

Rocks, Redox, and Remediation

Mining in Vermont

Grade Levels 9-12

Objectives: In order to understand the essential question of, “How do human activities affect the environment?” students study historic images of copper mining in Vermont. Students learn about the process of copper extraction, copper smelting (laboratory), and the environmental impacts. Students study the EPA and its Superfund program, and learn about the management of the environmental impacts of the Ely Mine Superfund site.

Time Needed: 4 hours

Vermont’s Framework of Standards and Learning Opportunities:

7.16 Natural Resources (resource extraction, distribution, processing, and disposal)

7.15 Theories, Systems, and Forces (interactions of humans, resources, and the environment)

7.12 Matter, Motion, Forces, and Energy (observe/measure chemical properties & reactions)

Grade Level Expectations:

Chemical Change S9-12:15 (balance chemical equations and predict reactants and products)

Materials & Resources:

Landscape Change Program Archive, www.uvm.edu/landscape, Image LS11771_000

“Ely Mining House,” for example.

EPA’s Superfund website, <http://www.epa.gov/superfund/index.htm> and other web and print resources (below)

Computer Projector for displaying images from the archive for the whole class

Environmental Impact Discussion Prompt List (below)

Superfund Question List (below)

Activities:

1. Hook Your Students Students examine a dramatic image of a Vermont mine, develop questions about it, and search the <i>Landscape Change Archive</i> for answers.	4. Culminating Activity Students prepare and submit comments to the <i>Landscape Change</i> website, explaining the chemistry of roasting and smelting, and the environmental impacts of mining.
2. Introduce Concepts Students discover how they use copper in their own lives and how copper is produced (chemistry laboratory smelting reaction).	5. Assessment <i>Formative:</i> Discussions and homework assignments provide opportunities for adaptation of lessons. <i>Summative:</i> Rubric (below) for culminating activity.
3. Apply Skills Students write and then balance a formula for the smelting reaction they have witnessed. Students examine photographs and chemical formulas for evidence of environmental impacts, and discuss local versus global environmental impacts.	6. Extensions <ul style="list-style-type: none">• Explore acid-base reactions (sulfides increase metal contamination). Include lab activity and compare with previous redox reactions.• Research bioremediation of toxicity at mine sites. Follow up by creating a living machine in the classroom.

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Lesson Plan Details

Detailed summary of curricular format:

Overview: Students will observe a historic image without knowing where or when it was taken. They will make observations and generate a list of questions, which they will then answer through their own research in the Landscape Change archive. After discovering that the image is of a copper mine in Vermont, students will explore how they use copper in their own lives. They will learn how copper is produced by participating in a chemistry laboratory activity. Moving on to study the environmental impacts of copper mining and extraction, students will discuss environmental impacts, research the EPA's Superfund program, and learn about current environmental and health concerns related to Vermont's historic mine sites. Student work will culminate in the writing of two comments to be submitted to the Landscape Change Program. These comments will be reviewed by LCP staff before potentially being published on the website.

1. Day One: The Hook (One 60 minute class period): Show a dramatic image of an early mining site, for example LS11771_000 "Ely Mining Houses." Allow students 10 minutes to examine image in detail and write down two lists: observations and questions. Allow students to share their observations first, scribing for them (or allowing a student to scribe) onto the board or sheet of poster paper. Allow students to share their questions and write them down as well, leaving space for answers later during the lesson. Add questions if student list is weak, potentially including:
 - Where is this?
 - When was the picture taken?
 - What were the buildings used for?
 - What are the big piles of stone?
 - Why are there no trees?

Next, pose a challenge to the students: answer the questions they have developed using the Landscape Change Program. The first student to find out what was being mined should shout out the answer. Introduce students to the Landscape Change Program website, giving them a brief introduction to navigating the search engine, and then telling them that they will have 20 minutes to explore the website and try to answer some of the questions they have listed. (Be sure that they have enough information to find relevant images on the site. If they have figured out that the site is a mine, they should be on the right track. If they have not gotten that far, let them know that the site is in Ely, Vermont, a town that no longer exists. They can use "Ely" as a search term.) Have each student select one image that s/he finds most interesting or informative, and write down the image number.

When time is up, gather class back together to wrap up. Have students share answers to the questions, and write these on the board. If possible, use a projector to show the Landscape Change website. Using LS number, pull up

images that students found valuable and allow students to share what they got from these images.

Assign homework: Research as necessary to discover two objects you rely on in your daily life that contain copper. Answer the question, “What properties of copper make it an appropriate material for these products?”

2. Day Two: Where’s the copper?: Yesterday students explored visual images of Vermont’s historic copper mines. Today they will explore copper as a resource, answering two questions: why do we need copper? how do we get copper? Start by having students share the results of their research (the homework). Students should have discovered that copper is ductile and a good conductor of electricity, making it useful in electronics (as well as numerous other uses). In fact, copper is so valuable that robbers break into homes for the sole purpose of stealing copper wire and pipes to sell. If possible, have some copper wire, pennies, and other forms of copper available to pass around to students. Discuss some of the household uses that would have been common when the Ely Mine was in operation.

