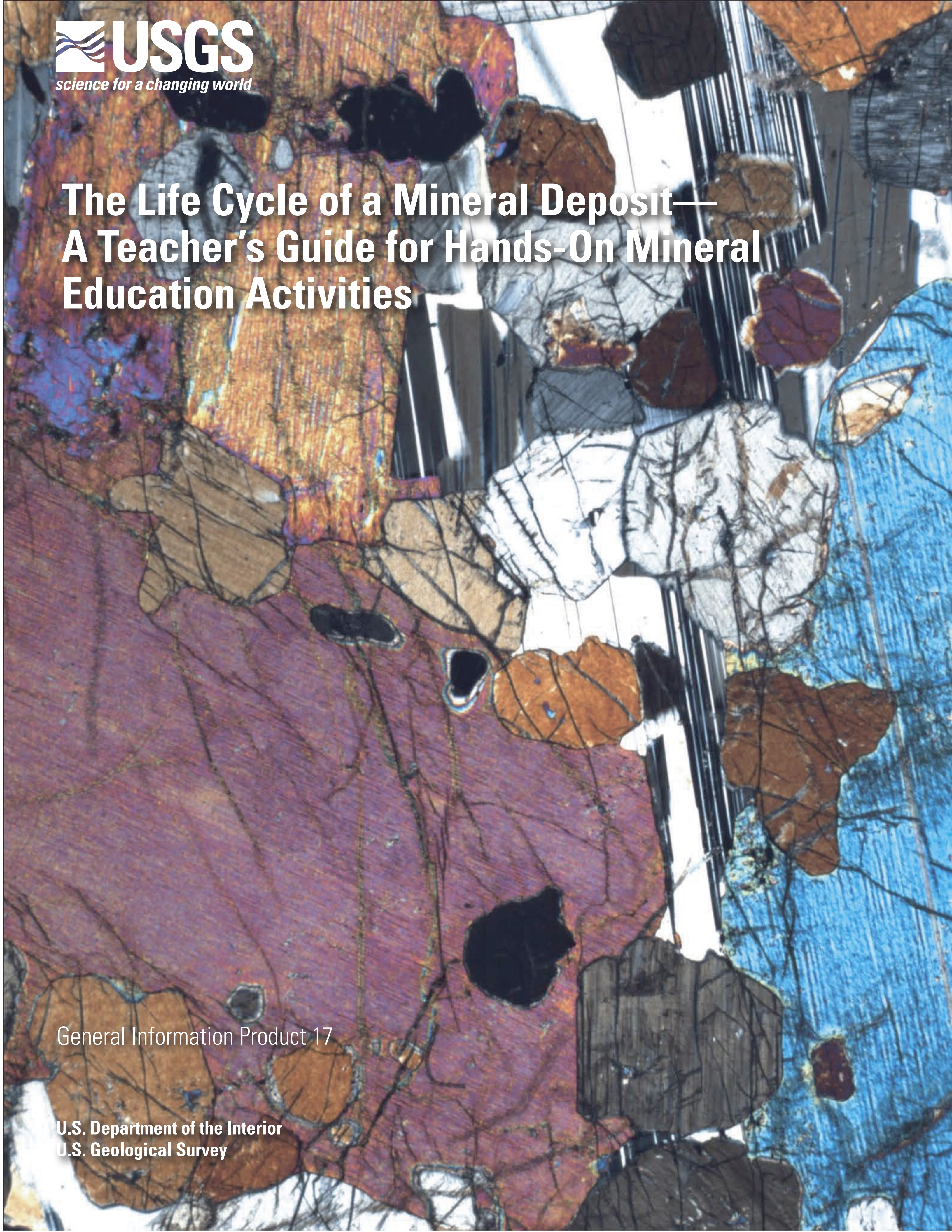

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The Life Cycle of a Mineral Deposit—A Teacher's Guide for Hands-On Mineral Education Activities

General Information Product 17

U.S. Department of the Interior
U.S. Geological Survey

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By Dave Frank, John Galloway, and Ken Assmus

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Cover. A thin slice of an igneous rock viewed under a polarizing microscope. The colors and textures can be used to identify minerals and the rock type. This rock is from South Africa and contains economically important deposits of Platinum Group Elements (PGE). Similar rock types are used as decorative facing for buildings and also for countertops.

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Preface

This teacher's guide defines what a mineral deposit is and how a mineral deposit is identified and measured, how the mineral resources are extracted, and how the mining site is reclaimed; how minerals and mineral resources are processed; and how we use mineral resources in our every day lives. Included are 10 activity-based learning exercises that educate students on basic geologic concepts; the processes of finding, identifying, and extracting the resources from a mineral deposit; and the uses of minerals. The guide is intended for grades 5 through 8 science teachers and students and is designed to meet the National Science Content Standards as defined by the National Research Council (1996). Several of these activities can be modified to meet the National Science Content Standards for grades 9 through 12. To assist in the understanding of some of the geology and mineral terms, see the Glossary (appendix 1) and Minerals and Their Uses (appendix 2).

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Introduction

The process of finding or exploring for a mineral deposit, extracting or mining the resource, recovering the resource, also known as beneficiation, and reclaiming the land mined can be described as the "life cycle" of a mineral deposit. The complete process is time consuming and expensive, requiring the use of modern technology and equipment, and may take many years to complete. Sometimes one entity or company completes the entire process from discovery to reclamation, but often it requires multiple groups with specialized experience working together.

Mineral deposits are the source of many important commodities, such as copper and gold, used by our society, but it is important to realize that mineral deposits are a nonrenewable resource. Once mined, they are exhausted, and another source must be found. New mineral deposits are being continuously created by the Earth but may take millions of years to form. Mineral deposits differ from renewable resources, such as agricultural and timber products, which may be replenished within a few months to several years.

What is a Mineral Deposit?

The technical definition of a mineral is a naturally occurring, inorganic, homogeneous solid with a definite chemical composition and an ordered atomic arrangement. In more general terms, a mineral is a substance that is (1) made of a single element like gold (Au) or a compound of elements like salt (NaCl) and (or) (2) a building block of rock (for example, granite is composed primarily of the minerals quartz and feldspar). Minerals may be metallic, like gold, or nonmetallic, such as talc. Oil, natural gas, and coal are generally considered to be "energy minerals" and are not discussed in this report. Additional mineral resource terms are:

1. *Aggregate*—A rock or mineral material used separately and as filler in cement, asphalt, plaster, and other materials.

2. *Alloy*—A substance having metallic properties and composed of two or more chemical elements, of which at least one is a metal.

3. *Element*—A substance whose atoms have the same atomic number.

4. *Metal*—A class of chemical elements, such as iron, gold, and aluminum, that have a characteristic luster, are good conductors of heat and electricity, and are opaque, fusible, and generally malleable and ductile.

5. *Ore*—The naturally occurring material from which a mineral or minerals of economic value can be extracted.

6. *Rock*—A naturally formed material composed of a mineral or minerals; any hard consolidated material derived from the Earth (Kesler, 1994; Hudson, Fox, and Plumlee, 1999).

Minerals occur in a range of concentrations, not all of which have economic significance:

- A mineral occurrence is a concentration of a mineral (usually considered in terms of some commodity, such as copper, barite, or gold) that is considered valuable by someone somewhere or that is of scientific or technical interest.

- A mineral deposit is a mineral occurrence of sufficient size and grade (concentration) to enable extraction under the most favorable conditions.

- An ore deposit is a mineral deposit that has been tested and is known to be of sufficient size, grade, and accessibility to be mined at a profit. Testing commonly consists of surface mapping and sampling, as well as drilling through the deposit.

Where and How Do Mineral Deposits Occur?

The Rock Cycle and Plate Tectonics

Two cycles determine how mineral deposits are formed—the rock cycle and the tectonic cycle (fig. 1). Heat from the Earth's interior melts some of the rocks in the crust (the upper part of the lithosphere). Molten rocks lower in density than the surrounding cooler material rise toward the Earth's surface and eventually cool and harden near to or on the surface. The composition, temperature, pressure, and cooling process of the molten material determine the minerals and rock types formed. These are called igneous rocks and contain original or primary minerals. When these rocks are subjected to chemical and physical processes, such as freezing and thawing, they break apart into smaller fragments forming sediments. These smaller particles that compose the sediments can be physically transported and redeposited by gravity, water, and wind. If the redeposited particles are bound together by compaction or cementation (formation of new secondary minerals in the spaces between the loose particles), sedimentary rocks are formed. In regions where the Earth's interior temperature and pressure are high enough to change the chemical composition and mineralogy of buried igneous or sedimentary rocks, without completely melting them, metamorphic rocks are formed. Distinct groups or assemblages of minerals are typically associated with the formation of each of the three major rock types—igneous, sedimentary, and metamorphic rocks.

Plate tectonics (see fig. 1) play a major role in the processes of mineral and rock formation. In geologic terms, a plate is a large, "rigid" slab of solid rock. The word tectonics comes from the Greek root "to build." The term plate tectonics refers to the process by which the Earth's crust is formed and moved. The theory of plate tectonics states that the Earth's outermost layer, the crust, is fragmented into a dozen or more plates of various sizes that are moving relative to one another as they are slowly transported on top of and by hotter, more mobile material (Kious and Tilling, 1996). Scientists now have a fairly good understanding of how the plates move and how earthquake activity relates to such movement. Most movement occurs along narrow zones between plates where the effects of tectonic forces are most evident.

There are four types of plate boundaries:

- Divergent boundaries—where new crust is generated as the plates pull away from each other.
- Convergent boundaries—where crust is destroyed as one plate dives under another.
- Transform boundaries—where crust is neither produced nor destroyed as the plates slide horizontally past each other.
- Plate boundary zones—broad belts in which boundaries are not well defined and the effects of plate interaction are unclear (Kious and Tilling, 1996).

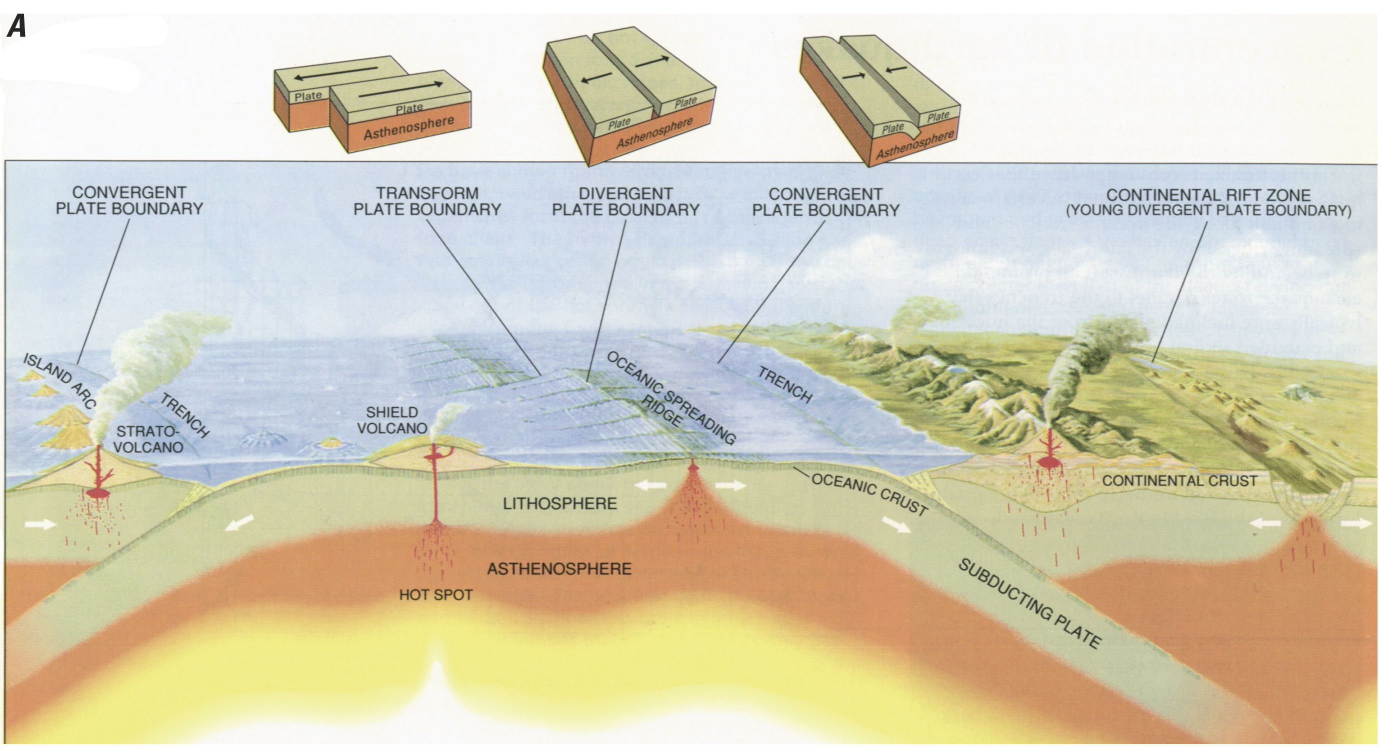


Figure 1.—Cross sections of Earth's crust and mantle, showing the (*A*) plate tectonic cycle (Kious, and Tilling, 1996) and (*B*) rock cycle (Stoffer, 2002).

