

Concentrating on Copper: An Exploration of Mineral Commodities

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Grades 9-12 (Earth/Geosciences)

I. Description of Lesson

Introduction

Understanding market price fluctuations is difficult for the average consumer as they are not often cognizant of what raw materials are used for various products. The goal of this lesson is to illustrate as many of the economic principles related to mineral commodities as possible and, as the lesson is ideally taught in the context of an earth or environmental science course, to couple these principles with the realities of mineral mining and subsequent processes required to produce a raw material from an ore. The lesson uses copper as an analog for such commodities. While the scope of this lesson is, then, quite unusual for high school students, these concepts are quite necessary to produce a populace who can make educated, socially-responsible, and economically-prudent decisions in both their political and personal lives.

Background

This lesson is ideal for any situation where the goal is to teach earth or environmental science students about the realities of mineral commodities, how they are extracted, and how supply and demand for them work to create that market, produce goods, and affect the environment. In the real world, most of the supply-chain for such products is hidden from the end-use consumer. This is certainly not intentional on the part of governments and corporations, necessarily, but is pretty typical due to the remote nature of most mining operations and the lack of contact that consumers have with various mid-level parts of this supply chain. Typically, the only exposure to mineral commodity prices will occur when this consumer wishes to purchase a product that contains those minerals and whose price is observed to not be consistent over time. Petroleum is a common example of this in our everyday lives, but it is no different than any other. Thus, this lesson focuses on the life cycle of copper, which is a mineral commodity that most of us think little about in our day to day lives yet is just as prevalent and important as other commodities like petroleum.

II. Abstract

Summary

The lesson begins with students being engaged by the teacher weighing and sorting a pile of copper scrap. It will end, during the final moments of the class period or second class period, with the class figuring out how valuable that pile of scrap really is given current market prices. The teacher begins by connecting copper ore to volcanism, a set of content that should have already been discussed in class and so the prior knowledge should be able to be activated quite readily. There is then an opening activity where the students in class have several opportunities to mine for "ore" by kinesthetically moving around class and collecting objects of different colors that represent various ore grades with certain concentration factors. Class begins then, by illustrating the Law of Diminishing Returns in mineral mining.

The second stage of the lesson has several parts. Students will explore the supply-chain of copper production, from exploration to raw material. They will also conduct some simple mathematical calculations related to the amount of copper necessary to wire a new house which, later on, they will return to in order to explore how the cost of wiring this house has changed over time, using USGS historical copper price data for the last ten years. Students will also explore current commodity prices and how they are presently and

historically affected directly by changes in supply, demand, international events, natural disasters, and so on. Again, USGS mineral commodity data is used for this. Students are thus being exposed to real data used by economists, mining companies, and investors when making decisions related to these commodities.

The lesson continues with the teaching taking time to explain the geological and economic principles in some form of direct instruction. The form of instruction is left up to the teacher as the decision for how best to do this will depend upon the make up of a given class and the academic background and ability of the students. One interesting option available to the teacher is using a case study of copper production by exploring the concept of “Peak Copper” with the students and thus hitting on the important geological and economic concepts within that context.

The lesson ends in Phase IV with students returning to their colored object mining data from the first part of the class. They will be given more data about the ore that they mined and then calculate the profit of those mines, focusing only on the two colors of objects that had the highest concentration factor, as the lower two concentrations factors are essentially unminable at a profit.

Assessment is done throughout the activity and opportunities for such are listed below. A pre/post quiz is also given as a way of quantifying changes in student understanding and knowledge gained. Higher-level synthesis or other levels of exploration are better assessed with the more authentic methods provided below.

III. Economic Content Area and Key Objectives

Economic Objectives

Economics and Personal Finance:

- EPF.1 The student will demonstrate knowledge of basic economic concepts and structures by
- describing how consumers, businesses, and government decision makers face scarcity of resources and must make trade-offs and incur opportunity costs;
 - explaining that choices often have long-term unintended consequences;
 - describing how effective decision making requires comparing the additional costs (marginal costs) and additional benefits (marginal benefits);
 - identifying factors of production;
- EPF.2 The student will demonstrate knowledge of the role of producers and consumers in a market economy by
- explaining how businesses respond to consumer sovereignty;
 - identifying the role of entrepreneurs;
 - comparing the costs and benefits of different forms of business organization, including sole proprietorship, partnership, corporation, franchise, and cooperative;
 - describing how costs and revenues affect profit and supply;
 - describing how increased productivity affects costs of production and standard of living;

IV. Other Objectives Ancillary to the Economic Objectives

Other Objectives:

Algebra:

- A.9 The student, given a set of data, will interpret variation in real-world contexts.
- A.10 The student will compare and contrast multiple univariate data sets.
- A.11 The student will collect and analyze data, determine the equation of the curve of best fit in order to make predictions, and solve real-world problems, using mathematical models. Mathematical models will include linear and quadratic functions.

Earth Science:

- ES.1 The student will plan and conduct investigations in which
- volume, area, mass, elapsed time, direction, temperature, pressure, distance, density, and changes in elevation/depth are calculated utilizing the most appropriate tools;
 - technologies, including computers, probeware, and geospatial technologies, are used to collect, analyze, and report data and to demonstrate concepts and simulate experimental conditions;
 - scales, diagrams, charts, graphs, tables, imagery, models, and profiles are constructed and interpreted;
 - maps and globes are read and interpreted, including location by latitude and longitude;
 - variables are manipulated with repeated trials; and
 - current applications are used to reinforce Earth science concepts.
- ES.2 The student will demonstrate an understanding of the nature of science and scientific reasoning and logic. Key concepts include
- science explains and predicts the interactions and dynamics of complex Earth systems;
 - evidence is required to evaluate hypotheses and explanations;
 - observation and logic are essential for reaching a conclusion; and
 - evidence is evaluated for scientific theories.
- ES.4 The student will investigate and understand how to identify major rock-forming and ore minerals based on physical and chemical properties. Key concepts include
- hardness, color and streak, luster, cleavage, fracture, and unique properties; and
 - uses of minerals.
- ES.5 The student will investigate and understand the rock cycle as it relates to the origin and transformation of rock types and how to identify common rock types based on mineral composition and textures. Key concepts include
- igneous rocks;
 - sedimentary rocks; and
 - metamorphic rocks.
- ES.6 The student will investigate and understand the differences between renewable and nonrenewable resources. Key concepts include
- fossil fuels, minerals, rocks, water, and vegetation;
 - resources found in Virginia; and
 - environmental costs and benefits.
- ES.7 The student will investigate and understand geologic processes including plate tectonics. Key concepts include
- geologic processes and their resulting features; and
 - tectonic processes.

Chemistry:

- CH.1 The student will investigate and understand that experiments in which variables are measured, analyzed, and evaluated produce observations and verifiable data. Key concepts include
- designated laboratory techniques;
 - safe use of chemicals and equipment;
 - mathematical manipulations including SI units, scientific notation, linear equations, graphing, ratio and proportion, significant digits, and dimensional analysis;
 - use of appropriate technology including computers, graphing calculators, and probeware, for gathering data, communicating results, and using simulations to model concepts;
 - construction and defense of a scientific viewpoint; and
 - the use of current applications to reinforce chemistry concepts.

CH.3 The student will investigate and understand how conservation of energy and matter is expressed in chemical formulas and balanced equations. Key concepts include

- a) nomenclature;
- b) balancing chemical equations;
- c) writing chemical formulas;
- d) bonding types;
- e) reaction types; and
- f) reaction rates, kinetics, and equilibrium.

V. Instructional Process

Materials

- A small pile of scrap copper objects (optional)
- Images, at least what is included in appendices, for presentation
- Access to projection and a computer
- Internet Access
- Little colored squares of construction paper or other colored objects, in some quantity similar to what is discussed in Phase One below.
- Worksheets and commodity handouts copied (or, ideally each student would have a computer and just be provided with links to these documents)

Procedure

Phase One: Engage the Learner

Begin class by having, if possible, a pile of scrap copper items. These could be insulated wires (not connected to anything), old electronics, water pipes, etc. These props will elicit curiosity and can be referred to, at the end, as a source for raw copper. Students may ask questions, but be vague. While they assemble and conduct their bellwork, you can be weighing the items and jotting the weights of objects on the board. When they have finished their bellwork, then begin with the activity below. Consider ending class by looking up the [current price of copper scrap here](#) and figuring out how valuable your pile is! Check this website ahead of time for the various categories.

Opening Activity: Use if you wish to begin with a more active classroom and if you wish to focus more closely on the “Law of Diminishing Returns” inherent in mineral resources. This opening activity will focus on the “Concentration Factor” (CF), or the concentration of copper in an ore necessary, over the average crustal abundance of copper, for copper (or any other mineral commodity) to be economically recovered.

- 1) Most copper deposits are “porphyry deposits” that occur in association with iron-oxides, silver, gold, and other trace metals in “IOCG (Iron-Oxide Copper Gold)” deposits. Typically, these occur in igneous situations where hydrothermal waters rise up from around a magma chamber and leave concentrated ore in the rock surrounding the volcanic neck. These orebodies are typically porphyritic in their igneous texture, which is emblematic of the magma undergoing a two-phase cooling process. The cooling was slow at first, forming the phenocrysts (large crystals) of the porphyry and then was very rapid, forming the fine-grained groundmass. See [this image](#) for reference. It would be good to have this image projected on the board as you move into the actual opening activity. If a bellwork activity is needed, this would provide great imagery for activation prior learning focused on volcanism or igneous rocks.
- 2) The easiest to reach copper ore deposits are accessed first, in the real world, and versions of these with high CF values are rather rare. The crustal abundance of copper is 0.0058% and so a CF of 100-200 (minable concentrations of at least 0.58% ore and 99.42% gangue) Using four different colors of construction paper, cut small squares, perhaps 1”, in the following quantities:
 - a) Orange: 25 (CF=200)
 - b) Red: 50 (CF=100)
 - c) Green: 100 (CF=50)
 - d) Yellow: 200 (CF=25)
 - e) The orange and red squares represent minable ore deposits while the yellow and green squares represent non-economically viable deposits.
 - f) Beads or some objects of other colors can be used.

