Chapter 5: Mineral Resources of the Midwestern US

What is a mineral?

A **mineral** is a naturally occurring solid with a definite chemical composition and crystalline structure. Minerals provide the foundation of our everyday world. Not only do minerals make up the rocks we see around us in the Midwest, they are used in nearly every aspect of our lives. The minerals found in the rocks of the Midwest are used in industry, construction, machinery, technology, food, makeup, jewelry, and even the paper on which these words are printed.

Elements: The Building Blocks of Minerals

Elements are the building blocks of minerals. The mineral quartz, for example, is made of the elements silicon and oxygen. Most minerals present in nature are not composed of a single element, though there are exceptions such as gold (Au). Eight elements make up (by weight) 99% of the Earth's crust, with oxygen being by far the most abundant (46.4%). The remaining elements in the Earth's crust occur in very small amounts, some in concentrations of only a fraction of one percent (*Figure 5.1*). Since silicon (Si) and oxygen (O) are the most abundant elements in the crust by mass, it makes sense that quartz (SiO_2, silicon dioxide or silica) is one of the most common minerals in the Earth's crust and is found all over the Midwest.

Minerals provide the building blocks for rocks. For example, **granite**, an **igneous rock**, is typically made up of crystals of the minerals **feldspar**, **quartz**, **mica**, and **amphibole**. **Sandstone** may be made of cemented grains of feldspar, quartz, and mica. The minerals and the bonds between the crystals define a rock's color and resistance to **weathering**.

Metallic minerals are vital to the machinery and technology of modern civilization. However, metallic minerals occur in extremely small amounts in

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granite • *a common and widely occurring type of igneous rock.*

igneous rocks • *rocks derived from the cooling of magma underground or molten lava on the Earth's surface.*

feldspar • *an extremely common, rock-forming mineral found in igneous, metamorphic and sedimentary rocks.*

quartz • *the second most abundant mineral in the Earth's continental crust (after feldspar), made up of silicon and oxygen (SiO_2).*

mica • *a large group of sheetlike silicate minerals.*

amphibole • *a group of dark colored silicate minerals, or either igneous or metamorphic origin.*

CHAPTER AUTHOR

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5 Mineral Resources

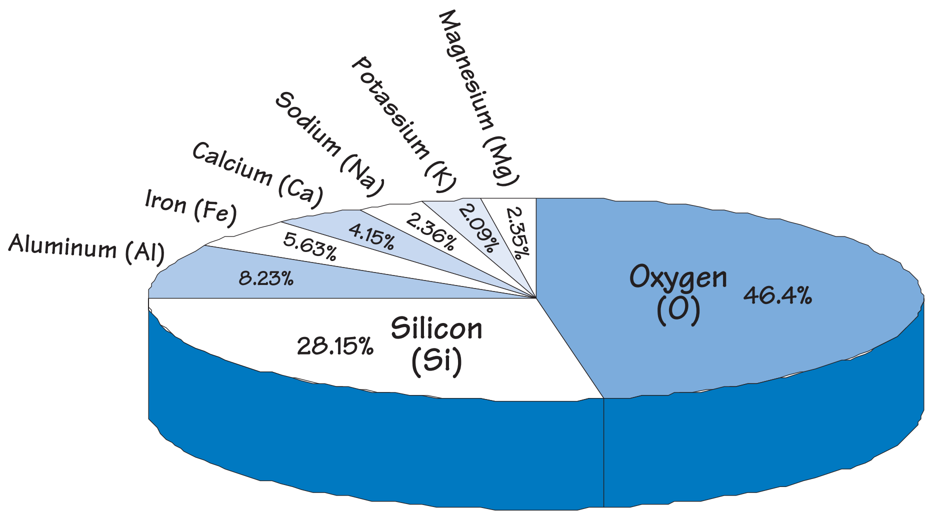

Figure 5.1: Mineral percentage by mass in the Earth's crust.

the **crust**. In addition, it is almost always necessary to process **ore** minerals in order to isolate the useful element. A mineral is called an ore when one or more of its elements can be profitably removed. For example, chalcopyrite ($CuFeS_2$), which contains **copper**, **iron**, and **sulfur**, is referred to as a copper ore when the copper can be profitably extracted from the iron and sulfur.