Mineral Deposits

The Earth's crust contains more than 100 naturally occurring elements. The crust, which ranges from 6 to 30 miles (10 to 50 km) thick, can be subdivided into two distinctly different parts—the oceanic crust and the continental crust—which differ in composition. Some of the common elements that make up the crust are in order of abundance oxygen (O), silicon (Si), aluminum (Al), iron (Fe), calcium (Ca), sodium (Na), potassium (K), and magnesium (Mg) (table 1). Although the same elements are present in both types of crusts, their concentrations are slightly different. The first eight elements listed in table 1 constitute more than 98 percent of all crustal material. Thus, one can refer to the distribution of elements in terms of their average crustal abundance. Many useful mineral commodities in the crust are present in very low abundances (table 2.). The mining industry cannot use most rocks in the Earth's crust as sources of metals or other elements because concentrations are too low to warrant extraction. Instead, the mining geologist looks for rocks where the desired mineral has been concentrated by some natural process.

Mineral deposits occur in various tectonic and geologic settings (fig. 1. and activity 1). Some mineral deposits may be formed in one place but be transported to another geographic location as a result of tectonic forces or other geologic processes. Thus, the study of tectonic processes and regional geology is important in understanding the distribution of mineral deposits.

Gold, for example, can be concentrated with other minerals in veins that form in fractures in rocks deep underground (typically, igneous rocks). Tectonic forces uplift these rocks forming mountain ranges where weathering and erosion expose the veins at the Earth's surface. Because mountain ranges are constantly worn down by erosion caused by water, ice, and wind, some of the gold veins are eventually deposited as nug-

Table 1. Abundances of the elements in the Earth's crust (modified from Nave, 2000).

Element	Approximate percent by weight
Oxygen	46.6
Silicon	27.7
Aluminum	8.1
Iron	5.0
Calcium	3.6
Sodium	2.8
Potassium	2.6
Magnesium	2.1
All others	1.5

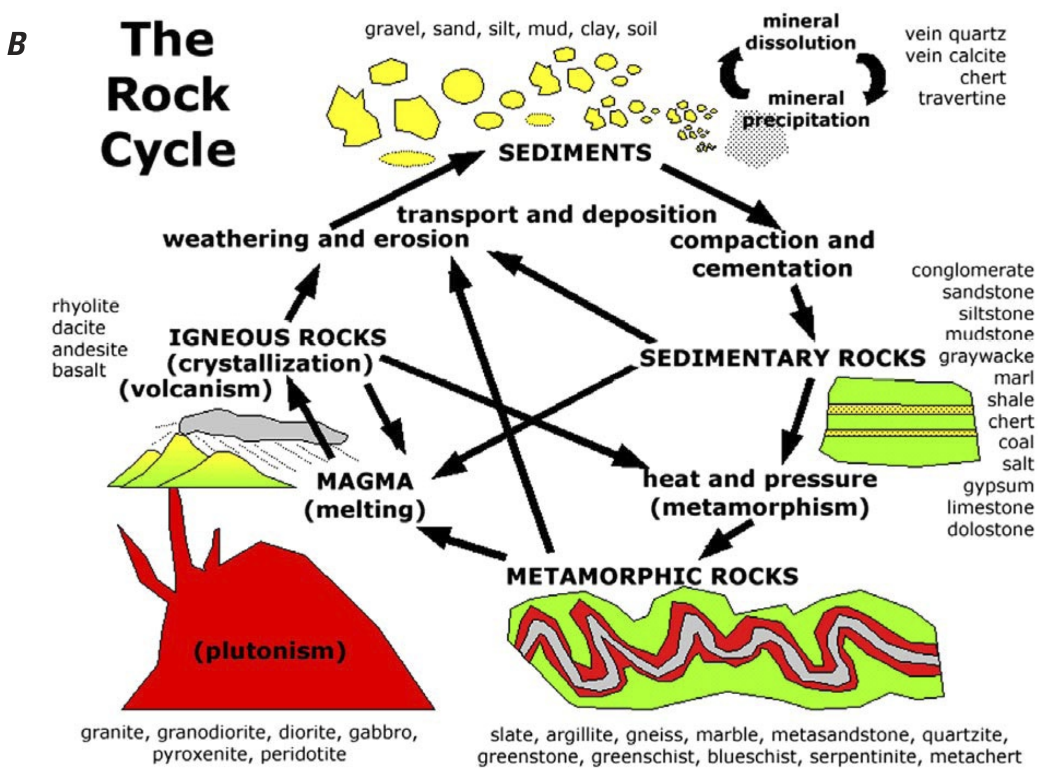


Figure 1.—Continued

Table 2. Average abundance of geochemically scarce metals from ore deposits in continental crust (modified from Skinner, 1976).

Element	Average abundance in continental crust, in percent
Copper	0.0058
Gold	0.0000002
Lead	0.0010
Mercury	0.0000002
Molybdenum	0.00012
Nickel	0.0072
Silver	0.000008
Tin	0.00015
Tungsten	0.00010
Uranium	0.00016

gets (see fig. 2), flakes, or flour-size material in sediments in streams and rivers. The gold, along with other minerals like platinum and garnet, is sometimes extracted directly from gravels (sedimentary rocks) in the streambed. Mineral deposits also form when preexisting rocks are deeply buried and changed over geologic time by heat and pressure (metamorphic rocks); for example, limestone is changed by metamorphism into marble.

Mineral Deposit Models

To better understand and predict how and where mineral deposits might occur, scientists develop mineral deposit models. These models are based on existing knowledge of regional geology and the characteristics of known mineral deposits. Similar mineral deposit types can be grouped together under a particular deposit model. Mineral deposit models can aid in identifying areas favorable for finding valuable deposits (Singer, 1995). There are hundreds of deposit models, and new models are being constructed as new types of deposits are identified. The U.S. Geological Survey (USGS) has produced a number of publications describing various mineral deposit types (Cox and Singer, 1986; Stoeser and Heran, 2000). A few examples of deposit model types are (1) deposits related to mafic and ultramafic intrusions in stable environments, (2) deposits related to marine mafic extrusive rocks, (3) deposits in clastic sedimentary rocks, (4) deposits related to regionally metamorphosed rocks, and (5) deposits related to surfical processes and unconformities.

How Are Mineral Deposits Found?

Finding a mineral deposit is the first step in the mining life cycle. Technologies used include, but are not limited to, exploration geology, geophysics, geochemistry, and satellite imagery.

Geology

Geology is the study of the planet Earth—the materials of which our planet is made, the processes that act on these materials, the products formed, and the history of the planet and its life forms since its origin (Neuendorf and others, 2005, see activity 2). Geologic investigations include reviews of the geologic literature, field surveys, and geologic mapping to determine areas favorable for mineral deposits.

Geophysics

Geophysical exploration involves searching for favorable mineral deposits using the physical properties of rocks, such as magnetic intensity and electrical conductivity. Geophysical investigations may include aeromagnetic or gravity surveys, ground-penetrating radar studies, or the use of seismic waves to show contrasting rock types. The selected rock units of interest might then be mapped and sampled to identify areas favorable for mineral deposits, and adjoining areas may also be investigated for the presence of mineral deposits.

Geochemistry

Geochemistry is the study of the distribution and amounts of elements in minerals, ores, rocks, soil, water, and the atmosphere and the study of the circulation of the elements in nature on the basis of the properties of their atoms and ions. Geochemical investigations commonly include soil sampling, stream sediment sampling, and rock sampling; even plants are also sampled in some studies. Various techniques are used to examine and measure the abundance, or concentration, of elements contained in the sample. The results may be used to define favorable areas for mineralization.

Satellite Imagery

The use of satellite imagery has become a valuable tool for exploration geologists. Geologists are now able to perform large-scale surveys of remote unexplored regions for the presence of geologic structures and key minerals that may indicate areas favorable for mineral deposits. Ground-based surveys are expensive, and one can often experience difficulty in mapping large-scale structures. However, large geological structures are often readily visible on satellite imagery. The National Aeronautics and Space Administration (NASA) presents an excellent tutorial on the use of remote sensing that can be found at http://rst.gsfc.nasa.gov/Homepage/Homepage.html (section 5 is titled Geological Applications II—Minerals and Petroleum Exploration).

How Big is the Deposit and How Much is it Worth?

The next step in the mining life-cycle is to identify and measure the known resources in order to determine if the mineral deposit has enough value to be mined. Identifying the size and grade of the deposit is accomplished by collecting drill-core samples of the ore body (see activity 3). These samples are analyzed for the concentration of elements of economic value. For a metallic commodity like gold, analyses are usually reported in ounces of pure gold (Au) per ton of rock. In other words, for every ton of rock removed, one can expect to retrieve a predetermined number of ounces of the desired commodity based on the results of an average sampling over the entire ore body. This measurement is called "grade of ore." Ore grades for metals such as iron, copper, lead, and zinc are often expressed in weight percent. A higher grade means more of the commodity per ton of rock.

For a nonmetallic commodity, such as sand and gravel or limestone, the resource is identified in terms of volume (cubic yards or meters) or weight (short or metric tons). The quality of ore is based on the amount and distribution of various grain sizes, from fine sand to gravel and boulders, or for limestone, the percent of calcium.

Examples of Mining Methods

Three main types of mining methods used to recover metallic and nonmetallic minerals are (1) underground mining, (2) surface (open pit) mining, and (3) placer mining. The location and shape of the deposit, strength of the rock, ore grade, mining costs, and current market price of the commodity are some of the determining factors for selecting which mining method is used.

Higher-grade metallic ores found in veins deep under the Earth's surface can be profitably mined using underground methods, which tend to be more expensive. Large tabular-shaped ore bodies, having long vertical or horizontal dimensions, or ore bodies lying more than 1,000 feet (300 m) below the surface are generally mined using underground methods as well. The underground mining method is accomplished by drilling and blasting rock, in order to access and separate ore from the surrounding waste rock. The blasted material is called muck. The muck is moved to the surface by truck, belt conveyor, or elevator. Once at the surface, the material is sent to a mill.

Lower grade metal ores found closer to the surface may be profitably mined using surface mining methods, which generally cost less than underground methods. Many industrial minerals are also mined using surface mining methods, as these ores are usually low in value and were deposited at or near the Earth's surface. Generally in a surface mine, hard rock must be drilled and blasted, although some minerals, such as diatomite, are soft enough to mine without blasting. Large mechanical shovels fill trucks with the broken rock that is then trucked out of the mine for processing.

Placer mining is used to recover valuable minerals from sediments in present-day river channels, beach sands, or ancient stream deposits. More than half of the world's titanium comes from placer mining of beach dunes and sands (Kesler, 1994). In placer operations, the mined material is washed through a trommel to eliminate the coarse materials and a sluice box to concentrate the "heavies." A trommel is a revolving cylindrical sieve used to size rock, and the bottom of the sluice has ridges

Figure 2. Gold nuggets from Lucky Gulch, Valdez Creek district, Cook Inlet region, Alaska, 1910. Inset shows a gold nugget. (USGS photos.)