Having established the value of copper, begin exploring how we get it. One of the most common ores of copper is chalcopyrite, and in fact this is the ore present at the Ely Mine. The chemical formula for chalcopyrite is CuFeS_2 . Two chemical reactions needed to happen at the old mine to turn a rock called chalcopyrite into metallic copper. First came *roasting*, which consists of the conversion of the sulfide ore into an oxide, CuO . Another product of the reaction is sulfur dioxide (SO_2), which can oxidize into sulfuric acid in the atmosphere, eventually contributing to acid rain.

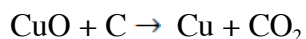
This point in the lesson provides an opportunity for teachers to introduce, review, or contextualize redox reactions, as the copper-containing mineral must be first oxidized, then reduced to isolate metallic copper. The following is a minimal exploration of the smelting reaction, but an additional lesson(s) could be inserted to teach oxidation numbers, different types of redox reactions, and balancing of redox reactions.

The next reaction occurs during a process called *smelting*, in which copper oxide is reduced to metallic copper by reaction with carbon. Write the reaction in words on the board: “copper oxide is reduced to metallic copper by reaction with carbon.” Explain that you are about to perform test tube smelting, and that the students’ challenge will be to determine whether a chemical change has taken place, and if so to write a balanced equation representing the reaction. This activity is taken from Herr and Cunningham (1999), page 267. It can be performed as a demonstration, or as a lab activity with students working in pairs or small groups.

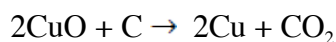
Mix approximately 2 grams of copper (II) oxide powder together with 4 grams of powdered charcoal. Pour the mixture into a Pyrex® or Kimax® test tube. Heat the test tube gently at first, tapping the tube with a glass rod to free trapped gas from the mixture. Once all the gas has escaped, heat the test tube vigorously in the hottest part of the flame for at least five minutes. *Always point the mouth of a heated test tube away from people.* Remove the test tube and allow it to cool in the air before pouring

out the powdered mixture. Notice that metallic copper (a reddish-brown deposit) remains on the surface of the test tube.

Have students identify the substance on the surface of the test tube. Using the sentence written on the board and their own observations, have students try to write out an equation for the reaction. Help guide them to get the following equation:



Students would have to reason to know that CO_2 forms in the reaction, so it may be necessary to prompt them by asking whether they observe a product other than copper metal. So, can they think of a colorless, odorless gas that contains both carbon and oxygen? Then have students balance the equation. They should end up with:



3. Day Three: Why aren't there trees in Ely?: Today students will re-examine the copper extraction reactions, as well as historic photographs, from the perspective of environmental impacts. First, have students return to the Landscape Change archive with two goals: (a) to find evidence in the images of the roasting and smelting processes (evidence includes: lack of trees, since wood was required to heat reactants and provide charcoal, the reducing agent for smelting; smoke; furnaces) and (b) to use the pictures to document environmental impacts of the mining activities. Return to the group to share findings, using projector to display images selected by students. Create a list on the board of evidence of environmental impact. Students are likely to focus on earth-moving and deforestation, as they leave the greatest scars on the landscape. Challenge students to recognize that these impacts are significant, but that they are local and concentrated. Do students see any evidence of impacts that would be more diffuse, affecting a larger region, or even having a global impact? They should deepen their exploration by looking back at the reactions involved in roasting and smelting. Both reactions require high temperatures, which are generated by burning wood, releasing carbon. Carbon dioxide is also released as a product of the smelting reaction ($\text{CuO} + \text{C} \rightarrow 2\text{Cu} + \text{CO}_2$). In addition, the release of sulfur dioxide in the roasting reaction contributes to acid rain. Allow time for discussion, using the following prompts.

Discussion Prompts:

- Which do you think are more severe and/or significant, the local or global impacts of copper mining? Why?
- Which impacts are easier to manage or abate?
- Though we still use copper, as Vermonters we no longer have to deal with its extraction in our backyards. Is this a good thing?

(At this point, you might choose to display images of modern copper mines, which can be found by doing a web image search using the search term “copper mine.”)

- Now that copper is being produced in huge, centralized mines far away from us, are we still subject to any of its environmental impacts? Which

impacts have decreased? Have any impacts intensified (here consider bringing up transportation and its environmental costs)?

Use the following question as a segue into the next activity:

- Do you think the Ely Mine site, which has been out of commission for a very long time, has any environmental impacts today?

After a few minutes of discussing the last question, explain that the Ely Mine is an EPA Superfund site. Hand out worksheet for homework assignment: to access the Superfund website to answer a series of questions. Students will have to navigate extensively around the site.

4. Day 4: Culminating Activity: Provide time at the beginning of class for students to share what they learned on the Superfund website and to ask any questions. This is a good time to talk about how fish were used as biological indicators of pollution and how sulfides increase metal contamination of water. Allow students to share their understanding and offer additional information or clarification as necessary.

