Lab Handout

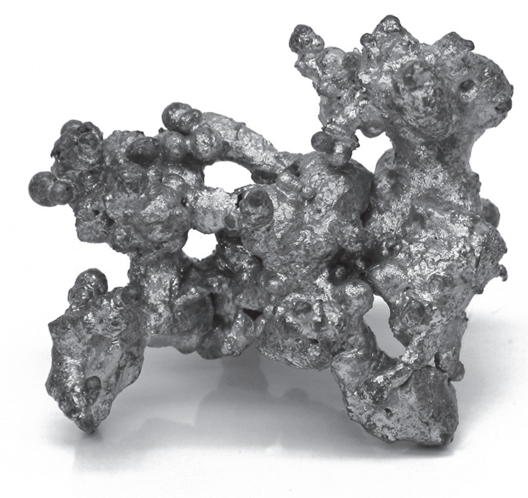
Lab 14. Distribution of Natural Resources: Which Proposal for a New Copper Mine Maximizes the Potential Benefits While Minimizing the Potential Costs?

Introduction

Copper is a useful metal because of its unique physical properties (see Figure L14.1). It is easily stretched, molded, and shaped; is resistant to corrosion; and is a good conductor of heat and electricity. People use copper to make the wires and pipes found in homes or businesses. In addition, manufacturing companies use copper to make the appliances (such as refrigerators and ovens) and consumer electronics (such as phones and computers) that we use in our homes every day. In addition, copper is an essential component in the motors, wiring, radiators, brakes, and bearings found in cars and trucks. The average car contains 1.5 kilometers (0.9 mile) of copper wire, and the total amount of copper in a vehicle can range from 20 kilograms (44 pounds) in a small car to 45 kilograms (99 pounds) in a large luxury or hybrid car (USGS 2009).

FIGURE L14.1

A sample of native copper extracted from a mine



Copper is a natural resource. Unfortunately, it is only located in a few specific sites around the world; these sites are called deposits. Earth scientists classify copper deposits based on the geologic process that created them. *Porphyry copper deposits,* which contain about 60% of the world's copper, form when a large mass of molten rock cools and solidifies deep in the Earth's crust. These deposits are large and often contain between 100 million to 5 billion metric tons of copper-bearing rock called ore. The ore in these deposits, however, only contains 0.2%–1% copper by weight. Porphyry copper deposits are often located in East Asia and in the mountainous regions of western North and South America. *Sediment-hosted copper deposits,* in contrast, form due to the deposition and subsequent cementation of sediments. Sediment-hosted copper deposits contain about 20% of the world's copper. These deposits are smaller than porphyry deposits and usually only contain 1 million to 100 million metric tons of ore. The ore in these deposits, however, often contains 2%–6% copper by weight. People have found sediment-hosted copper deposits in Zambia, Zaire, Europe, central Asia, and in the north central United States.

Most copper deposits, regardless of how they formed, have a definable boundary. An important component of the U.S. Geological Survey's (USGS) Mineral Resources Program is to identify the location and boundaries of untouched copper deposits, estimate the amount of copper that is likely in each one, and then share this information with scientists, other government agencies, and mining companies.

Copper deposits are often located far beneath Earth's surface. People therefore rely on mining companies to access and refine the copper in a deposit. A mining project often lasts for decades and include three major tasks. The first task in a mining project is to remove the ore from the deposit. Before miners can access the ore in a deposit, they must first remove the rock and soil that covers it. Miners call this rock and soil overburden. A deposit that is deeper costs more in terms of time and resources to access than a deposit that is near the surface. Mining companies tend to use underground or open-pit mining methods to remove overburden and the ore (see Figure L14.2 for an example of an open-pit copper mine).

The second major task is to separate the copper-based minerals from the ore. This task is called milling. This task is important because ore contains very little copper by weight, so

FIGURE L14.2

An open-pit copper mine in Bisbee, Arizona

most of the minerals within the ore is considered waste by mining companies. To separate the copper-based minerals from the ore, mining companies must first crush and grind the ore into a powder. Mining companies then use a method called froth flotation to separate the copper-based minerals from minerals that do not contain copper. The result of the froth flotation process is a solution called copper concentrate, which is about 25%–35% copper by weight.