Figure 3. Wooley Valley Mine, Idaho, which operated from 1955 to 1989 (USGS photograph by Phil Moyle).

(called riffles) and depressions to trap heavy minerals, such as gold, one of the heaviest minerals. Platinum and tin can also be recovered in this manner.

Recovery Methods

Regardless of the deposit type and mining process, one must separate the ore from the waste rock, once it has been removed from the ground (see activity 4). The mineral commodity can be separated from the waste rock by using one or more methods, and the separation is usually done in a mill.

One type of milling or recovery method is called flotation. The ore is crushed into a very fine powder, and the powder is put into an agitated, frothy slurry. Minerals may sink to the bottom or stick to the bubbles and rise to the top, where they are skimmed off. This process is used to separate the valuable metals from waste rock, after which the recovered metals are sent on for further processing. The waste material is either used as backfill in the mine or sent to a tailings pond, where the water is removed.

Cyanide heap leaching is one method used to extract low-grade gold from rock mined using open-pit methods. Again the rock is crushed and placed on a "leach pile" on a lined pad. A cyanide solution is sprayed or dripped on top of the pile. As the leach solution percolates down through the rock, the gold dissolves into the solution. This "pregnant" solution is then captured, and the gold is recovered by further processing. After the waste rock is cleaned, it may be used to backfill in the mine pit, when the mineral deposit is exhausted.

Reclamation Processes

The reclamation process takes place throughout the mining life cycle. The process of reclamation includes maintaining water and air quality and minimizing flooding, erosion, and damage to wildlife and habitat caused during the mining life cycle. The final step in the reclamation process is often topsoil replacement and revegetation with suitable plant species (California Office of Mine Reclamation, 2004). Habitats must be maintained or restored to their prior condition once the mining process is completed. If displaced, native flora and fauna are reintroduced. Water used during the milling process is collected and reused or cleaned before being restored to the hydrosphere. Underground mines may be backfilled or sealed or may be preserved for bat habitat. To take a trip through a mine see Bat Conservation International (2004). Open-pit mines are often backfilled or reshaped to become natural areas or pit lakes suitable for waterfowl and fish (fig. 3). Tailings ponds may be drained, covered and planted with vegetation, or turned into wetlands. See activity 4 for an example of reclamation cost. An overview of how the mining industry recognizes the potential impacts of mining operations on the environment can be found in Hudson, Fox, and Plumlee (1999).

Hands-On Activities

This section contains activity-based teaching guides designed to educate students about geology, plate tectonics, and mineral resources and how mineral resources are found, extracted, processed, and used. The teaching guides are suited for the entire K-12 grade level range, but some may be best suited for the 5-8 or 9-12 grade levels (table 3). Each activity includes a required list of materials (most of which can be found in the home), instructions, discussion questions, and summaries of the activities[1]. The activities are as follows:

- **Basic Geology—Concepts**

  Activity 1—Orange Peel Plate Tectonics

  Activity 2—Peanut Butter and Jelly Geology
- **Exploring for Minerals**

  Activity 3—Cupcake Core Sampling
- **Extracting Minerals**

  Activity 4—Chocolate Chip Cookie Mining

  Activity 5—Extracting Metal (copper) from a Rock
- **Uses of Minerals**

  Activity 6—Minerals in your Body

  Activity 7—The Mineral Talc or "Rocks on Your Face"

  Activity 8—Make Your Own Toothpaste

  Activity 9—Mineral Flash Cards

  Activity 10—Personal Mineral Consumption
- **Mineral Resources and Economics**

  Activity 4—Chocolate Chip Cookie Mining

  Activity 9—Mineral Flash Cards

  Activity 10—Personal Mineral Consumption

Note to Teachers—Safety Issues

Foods are commonly used as instructional tools and in many hands-on activities presented here. A review of food use to demonstrate Earth-science concepts is presented by Francek and Winstanley (2004); however, they also note that there are potential problems associated with using food as an instructional tool. One of the main safety issues is that some foods, such as chocolate or peanut butter, could cause a student to have an allergic reaction. It is important that the instructor inform students and parents that you will be conducting a class activity that involves food, so that they can tell you if there are any health problems that should be addressed. Students with allergies to certain food groups may participate in the activities through observation, as long as their allergies are not induced by touch or smell of the food items used.

Remember, when doing any activity that involves the use of chemicals, be sure to use the proper Personal Protective Equipment (PPE), such as gloves, safety glasses, and laboratory coats.

[1] Many of these activities were modified from Women in Mining Education Foundation (2004), American Geological Institute (2005), Schneider (2004), and Stalter (2003).

Table 3. National Science Standards matrix for grades 5 through 8, showing the content standard(s) addressed by each activity; the complete standards are available from the National Research Council (1996).

Name of Activity	National Science Content Standards							Other Content Standards
	A	B	C	D	E	F	G	
Orange Peel Plate Tectonics	+			+	*	*		
Peanut Butter and Jelly Geology	+			+	*	*	*	
Cupcake Core Sampling	+			+	*	+		
Chocolate Chip Cookie Mining	+			+	*			Math
Extracting Metal (Copper) from a Rock	+	+	+	+	+	+		
Minerals in Your Body	+	+	+			+		Life Science/English
The Mineral Talc or "Rocks on Your Face"		+						
Making your own Toothpaste		+						
Mineral Flash Cards	+	+	+	*	*	+		Life Science/English
Personal Mineral Consumption	+			+		+	+	Math/English/Economics

KEY: + = Major Emphasis in Content

* = Minor Emphasis in Content

A = Science as Inquiry

- **Abilities necessary to do scientific inquiry**
- **Understandings about scientific inquiry**

B = Physical Science

- **Properties and changes of properties in matter**

C = Life Science

- **Structure and function in living systems**

D = Earth and Space Science

- **Structure of the earth system**
- **Earth's history**

E = Science and Technology

- **Abilities of technological design**
- **Understandings about science and technology**

F = Science in Personal and Social Perspectives

- **Populations, resources, and environments**
- **Natural hazards**
- **Risks and benefits**
- **Science and technology in society**

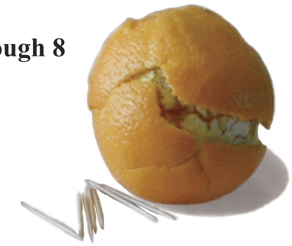
G = History and Nature of Science

- **Science as a human endeavor**
- **Nature of science**
- **History of science**

(Note: Activities may only address one of the listed subheadings of each lettered standard.)

Activity 1—Orange Peel Plate Tectonics

Suggested Grade Level: 5 through 8



Objective: Students will learn that the Earth's surface is made up of tectonic plates, which collide and shift causing earthquakes and producing volcanoes.

Materials: One orange for each student and 1 box of round toothpicks

Instructions:

STEP 1. Discuss with the students that the Earth is spherical like an orange, but because the Earth is so large we cannot see the roundness of our own planet unless we see it from outer space.

STEP 2. Instruct the students to peel the orange without the use of a knife and to peel it into at least five pieces. This peel represents the part of the Earth called the crust. Each segment of the peel represents a tectonic plate.

STEP 3. Discuss the "flatness" of each section of peel. The peel does not appear to be as round as when it was wrapped around the orange in one piece.

STEP 4. Have the students replace the peel on the orange, securing it with toothpicks. Think of this as a spherical jigsaw puzzle.

STEP 5. Once the pieces of the peel are placed back on the orange, it can be pointed out that this is now a more accurate representation of the Earth's crust. This is a good time to discuss the concept of plate tectonics. The cracks in the orange peel represent plate boundaries, "faults" or "spreading centers" or "subduction zones" where the Earth's plates (pieces of orange peel) shift and collide. Now is also the time to discuss the relationship between plate boundaries and the present-day distribution of earthquake and volcanic activity.

Evaluation and Discussion:

1. The Earth's surface is divided into more than 12 rigid crustal plates. Have students list the names of these tectonic plates.

2. What types of boundaries does each crustal plate have?

3. In which oceans are ocean ridges or spreading centers found?

4. In which oceans are convergent or collisional boundaries found?

5. What is the relationship between plate boundaries and the distribution of earthquakes?

6. What is the relationship between plate boundaries and the distribution of volcanoes?

Answers to these questions and additional information on plate tectonics can be found in "This Dynamic Planet" (Simkin and others, 1994) a USGS map (**http://pubs.usgs.gov/pdf/planet.html**) and in "This Dynamic Earth: the Story of Plate Tectonics" (Kious and Tilling, 1996) (**http://pubs.usgs.gov/publications/text/dynamic.html**). The map "This Dynamic Planet" shows the Earth's physiographic features, the current movements of its major tectonic plates, and the locations of its volcanoes, earthquakes, and impact craters. The use of color and shaded relief helps the reader to identify significant features of the land surface and the ocean floor. More than 1,500 volcanoes active during the past 10,000 years are plotted on the map in four age categories. The locations (epicenters) of more than 24,000 earthquakes, largely from 1960 through 1990, are plotted in three magnitude categories and in two depth ranges.

Activity 2—Peanut Butter and Jelly Geology

Suggested Grade Level: 5 through 8

Objective: In this project students will learn how natural forces shape the rock layers of the Earth's crust. It usually takes 45 to 60 minutes to complete this activity.

Materials (for each pair of students):

One slice of white bread
One slice of whole wheat bread
One slice of dark rye bread
Two tablespoons of jam or jelly
Two tablespoons of peanut butter (crunchy) mixed with raisins
Two paper plates
Wooden tongue depressor or plastic knife
Measuring spoons for serving jelly

Instructions:

STEP 1. Have students work in pairs. Each pair will need a paper plate with the above ingredients.

STEP 2. Tell the students you will show them how to make and manipulate a sandwich in the same way that natural forces shape layers of rock.

STEP 3. Have all students place the white bread on a paper plate. Next, spread the peanut butter on the white bread. Next, add the whole wheat bread and cover with jelly. Next, add the rye bread.

STEP 4. Have the students call the layers just what they are. If you have been studying rocks and the students are familiar with the various rock types, have them name the various layers of the sandwich. They can use imaginative rock names such as "wholesome shale" for whole wheat bread or "sticky conglomerate" for chunky peanut butter.

STEP 5. As the students add the various parts to their sandwich, which represent various layers of the crust, keep track of their progress by drawing a diagram on the chalkboard of the various layers. All students should have identical three layer sandwiches.

Evaluation and Discussion:

1. When all the sandwiches are assembled, discuss the concept of how some rocks in the Earth's crust are layered. Note that geologists rarely find rocks as flat and horizontal layers. Often they will see layers that are bent or broken. To illustrate these structures, have the students gently bend their sandwich to form an arch. (Always keep the oldest layer, white bread, on the bottom). This structural form is called an "anticline."
2. Now, have students bend the sandwich to form a trough. This structure is called a "syncline." Adding pressure to a horizontal layer can cause it to bend up or down, one-way in which mountains and valleys are formed.
3. Sometimes blocks of the Earth's crust move up or down along major fractures or "faults." This type of movement can cause earthquakes. Have the students cut their sandwich in half and move one half up or down. Have the students determine which side moved up or down? Either the left side moved up and the right side moved down or the other way around. You can see this movement because of the different layers of the sandwich. This is called a "vertical fault." Have students draw a picture of this type of fault movement. You can also create another type of fault, a "lateral fault." Have the students slide the two parts of the sandwich past each other (sideways) on the same level to produce lateral fault movement. This type of movement causes earthquakes on the San Andreas Fault in California.

This project has other ways to demonstrate how the Earth is layered and how the various layers can be deformed; be creative and have fun! Some of the questions that can be addressed are:

1. What is the oldest part of your sandwich? (bottom layer, white bread, first piece used)
2. What is the youngest layer? (top piece, rye bread, last piece to be put on)
3. If the middle of the sandwich layers bend upward, what type of structure do you have? (anticline)
4. If the middle layers of the sandwich layers bend downward, what type of structure do you have? (syncline)
5. If the sandwich is broken (cut), look at the relationship of the various layers to tell what type of fault movement you have.