Next, introduce the final activity. Each student will prepare two comments to submit to the Landscape Change Program. After review by program staff, those comments may be posted on the website. The first comment should relate to a specific image from the archive and explain some component of the copper mining and extraction process, including the chemistry involved. The comment should explain how the chosen image shows evidence of that activity. The second comment should explain at least one of the environmental impacts of copper mining. Again, the comment must relate directly to a chosen image from the archive. This activity will require students to return to the archive to select two images to comment on. Students will also need to continue the research that they began on the Superfund site. Provide them with the website for the Agency for Toxic Substances and Disease Registry website (<http://www.atsdr.cdc.gov/toxfaq.html>) which provides information on the toxicity of the various metals (aluminum, cadmium, cobalt, copper, zinc, iron, manganese, and lead) that have been found in higher-than-background levels at the Elizabeth Mine site. In addition, more research material on the Elizabeth Mine is available at <http://minerals.usgs.gov/east/environment/vt.html> and www.epa.gov/superfund/programs/aml/tech/elizabeth.pdf. Provide these website URLs to students.

Comments should be submitted to the teacher, along with the LS numbers of their chosen images, for review and grading before they are submitted to the program. Allow time for revisions, if necessary.

Bibliography

Herr, Norman, and James Cunningham. 1999. *Hands-On Chemistry Activities with Real-Life Applications*. San Francisco: Josey-Bass, A Wiley Imprint.

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Environmental Impact Discussion Prompt List

Facilitate a class discussion about mining's environmental impacts. If discussion tends to be dominated by a minority of the students, then tell students that they must be silent for 1 minute after each question. They should think about their answer and can make notes about their thoughts if they choose. Then proceed, having students raise their hands before speaking.

Discussion Prompts:

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- Though we still use copper, as Vermonters we no longer have to deal with its extraction in our backyards. Is this a good thing?
- Now that copper is being produced in huge, centralized mines far away from us, are we still subject to any of its environmental impacts? Which impacts have decreased? Have any impacts intensified (here consider bringing up transportation and its environmental costs)?

Use the following question as a segue into the next activity:

- Do you think the Ely Mine site, which has been out of commission for a very long time, has any environmental impacts today?

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Superfund Questions

Go to the Superfund website (<http://www.epa.gov/superfund/index.htm>) and write down your answers to the following questions. Be prepared! You will need to navigate through many of the website's pages and will need to do a fair amount of reading.

1. What is the EPA?
2. What is Superfund?
3. What is the purpose of the National Priorities List (NPL)?
4. How many sites in Vermont are on the NPL?
5. Find the site description for Ely Mine. How were fish species used as biological indicators of contamination at the site?
6. How does the presence of sulfides in the mine's tailings piles contribute to increased metal levels in the runoff?
7. What stage in the Superfund process is the Ely Mine currently in?
8. Find information pertaining to the Elizabeth Mine in Stafford, Vermont. Compare and contrast this site with the Ely Mine. Use the opposite side of this page as necessary.

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Comment Rubric

Comment 1: Copper Extraction Process

Teacher Score	Criteria	4	3	2	1
_____ 35	CONTENT -- Comment should include an explanation of some component of the copper extraction process. Comment should refer directly to the image, pointing out observable evidence of the explained process.	Shows excellent understanding of the chemical processes involved in copper extraction, and clearly explains how the image shows evidence of on-site copper extraction.	Shows good understanding of copper extraction process and relates that to selected image.	Shows some understanding of mining impacts. Refers, at least briefly, to image.	Shows limited understanding of copper extraction. May not relate specifically to image.
_____ 15	MECHANICS -- Comment should be clear and understandable with no typos or grammatical errors.	Comment is error-free, clearly written, and pleasant to read!	Comment is clear and error-free.	Comment may include some minor typos or grammatical errors.	Comment has not been adequately proof-read; it has several errors.

Comment 2: Environmental/Health Impacts of Mining

Teacher Score	Criteria	4	3	2	1
_____ 35	CONTENT -- Comment should include an explanation of some component of the copper extraction process. Comment should refer directly to the image, pointing out observable evidence of the explained process.	Shows excellent understanding of impacts of copper mining, including the health or environmental effects of a particular contaminant. Also clearly explains how the image shows evidence of impacts.	Shows good understanding of environmental and health impacts of mining and points out evidence in image.	Shows some understanding of mining impacts. Refers, at least briefly, to image.	Shows limited understanding of mining impacts. May not relate specifically to image.
_____ 15	MECHANICS -- Comment should be clear and understandable with no typos or grammatical errors.	Comment is error-free, clearly written, and pleasant to read!	Comment is clear and error-free.	Comment may include some minor typos or grammatical errors.	Comment has not been adequately proof-read; it has several errors.

Score from Comment 1

+ _____
Score from Comment 2

Total Score

Additional Comments: