EDC

Earth Science

TEACHER EDITION

LAB-AIDS
Experiencing Science

The following pages are select samples from

EDC Earth Science

Included in this packet are sections from the *Teacher Edition* to be used in conjunction with the provided sample equipment and *Student Book* pages. We encourage the use of all provided sample materials in or out of a classroom to properly understand the seamless integration between equipment, student materials, and teacher resources.

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CONTENTS

CHAPTER FIFTEEN

Hidden Treasures in Rocks: Mineral Resources

Overview

In modern society it's easy to feel isolated from the natural world and not appreciate how intimately humans are connected to Earth's systems. In this first chapter of Unit 6, students begin to explore their personal relationship with the geosphere, focusing on the mineral resources Earth provides that make modern life possible.

Minerals and materials extracted from minerals are used for a wide variety of purposes, from electrical wiring to airplane construction. To find these valuable materials, scientists must understand how they are concentrated into economically viable ore deposits over long periods of time by geological processes. Mining geologists use their understanding of plate tectonics and sedimentary processes to locate these important resources. The recovery and processing of minerals is not only costly monetarily but also in terms of energy use and environmental impacts.

In this chapter, students explore the properties that make certain minerals valuable and study what it takes to be successful in finding, mining, and processing a mineral resource. They become experts in a process by which mineral ores are concentrated within Earth's crust and develop a demonstration with which they teach what they have learned to their classmates. They learn about the variety of methods for mining mineral ore and about the steps typically necessary to process and refine the ore into useful materials. Ultimately, they prepare a business plan that describes how they would develop and market a mineral resource.

Goals for Student Understanding

This table shows alignment of *Framework for K–12 Science Education* (the *Framework*) content, practices of science and engineering, and crosscutting concepts with chapter learning objectives. This is not intended to be used as a checklist, but it shows how students' learning experiences in *EDC Earth Science* map to the *Framework* goals.

Chapter Learning Objective	Framework Content, Practices, and Crosscutting Concepts	Where Taught
Students understand that the majority of the minerals that modern civilization relies on are relatively rare in Earth's crust. Such minerals are concentrated into economically viable ore deposits by natural geologic processes. Scientists use their understanding of these geologic processes to locate mineral resources.	ESS3.A.1, ESS3.A.2 Analyzing and interpreting data Planning and carrying out investigations Using mathematics and computational thinking Constructing explanations Engaging in argument from evidence Obtaining, evaluating, and communicating information Scale, proportion, and quantity Systems and systems models Energy and matter	*Activity 1*—"Where Are the Mineral Ores?" *Activity 2*—"Prospecting for Mineral Ore"
Students know that mineral ores are extracted from Earth in a variety of ways, including surface pit mining, dredging, and deep mining by tunneling below Earth's surface. The minerals are then purified and processed into useful materials by refining and smelting techniques. These methods are expensive, are energy intensive, and have associated environmental impacts.	ESS3.A.3 Using mathematics and computational thinking Planning and carrying out investigations Constructing explanations Engaging in argument from evidence Obtaining, evaluating, and communicating information Cause and effect Energy and matter	*Reading*—"From Rocks to Riches—Mining and Processing Mineral Ore" *Activity 3*—"Refining an Ore"

Possible Misconceptions and Barriers to Learning

To understand how mineral deposits form within Earth, students need to visualize processes that occur underground and over very long periods of time. Understanding the chemical processes involved requires that students visualize processes that occur on a scale too small to see. This may be difficult for some students.

Assessment Outcomes

Students should be able to

1. demonstrate and explain some of the processes and conditions that lead to the development of economically viable mineral deposits.
2. use data from chemical tests and topographic maps to determine the likely location of mineral ore.
3. describe methods for extracting and processing mineral resources.
4. perform an experiment to demonstrate a way to refine mineral ores.
5. explain the costs associated with finding, extracting, and processing mineral resources. including hidden costs associated with environmental harm.

Assessment Strategies

Students have a number of opportunities in this chapter to show their initial and developing understanding of mineral resources and their importance to modern society. By taking note of the answers given by students completing group work or working individually, you can determine pacing, identify which concepts need more or less emphasis, and gauge students' understanding of the content by the end of the chapter. The following table summarizes the formative and summative assessment opportunities.

The table also provides an alignment between the student assessment outcomes and the assessment items at the end of the chapter. You should determine ahead of time which of these assessment opportunities you will evaluate formally (assign a grade) and which you will evaluate more informally. In general, the *Consider* and *Investigate* sections provide opportunities for formative assessment, and the *Process* section provides opportunities for summative assessment.

Opportunities	Information Gathered
Consider	
Brainstorming	Students' current understandings of the natural sources of materials in the objects around them
What's the Story?—"Pikes Peak or Bust: 1859"	Students' initial ideas about why certain minerals are valuable and how one would obtain them
Task—"What Makes a Metal, Rock, or Mineral Valuable?"	Students' abilities to recognize what makes certain minerals valuable enough that people would invest large sums of money in finding them; their initial ideas about the scientific knowledge necessary to be successful in the mining business.
Investigate	
Activity 1—"Where Are the Mineral Ores?"	Assessment Outcome 1 (Assessment items 1, 2, 4, 5)
Activity 2—"Prospecting for Mineral Ore"	Assessment Outcomes 2 and 5 (Assessment items 7, 9, 12)
Reading—"From Rocks to Riches—Mining and Processing Mineral Ore"	Assessment Outcomes 3 and 5 (Assessment items 7, 10, 12, 13)
Activity 3—"Refining an Ore"	Assessment Outcomes 4 and 5 (Assessment items 7, 12)
Address the Challenge	The student's ability to synthesize the key concepts covered in this chapter.
Process	
Share	Students' abilities to communicate their understandings of the key concepts covered in this chapter
Discuss	Students' understandings of the type of scientific knowledge that is necessary to obtain and use mineral resources; their ideas about the importance of mineral resources to the technological advancement of society and their thoughts about how to minimize environmental damage.
Assessment	Students' understandings of the range of concepts presented throughout the chapter; these questions can be used in class, for homework, or as a quiz at the end of the chapter

Scope and Sequence

The following is provided to help with your lesson planning, and should be adjusted according to the needs and interests of your classroom, and the tasks and readings you assign as homework.

WEEK			DAY		PREVIEW
1	**Consider**		1	*Brainstorming*	Students brainstorm about their understanding of what the objects around them are made of and where these materials came from.
			2	*What's the Story?*—"Pikes Peak or Bust: 1859" *Task*—"What Makes a Metal, Rock, or Mineral Valuable?"	• Students read a story about a prospector who finds gold in a mountain stream. They begin to think about why mineral resources are valuable and how to obtain them. • Students explore what makes certain minerals valuable, investigate the useful properties of some metals ,and review facts and figures about the quantities of rocks, minerals, and minerals they use in their lifetime.
	Investigate	Gather Knowledge	3	Introduce *Challenge*	Students gain expertise in the ways that mineral deposits form within Earth and, preparing a physical demonstration, share this information with their classmates.
			4	*Activity 1*—"Where Are the Mineral Ores?"	
			5	*Activity 2*—"Prospecting for Mineral Ore"	Students perform chemical tests and search for a layer of rock that contains the valuable mineral molybdenum.
2			6	*Reading*—"From Rocks to Riches—Mining and Processing Mineral Ore"	Students learn about how mineral ores are found, mined, and processed to make useful materials. They think about the costs of using mineral resources in terms of energy use and environmental impacts.
			7	*Activity 3*—"Refining an Ore"	Students perform a two-part process to refine copper from malachite.
		Address the Challenge	8	Research business plan	Students develop a business plan that describes how they would develop and market a mineral resource. They apply the knowledge gained in this chapter to research why people want this material. They propose a strategy for finding the mineral ore and describe how the ore forms and how it is found, mined, and processed. They summarize this strategy in a handout, such as a brochure, and prepare to share their plans with their classmates.
			9	Write business plan and develop sales pitch	
	Process		10	*Share* business plans and sales pitches	Students share their business plans by presenting a brief sales pitch to their classmates. They are given the opportunity to invest in their classmates' plans.
3			11	*Discuss*	Students discuss the broader implications of society's dependence on mineral resources. They think about how mineral resources have allowed civilization to advance technologically, the true costs of extracting and using this natural resource, and the environmental impacts.
			14	*Final Reading*—"Ore from Earth"	Students read about and consider the impact of extracting ores from the Earth.
	Assessment		15	*Summative Assessment*	

Materials and Preparation

Note: All reproducible pages (Student Sheets, Literacy Supplements, and Resource Supplements) and many images from the student book can be found in the Teacher Resources as PDFs or slide presentations.