- 3) Before class begins, distribute the paper squares throughout the room. Also, keep your room in good order so that, when students move around to seek out their ore, they inadvertently move desks and such. You can discuss these acts of physical disruption in the classroom as environmental degradation from mining.
- 4) After bellwork, have them work individually to collect as much “ore” as they can. However, you must give them time limits. Unleash them as follows:
 - a) Stage 1: 15 seconds
 - b) Stage 2: 15 seconds
 - c) Stage 3: 15 seconds
 - d) Note: Keeping the time limit the same is important because you want to use the time to illustrate effort.
- 5) After each stage, students should be given a few moments to completely sit down, record their ore collections, and ready themselves for the next stage.
- 6) Have students tabulate their data in graphical form.
- 7) Create a set of class graphs illustrating the “ore grades” collected by stages. [Use this](#), if you wish.
- 8) It should be clear that most of the valuable ore (CF=200) was found early on and most of the other ore grades were also found early on. Bring the discussion here back to the cross-section of the volcano being projected. Discuss, as a class, where the most and least concentrated orebodies might be found and why.
- 9) Discuss how this entire activity illustrated diminishing returns. Students should discuss how, for the same amount of effort over time, they recovered fewer and fewer ore deposits.
- 10) Discuss the environmental degradation caused by the production of the ore (the movement of desks, etc. in the flurry of activity) and then implement a quick “reclamation plan” by having them fix the room.

Phase Two: Explore the Concept

Phase IIa: Concentration Factor and Ore Grade Extension

- 1) What makes an “ore”, or mineral commodity, extractable at a profit? It all depends upon the “concentration factor”, which is obtained by dividing the “Minable Grade” in weight percent, or ore grade where the ore is profitable, by the average crustal elemental abundance in weight percent. Students should calculate the concentration factors of some common ores in order to first draw some conclusions about which ores are more valuable.
 - a) Pass out [this worksheet](#). Some commodities (commodities = elements in this exercise) are more valuable than others. To be economical, ore deposits must contain sufficient amount of the commodity of interest to make mining profitable. Have students complete the table by dividing the numbers A/B for the concentration factor. Then, have them answer the questions below and on their worksheet.
 - i) **Question:** To be considered a mineral commodity, an orebody has to reach an ore concentration of at least the concentration factor (CF). How does copper compare to other commonly mined mineral resources?
 - ii) **Question:** How does the concentration factor likely related to the costs of production of that ore? Think about the amount of wasted rock (gangue) versus ore in the early stages of production. How might the concentration factor affect the decision to mine underground (more expensive process) rather than on the surface (less expensive process)?
 - iii) **Question:** Why are some mineral commodities inherently more valued than others, even prior to the start of any mining? What role does demand play in their value?

Phase IIb: Ore and Gangue

- 2) Allow the students about 10 minutes to explore the math connection below. Then, discuss it as a group. The answer will lead into Part II of Phase II below.

- a) Pose the following question to the group: “Suppose that you are building a new house. It will take about 90 kg (198 pounds) of copper to do the electrical wiring. In order to get the copper in the first place, someone needs to mine solid rock that contains copper, extract the copper minerals, throw away the waste rock, and smelt the copper minerals to produce copper metal. Rocks mined for copper typically contain only very small percentages of copper—about 0.7% in the case of most of the big porphyry copper deposits of the world. How much rock would someone have to mine in order to extract enough copper to wire your new house?”
- b) Here is the answer: “A block weighing about 12,860 kg (almost 28,300 pounds, or over 14 tons)!! The copper ore forms only 0.7% of the rock. We need to find a number that we can multiply by .007 to get 90 kg. Dividing 90 kg by .007 will give us that number—approximately 12,860 kg. Multiplying that number by 2.2 pounds/kg would give us the number of pounds (about 28,300 pounds). Dividing by 2000 pounds/ton would give us the number of tons (more than 14 tons). Remember that, of the 12,860 kg mined, 12,770 kg were thrown away to get your 90 kg of copper... Now, think about the number of people on your street. How much rock would have had to be mined in order to wire all the houses on your street? How much rock was thrown away?”
- c) Discuss the problem and answer as a class. This problem is essentially focused on the amount of “ore” and “gangue” for which this home’s construction is responsible.

Phase IIc: Copper, Copper, Everywhere!

- 3) After the demonstration above, it is time to make a connection with the use of copper, as an analog for other mineral commodities, in the everyday life of the students. Begin with [this video](#). While watching, have students: **I. Create their own individual flowcharts for the production of copper**, and **II. Create a list of “things” they use daily that make use of this copper**. Feel free to pause the video as necessary. After the video, and after students seem finished, discuss their resulting information from I and II above as a group. There is a great deal of information here, but it would be excellent to discuss economic concepts such as:
 - a) What is a “commodity”?
 - b) Where are mineral commodities, like copper, bought and sold?
 - c) How does “demand” for a commodity lead to its production?
 - d) How prices are affected by this demand as well as other factors such as the efficient management of the “production supply chain” as a whole?
 - e) How might the “scale of production” affect the ultimate cost of production for small-scale producers versus large-scale producers?
 - f) What is “ore concentration” and why might it be important?
 - g) How might global “supply” and overall “production” affect prices on the commodity markets?
 - h) Do not expect to do more than introduce the discussion of these complex ideas here. We will revisit these questions at the end of the lesson.

Phase IIc: Copper on the Commodity Market

- 4) Students now have a good image of how copper goes from raw ore to various products. Using real-time current and historical commodity prices along with USGS fact-sheets, you will now separate students into small groups of two, present them with data, and have them come up with explanations for what they see in the graph.
 - a) Have read, and pass out to each pair of students, a downloaded version of the graph for historic copper prices as found at this [website](#). You could also project this graph for the whole class.
 - b) Have ready USGS Data sheets for the years [2005](#), [2008](#), and [2015](#). Do not pass them out until the appointed time below.
 - c) Students should first analyze the commodity price graph provided above and identify apparent trends in historic copper prices. Give them a few minutes to do this and be sure to

have them speculate on what aspects of the entire copper production process (from demand through fabrication of materials) might be affecting any observed trends over time.

- d) Pass out the USGS data sheets for the above-mentioned years. Give students 15-20 minutes to explore these sheets. There is a great deal of information here, but if they seem lost, direct them to the sections that deal with “Events, Trends, and Issues”. From there, the other data may begin to make good sense.

Phase IIe: Your Home and Copper Commodity Price Fluctuations

- 5) **Class Discussion:** It is now time to connect that 90kg of copper to economics. Have students explore how the calculated copper in their homes might have affected the price of their electrical and/or plumbing installations during the following time periods. Do the calculations as a class, but have them record the final costs for the home discussed in Part IIb for the years examined above in Part IIc: 2004, 2007, and current prices for 2015. **For reference, 1kg = 2.2 lbs.**

- a) Be sure to stress to them that the prices they are calculating are prices paid by those industries who produce wire, electronics, pipes, etc. Therefore, these calculated prices are only useful as an analog for the actual price of the materials used in their homes.
- b) Once the producers obtain raw ingots/cathodes, there are additional costs added in before the copper ever reaches the end-user/consumer/homeowner. Brainstorm what those might be as a class.
- c) The class should come up with something that looks like this:
- i) Copper ingots obtained by industry
 - ii) Industry melts copper, metallurgically alters it if necessary, and forms it into its final product.
 - iii) Industry sells this product with embedded profit margin.
 - iv) Distributors purchase these products from industry and sell them, at profit, to retail outlets and supply houses.
 - v) Installers and homeowners purchase copper or copper-containing products from retail outlets who also make a profit on this sale.
 - vi) If the homeowner hires an installer, the installer also charges for labor and other expenses.
 - vii) End with this exploration as a class.

(1) 12-2 wire is a commonly used grounded Romex used to wire outlets and most other 110v electrical appliances in homes. Currently, 12-2 electrical wire at Lowes is \$60 for a 250ft roll. How much is a foot of wire? (**\$0.24/ft**)

(2) There is about **1lb of copper in 20ft** of 12-2 wire. How much copper is there in 1ft of this wire? (**0.05lb/ft**)

(3) Assuming that **ONLY** 12-2 wire is used in the construction in Part I, how many feet of this wire is necessary if 90kg (198.4lb) of copper are used? (**3,968.2ft**)

(4) How much will this wire then cost the homeowner? (**\$952.37**)

(5) How does this cost compare with the current raw price for that copper on the commodity market (Use [this table](#) for that price)? (**as of May 10, 2015, 90kg of copper would cost \$575.59 at the current price of \$2.901/lb**)

(6) This last answer will vary, depending upon when this investigation is completed. What percentage of the whole cost to the homeowner for the wire is rolled up (pun intended!) into the cost of that wire? (**$(\$575.59/\$952.37)*100 = 60.44\%$**)

(7) Copper is expensive to produce!