Additional Resources:

Alpha, T.A., and Lahr, J.C., 1990, Seven paper models that describe faulting in the Earth: U.S. Geological Survey Open-File Report 90-257 [URL: http://wrgis.wr.usgs.gov/docs/parks/deform/7modelsa.html].

U.S. Geological Survey, 2002, A Model of three faults: U.S. Geological Survey Learning Web [URL: http://interactive2.usgs.gov/learningweb/teachers/faults.htm].

Activity 3—Cupcake Core Sampling

Suggested Grade Level: 5 through 8

Objective: To demonstrate how geologists can find (discover) mineral deposits that are buried in the Earth's crust and determine what their distribution is by collecting and analyzing cores.

Materials:

White cupcake mix
Foil baking cups
Drawing paper
Frosting
Plastic knives
Food coloring
Toothpicks
Plastic transparent straws

Instructions:

Make white batter cupcakes with at least three layers of colored batter. You can use red for "zinc," blue for "copper," and yellow for "gold." Thickness differences and irregularities in the layers are encouraged. Frost each cupcake. Provide each student with a cupcake, clear straw, toothpick, and drawing paper. Foil baking cups and frosting will prevent the students from seeing the interior of the cupcakes in much the same way that a geologist can't see the interior of the Earth.

STEP 1. Give each student a cupcake and a piece of drawing paper or photocopies of figure 4.

STEP 2. If drawing paper is used, ask the students to fold it into four sections (see fig. 4). Have them draw on one of the sections what they think the inside of the cupcake would look like if there were three different layers present (use fig. 4*A*).

STEP 3. Ask the students how they might get more information about the internal structure of the cupcake without peeling the foil or cutting it open with a knife. (Discussion)

STEP 4. Someone may suggest using the straw to take a "core sample." Demonstrate to the students how to rotate and push the straw to "drill" into the cupcake and pull out a sample (straws can be cut to a length slightly longer than the depth of the cupcake).

STEP 5. Have the students take a core sample from the center of the cupcake.

STEP 6. The students should make a second drawing of their cupcake based on the information from the core sample (use fig. 4*B*). This would represent the first exploration drill hole.

STEP 7. Have the students take two additional core samples either side of the center hole (line up the drill holes across the cupcake). The students should make a new drawing based upon this new data (use fig. 4*C*).

STEP 8. Have the students cut open their cupcakes, bisecting the drill holes. Have the students make a final cross section of the inside of their cupcake and compare it to their previous drawings (use fig. 4*D*). Discuss how additional drill holes give a better understanding of the "mineral deposit."

[Hint: Keep relating what the students are doing to what real-life geologists do. Nobody eats until the discussion is complete!]

Evaluation and Discussion:

Questions to have the students answer are:

1. How are your cross sections different from the initial cross section you made before collecting core samples? Does the collection of additional information help determine where the various layers are?
2. Were the mineral deposits—red layers for zinc, blue layer for copper, and yellow layer for gold—evenly distributed in the cupcake?
3. If you could collect two, three, or four cores from the cupcake, where would you drill your cores and why?
4. Can the cores tell you how deep the various layers are?
5. If you could not collect cores, discuss another method for collecting data to determine what the subsurface material would be like.

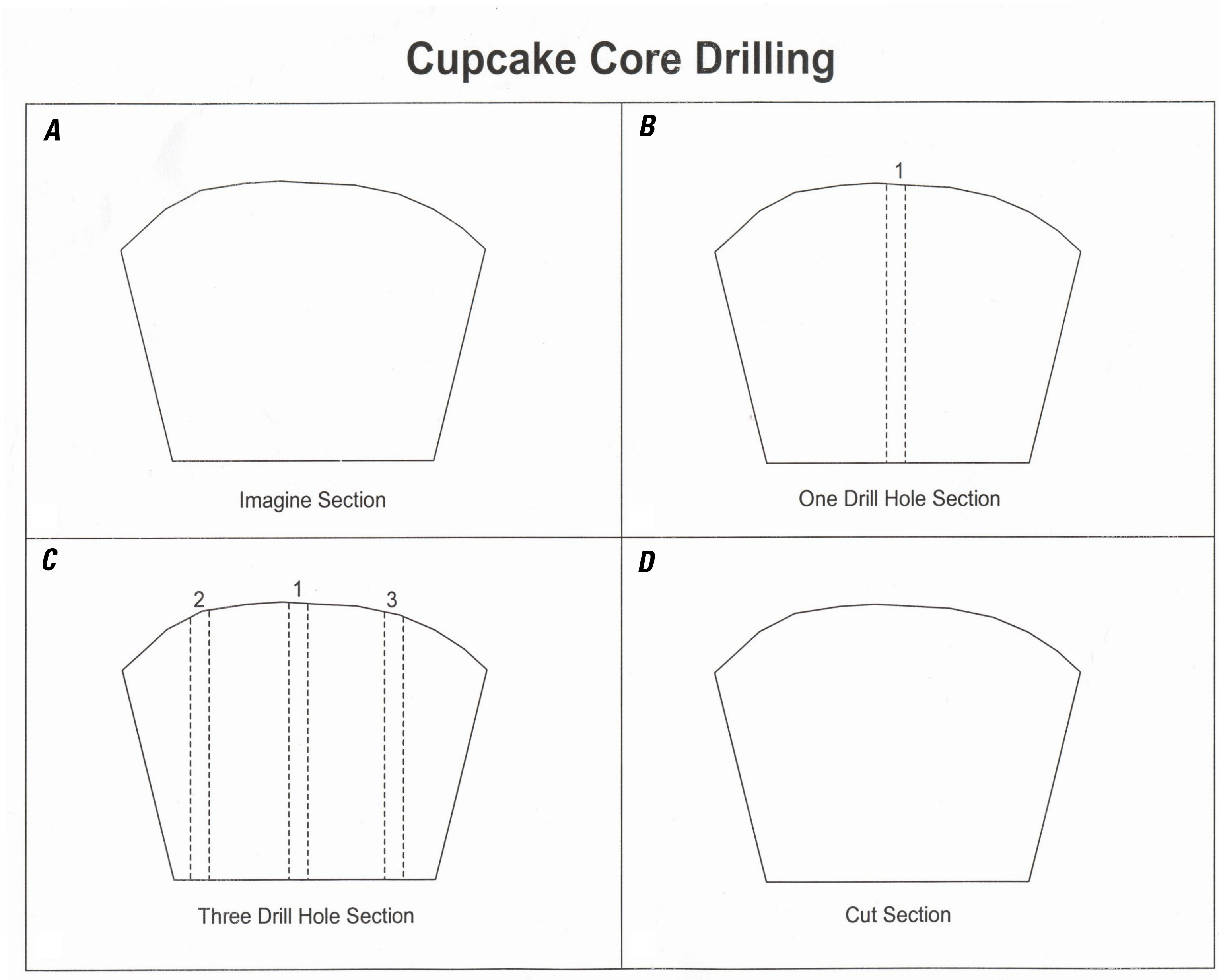


Figure 4. Template for drawing cupcake core-drilling cross sections.

Activity 4—Chocolate Chip Cookie Mining

Suggested Grade Level: 5 through 8

Objective: The purpose of this game is to give the students an introduction to the economics of mining. Each student buys "property," purchases the "mining equipment," pays for the "mining operation cost," and completes "reclamation" of his or her property while receiving money for the "ore mined."

Students must make decisions on which property to buy and which tools to use, some of the same decisions that must be made in the mining industry. The objective of the game is to learn how to run a profitable mining operation that is environmentally sound.

Materials:

Play money
Large square graph paper
3 different brands of chocolate chip cookies
Flat toothpicks
Round toothpicks
Paper clips
Pencils

Instructions:

Each student starts with $19 of cookie mining money.
Each student receives a sheet of graph paper.
Each student must buy his/her own "mining property" (cookie); only one property per student.

Cookies for sale are:
Brand 1—$3.00
Brand 2—$5.00
Brand 3—$7.00

STEP 1. Have the students purchase a "mining property" (cookie).

STEP 2. After the cookie is bought, the student places thecookie on the graph paper and using a pencil traces the outline of the cookie. The student must then count each square that falls inside the circle. (Note: Count squares that are one-half or more inside the circle as a full square. Do not count squares having less than one-half of their area inside the circle.)

STEP 3. Now each student must buy his/her own "mining equipment." More than one piece of equipment may be purchased. (Note: Equipment may not be shared between players.)

Mining equipment costs:
Flat toothpick—$2.00
Round toothpick—$4.00
Paper clip—$6.00

STEP 4. Have the students mine their property, removing the chocolate chips, following the rules below.

Rules:

(1) No student can use his or her fingers to hold the cookie. The only things that can touch the cookie are the mining tools and the paper the cookie is sitting on.

(2) Students should be allowed a maximum of 5 minutes to "mine" their cookie. Players that finish before the 5 minutes are up should only use the actual time spent "mining" to calculate mining cost ($1.00 per minute).

(3) A student can purchase as many mining tools as he or she desires, and the tools can be of different types.

(4) If the mining tools break, they are no longer useable, and a new tool must be purchased.

(5) Sale of the chocolate chips brings $2.00 per chip; broken chips can be combined to make 1 whole chip.

(6) After the cookie has been "mined," what is left of the cookie must be placed back into the circled area on the graph paper. This can only be accomplished using the mining tools—no fingers or hands allowed.

(7) Reclamation cost is $1.00 per graph-paper square.

(8) Apply profit calculation: Revenue (chips mined at $2.00 each) minus Costs (property, tools, mining, and reclamation costs) = Profit.

(9) The player with the largest net profit at the end of the game wins.

(10) All players WIN at the end, because they get to eat what's left of their cookie!

Evaluation and Discussion:

Have the students discuss the following:

1. Which cookie gives you the best return (profit) for your mining efforts?
2. What is the best mining equipment?
3. What is the total cost of reclamation?
4. Would you use different mining equipment with different types of cookies?
5. Is the type of equipment you use related to your mining cost?
6. What would you do if you owned properties with different types of resources (cookies)? What decisions would you make?
7. What economic choices did you make as you mined your property?

Activity 5—Extracting Metal (Copper) From A Rock

Suggested Grade Level: 5 through 8

Objective: The lesson objective is to demonstrate how metal (copper) can be extracted from mined rock through a process called "solvent extraction."

Materials:

Small plastic container
2 tablespoons of crushed oxide copper ore
2 to 4 oz. of diluted (5% solution) sulfuric acid (H_2SO_4)
2 clean iron nails (not galvanized roofing nails or coated finish nails)
Steel wool
Safety goggles
Rubber gloves
Laboratory coat

Instructions:

STEP 1. Put approximately two tablespoons of crushed oxide copper ore into the plastic container.

STEP 2. Completely cover the crushed rock with diluted (5% solution) sulfuric acid (H_2SO_4).

STEP 3. Wait 5 to 10 minutes for the copper to dissolve and a blue solution to appear.

STEP 4. Next dip a clean iron nail into the solution. The iron nails should be cleaned before use with steel wool to remove any residual wax.

STEP 5. Through ion exchange, the positive iron ions attract the copper ions in solution and copper instantly plates onto the iron nail.

Note: Perform this activity in a well ventilated area, avoid breathing any fumes produced. Remember, when doing any activity that involves the use of chemicals, be sure to use the proper Personal Protective Equipment (PPE), such as gloves, safety glasses, and laboratory coats. Although relatively dilute, every precaution should be taken to keep the acid from touching skin or clothing. If you get some acid on your skin, rinse the skin immediately with plenty of cold water. Remember to dispose of the remaining blue solution properly; be sure to dilute the solution with 1 gallon of water, and wash the plastic container thoroughly.

Evaluation and Discussion:

Extraction of metals from ores is usually a two-step process. Step one is to produce a concentrate of the ore mineral. This is what you did by adding the crushed copper ore that contains both copper carbonate ($CuCO_3$) and copper hydroxide ($Cu(OH)_2$) minerals. The next step is to use a caustic solution (acid) to leach (dissolve) the metal from the ore or concentrate. The metal is recovered from solution by an electrolytic process known as electrowinning. This is where a pure metal is precipitated onto the cathode of an electrochemical cell. Many types of metals are recovered using this system referred to as solvent extraction-electrowinning (SX-EW). With the help of electricity, copper can be electroplated onto large (4 foot by 4 foot) stainless-steel plates, producing approximately 200 pounds of copper on each side of a plate in 3 to 5 days.

The activity you preformed involved crushing the copper ore and treating it with a weak solution of sulfuric acid. The acid solution resulting from this treatment contained a high concentration of dissolved copper sulfate. To precipitate the copper an iron nail was added. The iron nail reacts with dissolved copper sulfate to produce solid copper and dissolved iron sulfate. The remaining iron sulfate is a by product that must be either used or disposed of. As mentioned above, copper can also be extracted from an acid solution through the use of electrolytic methods.

Group questions:

1. Where is copper ore found?
2. How is copper recovered and processed?
3. How much energy is involved in processing copper ore?
4. Think about the cost of finding, crushing, and transporting the ore to a processing plant and the cost of electricity.
5. How would our daily lives be affected if all the copper on Earth disappeared? (Hint: Copper is a good conductor of both heat and electricity. More than 70% of the copper consumed in the United States is used for electrical purposes. Copper is used in many industrial processes, airplane and automobile manufacturing, plumbing, and in major communications systems that use copper circuits and wires.)

Additional Resources:

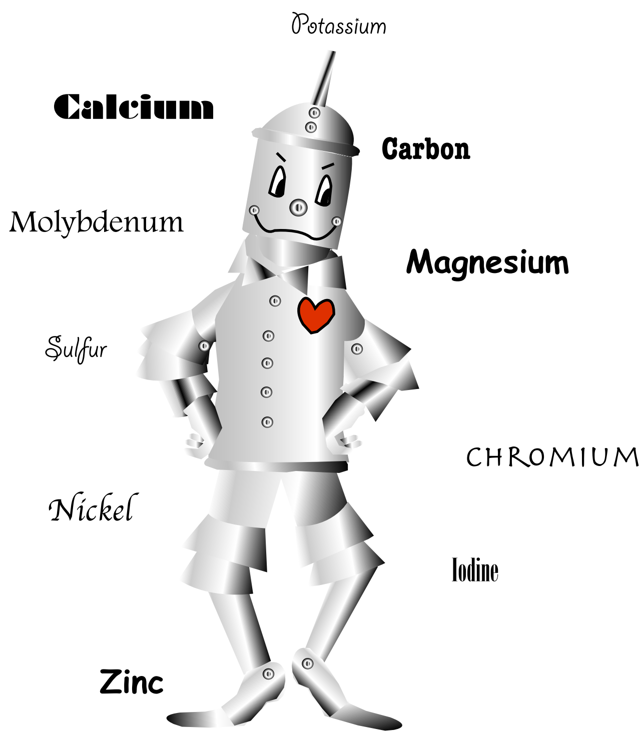
Brown, Phil, 2004, Extraction of Metals: [URL: http://www.wpbschoolhouse.btinternet.co.uk/page04/Mextract.htm#copper/].

University of California, 2000, Material Resources: The Regents of the University of California [URL:http://www.sepup.com/docs1/SnS_print_samples.pdf/SnS_TG-24_Copier_Extraction.pdf].

U.S. Geological Survey, 2005a, Minerals Information: [URL: http://minerals.usgs.gov/minerals/].

Activity 6—Minerals in Your Body

Suggested Grade Level: 5 through 8



Objective: This is an exercise to help students learn about the distribution of elements in their bodies. Which elements are important for growth and development? Which of these elements are derived from minerals? Do the quantities of these elements change through time, as they grow?

Materials:

Copy of table 4 for each student

Instructions:

Oxygen (O) is the most abundant element in the Earth's crust and in your body. Remember, that an element is a substance whose atoms have the same atomic number, and a mineral may be composed of a single element like copper (Cu) or a compound of elements like halite or "salt" (NaCl). For a 66 pound (30 kg person) 40.3 pounds (18.3 kg) of oxygen (61% of total body weight) is found in the body in the form of water, proteins, nucleic acids, carbohydrates, and fats.

Minerals in their elemental form are important as they are used by protein "enzymes" to run most of the body's chemical reactions. More than 30 elements play a key role in helping plants and animals live a healthy life. Elements are the basic building blocks of life. Our bodies use various elements such as calcium to build strong bones, iron to make tendons and ligaments, and iron to help blood carry oxygen. The greatest source of these elements is the food we eat. Sometimes we need to take additional dietary supplements, such as vitamins, to assure that we maintain the proper chemical balance in our body.

STEP 1. Using table 4, have the student find the amount of minerals in their body, based on their weight.

STEP 2. Assign an element (preferably a mineral) to each student or group of students to study. Have the students present their findings to the class as part of a group discussion or as part of a writing assignment.

Evaluation and Discussion:

Once each student or group of students has obtained information on his/her element, have the student(s) present their findings to the class. Discussion items should include what biological functions (role) the element has for growth and development.

You can lead the class in a general discussion by asking the following questions:

1. Which elements are important for growth and development?
2. Does the makeup (distribution) of these elements change as you get older?
3. What is the biological role of these elements?
4. For Grades 9 to 12, have the students discuss the role of (certain elements)—Mg, Ca, Zn—as they are used by protein "enzymes" to run most of the body's chemical reactions.
5. For Grades 9 to 12, have the students discuss the relation between minerals and vitamins.

Additional Resources:

American Salt Institute: [URL: http://www.saltinstitute.org/15.html].

Mineral Information Institute, 2004a, The role of elements in life processes: [URL: http://www.mii.org/periodic/LifeElement.html].

Winter, Mark, 2005, WebElements™ Periodic Table: [URL: http://www.webelements.com/].

Table 4. The most common elements in the human body (data derived from Winters, 2005).

ELEMENT		30 kg person[1]	40 kg person[2]	50 kg person[3]
Name	Symbol	Grams	Grams	Grams
Oxygen	O	18,300	24,400	30,500
Carbon	C	6,900	9,200	11,500
Hydrogen	H	3,000	4,000	5,000
Nitrogen	N	780	1,040	1,300
Calcium	Ca	420	560	700
Phosphorus	P	330	440	550
Potassium	K	60	80	120
Sodium	Na	42	56	70
Chlorine	Cl	36	48	60
Magnesium	Mg	8.1	10.8	13.5
Silicon	Si	7.8	10.4	13
Iron	Fe	1.8	2.4	3
Zinc	Zn	0.99	1.32	1.65
Copper	Cu	0.03	0.04	0.05

[1] 30 kg person = 67.5 pound person
[2] 40 kg person = 88 pound person
[3] 50 kg person = 110 pound person
1 gram (g) = 0.03527 ounces
1 kilogram (kg) = 2.205 pounds

Activity 7—The Mineral Talc or "Rocks on Your Face"

Suggested Grade Level: 5 through 8

Objective: Students will learn about the chemical characteristics of minerals. Talc may have been the first mineral that most students came into close contact with. Talc is the main ingredient in talcum powder, which is used to prevent diaper rash.

Materials:

Talc (solid piece)
100-grit sandpaper
220-grit sandpaper
600-grit sandpaper
No. 4 (0000) steel wool
Old blue jean rag or soft cloth

Instructions:

STEP 1. The talc can be cut on a wood band saw to obtain a flat surface to polish.

STEP 2. Start with the 100-grit sandpaper; sand the flat surface until you have made a small pile of talcum or "baby powder." Remember, it doesn't smell like baby powder because no fragrance has been added. Feel how soft and smooth the powder is.

STEP 3. With the 220-grit sandpaper, continue to sand the same flat surface taking out all the deep scratches. You will notice that the powder is finer; it is the same as that used in cosmetics (this is why we call it "Rocks on your Face").

STEP 4. Use the 600-grit black sand paper to produce an even finer powder. Such fine powder is used in deodorants and in making paper, plastics, and paint.

STEP 5. With the no. 4 (0000) steel wool you will be able to take out the last of the scratches on the talc block and produce a very fine powder like that used on the outside of chewing gum. Remember, its not powdered sugar but talc that keeps the gum from sticking to the wrapper.

STEP 6. With an old blue jean rag or soft cloth you can rub really hard to polish the talc surface by hand to a gloss.

Evaluation and Discussion:

Below is a list of mineralogical and physical characteristics of talc.

Mineralogical characteristics:

- Chemistry—Magnesium Silicate Hydroxide, $Mg_3Si_4O_{10}(OH)_2$
- Class—Silicates
- Group—Clays (the Montmorillonite/Smectite Group)

Physical characteristics (see Plante, Peck, and von Bargen, 2003 for an on-line description of the basic properties of minerals):

- Color—green, gray and white to almost silver.
- Luster—dull to pearly or greasy.
- Hardness—1 (can leave mark on paper and be scratched with a fingernail).
- Specific Gravity—2.7 to 2.8 (average).
- Streak—white.
- Other Characteristics—cleavage flakes are slightly flexible but not elastic, and talc has a soapy feel to the touch (talc is sometimes called soapstone).
- Best Field Indicators—softness, color, soapy feel, luster, and cleavage.

Evaluation and Discussion:

Talc is an important industrial mineral. Its resistance to heat, electricity, and acids make it an ideal surface for laboratory counters tops, electrical switchboards, and artwork (soapstone carvings). Talc is used as an ingredient in paints, plastics, paper, rubber products, roofing materials, ceramics, and insecticides. It is most commonly known as the primary ingredient in talcum powder. Talc is also used in deodorants and cosmetics and is even found on chewing gum. Have the students read the labels from a variety of cosmetic products. Is talc listed as one of the ingredients? Have the students discuss how talc is used in their daily lives.

Additional Resources:

Plante, Alan, Peck, Donald, and von Bargen, Donald, 2003, Mineral Identification Key II: [URL: http://www.minsocam.org/MSA/collectors_corner/id/mineral_id_keyi1.htm].

U.S. Geological Survey, 2005a, Minerals Information: [URL: http://minerals.usgs.gov/minerals/].

Weisgarber, S.L., and Van Doren, Lisa, 2004, Rocks and minerals everywhere: Ohio Department of Natural Resources Hands on Earth Science No. 6 [URL: http://www.dnr.state.oh.us/geosurvey/pdf/ho06.pdf].

Activity 8—Make Your Own Toothpaste

Suggested Grade Level: 5 through 8

Objective: The Earth is made of materials that have distinct properties and provide resources for human activities. Students will learn about the basic composition of a product (toothpaste) that they use on a daily basis. This activity can lead to a discussion of what products we use on a daily basis and the importance of minerals in our environment (refer to the following: Frank and others, 2001; Weathers and others, 2001).

Materials:

3 colored antacid tablets (about 1 tsp of powder)
1/8 tsp baking soda
3 to 4 drops of water
Small paper or plastic cup (like the kind you put ketchup in at fast-food restaurants)
Small mortar and pestle

Instructions:

STEP 1. Pick an antacid color to use to make white, green, or pink toothpaste.

STEP 2. Grind 3 antacid tablets into powder using a mortar and pestle (coffee grinder will work for bulk amounts).

STEP 3. Place powder in plastic/paper cup.

STEP 4. Add baking soda and water.

STEP 5. Stir using toothpick until a paste forms.

Evaluation and Discussion:

Ask your students the following questions:

1. What ingredients are listed on a container of toothpaste?
2. How do the ingredients you used to make your own toothpaste compare with what is listed on the container of store bought toothpaste?
3. What are the active ingredients in toothpaste?
4. Antacid tablets contain silica and calcium carbonates, which work as abrasives keeping plaque from building up on teeth. Calcium carbonate is derived from mined and processed limestone, and baking soda is obtained from the mineral trona. When the right amount of water is combined with the powered minerals, it forms a paste. The average toothpaste purchased by consumers today contains some or all of the above ingredients. The toothpaste tube contains aluminum, from bauxite, and plastics, derived from petroleum products.
5. Was toothpaste always put into a tube container? Have student's research antique toothpaste containers. Modern toothpaste was developed in the 1800s. Soap was added to toothpaste in 1824. By the 1850s, chalk was added to toothpaste. Colgate was the first company to mass-produce toothpaste in jars. The first collapsible tube of toothpaste was manufactured in 1896.

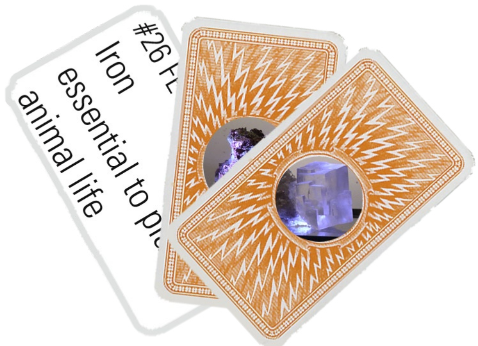
Additional Resources:

Prencipe, M., Masters, J.G., Thomas, K.P., and Novfleet, J., 1995, Squeezing out a better toothpaste: American Chemical Society, Chemtech, Dec. 1995 [http://pubs.acs.org/hotartcl/chemtech/95/dec/dec.html].

Weisgarber, S.L., and Van Doren, Lisa, 2004, Rocks and minerals everywhere: Ohio Department of Natural Resources Hands on Earth Science No. 6 [URL: http://www.dnr.state.oh.us/geosurvey/pdf/ho06.pdf].

Activity 9—Mineral Flash Cards

Suggested Grade Level: 5 through 8



Objective: Every segment of society uses minerals or a product of mineral resources everyday. The roads on which we drive and the buildings in which we live, learn, and work all contain minerals. The student will gain a better understanding of the importance of minerals to our economy and environment by understanding how commonly used metallic and nonmetallic minerals, ore minerals, mineral byproducts, and rock types are used to make products we use in our daily lives.

Materials:

Flash cards (5 × 7 inch); number of cards required will vary depending on the assignment. (Refer to appendix 2, Minerals and Their Uses.)

Instructions:

Give each student one to five cards. For Grades 9 to 12 each student will have 2 cards for each assigned mineral or commodity. Figure 5 is an example of a template you can use.

STEP 1. From appendix 2, randomly assign each student one to five minerals or commodities.

STEP 2. At the top of each card, have the student write the name of the assigned mineral or commodity.

STEP 3. Assign the following:

For grades 5 to 8 have the students answer the following five questions, which should be listed on each card.

1. What is the chemical composition of the resource?
2. What is the source of the mineral/commodity?
3. How is it obtained (mined)?
4. Where is it mined, and is it mined in your state?
5. What are two uses for this resource?

For grades 9 to 12, have the students use an additional card and answer the following 6 questions.

1. What is the domestic (United States) production of this resource?
2. How much does the United States consume on a yearly basis?
3. How much does the United States import on a yearly basis?
4. What is the current world distribution of the resource? (major countries producing the resource)
5. What is the current market price of this resource? Has the market price changed over time?
6. Can this mineral be recycled?

Evaluation and Discussion:

Each student (cards can be assigned to a group of students) should think about and answer the questions and be able to present the information to the class. You can also have students write an essay based on what they have learned about the assigned commodities. Examples of completed cards are shown in figure 5.

Additional Resources:

Barthelmy, David, 2005, Mineralogy Database: [URL: http://webmineral.com/index.shtml]. (This mineral database contains 4,442 individual mineral species descriptions with links and a comprehensive image library.)

Winter, Mark, 2005, WebElements™ Periodic Table: [URL: http://www.webelements.com/].

Kesler, S.E., 1994, Mineral resources, economics, and the environment: New York, N.Y., MacMillan College Publishing Company, 391 p.

U.S. Geological Survey, 2005a, Minerals Information: [URL: http://minerals.usgs.gov/minerals/].

Figure 5. Examples of flash cards used in activity 9. *A,* an example of questions to use for card 1 (grades 5-12); *B,* an example of questions to use for card 2 (grades 9-12); *C*, an example of a completed card 1; *D,* an example of a completed card 2.

(*A*) CARD 1

Assigned mineral or commodity:

1. CHEMICAL COMPOSITION:

2. SOURCE:

3. HOW IS IT MINED?

4. WHERE IS IT FOUND?

5. NAME TWO USES.

   (a)

   (b)

6. SOURCE OF YOUR INFORMATION:

(*B*) CARD 2

Assigned mineral or commodity:

1. DOMESTIC PRODUCTION:

2. DOMESTIC CONSUMPTION:

3. U.S. IMPORTS:

4. CURRENT MARKET VALUE:

5. WORLD or UNITED STATES DISTRIBUTION:

6. RECYCLED:

7. SOURCE OF YOUR INFORMATION:

(*C*) CARD 1

Assigned mineral or commodity: CADMIUM

1. CHEMICAL COMPOSITION: Symbol Cd.

2. SOURCE: Ore mineral, Greenockite CdS, and Sphalerite (Zn,Cd)S. Cadium is associated with zinc deposits. Sphalerite is found almost entirely in hydrothermal deposits. “Sedimentary exhalative (sedex) deposits consist of layers of lead-zinc-iron sulfide that were precipitated by submarine hot springs that flowed into basins filled with fine-grained, clastic sediments” (Kesler, 1994, p. 215).

3. HOW IS IT MINED? Extracted as a byproduct of the mining and processing of zinc ores. “Primary cadmium metal in the United States is produced by two companies, one in Illinois and one in Tennessee, as a byproduct of smelting and refining of zinc metals from sulfide ore concentrates” (USGS, 2005a).

4. WHERE IS IT FOUND? Cadmium is refined in 27 countries. The United States is the world’s second largest refiner.

5. NAME TWO USES:
(a) Seventy-five percent of the cadium consumed goes into nickel cadium (NiCd) batteries.
(b) Twelve percent of the cadium consumed is used as pigments for glass, plastics, and paints.

6. SOURCE OF YOUR INFORMATION. Kesler, 1994; Butterman and Plachy, 2004.

(*D*) CARD 2

Assigned mineral or commodity: CADMIUM

1. DOMESTIC PRODUCTION: 700 metric tons (2002 data).

2. DOMESTIC CONSUMPTION: 2,250 metric tons (2002 data). The United States is the third largest world consumer of cadmium.

3. U.S. IMPORTS: 25 metric tons (2002 data).

4. CURRENT MARKET VALUE: $639.00/metric ton (2002 data).

5: WORLD or UNITED STATES DISTRIBUTION: Refined in 27 countries.

6. RECYCLED: In the United States the recycling of NiCd batteries provides a source of secondary cadmium (Plachy, 2003).

7. SOURCE OF YOUR INFORMATION: Kesler, 1994; Kelley and others, 2004; Plachy, 2003; USGS, 2004 and 2005a.

Activity 10—Personal Mineral Consumption

Suggested Grade Level: 5 through 8

Objective: Students will calculate the total amount of selected minerals they consume in a lifetime. The exercise will look at mineral production from the "demand side"—what we consume on a yearly basis. The exercise will also help students learn to critically think about how their lives may be affected if the supply (availability) of a mineral resource changes.

Materials:

Figure 6
Copy of worksheet 1 and 2 (figs. 7, 8)

Instructions:

This exercise can be done on an individual basis or as a class project. Have the students find the current cost for the commodities listed on worksheet 1 and complete worksheets 1 and 2. Mineral and economic information can be obtained from the following sources:

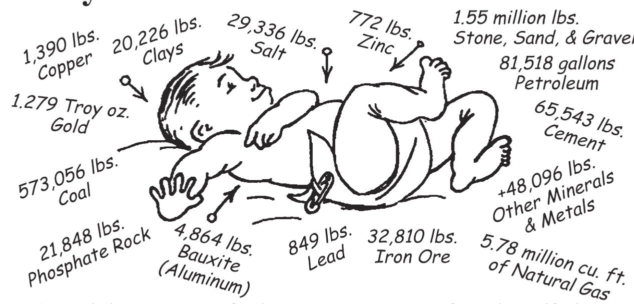
- Business section of most major newspapers, such as the New York Times, Wall Street Journal, Financial Times.
- Mineral and Economic information from the USGS (2004 and 2005c).
- Doing an on-line search for a specific commodity.

Using Worksheet 1:

STEP 1. Our society is based on mineral resources. Column A lists eight minerals or commodities that we use on a daily basis, whether metals for machinery, mineral fertilizers for agriculture, or aggregates for construction. Have the students look at the list and have them name several products which are made from the minerals or commodities listed in column A. (Refer to appendix 2, Minerals and Their Uses.) The values obtained for this exercise are the values listed for each commodity in fig. 9. (Note: For the purpose of this exercise, we have combined the 1.55 million pounds of stone, sand, and gravel (fig. 9) as one entry—1.55 million pounds of sand/gravel (construction)).

STEP 2. Column B lists the estimated number of pounds (or metric ton equivalent) of each commodity that a person will use in his/her lifetime. Determine the cost per pound or metric ton for each commodity and enter the number in the appropriate column—column C, cost per pound, or column D, cost per metric ton. Note that the cost for aluminum, copper, and lead is usually quoted in dollars per pound ($/pound); cost for cement, iron ore, phosphate, salt, and sand/gravel is usually quoted in dollars per metric ton ($/ton).

Every American Born Will Need . . .



3.5 **million pounds of minerals, metals, and fuels in a lifetime**

Figure 6. Every American Born Will Need...(from Mineral Information Institute, 2004b; used with permission).

STEP 3. Multiply the price in column B (pounds or metric ton) times either column C (Cost $/pound) or D (Cost $/metric ton) and enter the number in column E. Column E will give you the total value ($) of the commodity you consumed in your lifetime.

STEP 4. Next divide column E by 75 (estimated life expectancy) and enter the number in column F. Column F will give you the dollar value for each commodity you use per year.

STEP 5. Total the values for column E and column F and enter them at the bottom right of the worksheet.

Using Worksheet 2:

STEP 1. Write the total value obtained from worksheet 1, column F, in column A of worksheet 2.

STEP 2. Write your age in column B.

STEP 3. Multiply column A (Total $ Value used/year) times column B (Your age) and enter the number in column C. Column C represents the dollar amount of the selected commodities you have used since you were born (Total $ Value used).

STEP 4. Subtract your age from 75. Multiply this value with the value in column A and enter it in column D. This will give you the Total future $ Value used.

STEP 5. Add the values from column C and D together and enter it in column E. Column E represents the $ Value used in a lifetime. (Note: this should be the same value, to the nearest dollar, as the total value for column E on worksheet 1.)

Examples of completed worksheets 1 and 2 are given in figure 9.

Evaluation and Discussion:

Have students study one resource and write an essay on how their lives would change if that resource were no longer available. Have the students think about the following:

1. Why would a resource become rare?
2. Is it renewable or nonrenewable?

3. What is its global distribution, and what nations have the most of the resource?
4. What are the costs related to extraction and processing of the resource? How does cost affect the demand for the resource?
5. What is the relationship between the value of the resource and gross domestic productivity?
6. What has happened to the price of the resource through time
7. What would happen to demand if the population increased or decreased?
9. What would happen to demand if the resource was found only in one or two nations?
10. What would happen to demand if a "substitute" commodity was found?

An excellent source for understanding how the United States nonfuel mineral industry has changed through time is presented by the USGS (2005b):

> At the beginning of the [20th] century, some minerals and metals industries were well established, such as those of copper, gold, lead, lime, and salt; some industries were just beginning, such as aluminum and lithium; and some materials, such as germanium, magnesium, and titanium, had not been commercially produced. Mining was labor intensive and could be dangerous. In 1900, U.S. minerals consumption was less than 100 million metric tons. By 2000, U.S. minerals consumption had increased to more than 3.3 billion metric tons, and included not only the materials that constitute the bulk of consumption—crushed stone and steel—but some of the materials for which there were no uses in 1900. Improved safety measures and technological advancements in mining and processing methods have made mining safer and increased efficiency. The time line showing events that have affected the U.S. minerals industry during the 20th century is a representative list of individual events that have influenced the production and/or consumption of a single commodity or a group of commodities. In many cases, changes to the U.S. minerals industry were evolutionary and not marked by a single event. For example, the development of the electrical power generation and distribution industries throughout the first half of the 20th century provided new markets for aluminum, copper, and steel, but no one event in this time period is considered to be pivotal.

An additional source of historical information is presented by Moyer (2004) as an on-line PowerPoint digital movie package that displays patterns of Nevada mineral activity from 1851 to 1995 and historical factors that influenced these patterns. The digital package consists of a full length educational movie with text and two short animations showing the evolving patterns of significant Nevada mineral deposits and mining districts over selected decades.

A	B		C	D	E	F
	Amount used per American in a lifetime					
Mineral/commodity	Pounds	Metric tons	Cost $/pound	Cost $/metric ton	$ Value used in a lifetime	$ Value used per year
Aluminum	4864	2.4		$	$	$
Cement	65,543	32.7		$	$	$
Copper	1390	0.69		$	$	$
Iron ore	32,810	16.4		$	$	$
Lead	849	0.42		$	$	$
Phosphate	21,848	10.92		$	$	$
Salt	32,061	16.03		$	$	$
Sand/gravel (construction)	1,550,000	775.00		$	$	$
				TOTAL	$	$

Figure 7. Worksheet 1 Activity 10—personal mineral consumption.

A	B	C	D	E
Total $ Value used/year	Your age	Total $ Value used	Total future $ Value used	$ Value used in a lifetime
$		$	$	$
$		$	$	$
$		$	$	$
$		$	$	$

Figure 8. Worksheet 2 Activity 10—personal mineral consumption.

Worksheet 1

A	B		C	D	E	F
Mineral/commodity	Amount used per American in a lifetime: Pounds	Amount used per American in a lifetime: Metric tons	Cost $/pound	Cost $/metric ton	$ Value used in a lifetime	$ Value used per year
Aluminum	4864	2.4		$1,550.00	$3,720.00	$49.60
Cement	65,543	32.7		$76.00	$2,485.20	$33.14
Copper	1390	0.69		$1,559.00	$1,075.71	$14.34
Iron ore	32,810	16.4		$25.83	$423.61	$5.65
Lead	849	0.42		$961.00	$403.62	$5.38
Phosphate	21,848	10.92		$28.75	$313.95	$4.19
Salt	32,061	16.03		$26.29	$421.43	$5.62
Sand/gravel (construction)	1,550,000	775.00		$5.07	$3,929.25	$52.39
				TOTAL	$12,772.77	$170.30

Worksheet 2

A	B	C	D	E
Total $ Value use/year	Your age	Total $ Value used	Total future $ Value used	$ Value used in a lifetime
$170.30	8	$1,362.40	$11,410.10	$12,772.50
$170.30	10	$1,703.00	$11,069.50	$12,772.50
$170.30	12	$2,043.60	$10,728.90	$12,772.50
$170.30	14	$2,384.20	$10,388.30	$12,772.50

Values set at 1992 prices. Current prices can be found at http://minerals.usgs.gov/minerals/pubs/mcs/.

Figure 9. Examples of completed worksheets for Activity 10.

How to Obtain Mineral Specimens

There are many sources for mineral specimens. Check your local yellow pages under lapidary, rock or gem shop, or mineral specimens. Many operating mines and mining companies have websites, and some active mines will send ore if you request it. To find a location of a mine, go to the U.S. Geological Survey Minerals Web Site (http://minerals.usgs.gov/minerals) and select the Mine and Mineral Processing Plant Locations link. The Association of American State Geologists (http://www.stategeologists.org/) lists individual state geological surveys that may have additional information on mines and mining in their states.

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Appendixes 1–2

Appendix 1.—Glossary

Aggregates Particles of rocks. Natural sand, gravel, and crushed rock are important aggregates used in the construction industry.

Anticline Layers of rock folded into the shape of an arch. The youngest rock layers are on the outer layer of the arch, and the oldest layers are at the core of the fold. Anticlines with reservoir-quality rocks in their core and impermeable rocks in the outer layers of the fold are excellent traps for oil and gas and are therefore important in petroleum exploration and extraction. The opposite of a syncline.

Asthenosphere The layer of the Earth's interior below the lithosphere. The "plastic-like"material in the asthenosphere is weak, able to flow and convect, and the rigid tectonic plates of the lithosphere rest on and move over the asthenosphere.

Average crustal abundance The average amount of an element contained in the Earth's crust.

Bedrock Solid rock that underlies unconsolidated material (sediments) near the surface.

Beneficiation Improvement of the grade of ore by milling, floatation, sintering, gravity, concentration, or other process.

Byproduct A secondary or additional product; something produced, as in the course of a manufacture, in addition to the principal product.

Commodity An article of trade or commerce, especially an agricultural or mining product that can be processed and resold.

Covergent boundary A boundary where two of the Earth's tectonic plates are moving toward one another. Most convergent plate boundaries are called "subduction zones" because one of the plates moves down, or is "subducted," beneath the other. A subduction zone is usually marked by a deep trench on the sea floor. An example is the Cascadia Subduction Zone offshore of Washington, Oregon, and northern California. Earthquakes in subduction zones are common.

Divergent boundary A boundary where two of the Earth's tectonic plates are moving away from each other. This generally occurs along "oceanic spreading ridges," submarine features that are impressive mountain ranges. New ocean floor is produced along the spreading ridges as molten rock (magma) from the Earth's mantle rises into their crests (axes) to form new oceanic crust. About an equal volume of old crust is lost each year along convergent plate boundaries, so the overall size of the Earth stays the same.

Erosion The general process by which the materials of the Earth's crust are loosened, dissolved, or worn away and simultaneously moved from one place to another by natural agencies.

Fault A fracture or crack along which two blocks of rock slide past one another. Blocks can be displaced vertically (vertical fault) or horizontally (lateral or strike-slip fault). Movement on active faults may occur rapidly, in the form of an earthquake, or slowly.

Grade of ore The concentration of a desired commodity within an ore deposit.

Hydrosphere The hydrosphere includes all water on Earth.

Igneous rock Rock formed when molten rock has cooled and solidified, either intrusive (granite) cooling inside the Earth or extrusive (basalt) cooling on the surface.

Lithosphere The outermost shell of the Earth, which is composed of a mosaic of a dozen or so large, rigid slabs of rock called "lithospheric" or "tectonic" plates.

Mafic Dark-colored intrusive igneous rock, such as basalt, composed chiefly of minerals such as olivine and pyroxene that contain abundant magnesium and iron. The term mafic also applies to dark-colored minerals rich in iron and magnesium as a group and to metamorphic rocks composed of these minerals.

Metallic mineral A naturally occurring substance that has metallic properties, such as high luster, conductivity, opaqueness, and ductility; pertaining to minerals from which a metal or metals can be extracted.

Metamorphic rock Any rock derived from preexisting rocks by mineralogical, chemical, and (or) structural changes, essentially in the solid state, in response to marked changes in temperature, pressure, shearing stress, and chemical environment, generally at depth in the Earth's crust.

Mineral A naturally occurring inorganic element or compound having an orderly internal structure and characteristic chemical composition, crystal form, and physical properties.

Mineralization The process or processes by which a mineral or minerals are introduced into a rock, resulting in a valuable or potentially valuable deposit.

Mineral deposit A mineral occurrence of sufficient size and grade (concentration) that it might, under the most favorable of circumstances, be considered to have economic potential.

Mineral occurrence A concentration of a mineral (usually considered in terms of some commodity, such as gold) that is considered valuable by someone somewhere or that is of scientific or technical interest. In rare instances, the commodity might not even be concentrated above its average crustal abundance.

Mining life-cycle The processes of deposit exploration and identification; quantitative and qualitative measurement of the deposit; extraction of material and ore beneficiation; and site reclamation.

Muck The material left behind after blasting during the underground mining process.

Non-metallic mineral A naturally occurring substance that does not have metallic properties, such as high luster, conductivity, opaqueness, and ductility.

Ore deposit A mineral deposit that has been tested and is known to be of sufficient size, grade, and accessibility to be producible at a profit.

Reclamation The process of reestablishing stable soils and vegetation in disturbed areas.

Sedimentary rock A "clastic" rock resulting from the consolidation of loose fragments of mechanically formed fragments of older rocks (sandstone), a "chemical" rock formed by precipitation (salt), or an "organic" rock composed of the remains or secretions of plants and animals (certain limestones).

Spreading center Associated with a divergent boundary. A spreading center is an area where new crust is formed.

Subduction zone Associated with a convergent boundary. A region where one crustal block descends beneath another crustal block

Syncline Layers of rock folded into the shape of a trough or "U." The youngest rock layers are at the core of the fold, and the oldest layers on the outer surface of the fold. Synclines do not usually form traps for oil and gas. The opposite of an anticline.

Tectonic plate One of the several large, relatively strong "plates" that constitute the Earth's outer layer. Convection in the underlying astenoshere causes these plates to move relative to each other at an average rate of less than an inch per year. Movements on the faults that define plate boundaries produce most earthquakes.

Tectonics A branch of geology dealing with the broad architecture of the outer part of the Earth, that is, the regional assembling of structural or deformational features, a study of their mutual relations, origin and historical evolution.

Ultramafic Igneous rocks with very low silica content (less than 45%), usually composed of greater than 90 % mafic minerals. Such rocks are typical of the Earth's mantle.

Unconformity A surface or break between layers of rock representing a substantial gap in geologic time. For example, such a break exists where a rock unit overlies the heavily eroded surface of an older rock unit.

Vein A fracture in rock that has been sealed with minerals precipitated from a solution.

Weight percent The percentage of a component relative to the total weight of an item. A common way to express concentrations of an element, sometimes referred to as mass percent.

Appendix 2.—Minerals and Their Uses

Every segment of society uses minerals and mineral resources everyday. The roads we ride or drive on and the buildings we live learn and work in all contain minerals. Below is a selected list of commonly used metallic and non-metallic minerals, ore minerals, mineral byproducts, aggregates, and rock types that are used to make products we use in our daily life (see Frank, Weathers, and Galloway, 2001; Weathers, Galloway, and Frank, 2001).

Aggregates Natural aggregates include sand, gravel, and crushed stone. Aggregates are composed of rock fragments that may be used in their natural state or after mechanical processing, such as crushing, washing, or sizing. Recycled aggregates consist mainly of crushed concrete and crushed asphalt pavement (Goonan, 1999). For additional information on aggregates see Tepordei (1997).

Aluminum Aluminum is the most abundant metallic element in the Earth's crust. Bauxite ore is the main source of aluminum. Aluminum is used in automobiles and airplanes (36%), bottling and canning industries (25%), building and electrical (14%) and in other applications (25%).

Asbestos Asbestos is a class of minerals that can be readily separated into thin, strong fibers that are flexible, heat resistant, and chemically inert. Asbestos minerals are used in fireproof fabrics, yarn, cloth, and paper and paint filler. Asbestos is used to make friction products, asbestos cement pipes and sheets, coatings and compounds, packing and gaskets, roofing and flooring products, paints and caulking, and chemical filters. Fibers are dangerous when breathed, so uses must protect against fibers becoming airborne.

Basalt Basalt is an extrusive igneous rock. Crushed basalt is used for railroad ballast, aggregate in highway construction, and is a major component of asphalt.

Barium Barium is an element, derived primarily from the mineral barite, and used as a heavy additive in oil-well-drilling mud, paints, rubber, plastic and paper; production of barium chemicals; and glass manufacturing.

Beryllium Beryllium, an element commonly associated with igneous rocks, has industrial and nuclear defense applications and is used in light, very strong alloys for the aircraft industry. Beryllium salts are used in x-ray tubes and as a deoxidizer in bronze metallurgy. The gemstones of beryl, a beryllium mineral, are emerald and aquamarine.

Bromine Bromine, recovered commercially through the treatment of seawater brines, is used in leaded gasoline, fire extinguishers and retardants, well-completion fluids, and sanitary preparations. Bromine is the only liquid nonmetallic element.

Cadmium Cadmium is used in plating and alloying, pigments, plastics, and batteries. Cadmium is obtained from the ore minerals Sphalerite (Zn,Cd)S and Greenockite (CdS)

Cement Cement is used for building materials, stucco, and mortar. Cement is "a mixture of powdered lime, clay, and other minerals that crystallize to form a hard solid when water is added (hydraulic cement) or as a binding material in concrete" (Kesler, 1994). An excellent overview of cement, its chemistry, and properties can be found in MacLaren and White (2003).

Chromium Chromium is used in the production of stainless and heat-resistant steel, full-alloy steel, super alloys and other alloys. Chromium is obtained from the ore mineral Chromite $(Mg,Fe)(Cr,Al,Fe)_2O_4$

Clays There are many different clay minerals that are used for industrial applications. Clays are used in the manufacturing of paper, refractories, rubber, ball clay, dinnerware and pottery, floor and wall tile, sanitary wear, fire clay, firebricks, foundry sands, drilling mud, iron-ore pelletizing, absorbent and filtering materials, construction materials, and cosmetics.

Cobalt Half of the consumption of cobalt is used in corrosion- and abrasion-resistant alloys with steel, nickel, and other metals for the production of industrial engines. Other uses of cobalt metal include magnets and cutting tools. Cobalt salts are used to produce a blue color in paint pigments, porcelain, glass, and pottery. Cobalt is obtained from the ore minerals Linneaite (Co_3S_4), Cobaltite $(Mg,Fe)(Cr,Al,Fe)_2O_4$, and $(Fe,Ni,Co)_{1-x}S_x$.

Copper Copper is used in electric cables and wires, switches, plumbing; heating, electrical, and roofing materials; electronic components; industrial machinery and equipment; transportation; consumer and general products; coins; and jewelry.

Diatomite Diatomite is a rock composed of the skeletons of diatoms, single-celled organisms with skeletons made of silica, which are found in fresh and salt water. Diatomite is primarily used for filtration of drinks, such as juices and wines, but it is also being used as filler in paints and pharmaceuticals and environmental cleanup technologies.

Dolomite Dolomite is the near twin-sister rock to limestone. Like limestone, it typically forms in a marine environment but also as has a primary magnesium component. Dolomite is used in agriculture, chemical and industrial applications, cement construction, refractories, and environmental industries.

Feldspar Feldspar is a rock-forming mineral. It is used in glass and ceramic industries; pottery, porcelain and enamelware; soaps; bond for abrasive wheels; cement; glues; fertilizer; and tarred roofing materials and as a sizing, or filler, in textiles and paper applications.

Fluorite Fluorite is used in production of hydrofluoric acid, which is used in the pottery, ceramics, optical, electroplating, and plastics industries. It is also used in the metallurgical treatment of bauxite, as a flux in open-hearth steel furnaces, and in metal smelting, as well as in carbon electrodes, emery wheels, electric arc welders, and toothpaste as a source of fluorine.

Garnet Garnet is used in water filtration, electronic components, ceramics, glass, jewelry, and abrasives used in wood furniture and transport manufacturing. "Garnet is a common metamorphic mineral that becomes abundant enough to mine in a few rocks" (Kesler, 1994).

Germanium "Most germanium is recovered as a byproduct of zinc smelting. It is also found in some copper ores" (Kesler, 1994). Applications include use in fiber-optic components, which are replacing copper in long-distance telecommunication lines, as well as in camera lenses and other glasses and infrared lenses.

Gold Gold is used in dentistry and medicine, jewelry and arts, medallions and coins, and in ingots. It is also used for scientific and electronic instruments, computer circuitry, as an electrolyte in the electroplating industry, and in many applications for the aerospace industry.

Granite Granite can be cut into large blocks and used as a building stone. When polished, it is used for monuments, headstones, countertops, statues, and facing on buildings. It is also suitable for railroad ballast and for road aggregate in highway construction.

Graphite Graphite is the crystal form of carbon. Graphite is used as a dry lubricant and steel hardener and for brake linings and the production of "lead" in pencils. Most graphite production comes from Korea, India, and Mexico.

Gypsum Processed gypsum is used in industrial or building plaster, prefabricated wallboard, cement manufacture, and for agriculture.

Halite Halite (salt) is used in the human and animal diet, primarily as food seasoning and as a food preservation. It is also used to prepare sodium hydroxide, soda ash, caustic soda, hydrochloric acid, chlorine, and metallic sodium, and it is used in ceramic glazes, metallurgy, curing of hides, mineral waters, soap manufacture, home water softeners, highway deicing, photography, and scientific equipment for optical parts. An excellent review of the salt industry can be found at http://www.saltinstitute.org/15.html.

Industrial Diamond Industrial diamonds are those that can not be used as gems. Large diamonds are used in tools and drilling bits to cut rock and small stone. Small diamonds, also known as dust or grit, are used for cutting and polishing stone and ceramic products.

Iron Ore Iron ore is used to manufacture steels of various types and other metallurgical products, such as magnets, auto parts, and catalysts. Most U.S. production is from Minnesota and Michigan. The Earth's crust contains about 5% iron, the fourth most abundant element in the crust.

Lead Lead is used in batteries, construction, ammunition, television tubes, nuclear shielding, ceramics, weights, and tubes or containers. The United States is largest producer (mainly from Missouri), consumer, and recycler of lead metal.

Limestone "A sedimentary rock consisting largely of the minerals calcite and aragonite, which have the same composition $CaCO_3$" (Kesler, 1994). Limestone, along with dolomite, is one of the basic building blocks of the construction industry. Limestone is used as aggregate, building stone, cement, and lime and in fluxes, glass, refractories, fillers, abrasives, soil conditioners, and a host of chemical processes.

Magnesium Magnesium (see dolomite) is used in cement, rubber, paper, insulation, chemicals and fertilizers, animal feed, and pharmaceuticals. Magnesium is obtained from the ore minerals Olivine $(Fe,Mg)_2SiO_4$, Magnesite $MgCO_3$, and Dolomite $CaMg(CO_3)_2$.

Manganese Manganese is essential to iron and steel production. Manganese is obtained from the ore minerals Braunite $(Mn,Si)_2O_3$, Pyrolusite MnO_2, and Psilomelane $BaMn_9O_{18}•2H_2O$.

Mercury Mercury is extracted from the mineral cinnabar and is used in electrical products, electrolytic production of chlorine and caustic soda, paint, and industrial and control instruments (thermometers and thermostats).

Mica Mica minerals commonly occur as flakes, scales, or shreds. Sheet muscovite (white) mica is used in electronic insulators, paints, as joint cement, as a dusting agent, in well-drilling mud and lubricants, and in plastics, roofing, rubber, and welding rods.

Molybdenum Molybdenum is used in stainless steels (21%), tool steels (9%), cast irons (7%), and chemical lubricants (8%), and in other applications (55%). It is commonly used to make automotive parts, construction equipment, gas transmission pipes, and as a pure metal molybdenum is used as filament supports in light bulbs, metalworking dies, and furnace parts because of its high melting temperature (2,623°C).

Nickel Nickel is vital as an alloy to stainless steel, and it plays a key roll in the chemical and aerospace industries. Leading producers are Canada, Norway, and Russia.

Phosphate rock Primarily a sedimentary rock used to produce phosphoric acid and ammoniated phosphate fertilizers, feed additives for livestock, elemental phosphorus, and a variety of phosphate chemicals for industrial and home consumers. The majority of U.S. production comes from Florida, North Carolina, Idaho, and Utah.

Platinum Group Metals (PGMs) PGM's include platinum, palladium, rhodium, iridium, osmium, and ruthenium. These elements commonly occur together in nature and are among the scarcest of the metallic elements. Platinum is used principally in catalytic converters for the control of automobile and industrial plant emissions; in jewelry; in catalysts to produce acids, organic chemicals, and pharmaceuticals; and in dental alloys used for making crowns and bridges.

Potash Potash is an industry term that refers to a group of water-soluble salts containing the element potassium, as well as to ores containing these salts (Kesler, 1994). Potash is used in fertilizer, medicine, the chemical industry, and to produce decorative color effects on brass, bronze, and nickel.

Pyrite Pyrite (fools gold) is used in the manufacture of sulfur, sulfuric acid, and sulfur dioxide; pellets of pressed pyrite dust are used to recover iron, gold, copper, cobalt, and nickel.

Quartz Quartz crystals are popular as a semiprecious gemstone; crystalline varieties include amethyst, citrine, rose quartz, and smoky quartz. Because of its piezoelectric properties (the ability to generate electricity under mechanical stress), quartz is used for pressure gauges, oscillators, resonators, and wave stabilizers. Quartz is also used in the manufacture of glass, paints, abrasives, refractories, and precision instruments.

Sandstone Sandstone is used as a building stone, road bases and coverings, construction fill, concrete, railroad ballast, and snow and ice control.

Silica Silica is used in the manufacture of computer chips, glass and refractory materials, ceramics, abrasives, and water filtration; and is a component of hydraulic cements, a filler in cosmetics, pharmaceuticals, paper, and insecticides; as an anti-caking agent in foods; a flatting agent in paint, and as a thermal insulator.

Silicon Silicon is used in iron, steel, and aluminum, as well as in the chemical and electronic industries.

Silver Silver is used in photography, chemistry, electrical and electronic products (because of its very high conductivity), fine silverware, electroplated wire, jewelry, coins, and brazing alloys and solders.

Sulfur Sulfur is widely used in manufacturing processes, drugs, and fertilizers.

Talc The primary use for talc is in the production of paper. Ground talc is used as filler in ceramics, paint, paper, roofing, plastics, cosmetics, and in agriculture. Talc is found in many common household products, such as baby (talcum) powder, deodorant, and makeup. Very pure talc is used in fine arts and is called soapstone. It is often used to carve figurines.

Tin Tin is used in the manufacture of cans and containers, electrical equipment, and chemicals.

Titanium Titanium is a metal used mostly in jet engines, airframes, and space and missile applications. In powdered form, titanium is used as a white pigment for paints, paper, plastics, rubber, and other materials.

Trona Trona is used in glass container manufacture, fiberglass, specialty glass, flat glass, liquid detergents, medicine, food additives, photography, cleaning and boiler compounds, and control of water pH. Trona is mined mainly in Wyoming.

Tungsten Tungsten is used in steel production, metalworking, cutting applications, construction electrical machinery and equipment, transportation equipment, light bulbs, carbide drilling equipment, heat and radiation shielding, textile dyes, enamels, paints, and for coloring glass.

Uranium Uranium is a radioactive material used in nuclear defense systems and for nuclear generation of electricity. It is also used in nuclear-medicine x-ray machines, atomic dating, and electronic instruments.

Zeolites Some of the uses of zeolite minerals include aquaculture (for removing ammonia from the water in fish hatcheries), water softener, catalysts, cat litter, odor control, and removing radioactive ions from nuclear-plant effluent.

Zinc Zinc is used as protective coating on steel, as die casting, as an alloying metal with copper to make brass, and as chemical compounds in rubber and paint. Additional uses include galvanizing iron, electroplating, metal spraying, automotive parts, electrical fuses, anodes, dry-cell batteries, nutrition, chemicals, roof gutters, cable wrapping, and pennies. Zinc oxide is used in medicine, paints, vulcanizing rubber, and sun-block lotions.

Zirconium Zirconium is a metal recovered from zircon. "Zircon is used in mineral form in refractory products, where it is valued for its high melting temperature of 2,550°C. Some zircon is processed by chemical leaching to yield elemental zirconium. The best known use for zirconium metal is in nuclear reactors, where zirconium contains the fuel" (Kesler, 1994).