The third major task is to make a pure copper metal that is usable by manufacturers. Mining companies accomplish this task by first mixing the copper concentrate with silica and the heating the mixture to 1200°C. This process, which is called smelting, removes many impurities and produces a liquid of copper sulfide that is about 60% copper by weight. This liquid is called copper matte. The mining company then heats the copper matte to remove the sulfur and produce a material called blister copper, which is about 99% copper by weight. Next, the blister copper is refined and molded into sheets so it can go through a chemical process called electrolysis that removes the few remaining impurities in the metal. After the electrolysis is complete, the resulting copper metal is about 99.95% pure. The mining company can then sell the pure copper by the pound to various manufacturing companies.

Like the majority of human activities, accessing and refining copper produces waste materials. Waste is a general term for any material that currently has little or no economic value. There are different types of mine waste materials that vary in their physical and chemical composition, their potential for environmental contamination, and how mine companies manage them over time. There are five major categories of mine waste:

- *Overburden* is the excess soil and rock that is removed to gain access to the mineral-rich ore. Overburden consists of acid-generating and non-acid-generating rock. Water that flows over or through acid-generating rock becomes more acidic. This acidic water can enter a nearby stream, river, or lake and cause environmental contamination.
- *Tailings* is a water-based slurry that is produced when a mineral is separated from an ore. It consists of finely ground rock, mineral waste products, and toxic processing chemicals. Mine companies typically store tailings in large artificial ponds (see Figure L14.3, p. 350). However, some companies are considering dumping tailings into oceans as an alternative method for disposal.
- *Slag* is a by-product of smelting. It consists of iron oxide and silicon dioxide. Slag is nontoxic and can be used to make concrete, roads, the grit used in sandblasters, and blocks for buildings.
- *Atmospheric emissions* include dust and the sulfur oxides from the smelting process. Atmospheric emissions vary in their composition and potential for environmental contamination.

FIGURE L14.3

Aerial photograph of the Kennecott mine tailings storage pond near Salt Lake City, Utah

- *Mine water* is the water that is used to extract, crush, and grind ore and to control dust. It often contains dissolved minerals and metals or trace amounts of processing chemicals. Mine water can enter nearby streams, rivers, and lakes and cause environmental contamination.

Although many historic mining operations were not required to conduct their mining activities in ways that would reduce the negative impact on the environment, current federal and state regulations now require mining operations to use environmentally sound practices to minimize the effects of mineral development on human and ecosystem health. In this investigation, you will have an opportunity to examine several different proposals for developing and managing a copper mining operation to determine which one maximizes the benefits of mining copper while minimizing the potential costs. This is important to consider because the United States currently uses more copper (1.8 million metric tons in 2016) for construction and manufacturing than it produces (1.41 million tons in 2016). Although the United States can reduce its need for new copper mining projects by implementing more conservation, reuse, and recycling programs, it is also important to consider ways to minimize the impact of mining projects when new ones are needed.

Your Task

Use what you know about the uneven distribution of natural resources; the economic, social, and environmental costs associated with accessing natural resources; the importance of looking for patterns; and the nature of cause-and-effect relationships to identify the best proposal for starting a new copper mining project. Your assessment of each proposal must include an analysis of the potential benefits and costs associated with each proposal to determine which one has the highest benefit-to-cost ratio.

The guiding question of this investigation is, ***Which proposal for a new copper mine maximizes the potential benefits while minimizing the potential costs?***

Materials

You may use the following resources during your investigation:

- Google Earth is an interactive map available at *www.google.com/earth*, and Google Maps is an interactive map available at *https://maps.google.com.*
- The U.S. Geological Survey (USGS) Global Assessment of Undiscovered Copper Resources is available at *https://mrdata.usgs.gov/sir20105090z*. This interactive map and database includes information about copper deposits all over the world.
- The USGS Mineral Commodity Summaries is available at *https://minerals.usgs.gov/minerals/pubs/mcs.* This online publication includes information about the market price of copper.
- Surf Your Watershed is available at *https://cfpub.epa.gov/surf/locate/index.cfm*. This Environmental Protection Agency (EPA) database provides information about stream water quality in different watersheds.
- The U.S. Fish and Wildlife Service Environmental Conservation Online System (ECOS) is available at *https://ecos.fws.gov/ecp/report/table/critical-habitat.html.* This system includes an interactive map that shows the location of protected habitats for threatened and endangered species.

Safety Precautions

Follow all normal lab safety rules.

Investigation Proposal Required? ☐ Yes ☐ No

Getting Started

Your teacher will give you several different copper mine proposals to evaluate. These proposals include different plans for accessing and refining the copper from a specific deposit within the United States. Mining companies must submit a proposal, which outlines their overall plan for developing and managing the extraction of a natural resource such as copper, to state and federal agencies for approval when they want to open a new mine. The overall plan for the mining project must be approved at both the state and federal level before the mining company can start digging. The copper mine proposals that you use during this investigation include the following information:

- Location of the mine
- Mining method
- Estimated life span of the mine
- Estimated number of new jobs that will be created when the mine opens
- Size of the site
- Total amount of ore (rock with copper in it) to be removed from the site
- Ore extraction rate
- Amount of waste that will be produced
- Waste management plan
- Expenses associated with opening, operating, and closing the mine

You will need to conduct a benefit-and-cost analysis of each proposal to determine which mine plan is the best one. A benefit-and-cost analysis requires the identification of the potential benefits of starting a new mining project and all the potential costs associated with opening, operating, and the closing the mine. Potential benefits associated with starting a new copper mine include such things as how much copper is in the deposit, how easy the deposit will be to access, how much ore that can be removed from the deposit, and the overall value of the copper on the open market. A mine can also have a positive impact on the local economy because it can create new jobs for people who live in that area. The potential costs, in contrast, include the amount of money needed to open, operate, and then close the mine, the negative impacts of mine waste on ecosystem health, and how the mine will be viewed by people who live in the area. You will therefore need to consider all of these issues, and potentially several others, as you conduct a benefit-and-cost analysis of each proposal during this investigation.

The first step in your benefit-and-cost analysis is to determine the location of each mine. To accomplish this step, you can enter the coordinates included with each proposal into Google Earth and/or Google Maps.

The second step in your benefit-and-cost analysis is to learn more about the copper deposit at a proposed location. You will need to use the USGS Global Assessment of Undiscovered Copper Resources database to accomplish this step. To use this database, simply zoom in on the location of the proposed mine on the interactive map. You can then click on the different deposits marked on the map until you find the name of the deposit you are interested in learning more about. You can then click on the name of the deposit to bring up information about it. As you use this resource, be sure to think about the following questions:

- What information will help you determine the potential benefits and costs of mining at this location?
- What would make one deposit more valuable than another deposit?
- How can you use mathematics to determine how much copper the mine could potentially produce based on the proposed amount of ore (rock with copper in it) that will be removed from the site?

The third step in your benefit-and-cost analysis is to determine the overall value of a proposed mine or the amount of revenue a mining company could potentially generate given the overall plan for a proposed mine. This is important to consider because a mine must be profitable to stay open. A mining company, in other words, must generate more money from selling the copper that it extracts from the mine than it spends to open, operate, and then close the mine. To determine how much money a mining company could make by selling the copper that it extracts from a mine, you can use the USGS Mineral Commodity Summaries. As you use this resource, be sure to think about the following questions:

- What information will help you determine the potential value of the copper in a deposit?
- How can you use mathematics to determine how much money a mining company could generate per day based on each copper mine proposal?
- What information will help you determine the potential cost of operating a proposed mine?
- How can you use mathematics to determine if a proposed mine will be profitable or not?

The fourth step in your benefit-and-cost analysis is to investigate the potential environmental impacts of each mine proposal. Mines can produce waste that can pollute water, contaminate soil, and destroy habitats. To determine potential environmental impacts of opening and operating mines, you will need to identify any streams, lakes, and important wildlife habitats around proposed mine sites. You can determine which streams and lakes are located near the proposed mine site by using Google Earth and/or Google Maps. You can also check the current water quality of these streams and lakes by accessing the Surf Your Watershed database. You can determine if there are any protected habitats of threatened or endangered species near a proposed mine by accessing the U.S. Fish and Wildlife Service Environmental Conservation Online System. As you use these resources, be sure to think about the following questions:

- What information will help you determine the potential environmental impacts of opening, operating, and closing a mine?
- What measurement scale or scales should you use to collect data?
- How can you describe or quantify the potential environmental impact of each proposed mine?
- What cause-and-effect relationships will you need to keep in mind as you use these resources?

The final step in your benefit-and-cost analysis is to choose between the different proposals based on the strengths and weakness of each one. To evaluate the trade-offs in each proposal fairly, you may want to create a decision matrix. A decision matrix includes rows for each proposal and columns that provide different evaluation criteria. Table L14.1 is an example of a decision matrix. Evaluation criteria might include such things as potential value of extracted copper, amount of waste produced, waste management plan, and potential habitat loss. You will need to determine which evaluation criteria to use based on what you know about the uneven distribution of natural resources and the economic, social, and environmental costs that are often associated with accessing natural resources. Once you have determined the evaluation criteria that your group will use, rank order each proposal on each criterion. Give the best option the highest number (which is a 4 if there are four different mining proposals) and the worst option a 1. You can then total the rankings, and the proposal with the highest overall score is the best one.

TABLE L14.1

An example of a decision matrix

Proposal	Evaluation criteria					Overall score
	1	2	3	4	5	
A						
B						
C						
D						

Connections to the Nature of Scientific Knowledge and Scientific Inquiry

As you work through your investigation, be sure to think about

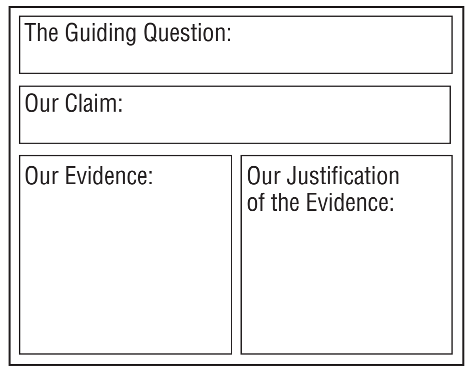
- how scientific knowledge changes over time, and
- the types of questions that scientists can investigate.

Initial Argument

Once your group has finished collecting and analyzing your data, your group will need to develop an initial argument. Your initial argument needs to include a claim, evidence supporting your claim, and a justification of the evidence. The *claim* is your group's answer to the guiding question. The *evidence* is an analysis and interpretation of your data. Finally, the *justification* of the evidence is why your group thinks the evidence matters. The justification of the evidence is important because scientists can use different kinds of evidence to support their claims. Your group will create your initial argument on a whiteboard. Your whiteboard should include all the information shown in Figure L14.4.

FIGURE L14.4

Argument presentation on a whiteboard



Argumentation Session

The argumentation session allows all of the groups to share their arguments. One or two members of each group will stay at the lab station to share that group's argument, while the other members of the group go to the other lab stations to listen to and critique the other arguments. This is similar to what scientists do when they propose, support, evaluate, and refine new ideas during a poster session at a conference. If you are presenting your group's argument, your goal is to share your ideas and answer questions. You should also keep a record of the critiques and suggestions made by your classmates so you can use this feedback to make your initial argument stronger. You can keep track of specific critiques and suggestions for improvement that your classmates mention in the space below.

Critiques of our initial argument and suggestions for improvement:

If you are critiquing your classmates' arguments, your goal is to look for mistakes in their arguments and offer suggestions for improvement so these mistakes can be fixed. You should look for ways to make your initial argument stronger by looking for things that the other groups did well. You can keep track of interesting ideas that you see and hear during the argumentation in the space below. You can also use this space to keep track of any questions that you will need to discuss with your team.

Interesting ideas from other groups or questions to take back to my group:

Once the argumentation session is complete, you will have a chance to meet with your group and revise your initial argument. Your group might need to gather more data or design a way to test one or more alternative claims as part of this process. Remember, your goal at this stage of the investigation is to develop the best argument possible.

Report

Once you have completed your research, you will need to prepare an *investigation report* that consists of three sections. Each section should provide an answer for the following questions:

1. What question were you trying to answer and why?
2. What did you do to answer your question and why?
3. What is your argument?

Your report should answer these questions in two pages or less. You should write your report using a word processing application (such as Word, Pages, or Google Docs), if possible, to make it easier for you to edit and revise it later. You should embed any diagrams, figures, or tables into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable or valid.

Reference

U.S. Geological Survey (USGS). 2009. Copper—A metal for the ages. U.S. Department of the Interior, USGS. Available online at *https://pubs.usgs.gov/fs/2009/3031/FS2009-3031.pdf*.