Phase Three: Explain the Concept and Define the Terms

- 1) At this point, most of the necessary content has been explored by students. The teacher can choose to “Explain” these concepts from Phase II and contained in the definitions below in a variety of ways. Begin with the geology. Some good examples of diagrams and images that should form the core of any explanations regarding the geology are contained [in this document](#). Some other examples follow:
 - a) Case Study - The class can read an article on “The Coming Copper Peak” (included here). Students can be divided into small groups and given several of the definitions below to explore and explain in the context of the case study/article. - More Complex, more effective
- 2) Here are some of the important terms used herein and their definitions relative to economic geology:
 - a) Commodity - A raw material or primary agricultural product that can be bought and sold, such as copper or coffee.
 - b) Demand Curve - A graph depicting the relationship between a series of prices of a certain commodity and the amount of it that consumers are willing and able to purchase at that given price.
 - c) Supply Curve - A graph depicted the relationship between a series of prices of a certain commodity and the amount of it available for production.
 - d) The Four Basic Laws of Supply and Demand ([Reference graph](#)):
 - i) If demand increases (demand curve shifts to the right) and supply remains unchanged, a shortage occurs, leading to a higher equilibrium price.
 - ii) If demand decreases (demand curve shifts to the left) and supply remains unchanged, a surplus occurs, leading to a lower equilibrium price.
 - iii) If demand remains unchanged and supply increases (supply curve shifts to the right), a surplus occurs, leading to a lower equilibrium price.
 - iv) If demand remains unchanged and supply decreases (supply curve shifts to the left), a shortage occurs, leading to a higher equilibrium price.
 - e) Production - A process of combining various material inputs and immaterial inputs (plans, know-how) in order to make something for consumption (the output).
 - f) Supply Chain - Is a system of organizations, people, activities, information, and resources involved in moving a product or service from [supplier](#) to customer.
 - g) Scale of Production - A measure of the amount of production possible relative to the amount of investment available.
 - h) Economies of Scale - the cost advantages that enterprises obtain due to size, output, or scale of operation, with cost per unit of output generally decreasing with increasing scale as fixed costs are spread out over more units of output.
 - i) Ore Concentration - Quantity of minable ore in weight percent divided by the average crustal abundance in weight percent. The resultant factor is the concentration multiplier necessary for an ore to be economically viable as a minable resource.
 - j) Orebody - The body of rock that contains an ore.
 - k) Ore - A type of rock that contains sufficient minerals with important elements including metals that can be economically extracted from the rock
- 3) Lead the class discussion after giving students about 30 minutes to read and discuss the article. The article CAN be given to them ahead of time, for homework, prior to this lesson OR given to students between class periods in the event that this lesson extends to two full 90 minute periods.

Phase Four: Elaborate on the Concept

- 1) After “Phase Three”, return to the opening activity. Students should still have their data tables from the squares that they collected. Here is what the initial numbers were:
 - a) Orange: 25 (CF=200) (Ore Concentration = 1.16%)
 - b) Red: 50 (CF=100) (Ore Concentration = 0.58%)

- c) Green: 100 (CF=50) (Ore Concentration = 0.29%)
- d) Yellow: 200 (CF=25) (Ore Concentration = 0.16%)
- e) Now, we will assign a value to each of these “ores”. First, have students calculate the “ore concentration” of each ore above. The answers are listed above for the teacher. This is the concentration of the actual ore.
- f) Have students disregard any of their green and yellow squares for now. Under current market conditions, explain, these are not minable.
- g) The orange sites contains 55,000 tons of ore, minable at a cost of \$30/ton with a reclamation plan that will cost \$600,000. The red sites contain 55,000 tons or ore, minable at a cost of \$20/ton and with a \$350,000 reclamation plan.
- h) Have students fill in the section of the worksheet for Phase 4. They need to calculate the profit margin for each of these ores.
 - i) Discuss which is the best to mine and why? What other factors are necessary to consider?
- 2) This would be an excellent time to return to the pile of scrap copper in the front of the classroom. As a class, use current copper scrap prices to determine how valuable the pile is. Students can “mine” copper away from class - but do remind them that they would need to do so legally.
- 3) At this stage, the initial lesson is over. However, the concepts contained herein can easily be extended, ideally, to other mineral commodities. Some suggestions for further students research, as groups or as individuals, are provided below.
 - a) Can we describe the 2014-2015 drop in oil prices using some of the concepts here?
 - b) How has hydraulic fracturing for natural gas affected natural gas prices?
 - c) The Bower-Campbell zinc Mine is located in Timberville, VA and contains an orebody that has a minable concentration of 0.15 weight percent. Discuss the value and potential of re-opening this mine (production ceased in 1962, just after the government ended zinc stockpiling). See [this document](#) for reference.
- 4) Consider doing a chemical demonstration of Copper Ore extraction from the carbonate-hosted malachite deposits.
 - a) Prepare by studying the websites at the two links below well before class. You will engage the students by conducting a simple chemical demonstration of copper extraction.
 - b) Set up the copper extraction demonstration using the equipment and procedure listed at this [website](#). A sample of malachite will need to be crushed, some really basic lab apparatus assembled (along with requisite lab safety equipment), and a quantity of 1M sulfuric acid available for use. All Students should be spectators only as this demonstration may, or may not, be conducted within a chemistry lab.
 - c) Begin the demonstration by just describing what you are doing in very basic terms. The reaction is as follows:

$$\text{Cu(OH)}_2 + \text{H}_2\text{SO}_4 \text{ ----> } 2\text{H}_2\text{O} + \text{CuSO}_4$$
 - d) Additional background on this and how the metals industry uses this process for copper extraction from sulfate minerals can be found at this [website](#) also.
 - e) Make observations, discuss the equation above, but leave open ends for exploration.

Phase Five: Evaluate students' Understanding of the Concept

Below are sources of evaluation for student understanding:

- 1) Phase II, Part I - Successful completion of math problem and discussion
- 2) Phase II, Part II - Flowchart of copper production
- 3) Phase II, Parts III-IV - Participation in class discussion
- 4) Phase III - Article presentations
- 5) Copper worksheet answers
- 6) Quiz (teacher-created pre/post quiz)

VI. Evaluation

Closure

Class should close, if possible, by calculating the value of the scrap pile provided by the teacher. Many of these geological and economic concepts can be re-examined here as “mining” scrap does not have nearly the supply-chain that mining ore has and so the market forces are a little different. Use can again be made of the USGS handouts because scrapping is discussed on those as important sources of copper.

When tested with classes, this lesson had a very positive outcome. While it may be necessary to pick and choose a little when it comes to the activities in Phase II, in the interest of time, students in grades 10-12 begin with such a deficit of economic understanding that there is potential for massive gains. In the classes in which this lesson was tested, using the formal evaluation included in the appendix, there was a 72% increase in students’ understandings of the basic economics associated with mineral commodities from start to finish. In general, these topics are not discussed in regular classes, despite their importance in everyday life, so this lesson has great potential for dramatically improving future workers’ understandings of materials, their acquisition, the geology involved, and the economics that move all of it.

Assessment

Phase V focuses on assessment. The variety of methods above, as well as any others, are up to the teacher’s discretion as every class is unique, has different backgrounds, and different needs. A variety of authentic and traditional options are presented in Phase V above.

Appendix

Important Links

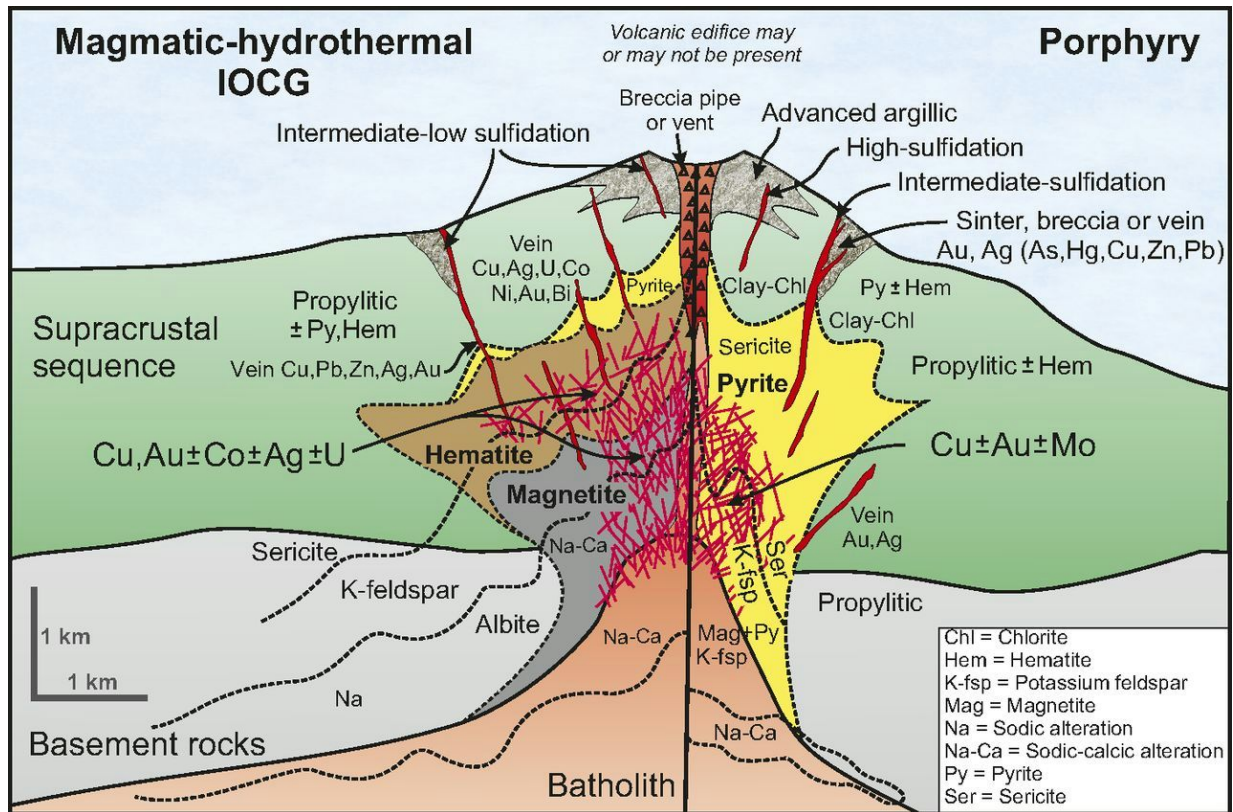
Some economic geology background on copper ore:

Copper Investing News - "[World-Class Copper Deposits](#)"
Tulane University - "[Mineral Resources](#)"

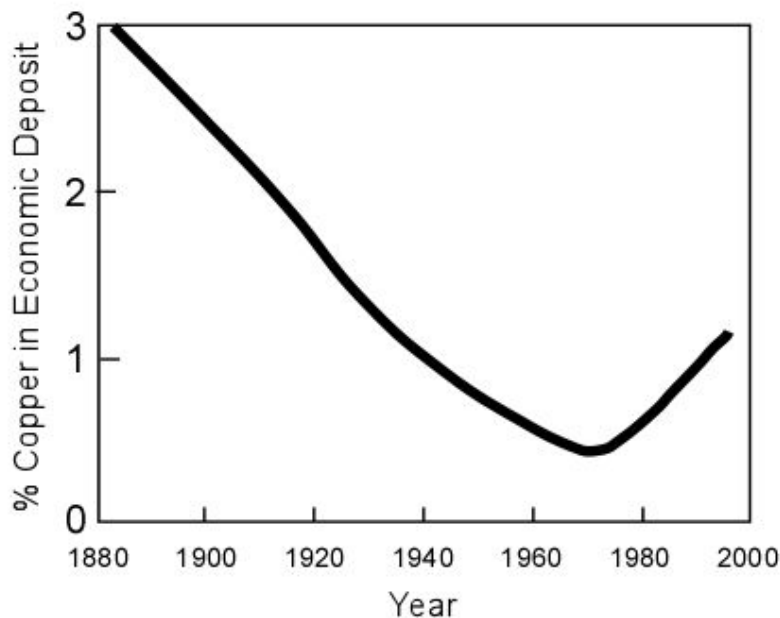
Links to other good economic and mining geology lessons:

[Discover Education Copper Mining Lesson](#)
[Caterpillar "Ground Rules" Lessons](#)

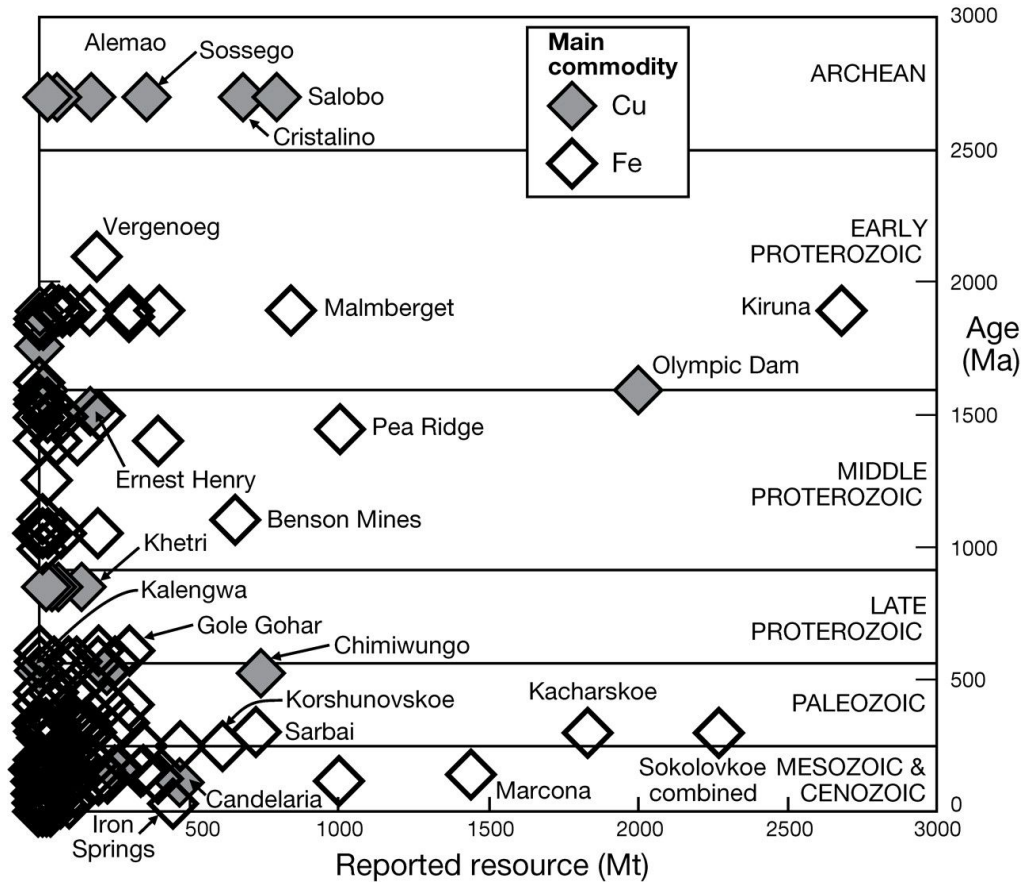
Useful Images



Richards, Jeremy P. and A. Hamid Mumin, 2013. Magmatic-hydrothermal processes within an evolving Earth: Iron oxide-copper-gold and porphyry Cu ± Mo ± Au deposits. *Geology*, July 2013, v. 41, p. 767-770.



Changes in ore grade over time. This is a good illustration of diminishing returns through the 1970s. Improved methods of extracting difficult ore have led to a surge in available ore of a higher grade that was not minable in earlier decades. From: <http://www.tulane.edu/~sanelson/eens1110/minresources.htm>



Formation of copper porphyry resources through geologic time. From: <http://econgeol.geoscienceworld.org/content/105/3/641/F1.large.jpg>



IOCG copper porphyry example. Note the combination of a fine-grained matrix with larger phenocrysts in the center of the sample depicted in the image above. From: http://upload.wikimedia.org/wikipedia/commons/7/7f/Prominent_hill_ore_cpy.jpg

Concentrating on Copper: An Exploration of Mineral Commodities

Phase IIa: Exploration of some of the major economic factors related to copper mining.

Some commodities (commodities = elements in this exercise) are more valuable than others. To be economical, ore deposits must contain sufficient amount of the commodity of interest to make mining profitable. "Mineable wt%," which geologists call **minable grade**, values are given in the table below. Use the data to calculate the *concentration factor* for each commodity. (*Concentration factor* is the amount it must be enriched over normal crustal abundance to be economically minable.)

	A	B	B/A
Ore Metal	Crustal Wt %	Minable Ore Grade (wt %)	Concentration Factor (CF)
Aluminum Al	8.0	28.0	
Iron Fe	5.8	40.0	
Copper Cu	0.0058	0.52	
Nickel Ni	0.0072	1.08	
Zinc Zn	0.0082	2.46	
Uranium U	0.00016	0.19	
Lead Pb	0.00010	0.20	
Gold Au	0.0000002	0.0008	
Mercury Hg	0.000002	0.2	
Tin Sn	0.0002	0.5	

- 1) To be considered a mineral commodity, an orebody has to reach an ore concentration of at least the concentration factor (CF). How does copper compare to other commonly mined mineral resources?

- 2) How does the concentration factor likely related to the costs of production of that ore? Think about the amount of wasted rock (gangue) versus ore in the early stages of production. How might the concentration factor affect the decision to mine underground (more expensive process) rather than on the surface (less expensive process)?

- 3) Why are some mineral commodities inherently more precious than others, even prior to any mining even beginning?

Phase IIb: Have students explore the concepts of “ore” and “gangue” using the following problem of building a home.

“Suppose that you are building a new house. It will take about 90 kg (198 pounds) of copper to do the electrical wiring. In order to get the copper in the first place, someone needs to mine solid rock that contains copper, extract the copper minerals, throw away the waste rock, and smelt the copper minerals to produce copper metal. Rocks mined for copper typically contain only very small percentages of copper—about 0.7% in the case of most of the big porphyry copper deposits of the world. How much rock would someone have to mine in order to extract enough copper to wire your new house?”

Show Your Work!

Question: Much of this “gangue” rock contains small amounts of other metals as well as elements that are environmentally dangerous, such as mercury. Why is it important that it is dumped or processed properly?

Phase IIc: Diagram your flowchart for the copper production supply chain below as you watch the video with the class.

Lists some things that you use daily that contain copper:

Question: As an end-user of copper in the modern world, what are some things for which you might have to learn to do without if copper reserves were to run out?

Phase II: The price of copper changes due to changes in demand, supply, natural disasters, and many other factors. How have copper prices behaved historically and what is the future of copper globally?

List some possible explanations for the long-term fluctuations you see in the price of copper.

When did some of the key events occur and what happened to the price?

Analyze the data for the USGS Mineral Commodity Summaries for the years below and describe for each what was happening in the world to affect the prices during those years:

2004:

Cost to wire home in this year: \$_____ (Part IIe, class discussion)

2007:

Cost to wire home in this year: \$_____ (Part IIe, class discussion)

2014:

Cost to wire home in this year: \$_____ (Part IIe, class discussion)

Phase III: Take notes in your notebook on what the teacher has to say regarding the following important terms.

- 1) Law of Diminishing Returns
- 2) Commodity
- 3) Demand Curve
- 4) Supply Curve
- 5) The Four Basic Laws of Supply and Demand:
 - a)
 - b)
 - c)
 - d)
- 6) Production
- 7) Supply Chain
- 8) Scale of Production
- 9) Economies of Scale
- 10) Average Crustal Ore Concentration
- 11) Mineable Concentration
- 12) Concentration Factor
- 13) Profit Margin
- 14) Environmental Reclamation
- 15) Gangue
- 16) Orebody
- 17) Ore

Phase IV: Calculate the profit possible in each mining scenario based upon current prices.

Ore	CF	Tons of Ore	Tons of Copper	Pounds of Copper	Value of Copper	Cost of Mining/Ton of Copper	Total Cost of Mining Ore	Env. Protection Costs	Profit
Orange		55,000				\$30		\$600,000	
Red		55,000				\$20		\$350,000	

Question: Is the concentration of an ore the only consideration when choosing whether to mine it or not?

**Mineral Commodity Lesson
Pre/Post Quiz**

Directions: Answer the following questions honestly before, and after, the lesson. After marking your answer before, you will turn it in, and it will be returned to you for completion afterward.

1) A mineral commodity is any mineral resource that can be purchased on the market.

Before:

After:

T or F

T or F

2) In an orebody, the “gangue” is the waste rock that does not contain any useful ore.

Before:

After:

T or F

T or F

3) Prices for commodities, like copper, are controlled primarily by demand, not supply.

Before:

After:

T or F

T or F

4) As mining continues over time, the industry experiences diminishing returns, which affect prices.

Before:

After:

T or F

T or F

5) The market prices of raw materials do not affect the cost of products purchased by homeowners, but are absorbed by various other steps in the supply chain.

Before:

After:

T or F

T or F

6) There is a robust market for mineral commodities in the form of scrap.

Before:

After:

T or F

T or F

7) The concentration factor necessary for profitable mining is the same regardless of the commodity in question.

Before:

After:

T or F

T or F