You may choose to use the following optional Literacy Supplements:

- Literacy Supplement 15.1: *Anticipation Guide* for "From Rocks to Riches—Mining and Processing Mineral Ore"

Prior to the *Task*—"What Makes a Metal, Rock, or Mineral Valuable?"

1. Gather the materials listed below.

FOR EACH GROUP OF STUDENTS

- 1 copper strip
- 1 steel strip
- 1 aluminum strip
- 1 rock sample containing garnet (in schist)
- 1 talc sample
- 1 glass scratch plate
- (optional)1 conductivity tester*
- (optional) magnifying lenses*
- (optional) balance*

FOR EACH STUDENT

- Student Sheet 15.1: *Composition, Properties, and Uses of Common Metals and Minerals*

*not included in LAB-AIDS equipment package

Prior to *Activity 1*—"Where Are the Mineral Ores?"

1. Gather the materials listed below.

FOR THE CLASS

- materials* for students to use when building physical models, such as: sand, metal filings, rice, beakers, water, hot plate, sugar, salt or alum, objects of the same size that are less dense and denser than water (e.g., wood plugs and metal screws)

FOR EACH STUDENT

- (optional) Resource Supplement 15.1a: *Questions about the Expert Readings*

*not included in LAB-AIDS equipment package

Prior to *Activity 2*—"Prospecting for Mineral Ore"

1. Gather the materials listed below.

FOR THE CLASS

- 24 vials of Test Site Sediment Samples, labeled 1–24
- 24 stir sticks (1 for each vial of sediment sample)

FOR EACH GROUP OF STUDENTS

- 1 15-mL dropper bottle of molybdenum testing solution

FOR EACH TEAM OF STUDENTS

- $5,000 LAB-AIDS Mining Money
- 1 LAB-AIDS Chemplate
- 1 set of Sample Site Choice Cards
- 1 Prospector Peak Quadrangle Topographic Map

FOR EACH STUDENT

- Student Sheet 15.2: *Prospector Peak Sampling Map*
- safety eyewear*

*not included in LAB-AIDS equipment package

2. The 24 vials of sediment samples should be arranged so that you can easily access the sample requested, collect the "prospector" fees for obtaining and testing samples, and closely monitor what students do with the samples.

Prior to *Activity 3*—"Refining an Ore"

1. Gather the materials listed below.

FOR THE CLASS

- sample of malachite rock
- copper strip (or other sample of copper)
- supply of crushed malachite (need ~ 0.5 g /group)
- supply of iron powder (need ~ 0.1 g /group)
- container* for collecting liquid waste

FOR EACH GROUP OF STUDENTS

- 1 60-mL bottle of 1 M sulfuric acid (H_2SO_4)
- 1 LAB-AIDS AB tray
- 1 plastic filter funnel
- 1 coarse filter-paper circle
- 1 fine filter-paper circle (see Step 3 below)
- 1 30-mL graduated cup
- 1 plastic cup
- 1 white scoop
- 1 dropper
- 1 stir stick
- access to paper (or cloth) towels*

FOR EACH STUDENT

- safety eyewear*
- (optional) Resource Supplement 15.2: *Consider a Can*

*not included in LAB-AIDS equipment package

2. As the activity is written, students dispense their own 7.5-mL sample of 1 M sulfuric acid (H_2SO_4). You may instead choose to dispense the acid to each group as needed.

3. Because the filter-paper circle is not distributed until Procedure Step 13, it is not listed in the Student Book Materials list.

Prior to *Address the Challenge*

1. Gather the materials listed below.

FOR EACH STUDENT

- (optional) Resource Supplement 15.3: *Note Sheets for Business Plan Research* (helps students organize their research).

thickened, such as along convergent plate boundaries. This thickening pushes some rocks deeper into Earth, raising their temperature and increasing the pressure. Under these conditions, water can become heated and squeezed into cooler rocks, dissolving, reprecipitating minerals, and forming hydrothermal deposits. Magma bodies are often found deep at the roots of mountains where temperature and pressure conditions are high, and also beneath volcanoes that occur along subduction zones. The slow cooling of this magma can cause the concentration of minerals into ore deposits. As the mountains erode and rock is exposed at the surface, minerals from these rocks are transported downstream and deposited in placer deposits.

3. Gold is found in sedimentary rock in Africa. Describe how gold could have been concentrated in these rocks. *The sedimentary rocks may be composed of sediments that were eroded from mountains and deposited as placer deposits in river valleys.*

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gold, using the same technique used by Jackson to identify flecks of gold in the river sediment.

Analysis

Complete the following questions and record your answers in your notebook. Be prepared to share your answers with the rest of the class.

1. Describe a way that groundwater could become heated and then cool down. How does this relate to the formation of hydrothermal deposits?
2. If you look at the history of mining, it is clear that most concentrated mineral ores have been found in rocks associated with ancient or current mountain belts. Why is this the case?
3. Gold is found in sedimentary rock in Africa. Describe how gold could have been concentrated in these rocks.

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Now that you know how ore deposits form, you need a bit more practical information about how to find these resources. Do some mineral prospecting in the next activity.

ACTIVITY 2
Prospecting for Mineral Ore

Setting the Stage: How Do Geologists Look for Mineral Ore?

Geologists prospecting for a particular mineral ore must first have a good understanding of the geologic environment in which that mineral can become concentrated. Certain minerals, for example, are more typically found concentrated within cooled and crystallized magma bodies near subduction zones. Others are more typically found near rift zones, or alternatively, where hot water has flowed through fractures in sedimentary rock. Therefore, a geologist must be familiar with the geologic history of an area. Prospectors can learn about this from published maps and studies, and by studying satellite images. They also perform fieldwork—studying outcroppings of bedrock and rocks below the surface by drilling test borings, using equipment such as magnetometers, and even studying river sediments that have carried traces of minerals downstream from the ore source.

In this activity, search for a layer of rock that contains a valuable mineral called molybdenum (muh-LIB-duh-num). Economic and environmental considerations, especially in mountainous regions, would make the drilling of core samples nearly impossible. However, mining companies have come up with an effective method of tracking down the location of valuable ore deposits by testing sediments collected in strategic spots along river systems.

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ACTIVITY 2
Prospecting for Mineral Ore

In this activity, students are introduced to the basics of geochemistry and how it helps pinpoint possible mineral deposits of economic importance.

Facilitating *Activity 2*—"Prospecting for Mineral Ore"

- Put the 24 sediment samples someplace in the classroom where you can closely monitor how students handle the samples. Collect the money it would take to obtain a sample and test it. The samples are all numbered so as to correspond with the sampling sites noted on the river system of the Prospector Peak Quadrangle Topographic Map. In the real world, it is costly to both obtain and test sediment samples. Real mining companies must operate within a budget and cannot afford to waste money on over-testing. In this activity students' companies are faced with the same challenges. In this simulation, each mining company has $5,000 to spend and must pay the $500 cost of collecting and testing each sample.

As water works its way along the earth's surface and through the ground, it picks up small amounts of the minerals found in the rocks—not enough to create placer deposits in the river sediments such as the ones you learned about in Activity 1, but enough to leave clues that can be followed back to the original ore deposit in the bedrock. The closer the section of river is to an ore deposit, the greater the amount of it will be detectable on the river sediments.

Safety Note

Always use caution and wear safety eyewear when using Molybdenum Testing Solution. Quickly and thoroughly rinse off any that gets on you and report any spills to your teacher.

Materials

FOR EACH GROUP OF STUDENTS

- bottle of molybdenum test solution

FOR EACH TEAM OF STUDENTS

- $5,000 "Mining Money"
- Prospector Peak Quadrangle Topographic Map
- Student Sheet 15.2: *Prospector Peak Sampling Map*
- Set of Sample Site Choice Cards (1–24)
- Chemplate
- stir stick

FOR EACH STUDENT

- safety eyewear

Procedure

Record your observations and answers in your notebook as you work.

1. With your partner, form a mining company. Decide on a name for your company and record your company name and the names of its founders in your notebook.
2. Study the Prospector Peak Quadrangle Topographic Map, which uses contour lines to show points of equal elevation. Review the information provided in the bottom margin, and answer the following questions.
   a. What is the highest elevation on the map? The lowest elevation?
   b. What is the elevation difference between two contours?
   c. What would be the change in elevation for someone going from the top of Glacier Mountain to the river junction near Sample Site No. 9? (See the legend for the Sample Site symbol.)
   d. The river system is highlighted in blue and drains the section of land shown on the map. A main river and two major tributary streams make up the system. The main river flows down the valley between Bear Ridge and Prospector Peak. Using compass points (N, NW, NE, S, SW, SE, E, W), describe the direction the river is flowing. (*Hint:* The river will flow from higher elevations to lower elevations)
   e. Sediments are carried by water along the river over time. Which way are the sediments in the river moving?
3. Now it is time to begin gathering data to try to decide where the molybdenum ore deposit is located. Keep in mind the following:
   - Your mining company has a budget of $5,000 to spend exploring for the mineral molybdenum
   - You will have access to 24 different sediment samples taken from the river near each numbered location on your map.
   - Each sample will cost your company $500 to obtain and test so you will only be able to test a maximum of 10 samples.
   - All of your samples do not need to be selected at one time, but since time is money, you will need to make your decisions wisely and efficiently.

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- This activity is designed for students to work in teams of two while sharing some materials with another team of two.
- Have students read the introductory section. While they are reading, distribute a topographic map to each team of two.
- When students have finished reading the introduction, respond briefly to any questions or comments, and, if needed, review how to read and use a topographic map.
- Distribute the rest of the materials, and explain how each team will form a "mining company" that must carefully study the topographic map and decide which sample sites to test. Go over the following guidelines:
  - Each mining company has a strict budget that allows testing of no more than 10 sample sites.
  - Sample sites should be chosen and tested one (or two) at a time. Teams evaluate those test results, which helps them choose the next site(s) to test. Explain that they should record their test results on Student Sheet 15.2: *Prospector Peak Sampling Map,* which will also help them plan for further testing.
  - To obtain a sample, one student should bring the Chemplate, the sample site card(s) for the site(s) they want to sample, and enough LAB-AIDS money to obtain the sample(s) from the teacher or another designated facilitator.
  - *Note:* To minimize eavesdropping by rival companies, students are not to verbally communicate their sample site numbers but instead should silently use the appropriate Sample Site Choice Card to communicate which sample they want to test.
  - To test a sample, a student places one stir stick scoop full of the sample in a numbered well on the Chemplate, and returns to his or her team's work area. There they carefully add 1 drop of the molybdenum test solution to the sample, gently agitate the sample, wait 10–15 seconds, and observe the color. From the concentration range chart (Table 15.6) they determine the concentration of molybdenum in the sample.
  - Point out that teams should continue paying for and testing additional sample sites until they either run out of money or are confident that they have located a hot site containing a high concentation of molybdenum. Money not used for collecting and testing samples can be

used to purchase the mining rights to the land area around the hot site.

- Encourage students to begin the activity, and circulate to each team to make sure they are employing a logical system for tracing down the site of the molybdenum deposit. The most logical plan is to first choose a downstream sample site. If they find even a small amount of molybdenum, they then trace the concentration gradient upstream until the hot site is located.
- Once a team either locates the hot site or runs out of money, have them clean up their tools and respond to the Analysis questions.
- The colors and concentration ranges (in parts per billion) for the Sample Sites are listed below:

SAMPLE SITE COLORS AND CONCENTRATION RANGES (PARTS PER BILLION)

COLOR	MOLYBDENUM CONCENTRATION (PPB)	TEST SITE NUMBER(S)
yellow	less than 0.1	1–15, 23
blue	0.1–1.0	20–22, 24
blue/green	1.1–10.0	17–19
red	>10.0	16 “Hot Site”

4. Make a data table in your notebook with headings as shown in Table 15.5, but with 10 empty rows, one for each sample you will test.

Table 15.5: Sediment Sample Test Results

SEDIMENT SAMPLE SITE NO.	TEST COLOR	MOLYBDENUM CONCENTRATION (ppb)

5. Once your company decides which sample site(s) to test, send a representative with your Chemplate, and $500 per site, to purchase sample(s) from the teacher. Do not share information with other companies or speak the name of your sample site(s), in case “spies” from neighboring companies are listening. Use the Sample Site number cards to communicate.
6. Obtain one level stir-stick scoop of your purchased river sediment sample(s) and place it in an empty small well on the Chemplate. Return to your work area and, with your partner, carefully add 1 drop of the molybdenum test solution to each sample, and wait 10–15 seconds.
7. Observe the color of your sample(s). Use Table 15.6 to determine the concentration of molybdenum in each sample. Carefully record your results on your map in Student Sheet 15.2 as well as in your data table. Remember: The stronger the concentration, the closer the sampling spot is to the “mother lode” ore deposit.

Table 15.6: Concentration Range of Molybdenum

TEST COLOR	MOLYBDENUM CONCENTRATION IN PARTS PER BILLION (ppb)
Yellow	Less than 0.1
Blue	0.1–1.0
Blue-green	1.1–10.0
Red	> 10.0

8. Continue purchasing and testing additional sample sites until you either run out of money or are confident that you have located a “hot spot” for a deposit of molybdenum. Remember to record all your results in your data table.
9. Write up your recommendations for interested investors who may be willing to purchase the mineral rights and contribute money toward mining operations. Describe the following:
   a. The location of the area that you think should be mined for molybdenum ore.
   b. The logic your company used to decide which of the 24 sites to sample.
   c. The evidence you have that supports mining in your recommended location.
   d. The amount of money you spent locating the mineral resource. Do you have any left to purchase the mineral rights before other companies snatch them up?

Science Background

Prospecting by Water and Sediment Sampling and Analyses

As water works its way across Earth’s surface and through the ground, it picks up small amounts of the rocks and minerals found in the Earth materials it has encountered. Some of these are carried along as sediments, and others dissolve into the water. Tests of water and sediment samples collected from strategic locations along a river drainage basin can determine mineral abundance. With this information, a potentially valuable source of mineral, or “hot” site, is pinpointed. In this activity students test simulated “sediment samples” for the presence of “molybdenum.”

Responses to *Analysis* for *Activity 2*—“Prospecting for Mineral Ore”

1. You’ve just simulated what it’s like to explore for mineral ore by following traces in river sediments. Describe the type of work you might do if you actually had a career in the field of mineral exploration. What type of work might you do in the field? What type of work might you do in a laboratory or office? *Students’ responses may include field work collecting samples, lab work analyzing samples, and office work mapping results.*

2. Let’s say your mining company locates a molybdenum deposit and has purchased the mining rights. Removing the mineral from the ground requires digging a big open pit mine. The mineral itself makes up only a small percentage of the rock removed, so tons and tons of waste rock (called tailings) will have to be dumped nearby. On the other hand, the mine will bring jobs to the community. Weighing economic and environmental factors, do you think this deposit should be mined? Justify your answer. *Responses will vary widely. When discussing this question, emphasize the importance of looking at evidence (rather than leaning on opinion or emotion) when grappling with decisions that involve complex situations with many facets.*

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10. Wash out the chemplate, clean up your area, and return your materials to the proper location. Then, write answers to the Analysis questions and be prepared to share them with the class.

Analysis

Complete the following questions and record your answers in your notebook. Be prepared to share your answers with the rest of the class.

1. You’ve just simulated what it’s like to explore for mineral ore by following traces in river sediments. Describe the type of work you might do if you actually had a career in the field of mineral exploration. What type of work might you do in the field? What type of work might you do in a laboratory or office?
2. Let’s say your mining company locates a molybdenum deposit and has purchased the mining rights. Removomg the mineral from the ground requires digging a big open pit mine. The mineral itself makes up only a small percentage of the rock removed, so tons and tons of waste rock (called tailings) will have to be dumped nearby. On the other hand, the mine will bring jobs to the community. Weighing economic and environmental factors, do you think this deposit should be mined? Justify your answer.

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Finding the mineral ore is challenging work, but once you find it your work isn’t done. You then have to remove the ore from the ground and process it so that it’s useful. The next reading discusses how this is done.

READING

From Rocks to Riches—Mining and Processing Mineral Ore

FIGURE 15.8
The Bingham Canyon Mine in Utah is an open pit copper mine.

How Are Minerals Mined?

After a mineral ore is discovered, it must be removed from the ground and separated from the gangue (pronounced gang; the nonvaluable minerals also contained in the ore). A number of techniques are used to mine minerals.

Open Pit Mines

Sometimes, minerals are excavated in open pit mines, such as the copper mine in Figure 15.8, using heavy, earthmoving equipment such as bulldozers, scrapers,

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READING

From Rocks to Riches—Mining and Processing Mineral Ore

To help students understand how they might obtain a mineral resource, this reading describes methods of prospecting and some of the most common ways that the ore is mined. It also summarizes the steps typically involved in processing and refining ore to make useful materials. Have students complete this reading and the About the Reading questions that follow. Then discuss the questions as a class.

Teaching Strategies

You might want to have the class take a virtual field trip to some mines via Google Earth. Search for the Bingham Canyon copper mine in Utah, and “fly” through this enormous open pit mine. Search for Alma, Colorado, access the satellite map, follow the river valley south along Rte. 9, and observe the many places where dredging for placer deposits has occurred and the scars are still evident. If you have mines in your state, you might want to look for these mines as well.

Responses to *About the Reading* for “From Rocks to Riches”

1. To gain a better understanding of the scale of mining operations at the Bingham Canyon Mine in Utah, make some comparisons to objects that might be familiar to you.
   a. The Bingham Canyon Mine covers more than 2,000 acres. A typical city block covers approximately 5 acres. How many city blocks would fit in the areal extent of the mine? *Four hundred city blocks would fit in the mine.*
   b. The Bingham Canyon Mine is more than a half-mile deep. Compare this to the structures in Table 15.7. Would they fit in the m ine excavation? Would more than one of them stacked on top of each other fit? If so, how many would be in the stack?

STRUCTURE	HEIGHT (feet)
Empire State Building	1,472
Space Needle in Seattle	605
U.S. Capitol Building	288
Your school building	___ (*Hint:* one story = ~12 feet)

If two Empire State Buildings were stacked on top of each other, the top one would just stick out of the mine: the depth of the mine is ½ mile, or 2,640 feet, so 1.8 Empire State Buildings, 4.4 Space Needles, or 9.2 U.S. Capitol Buildings would fit. If the school is two stories tall, approximately 110 school buildings stacked on top of each other would fill the mine to its full depth.

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and draglines, as well as blasting. Some of these open pit mines are huge, and the trucks used to excavate rocks have wheels taller than a person. The Bagger 288, shown in Figure 15.9, weighs 13,500 tons, and it is 311 feet tall and 705 feet long! The Bingham Canyon Mine, also known as the Kennecott Copper Mine, in Bingham, Utah, is one of the largest of all human-made excavations. It covers almost 2,000 acres, stretches more than 2.5 miles across at the rim, and is more than a half mile deep. It is so large that it is visible to the naked eye from the orbiting space shuttle. More than $6 billion worth of copper and other minerals have been excavated from this mine. This includes more than 17 million tons of copper, 715 tons of gold, 5,900 tons of silver, and 380,000 tons of molybdenum!

FIGURE 15.9
The Bagger 288 bucket-wheel excavator is one of the largest land vehicles of all time.

Dredging for Placer Deposits

The mining of placer deposits from riverbeds also involves moving impressive amounts of earth materials, as shown in Figure 15.10. Dredges, often as large as a three-story house, process as much as 1,000 tons of sand and gravel per hour. They use buckets on a continuous chain or rotary cutting heads and a suction hose to remove material from below the water surface. The mineral particles are separated from the sand and gravel, and conveyors on the dredge then deposit the waste in the area already excavated.

FIGURE 15.10
The sediment in this river valley in Russia has been dredged to recover platinum placer deposits.

Deep Mining

Deeper mineral deposits are accessed by tunneling into rock below the ground. Mines are often made by digging a vertical shaft where the desired mineral is concentrated. Then horizontal passages are excavated at different levels off of this shaft, as shown in Figure 15.11. The ore is drilled, blasted, or excavated, and transported back to the ground surface using mechanized carriers or conveyor belts.

Although the first minerals mined by humans were excavated from the surface, deeper and deeper mines are dug today to mine precious mineral resources. The deepest mines in the world are the gold mines in South Africa. Some of these mines are close to 4 km in depth. The TauTona Mine,

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   c. On April 10, 2013, a huge landslide sent nearly 70 million cubic meters of material tumbling thunderously down the side of the Bingham Canyon Copper pit. Some equipment was damaged but there were no human injuries because the mining company had installed special safety equipment to monitor slope stability in the mine. It was able to issue a warning and shut down operations before the slide occurred. Describe other safety issues that may need to be addressed when planning to develop a mineral resource. *Students may be familiar with some mining disasters that have been in the news—particularly those associated with deep mining, as people can become trapped when tunnels collapse, or be asphyxiated by toxic gases or low oxygen conditions. There are safety issues associated with the operation of large machinery used to excavate and convey mineral ore as well.*

Teaching Strategies

You may want to give students this question for extra credit:

If all the excavated materials from the Bingham Canyon Mine were piled up, approximately how big would that pile be? If this pile were dumped on New York City's Manhattan Island, how much would it cover? Show and explain your calculations.

Students will have to do some research to answer this question. Manhattan Island covers approximately 20 square miles, or 12,800 acres. Midtown Manhattan, which contains the majority of the city's skyscrapers, covers about 600 acres. If you assume the pile of excavated material was the same shape as the excavation, the pile would completely bury midtown Manhattan and would be higher than the tallest building.

3.9 km (2.4 miles) in depth, has about 800 kilometers (~500 miles) of tunnels and employs approximately 5,600 miners. It can take as much as one hour for a worker to travel from the surface to the bottom, descending in a cage at a rate of 16 meters a second. The pressure on the rocks at a depth of 3.5 km (2.2 mi) is more than 9,500 tons per square meter (900 times normal atmospheric pressure). Also, the temperature of Earth's rocky crust increases with depth. This means that miners need special cooling equipment to endure temperatures up to 59°C (138°F) while working.

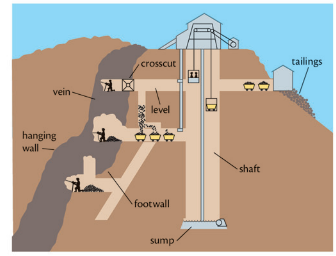

FIGURE 15.11
Deep mineral deposits are accessed and recovered by excavating vertical shafts and horizontal tunnels at different levels.

Processing the Minerals

A great deal of effort is involved in extracting minerals from the ground, but once removed, the work is not done. After the mineral ore is recovered, it is processed to separate it from the gangue and concentrate the mineral further. The first processing steps usually involve crushing the ore in a mill. Producing smaller pieces allows the subsequent steps of physically and chemically separating the desired mineral(s) from the waste to proceed more efficiently. Physical separation often uses acids or other caustic solutions.

Then the minerals are transported to industrial facilities where they are further processed. As mentioned previously, many of the metals you use must be extracted from minerals. This is done by a process called smelting, which involves heating the ore until it melts and then separating the desired metal from the molten mixture, as shown in Figure 15.12.

After smelting, the ore often requires further refining to remove even more impurities. Once refined, different molten metals can be combined in specific ratios to form an alloy. Alloys are usually harder, stronger, and more resistant to corrosion than the component metals, making them more useful. Steel is an alloy, consisting mainly of iron with smaller amounts of other elements. There

FIGURE 15.12
Smelting.

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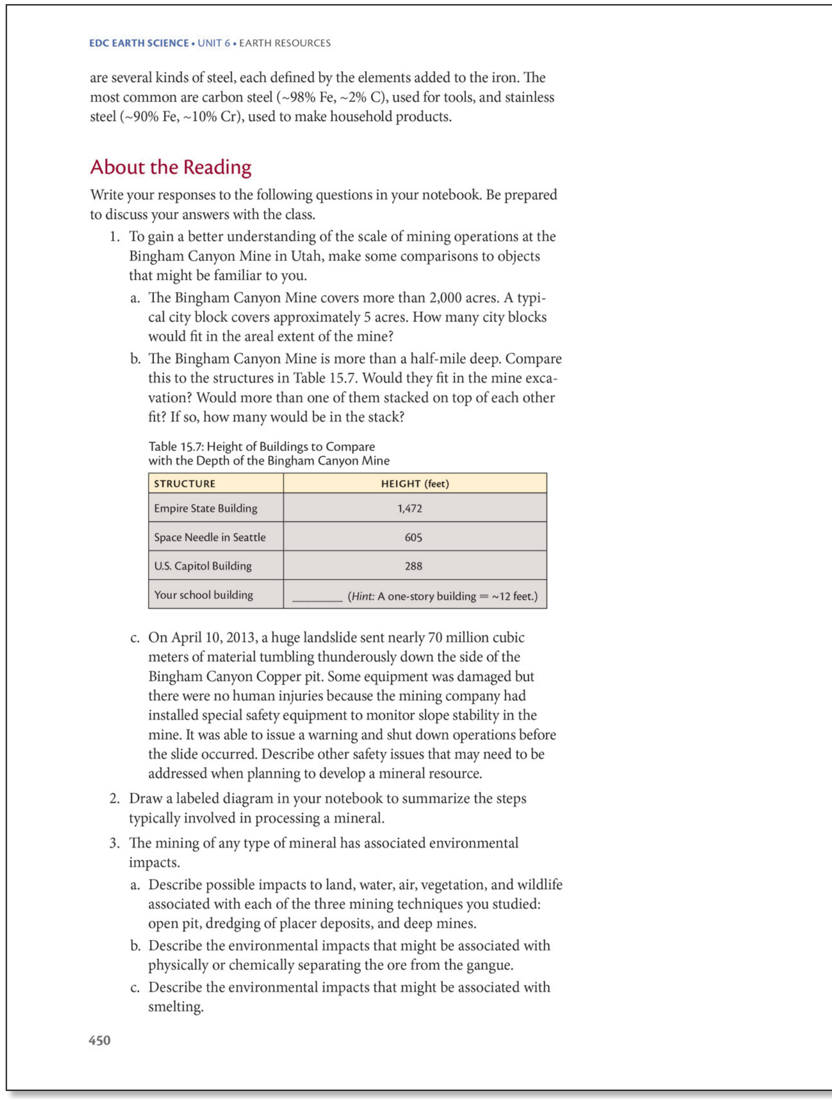
2. Draw a labeled diagram in your notebook that summarizes the steps typically involved in processing a mineral. *Students' diagrams should show that a mineral is typically 1) transported to a mill, crushed, and then separated from the gangue minerals by physical or chemical processes; and 2) transported to an industrial facility and further processed through smelting, in which the ore is heated to high temperatures. It might need to undergo further refining/purification or may be combined with other metals to form an alloy.*

3. The mining of any type of mineral has associated environmental impacts.
   a. Describe the types of impacts to land, water, air, vegetation, and wildlife associated with each of the three mining techniques you studied: open pit, dredging of placer deposits, and deep mines. *Open pit mining and dredging would destroy vegetation and wildlife along with soil necessary for plants to grow. Exposed earth materials could be eroded and carried into nearby streams and lakes, affecting fish and other wildlife that rely on clean water. Blasting, excavating, and transporting the ore could release particles into the air. Students may speculate that deep mines could disturb groundwater, and that the surface facilities associated with deep mines could be disruptive as well.*
   b. Describe the environmental impacts that might be associated with physically or chemically separating the ore from the gangue. *Separation of the ore from the gangue may require the use of chemicals, such as acids, that could potentially contaminate nearby surface water and groundwater. Gangue minerals would need to be disposed of. Students may or may not think of this, but some of the waste minerals could be toxic and could harm wildlife (as well as people).*

Teaching Strategies

You might want to split up the class and have groups brainstorm about part a, b, or c of Question 3. Then bring the class back together and discuss students' ideas.



EDC EARTH SCIENCE • UNIT 6 • EARTH RESOURCES

are several kinds of steel, each defined by the elements added to the iron. The most common are carbon steel (~98% Fe, ~2% C), used for tools, and stainless steel (~90% Fe, ~10% Cr), used to make household products.

About the Reading

Write your responses to the following questions in your notebook. Be prepared to discuss your answers with the class.

1. To gain a better understanding of the scale of mining operations at the Bingham Canyon Mine in Utah, make some comparisons to objects that might be familiar to you.
   a. The Bingham Canyon Mine covers more than 2,000 acres. A typical city block covers approximately 5 acres. How many city blocks would fit in the areal extent of the mine?
   b. The Bingham Canyon Mine is more than a half-mile deep. Compare this to the structures in Table 15.7. Would they fit in the mine excavation? Would more than one of them stacked on top of each other fit? If so, how many would be in the stack?

Table 15.7: Height of Buildings to Compare with the Depth of the Bingham Canyon Mine

STRUCTURE	HEIGHT (feet)
Empire State Building	1,472
Space Needle in Seattle	605
U.S. Capitol Building	288
Your school building	______ (*Hint:* A one-story building = ~12 feet.)

   c. On April 10, 2013, a huge landslide sent nearly 70 million cubic meters of material tumbling thunderously down the side of the Bingham Canyon Copper pit. Some equipment was damaged but there were no human injuries because the mining company had installed special safety equipment to monitor slope stability in the mine. It was able to issue a warning and shut down operations before the slide occurred. Describe other safety issues that may need to be addressed when planning to develop a mineral resource.
2. Draw a labeled diagram in your notebook to summarize the steps typically involved in processing a mineral.
3. The mining of any type of mineral has associated environmental impacts.
   a. Describe possible impacts to land, water, air, vegetation, and wildlife associated with each of the three mining techniques you studied: open pit, dredging of placer deposits, and deep mines.
   b. Describe the environmental impacts that might be associated with physically or chemically separating the ore from the gangue.
   c. Describe the environmental impacts that might be associated with smelting.

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c. Describe the environmental impacts that might be associated with smelting. *Because smelting generally involves heating the mineral to very high temperatures, there may be emissions of pollutants or greenhouse gases to the atmosphere associated with this process. Smelting is likely to generate other waste chemicals that could potentially contaminate the environment if not disposed of properly.*

4. Think about the entire process a material might go through from mining to a store shelf. Identify the points at which energy is used. *Mining the minerals would require large amounts of energy for blasting, excavation, and transportation. Energy would be required to crush the rock to separate the ore from the gangue. Smelting requires that the mineral be heated up to high temperatures, which would consume lots of energy. Manufacturing processes require various amounts of energy, depending on the products being made. Transportation between mines, processing facilities, manufacturing facilities, and stores also consumes energy.*

5. The environmental and safety equipment costs associated with mineral extraction and processing may be balanced by the benefits of using them. For example, processing aluminum requires large amounts of energy. However, the use of aluminum in automobiles and airplanes makes them lighter and more energy efficient. You've listed some of the environmental risks, safety precautions, and energy costs of mining and processing mineral resources in Questions 2, 3, and 4. Now list some of the benefits. How do they make your life better? *Answers will vary. Students may cite the benefits of owning cars and flying in airplanes. They may talk about the benefits of the construction materials made from minerals. They may also list a large variety of other items they enjoy or need in their lives. Some students may think of the economic benefits of mining and processing facilities because they provide jobs.*

Science Background

Recycling Aluminum

You might want students to complete Resource Supplement 15.2: *Consider a Can* (in Teacher Resources for Chapter 15), and talk about the benefits of recycling. Aluminum provides a compelling example of the amount of energy that can be saved and the reduction in environmental damage that recycling can achieve. Aluminum processing requires especially large amounts of energy. As of 2000, the aluminum industry was spending more than $2 billion annually on energy, the majority of which was for electricity used in the smelting process. In addition, aluminum production in the United States is the leading source of perfluorocarbons (PFCs), which are greenhouse gases more potent than CO_2. However, almost every aluminum product can be profitably recycled without loss of metal quality. Recycling eliminates 95 percent of the energy used and emissions associated with making new aluminum from bauxite ore.

LITERACY SUPPLEMENT

Anticipation Guide for "From Rocks to Riches—Mining and Processing Mineral Ore"

Before starting the activity, mark if you agree (Y) or disagree (N) with each statement below.

After completing the activity, mark a second time to show if you still agree (Y) or disagree (N). Correct any mistakes you find in the statements.

RESPONSE TO ANTICIPATION GUIDE FOR FROM ROCKS TO RICHES—MINING AND PROCESSING MINERAL ORE

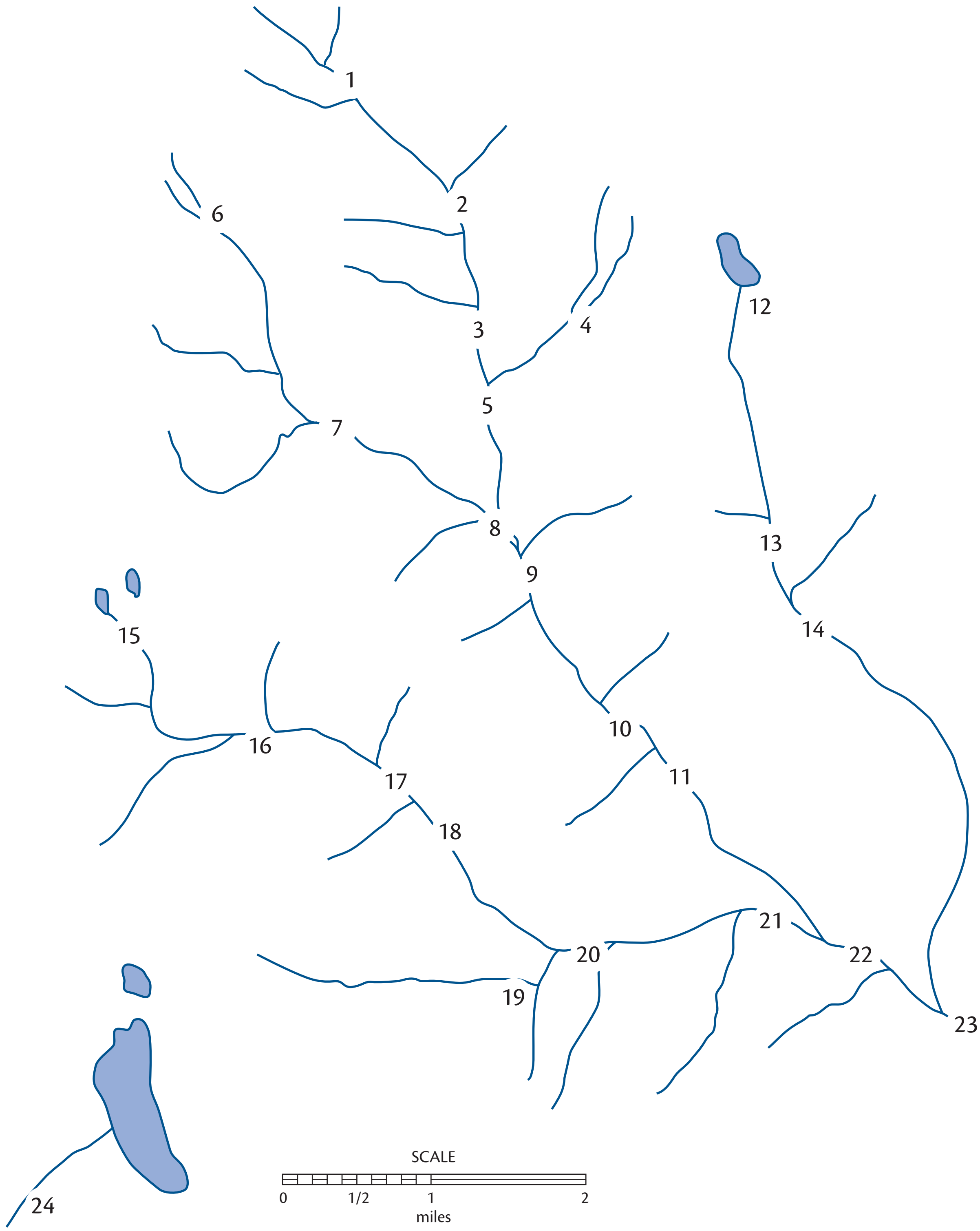
BEFORE	AFTER	
	N	~~Most minerals are easily obtained from Earth's surface and easily processed into the products we need.~~ *Most minerals are not found on the surface of Earth, but must be mined by excavating or tunneling into bedrock or sifting through river sediments with special equipment. Generally, they are separated chemically, and require processing to refine them into useful forms.*
	Y	Huge open pit mines, such as the Bingham Canyon Mine in Utah, are several miles wide and so large they can actually be seen from the orbiting space shuttle.
	Y	Deep mines, such as the gold mines in South Africa, are several miles deep and are so hot that miners require special cooling equipment to survive temperatures that might exceed 54.5°C (130°F).
	Y	Smelting involves heating the ore until it melts and then separating the desired metals from the mixture.

NAME ______________________ PERIOD ____________ DATE ____________

STUDENT SHEET 15.2

Prospector Peak Sampling Map

To go with *Activity 2*—“Prospecting for Mineral Ore”



NAME ______________________________PERIOD ______________ DATE ______________

LITERACY SUPPLEMENT 15.1

Anticipation Guide for "From Rocks to Riches—Mining and Processing Mineral Ore"

Before completing the chapter, decide whether you agree (Y) or disagree (N) with each statement, using the "before" column to mark your responses.

After completing the chapter, revisit each statement shown below and use the "after" column to mark your responses. Where you disagree (N), rewrite the statement to make it correct.

BEFORE	AFTER	
_____	_____	1. Most minerals are easily obtained from Earth's surface and easily processed into the products we need.
_____	_____	2. Huge open pit mines, such as the Bingham Canyon Mine in Utah, are several miles wide and so large they can actually be seen from the orbiting space shuttle.
_____	_____	3. Deep mines, such as gold mines in Africa, are several miles deep and are so hot that miners require special cooling equipment to survive temperatures that might exceed 54.5°C (130°F).

EDC EARTH SCIENCE SEMESTER 1

The first semester introduces students to Earth's systems and focuses on the hydrosphere and atmosphere. Students explore the sources of freshwater on the continents and the effects of currents in the world's oceans. They delve into the science of climate and climate change, exploring the factors that affect climate locally and globally and investigating the causes of climate change in Earth's past.

CHAPTER	SCIENCE CONCEPTS	LEARNING ACTIVITIES
INTRODUCING EARTH SCIENCE		
Chapter 1 Comparing Earth to Other Worlds	Introduction to Earth's systems; basic requirements for sustaining life	Students read an excerpt from a science fiction story about Mars colonists and analyze the resources necessary to sustain human populations on this neighboring planet.
UNIT 1: HYDROSPHERE: WATER IN EARTH'S SYSTEMS		
Chapter 2 Life's Blood: Seeking Water from Earth	Water cycle; surface water, groundwater, assessing and protecting water supplies	Students learn about droughts in Texas and Tennessee, and consider how access to plentiful and clean water is critical to human survival. They build their knowledge about how water is obtained by reviewing the water cycle and learning the science behind surface and groundwater supplies. After researching case studies from communities around the world, they get up close and personal, evaluating where their water comes from and whether their supply could be threatened in the future.
Chapter 3 Rivers of the Sea: Ocean Currents	Global patterns of ocean circulation; how wind and density differences drive ocean currents; global conveyor belt; El Niño	Students read a true story about Thor Heyerdahl, the explorer who set sail across the Pacific in the primitive raft Kon-Tiki to prove a theory. Drifting on an ocean current, he sought to show that people from South America could have migrated to Polynesia over 1,000 years ago without the benefit of developed seafaring vessels. Students gather knowledge about the science of ocean currents to decide whether his idea was crazy or had a chance of success.
UNIT 2: ATMOSPHERE AND CLIMATE		
Chapter 4 Local Connections: Regional Climate	Climate and weather; influence of latitude, atmospheric circulation, proximity to ocean, elevation, land features, and prevailing winds on regional climate	Students start their exploration of climate close to home, learning about the climate in their local area and comparing it to a chosen travel destination. Students learn how climate is measured and how it affects the flora and fauna of a landscape. They investigate key factors that cause climate to vary so much around the world.
Chapter 5 The Bigger Picture: Global Climate	Energy balance, albedo effect, greenhouse effect, carbon cycle, positive and negative feedback loops	Students read about a community in Alaska that is threatened by global warming and research the factors that influence global climate and can cause it to change. Based on what they've learned, they consider whether members of the Alaskan community should move or stay, and prepare recommendations to share at a public meeting.
Chapter 6 The Longest Experiment: Climate Change in Earth's History	Paleoclimatology, climate proxies, climate change in Earth's past, Milankovitch cycles, tectonic processes that influence climate, human impact on climate	Students explore two time periods in Earth's past when climate was very different from today—the warm Cretaceous and a glacial interval of the Pleistocene. Students study evidence—recorded in sediments, rocks, and ice—that climate has varied through Earth's history, and explore the factors that have contributed to these changes. They look at evidence that Earth's climate is changing now and how human activity and natural factors contribute to this change.
MID-YEAR CHALLENGE		
Chapter 7 Broadcast from the Future	Synthesis of concepts learned in the first part of the course	Students use the knowledge they have gained during the first semester of this course to make predictions about what Earth will be like in the year 2100. They communicate their predictions in a news broadcast from the future.

EDC EARTH SCIENCE SEMESTER 2

During the second semester of *EDC Earth Science*, students gain a deeper understanding of Earth's systems by exploring Earth's place in the universe and the workings of the geosphere. They study how solar systems form as part of the life cycle of stars and investigate how Earth's interior and surface are moving and changing. They examine evidence of tectonic plate movement as they investigate volcanic eruptions and earthquakes that have occurred in the western United States. They explore rock cycle processes and use clues in rocks to determine events that have happened in Earth's past. After gaining a greater appreciation of Earth's geosphere, students revisit the solid Earth from a human perspective. They explore how the geosphere provides critical natural resources, and how human's use of these resources has affected the balance of Earth's systems.

CHAPTER	SCIENCE CONCEPTS	LEARNING ACTIVITIES
UNIT 3: EARTH'S PLACE IN THE UNIVERSE		
Chapter 8 Stars, Planets, and Everything in Between: Solar System Origins	Solar system formation, Kepler's Laws, radioactive dating, life cycle of stars, spectroscopy	Students explore Earth's place in the universe by investigating how planets and solar systems form as part of the life cycles of stars. They gather evidence for the solar nebular theory from the observable patterns of motion in the solar system. They learn about methods for dating the age of Earth and other solar system objects. They investigate planets, asteroids, comets, and other solar system neighbors, and compare different models that account for the birth of the solar system and the life and death of stars. They learn about Kepler's Laws of Motion and investigate the geometry of movement of orbits. They conduct a mock trial to examine evidence for the solar nebular condensation theory, and examine line spectra used by astronomers to investigate the composition of objects located many light years from Earth.
Chapter 9 Journey to the Center of the Earth: Exploring Earth's Interior	Earth's interior structure and composition, internal sources of heat energy, seismic waves, introduction to plate tectonic theory, driving forces of plate movement	Students begin their exploration of the geosphere by looking down at their feet and wondering what lies below them. If they could dig through the floor, through the foundation of their building, through the soil and rocks, and keep going and going, what would they see? They explore Earth's internal structure, as well as the movements and changes that occur within the planet that have a profound effect on Earth's surface. Ultimately, students synthesize their understanding of Earth's interior by creating a "journey" into the earth, communicating scientific information about what they would encounter along the way.
UNIT 4: PLATE TECTONICS		
Chapter 10 On Shaky Ground: Earthquakes and Transform Boundaries	Transform-fault boundaries, earthquakes, physical and computer models, earthquake forecasting	Students read about the 1906 San Francisco earthquake and study the relationship of this event to the transform-fault boundary along the west coast of California. They use global-positioning-system (GPS) data to track plate motions, build a physical model to understand movements along the fault, and study computer models scientists use to forecast when and where earthquakes will occur.
Chapter 11 Sleeping Dragons? Subduction-Zone Volcanoes	Subduction zones, volcanoes and types of volcanic eruptions, technologies for volcano monitoring, data analyses	Students examine the relationship of the Cascade volcanoes in Washington, Oregon, and California to the subduction zone along the Northwest coast. They plot earthquake data to delineate a subduction zone and learn how scientists monitor changes beneath a volcano that may signal an imminent eruption. Ultimately, students apply information about the eruptive histories of the Cascade volcanoes, combined with current monitoring data, to assess the risk associated with living near volcanoes such as Mount Rainier.
Chapter 12 Clues on the Ocean Floor: Divergent Boundaries	Seafloor spreading, paleomagnetism, plate tectonics summary, landforms associated with plate boundaries	Students explore the process of seafloor spreading occurring along the Mid-Atlantic Ridge, looking for patterns in maps of earthquake distribution, seafloor topography, ocean crust age, and paleomagnetic data. They pull together what they've learned about plate tectonic processes that occur along divergent, convergent, and transform-plate boundaries.

UNIT 5: THE ROCK CYCLE		
Chapter 13 Mississippi Blues: Sedimentary Processes in a Delta	Erosion and deposition, deltaic processes, formation of sedimentary rock	Students investigate the ways in which river deltas build new land, reading about the plight of New Orleans in the aftermath of Hurricane Katrina. Students model the role the river played in forming the land in Louisiana and investigate why the land beneath New Orleans is sinking now. They use sediment core data to construct cross sections of the subsurface along levees that failed during Hurricane Katrina, and think about what can and should be done to keep this city from drowning in the future.
Chapter 14 A Solid Foundation: Building Earth's Crust	The nature of rocks and minerals, rock cycle, relative dating, Earth's history	Students read about James Hutton, known as the father of geology. They study samples of the rocks and minerals that make up the crust, and learn how to recognize clues that tell them true stories about Earth's history.
UNIT 6: EARTH RESOURCES		
Chapter 15 Hidden Treasures in Rocks: Mineral Resources	The geologic processes by which mineral ores are formed, mineral prospecting, mineral extraction and processing	Students explore the surprising extent to which they rely on Earth's crust for the materials in the objects around them. Putting themselves in the shoes of mineral prospectors, they gain expertise in the different ways that mineral ores become concentrated within Earth's crust. They analyze river-sediment samples to search for molybdenum ore and refine copper from samples of malachite. Ultimately, they devise their own business plans for developing a mineral resource.
Chapter 16 The Mystery of the Rub' al-Kahli: Energy Resources in Earth's Crust	Fossil fuel formation, petroleum resources and exploration technologies	Students read about the Rub' al-Kahli—a desolate desert landscape in Saudi Arabia that overlays one of the largest oil reservoirs in the world. Students investigate how oil reservoirs form naturally in Earth's crust, and how geologists go about finding this precious resource. They then use their new knowledge to figure out why there is so much more oil in some regions than there is in others.
FINAL CHALLENGE		
Chapter 17 A Different Earth	Synthesis of concepts learned in Earth Science 2	Students imagine a future when Earth's core has cooled completely. They use the knowledge they have gained about the geosphere to describe how this planet would be different.

requires students to synthesize their learning throughout the semester. The units within the two semesters are as follows:

EDC Earth Science Semester 1

Unit 1: Hydrosphere: Water in Earth's Systems
Unit 2: Atmosphere and Climate
Mid-Year Challenge

EDC Earth Science Semester 2

Unit 3: Earth's Place in the Universe
Unit 4: Plate Tectonics
Unit 5: The Rock Cycle
Unit 6: Earth Resources
Final Challenge

You will find more information regarding the content of this course at the beginning of each chapter in the teacher edition, along with information about the crosscutting concepts and scientific practices embedded in the chapter activities and readings.

NGSF ALIGNMENT

The following table shows the correlation between the concepts addressed in *EDC Earth Science* and *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012).

Correlation of *EDC Earth Science* with the *Next Generation Science Framework* Core Ideas High School (9–12)

	UNIT	CHAPTER
ESS1 EARTH'S PLACE IN THE UNIVERSE		
ESS1.A: THE UNIVERSE AND ITS STARS		
The star called the Sun is changing and will burn out over a life span of approximately 10 billion years.	3: Earth's Place in the Universe	8
The sun is just one of a myriad of stars in the Milky Way galaxy, and the Milky Way is just one of hundreds of billions of galaxies in the universe.	3: Earth's Place in the Universe	8
The study of stars' light spectra and brightnesses is used to identify compositional elements of stars, their movements, and their distances from Earth.	3: Earth's Place in the Universe	8
ESS1.B: THE EARTH AND THE SOLAR SYSTEM		
Kepler's Laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun.	3: Earth's Place in the Universe	8
Orbits may change due to the gravitational effects from, or collisions with, other bodies.	3: Earth's Place in the Universe	8
Gradual changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes.	2: Atmosphere and Climate	6
ESS1.C: THE HISTORY OF PLANET EARTH		
Radioactive-decay lifetimes and isotopic content in rocks provide a way of dating rock formations and thereby fixing the scale of geological time.	3: Earth's Place in the Universe 5: The Rock Cycle	8 14
The continents' rocks (some as old as 4 billion years or more) are much older than rocks on the ocean floor (less than 200 million years), where tectonic processes continually generate new rocks and remove old ones.	3: Earth's Place in the Universe 4: Plate Tectonics 5: The Rock Cycle	9 10–12 14
Although active geological processes, such as plate tectonics (link to ESS2.B) and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history.	3: Earth's Place in the Universe 4: Plate Tectonics 5: The Rock Cycle	8. 9 10–12 13, 14
ESS2: EARTH'S SYSTEMS		
ESS2.A: EARTH MATERIALS AND SYSTEMS		
Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. A deep knowledge of how feedbacks work within and among Earth's systems is still lacking, thus limiting scientists' ability to predict some changes and their impacts.	1: Hydrosphere: Water in Earth's Systems 2: Atmosphere and Climate 4: Plate Tectonics	2, 3 4–6 10, 11
Evidence from deep probes and seismic waves, reconstructions of historical changes in the earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid but plastic mantle, and a solid surface crust.	3: Earth's Place in the Universe	9

Correlation of *EDC Earth Science* with the *Next Generation Science Framework* Core Ideas High School (9–12)

	UNIT	CHAPTER
The top part of the mantle, along with the crust, forms structures known as tectonic plates. Motions of the mantle and its plates are driven by convection (i.e., the flow of matter due to the energy transfer from the interior outward and the gravitational movement of denser materials toward the interior).	3: Earth's Place in the Universe 4: Plate Tectonics	9 10–12
The geological record shows that changes to global and regional climate can be caused by interactions among changes in the sun's energy output or Earth's orbit, tectonic events, ocean circulation, volcanic activity, glaciers, vegetation, and human activities.	2: Atmosphere and Climate	4–6
These changes can occur on a variety of time scales from sudden (e.g., volcanic dust clouds) to intermediate (ice ages) to very-long-term tectonic cycles.	2: Atmosphere and Climate	4–6
ESS2.B: PLATE TECTONICS AND LARGE-SCALE SYSTEM INTERACTIONS		
The radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle. This energy moves through and out of the planet's interior, primarily by mantle convection.	3: Earth's Place in the Universe 4: Plate Tectonics	9 10
Plate tectonics can be viewed as the surface expression of mantle convection.	3: Earth's Place in the Universe 4: Plate Tectonics	9 10–12
ESS2.C: THE ROLES OF WATER IN EARTH'S SURFACE PROCESSES		
The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics.	1: Hydrosphere: Water in Earth's Systems 4: Plate Tectonics	2, 3 11
These properties include water's exceptional capacity to absorb, store, and release large amounts of energy; transmit sunlight; expand upon freezing; dissolve and transport materials; and lower the viscosities and melting points of rocks.	1: Hydrosphere: Water in Earth's Systems 2: Atmosphere and Climate 4: Plate Tectonics 5: The Rock Cycle 6: Earth Resources	2, 3 4–6 11 13, 14 15
ESS2.D: WEATHER AND CLIMATE		
Global climate is a dynamic balance on many different time scales among energy from the sun falling on Earth; the energy's reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems; and the energy's re-radiation into space.	2: Atmosphere and Climate	4–6
Climate change can occur if any part of Earth's systems is altered. Geological evidence indicates that past climate changes were either sudden changes caused by alterations in the atmosphere; longer term changes (e.g., ice ages) due to variations in solar output, Earth's orbit, or the tilt of its axis; or even more gradual atmospheric changes due to plants and other organisms that captured carbon dioxide and released oxygen.	2: Atmosphere and Climate	4–6
The time scales of these changes varied from a few to millions of years. Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.	2: Atmosphere and Climate	4–6
Global climate models incorporate scientists' best knowledge of physical and chemical processes and of the interactions of relevant systems. They are tested by their ability to fit past climate variations.	2: Atmosphere and Climate	6
Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise.	2: Atmosphere and Climate	6
The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and the biosphere. Hence the outcomes depend on human behaviors as well as on natural factors that involve complex feedbacks among Earth's systems.	2: Atmosphere and Climate	6
ESS2.E: BIOGEOLOGY		
The many dynamic and delicate feedbacks between the biosphere and other earth systems cause a continual coevolution of Earth's surface and the life that exists on it.	2: Atmosphere and Climate 3: Earth's Place in the Universe	4, 6 8

Correlation of *EDC Earth Science* with the *Next Generation Science Framework* Core Ideas High School (9–12)

	UNIT	CHAPTER
ESS3: EARTH AND HUMAN ACTIVITY		
ESS3.A: NATURAL RESOURCES		
Resource availability has guided the development of human society. All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks, as well as benefits.	1: Hydrosphere: Water in Earth's Systems 6: Earth Resources	2 15, 16
New technology and regulation can change the balance of these factors.	1: Hydrosphere: Water in Earth's Systems 6: Earth Resources	2 15, 16
ESS3.B: NATURAL HAZARDS		
Natural hazards and other geological events have shaped the course of human history by destroying buildings and cities, eroding land, changing the course of rivers, and reducing the amount of arable land.	4: Plate Tectonics 5: The Rock Cycle	10, 11 12, 13
These events have significantly altered the sizes of human populations and have driven human migrations.	1: Hydrosphere: Water in Earth's Systems 4: Plate Tectonics 5: The Rock Cycle	2 10, 11 13
Natural hazards can be local, regional, or global in origin, and their risks increase as populations grow. Human activities can contribute to the frequency and intensity of some natural hazards.	1: Hydrosphere: Water in Earth's Systems 4: Plate Tectonics 5: The Rock Cycle	2 10–12 13
ESS3.C: HUMAN IMPACTS ON EARTH SYSTEMS		
The sustainability of human societies and of the biodiversity that supports them require responsible management of natural resources not only to reduce existing adverse impacts but also to get things right in the first place.	1: Hydrosphere: Water in Earth's Systems 6: Earth Resources	2 15, 16
Scientists and engineers can make major contributions—for example, by developing technologies that produce less pollution and waste and that preclude ecosystem degradation.	1: Hydrosphere: Water in Earth's Systems 6: Earth Resources	2 15, 16
When the source of a problem is understood and international agreement can be reached, it has been possible to regulate activities to reverse or avoid some global impacts (e.g., acid rain, the ozone hole).	2: Atmosphere and Climate 6: Earth Resources	6 16
ESS3.D: GLOBAL CLIMATE CHANGE		
Because global climate changes usually happen too slowly for individuals to recognize them directly, scientific and engineering research—much of it based on studying and modeling past climate patterns—is essential.	2: Atmosphere and Climate	5, 6
The current situation is novel, not only because the magnitudes of humans' impacts are significant on a global scale but also because humans' abilities to model, predict, and manage future impacts are greater than ever before.	2: Atmosphere and Climate	5, 6
Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities, as well as to changes in human activities. Thus science and engineering will be essential both to understanding the possible impacts of global climate change and to informing decisions about how to slow its rate and consequences—for humanity as well as for the rest of the planet.	2: Atmosphere and Climate	5, 6