

Lab 11: Mineral extraction

To illustrate the point of an economic ore:

The tenor of an ore is the concentration of a metal in a particular ore. If there is enough metal, it is expressed as a percent by weight of the metal in an ore (for instance, copper ores are 0.5 to 10 % copper by weight); if there is very little metal, then it is expressed as a number of ounces of metal per ton of ore (or, metrically, the number of grams of metal per tonne of ore).

1. Gold falls in the “very little metal” category. Examine the ore rock from Aden (sample E1), California. Gold occurs in a couple of ways in nature: as concentrated bodies (such as nuggets and wires) or as disseminated (microscopically scattered) grains within a host rock. What type is the Aden ore?

2. The tenor of the Aden gold ore is about 2 ounces of gold per ton of ore rock. Aden is in production currently and is just breaking even when gold sells for \$500 per ounce on the New York spot market. Five years ago, gold was selling for \$250 per ounce; what tenor did the ore need to be in order for the Aden mine to at least break even?

3. a. Twenty-five years ago, gold was selling for \$641 per ounce (it was used as a hedge against the staggering inflation of the time). Given that the Aden mine’s costs were probably lower (mostly being salaries and safety equipment), would the mine have been open at the time?

- b. Fifteen years ago, gold had dropped to \$400 per ounce; would Aden have been open then? This is why investing in gold and gold-mining company stocks is so risky.

4. a. Sample E2 is an iron ore called taconite, and is found in a rock formation called a banded iron formation (BIF). How could you test for this iron?

- b. Of course, rust could be considered an iron ore, but the test from part a would fail; what is unique about BIF iron ore? Given the state of the Earth today, why is it unlikely that BIFs are still being generated on Earth?

5. a. Sample E3 is from Nickel Mountain, Oregon, and is nickel ore. The green mineral is garnierite, which is the principal nickel-bearing material. It has the chemical formula $\text{Ni}_3\text{Si}_2\text{O}_5(\text{OH})$. Using the atomic masses from the periodic table, calculate the tenor of nickel in garnierite.

b. To refine garnierite, the mineral is heated to 1400°C in an electric furnace and this reaction occurs: $2 \text{Ni}_3\text{Si}_2\text{O}_5(\text{OH}) \rightarrow 6 \text{Ni}$ (nickel metal) + 4SiO_2 (silica) + H_2O + O_2 . Of course, nature had to make the mineral in the first place. What Earth process generated garnierite? Hint: reverse the arrow in the equation, then look at the other materials and where they are found today.

6. There are four basic geologic settings for metallic ore deposits: hydrothermal (greater than 250°C alteration), weathering (less than 250°C alteration), igneous and sedimentary. Examine samples E4 through E7 and assign them to the geologic setting in which they were found. Give a justification for your choices!

Geologic setting	Sample number	Justification (make observations of sample consistent with your choice of setting)
Hydrothermal		
Igneous		
Sedimentary		
Weathering		

7. Sample E8 is a **pyrite** vein from the Britannia Beach copper mine in British Columbia. The host rock surrounding the vein is a metamorphosed basalt; note the **foliation** within that rock (the “layering”).

a. Does the orientation of the pyrite crystals in the vein conform to the foliation in the host rock?

b. Are the edges of the vein sharply defined?

c. What do the answers to the questions above suggest about the timing of the pyrite crystallization compared to the metamorphosis of the basalt (before, after, during)?

d. What is the white mineral within the pyrite? Did this mineral crystallize before, after or at the same time as the pyrite crystallized? How can you tell?

e. The white mineral crystallizes when the temperature of the water carrying its ions drops below 250°C. What type of deposit (see question 6) is this?

8. The blue mineral in sample E9 is **bornite**, which has the chemical formula Cu_5FeS_4 ; the golden mineral is **chalcopyrite**, which has the formula CuFeS_2 . Sample E10 contains the green mineral **chalcocite**, which has the formula Cu_2S . Bornite and chalcopyrite are called primary ore minerals because they were formed when the ore body was created by hydrothermal processes. Chalcocite is formed is considered a secondary ore mineral, because it was formed as a result of **supergene enrichment** of the primary minerals, which occurs when oxygen-rich water from the surface later seeps through the ore body.

a. Why is the process of turning primary minerals into secondary minerals considered enrichment? Exactly what is being enriched? Hint: look at the chemical formulae.

b. What role does water play in the enrichment? In other words, why is water necessary for the enrichment to occur?

9. Sample E11 is colloquially called **limonite**; more accurately, it is made mostly of the mineral **goethite**, which has a chemical formula of $\text{FeO}(\text{OH}) \cdot n\text{H}_2\text{O}$. Sample E12 is hematite, which has the formula Fe_2O_3 .

a. What color streak does hematite have? Recall the streak test from the minerals lab. Does the color of the streak resemble rust or does it resemble metallic iron?

b. Which of the two minerals is the weathering product of the other? Hint: water also plays a role in this. (Another way to look at this is that one of the minerals is **oxidized** to the other in the presence of air and water).

10. a. Sample E8 is part of a **massive-sulfide deposit**, which is a type of hydrothermal ore deposit. The interpretation of the particular ore body that E8 was part of is that that area was part of a complex of undersea thermal vents. Why, tectonically, is the location of the mine (coastal British Columbia) consistent with that interpretation?

b. Sample E11 is typically “mined” by scooping up large amounts of a certain type of **soil** and extracting the iron-bearing minerals. Find a list of soil types that end in “-sol” and determine which type of soil would be most worthwhile to mine for limonite. Where geographically would this type of soil be found?