Non-metallic minerals do not have the flash of a metal, though they may have the brilliance of a **diamond** or the silky appearance of **gypsum** ($CaSO_4{\cdot}2H_2O$). Generally much lighter in color than metallic minerals, non-metallic minerals can transmit light, at least along their edges or through small fragments.

Mineral Identification

Although defined by their chemical composition and crystal structure, minerals are identified based on their physical properties. A variety of properties must usually be employed in identifying a mineral, each eliminating possible alternatives.

Hardness is a very useful property for identification, as a given mineral can only exhibit a narrow range of hardnesses, and it is easily testable, which quickly and simply minimizes the number of possibilities. Hardness is important because it helps us understand why some rocks are more or less resistant to weathering and **erosion**. Quartz, with a rating of 7 on the **Mohs scale**, is a relatively hard mineral, but **calcite** ($CaCO_3$), rating 3 on the Mohs scale, is significantly softer. Therefore, it should be no surprise that quartz sandstone is much more resistant to erosion and weathering than is **limestone**, which is primarily made of the mineral calcite. Quartz is a very common mineral in the Earth's crust and is quite resistant due to its hardness and relative insolubility. Thus, quartz grains are the dominant mineral type in nearly all types of **sand**.

Color is helpful in identifying some minerals like sulfur, but it is uninformative or even misleading in others like garnet. **Luster** describes how light is reflected

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crust • *the uppermost, rigid outer layer of the Earth, composed of tectonic plates.*

copper • *a ductile, malleable, reddish-brown metallic element (Cu).*

iron • *a metallic chemical element (Fe).*

sulfur • *a bright yellow chemical element (S) that is essential to life.*

diamond • *a mineral form of carbon, with the highest hardness of any material.*

gypsum • *a soft sulfate mineral that is widely mined for its use as fertilizer and as a constituent of plaster.*

erosion • *the transport of weathered materials.*

calcite • *a carbonate mineral, consisting of calcium carbonate ($CaCO_3$).*

Mohs Scale of Hardness

In 1824, the Austrian mineralogist Friedrich Mohs selected ten minerals to which all other minerals could be compared to determine their relative hardness. The scale became known as Mohs scale of hardness, and it remains very useful as a means for identifying minerals or for quickly determining their hardness. A fingernail has a hardness of around 2, a penny 3, window glass 5.5, and a knife blade 6.5.

1	Talc
2	Gypsum
3	Calcite
4	Fluorite
5	Apatite
6	Feldspar
7	Quartz
8	Topaz
9	Corundum
10	Diamond

from a mineral's surface and can range from adamantine, seen in diamonds, to dull or earthy (effectively no luster), like kaolinite. **Crystal form**, if visible, can be diagnostic. For example, **fluorite** and calcite may appear superficially similar, but fluorite forms cubic crystals while calcite forms trigonal-rhombohedral crystals. Relatedly, crystals may have planes of weakness that cause them to break in characteristic ways, called **cleavage**. Or they may not, and instead display **fracture** when broken. Mica and **graphite** have very strong cleavage, allowing them to easily be broken into thin sheets, while quartz and glass (the latter not being a mineral) have no cleavage, instead displaying a distinctive curved fracture form known as conchoidal. The **density** of a mineral may also aid in identifying it (e.g., metals tend to be very dense). Finding the exact density is straightforward, but it does require measuring the volume of the sample. Placing an unknown mineral in water (or other liquid) to find its volume by displacement can be a risky undertaking since several minerals react violently with water, and many more break down with exposure. A mineral's **streak** is obtained by dragging it across a porcelain plate, effectively powdering it. The color of the powder eliminates conflating variables of external weathering, crystal habit, impurities, etc. Some minerals are **magnetic** (affected by magnetic fields), while a few are natural magnets (capable of producing a magnetic field).

Most minerals can be identified by process of elimination after examining a few of these properties and consulting a mineral identification guide. Mineral testing kits often include several common objects used to test hardness: a porcelain streak plate, a magnet, and a magnifying glass. Some minerals have rare properties, which may be more difficult to test. For example, there are minerals that exhibit **luminescence** of all types, giving off light due to a particular stimulus. Some minerals are **radioactive**, usually due to the inclusion of significant amounts of uranium, thorium, or potassium in their structure. **Carbonate** minerals will

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sand • *rock material in the form of loose, rounded, or angular grains, and formed as a result of the weathering and decomposition of rocks.*

crystal form • *a physical property of minerals, describing the shape of the mineral's crystal structure.*

fluorite • *the mineral form of calcium fluoride (CaF_2).*

graphite • *a mineral, and the most stable form of carbon.*

density • *a physical property of minerals, describing the mineral's mass per volume.*

streak • *a physical property of minerals, obtained by dragging the mineral across a porcelain plate and effectively powdering it.*

luminescence • *to give off light.*

radioactive • *when an unstable atom loses energy by emitting radiation.*

Mineral Resources

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effervesce • *to foam or fizz while releasing gas.*

double refraction • *the result of light passing through a material that splits it into two polarized sets of rays, doubling images viewed through that material.*

Precambrian • *a geologic time period that spans from the formation of Earth (4.6 billion years ago) to the beginning of the Cambrian (541 million years ago).*

effervesce when exposed to hydrochloric acid. **Double refraction** describes the result of light passing through a material that splits it into two polarized sets of rays, doubling images viewed through that material. For example, a single line on a sheet of paper will appear as two parallel lines when viewed through a clear calcite crystal.

There are many more interesting and distinguishing properties that minerals may possess, and there are many more elaborate and precise means for identifying them. The branch of geology that studies the chemical and physical properties and formation of minerals is called *mineralogy*.

What distinguishes a regular mineral from a gem?

Beauty, durability, and rarity of a mineral qualify it as a gemstone. Beauty refers to the luster, color, transparency, and brilliance of the mineral, though to some degree it is dependent on the skillfulness of the cut. Most gems, including tourmaline, topaz, and corundum, are durable because they are hard, making them scratch-resistant. On the Mohs scale of hardness, the majority of gemstones have values greater than 7. Isolated deposits of semi-precious gemstones can be found in each state in a variety of places, but they are not mined commercially (except as noted below), and precious gemstones are extremely rare in the Midwest.

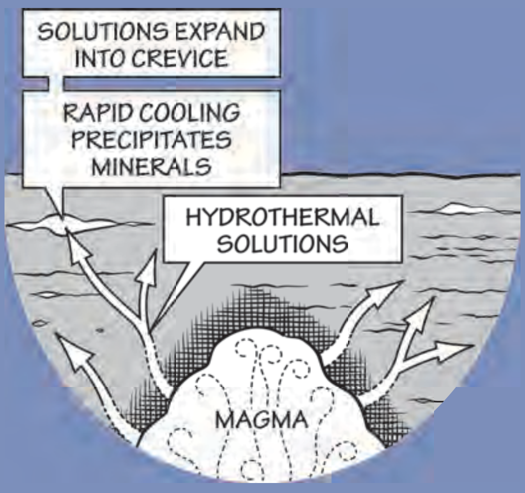
Mineral Formation

Geologists looking for particular minerals do not make haphazard guesses as to the location of ore bodies. The occurrence of minerals in the Earth's crust is due to the geologic processes that formed certain rock types in a given area. An understanding of the environments in which minerals form, the minerals that make up different rocks, and the geologic history of an area, all help geologists ascertain where minerals of interest are concentrated. Metallic minerals are often associated with igneous and metamorphic rocks, which typically occur in either very ancient rocks (**Precambrian**) or in areas of severe deformation of the crust, such as where continents have collided.

Mineral deposits may be formed in several ways: precipitation out of water, crystallization of **magma** or **lava**, **recrystallization** after exposure to heat and pressure, or the dissolution and later precipitation of minerals by hot water moving through cracks and openings in rock located well below the surface. A mineral is not necessarily restricted, however, to one method of concentration or environment of formation. For example, gypsum may form as a precipitate from evaporating water, but it is also associated with **volcanic** regions where limestone and sulfur gases from the volcano have interacted.

What are hydrothermal solutions?

Hot water enriched in salts such as sodium chloride (NaCl), potassium chloride (KCl), and calcium chloride ($CaCl_2$) is called a *hydrothermal solution*, or simply "brine." The brine is as salty or even saltier than seawater and, surprisingly, may contain minute bits of dissolved minerals such as gold, lead, copper, and zinc. The presence of salt in the water stops the metallic minerals from precipitating out of the brine because the chlorides in the salt preferentially bond with the metals. Additionally, because the brine is hot, the minerals are more easily dissolved, just as hot tea dissolves sugar more easily than cold tea does. These hot water brines can have varying origins. As magma cools, it releases its mineral-enriched, super-heated water into surrounding rock. Rainwater becomes a hydrothermal solution by picking up salt as it filters through rocks. Seawater, which is already enriched in salt, often becomes a hydrothermal solution in the vicinity of volcanic activity on the ocean floor where *tectonic plates* are pulling apart. Rapid cooling of the hydrothermal solution over short distances allows concentrations of minerals to be deposited. Water moving quickly through fractures and openings in the rock, experiencing changes in pressure or composition and being diluted with groundwater, can rapidly cool a hydrothermal solution.



Review

magma • *molten rock located below the surface of the Earth.*

lava • *molten rock located on the Earth's surface.*

recrystallization • *the change in structure of mineral crystals that make up rocks, or the formation of new mineral crystals within the rock.*

plate tectonics • *the way by which the plates of the Earth's crust move and interact with one another at their boundaries.*

5 Mineral Resources

Region 1

In the discussions of each region to follow, the focus is on the following: currently mined and other significant minerals; where the minerals are most common (though they may occur in other places as well); and how the minerals formed in each particular area relate to the surrounding rocks and geologic history.

Mineral Resources of the Superior Upland

Region 1

The Superior Upland portion of the **Canadian Shield** is composed mostly of igneous and metamorphosed Precambrian rock. Plumes of magma that welled up from the **mantle** (and then cooled) formed expanses of igneous rocks like granite, **basalt**, and **gabbro**. **Sedimentary rock**, including **banded iron formations**, formed as sediment slowly accumulated under the ancient ocean. Later, **metamorphism** converted much of the igneous rock into **gneiss** and the sedimentary rock into **quartzite**. Some **nickel**, copper, and platinum are produced in the region, but these are secondary products in the mining of the Superior Upland's dominant mineral resource: iron. Minnesota and Michigan are the states that produce, respectively, the most and second most iron ore in the US. The ore, primarily **hematite** (Fe_2O_3) and **magnetite** (Fe_3O_4), is mined from banded iron formations (*Figure 5.2*).

Banded iron formations **(BIFs) are rocks with regular, alternating thin layers of iron oxides (e.g., hematite and magnetite) and either shale or silicate minerals (e.g. chert, jasper, and agate). For example, BIFs in Michigan are composed of jasper between layers of hematite/magnetite and are found on Jasper Knob near Marquette. They are a primary source of iron ore, and their formation is discussed in Chapter 9: Climate.**

In Minnesota, iron is principally produced from the aptly named Biwabik Iron Formation in Itasca and Saint Louis Counties. Two large open pit mines operate in Marquette County, in the Marquette Range found in the north central portion of Michigan's Upper Peninsula. Most of the iron is used to make steel. The portion of the Superior Upland found in Wisconsin is not yet used for mineral resources. It is, however, quarried for stone used in construction and industry.

