L-3**  Ore-forming fluids, their movement, ore deposition, and wall rock alteration

**Textbooks:** GP: (307-396), MWA: (413-443), E: (104-113; 128-153)

**Lab 2:** 345 Mc Cone Hall: Pillikin podiform chromite Mine California; Rainbow Tungsten Skarn deposit, CA; Butte MT; Pre-Mainstage porphyry Cu mineralization

Week 3
Weds. Sept. 21 **L-4**  Ore deposits related to felsic to intermediate intrusive; porphyry Cu deposits at Butte Montana, skarn ore deposits, porphyry molybdenum deposits, wall rock alteration and district zoning.

**Reading:** Papers: Brimhall (1977; 1979; 1980); Brimhall and Ghiors, 1983
**Textbooks:** GP: (170-250; 397-531), E: (157-189; 213-232)

**Lab 3:** Regatta Bldg: Butte Main Stage vein systems; district zoning, changes with depth

Week 4
Weds. Sept. 28 **L-5**  Supergene leaching and secondary enrichment, residual enrichment and mass balance analysis and modeling, relict sulfide studies to define zoning of primary sulfides.

**Reading:** Papers: Brimhall et al (1985); Mote et al (2001 AB), Nishizumi et al, 2003
**Textbooks:** GP: (774 -836), E: (262-271)

**L-6**  Research Project scope- discussion of initial ideas

**Reading:** Papers: Brimhall and Crerar (1987)
**Textbooks:** G: (251-294), E: (44-50; 84-98)

**Lab 4:** Regatta Bldg Richmond: Porphyry copper deposits: Bingham Canyon Copper mine, Ajo, Morenci, Inspiration, San Manuel, Yerington, Nevada

Week 5
Weds. Oct. 5 **L-7**  Ore deposits related to submarine volcanism, volcanogenic massive sulfide ores, exhalative Hometake Gold Mine South Dakota, banded Fe formations,

**Textbooks:** GP: (572-686), MWA: (358-381)

**L-8**  Ores related to chemical sedimentation: Phosphorite, banded iron formation, stratabound copper deposits.

**Textbooks:** GP: (687-741), E: (190-212; 233-261)

**Lab 5**  Regatta Bld: Homestake Gold Mine, South Dakota; Banded Iron Formation- Biwabik and Mesabi.

**Textbooks:** GP: (743-773)

Week 6
Weds. Oct. 12 **L-9**  Successful mineral explorers, Olympic Dam Cu-U-REE deposit; Carbonatites and Rare earth elements deposits; Job Searching

**Textbooks:** Reading: MWA: (320-357), E: (114--120)
Ores related to clastic sedimentation, Witswatersrand gold deposit; Geothermal resources, epithermal Au-Hg-Ag ores, McLaughlin gold deposit California

Textbooks: GP: (532 -571)

Lab 6: Regatta Bldg: Witswatersrand gold deposits

Week 7
Weds. Oct. 19 L-11 Deposits related to subaerial volcanism, Carlin type gold deposits; epithermal Ag-Au deposits, lithium-enriched brines; Intrusion-related replacement deposits of Pb-Zn; Pb-Zn deposits.
Textbooks: GP: (532 -571), MWA: (382-412),

L-12 Regional geology of the Western US, Nevada geology, distribution of ore deposits, geothermal systems, digital mapping of ore deposits and wall rock alteration;
Textbooks: GP: (886 -934), Summary Volumes: WC: (221-242)

Lab 7 Regatta Bldg: New Almaden and New Idira Hg deposits of California, Tonopah silver deposits, Nevada, Comstock Nevada, Cripple Creek CO; Carbonate replacement silver and poly-metallic base metal deposits at Cerro Gordo CA and Darwin.

Week 8

L-15 Colorado Plateau roll type uranium ores, nuclear waste storage issues
Reading: Papers: Ague and Brimhall 1987, Ague and Brimhall 1988AB; Hildebrand (2009)

Lab 8: Regatta Bldg Radioactive dose measurements, dosage limits, environmental health and safety; Roll type uranium ores

Week 9
Weds. Nov. 2 L-16 Mineral resources, mineral economics, ore reserves, Mine safety, the role of an exploration geologist, Reconnaissance exploration, due diligence, Bre-X scandal
Digital Mapping of ore deposits and wall rock alteration
Textbooks: GP: (1-12), MWA: (1-18; 52-103), E: (3-23)

L-17 Remote sensing, geophysical exploration, mine remediation
Textbooks: MWA: (104-154)

No Lab this week

Week 10
Weds. Nov. 9 L-18 Earth materials for sustainable energy production, solar energy production; semiconductor materials
Textbooks: MWA: (155-178)

Lab 9: 355 McConde Hall: Sample preparation, crushing, grinding, and splitting
Week 11
Weds. Nov. 16 L-19 The business of exploration (by Ray Morley formerly of BHP); Industrial minerals, Zr, Ti, sand, gravel, aggregate, financial resource markets, Green technology resources, gold versus base metal market
E: (272-304 )
Hosted dinner for students at Saul’s Deli at 5:30 pm.
Textbooks: MWA: (179-252 and (353-278)
No Lab this week

Week 12
Weds. Nov. 23 No class so students can leave for Thanksgiving

Week 13
Weds. Nov. 30 Presentation of student research topics
30 minute time slots for each talk including discussion.

Research papers in Journals:

Brimhall, G.H., Preliminary fractionation patterns of ore metals through Earth history, Chem. Geol., v. 64, 1-16, 1987A.


Brimhall, G. H, 1979, Lithologic determination of mass transfer mechanisms of multiple stage porphyry copper mineralization at Butte, Montana: Vein formation by hypogene leaching and enrichment of potassium-silicate protore, Econ. Geol., v. 74, p. 556-589.


Brimhall, G.H. and Ghiorso, M.S., 1983, Origin and ore-forming consequences of the advanced argillic alteration process in hypogene environments by magmatic gas contamination of meteoric fluids, Econ. Geol., v. 78, p. 73-90.
Brimhall, G.H., Alpers, C.N. and Cunningham, A.B., 1985, Analysis of supergene ore-forming processes and ground water solute transport using mass balance principles, Econ. Geol., v. 80, p. 1227-1256.


Mote, T., Becker, T., Renne, P. and Brimhall, G., 2001B, Chronology of exotic mineralization at El Salvador, Chile by $^{40}$Ar/$^{39}$Ar dating of copper wad and supergene alunite: Econ. Geol., v. 96, p. 351-366.


Peabody, C. and Einaudi, M, 1992, Origin of petroleum and mercury in the Culver-Bear cinnabar deposit, Mayacmas district, California, Econ. Geol. V. 87, p. 1978-1993


Ague, J.J. and Brimhall, G.H., Geochemical modeling of steady state fluid flow and chemical reaction during supergene enrichment of porphyry copper deposits, Econ. Geol., v. 84, p. 506-528, 1989.