Canadian Shield • *the stable core of the North American continental landmass, containing some of the oldest rocks on Earth.*

mantle • *the layer of the Earth between the crust and core.*

basalt • *an extrusive igneous rock, and the most common rock type on the surface of the Earth.*

gabbro • *a usually coarse-grained, mafic and intrusive igneous rock.*

sedimentary rock • *formed through the accumulation and consolidation of grains of broken rock, crystals, skeletal fragments, and organic matter.*

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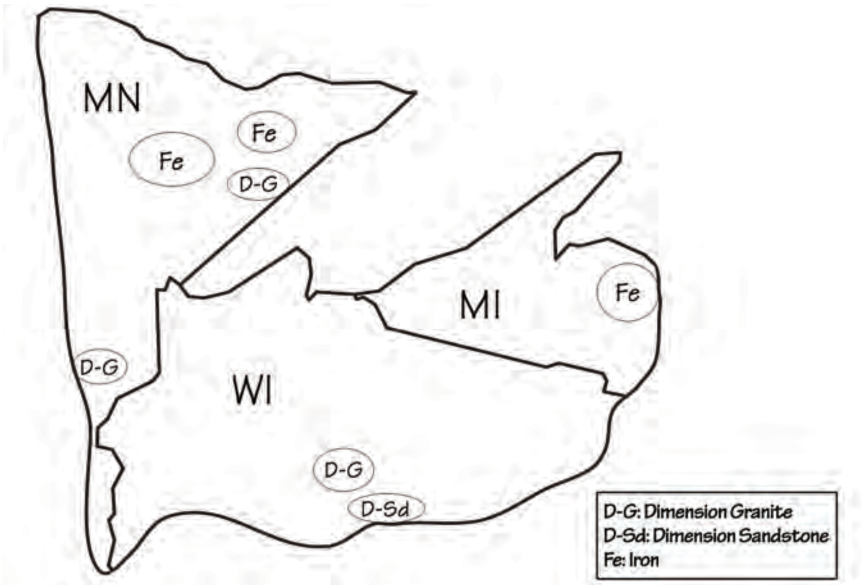


Figure 5.2: Principal mineral-producing localities in the Superior Upland, associated particularly with crystalline Precambrian basement rocks and sedimentary banded iron formations (see Chapter 1: Geologic History and Chapter 2: Rocks).

Mineral Resources of the Central Lowland

Region 2

The Central Lowland is not widely exploited for mineral resources because its near-surface minerals are not commercially valuable. Nearly all of the bedrock in this large region formed as sediment under shallow seas. Limestone and **shale**, the most common rocks, do not tend to be rich in commercially significant minerals, though the rocks themselves are often quarried for building materials. The ancient seas, like the modern ocean, contained dissolved **salts** that were eventually preserved in rocks around the Central Lowland. These **evaporite** minerals, formed by precipitation out of solution in water, are mined commercially in Michigan's Lower Peninsula, and, to a lesser extent, in Iowa.

Wells in Manistee County tap into deposits of **brine** rich in magnesium oxide, allowing Michigan to produce more magnesium compounds than any other state. Magnesium is relatively abundant in seawater, and the brines deposited under Michigan are the remains of an ancient sea that once covered Michigan and much of the Central Lowland. Marine deposits in Manistee County and Osceola County are also mined for **halite** (salt) and **potash** (in Osceola County alone), making the state a leading producer of those minerals as well (*Figure 5.3*).

Regions 1–2

metamorphic rocks • *rocks formed by the recrystallization and realignment of minerals in pre-existing sedimentary, igneous, and metamorphic rocks when exposed to high enough temperature and/or pressure.*

gneiss • *a metamorphic rock that may form from granite or layered sedimentary rock such as sandstone or siltstone.*

quartzite • *a hard metamorphic rock that was originally sandstone.*

nickel • *a ductile, silvery-white metallic element (Ni).*

evaporite • *a sedimentary rock created by the precipitation of minerals directly from seawater, including gypsum, carbonate, and halite.*

5 Mineral Resources

Region 2

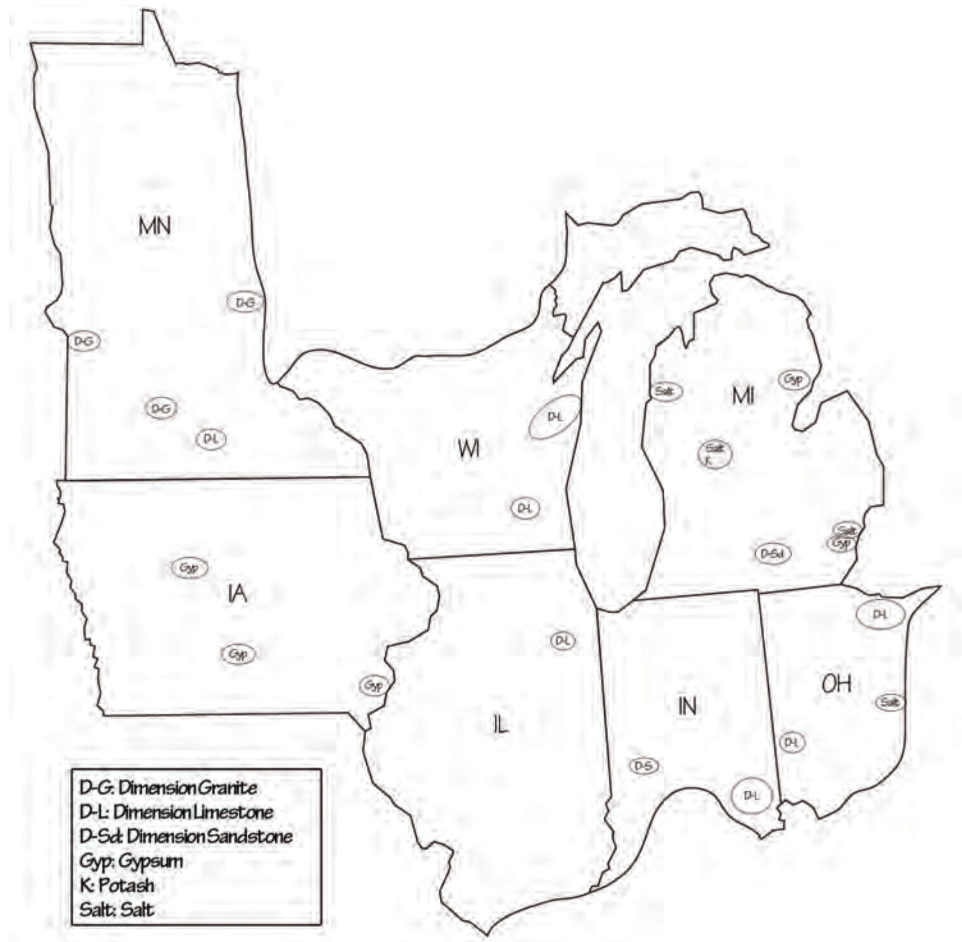


Figure 5.3: Principal mineral-producing localities in the Central Lowland, associated primarily with Paleozoic deposition of sand, carbonate sediments, and occasionally evaporates in warm shallow continental seas of the Paleozoic (see Chapter 1: Geologic History and Chapter 2: Rocks).

Halite (NaCl) is mined in two ways. When deposited in thick beds, salt can be excavated by mechanically carving and blasting it out. This method, called “room and pillar” mining, usually requires that pillars of salt be left at regular intervals to prevent the mine from collapsing (*Figure 5.4*). Another method, called solution mining, involves drilling a well into a layer of salt. In some cases, the salt exists as part of a brine that can then be pumped to the surface and the water removed, leaving salt. In others, fresh water is pumped down to dissolve the salt, and the solution is brought back to the surface where the salt is removed (*Figure 5.5*).

Potash is a name used for a variety of salts containing potassium, with mined potash being primarily potassium chloride (KCl). The majority of potash is used as fertilizer, but an increasing amount is being used in a variety of other ways: water softening, snow melting, a variety of industrial processes, as a medicine, and to produce potassium carbonate (K_2CO_3).

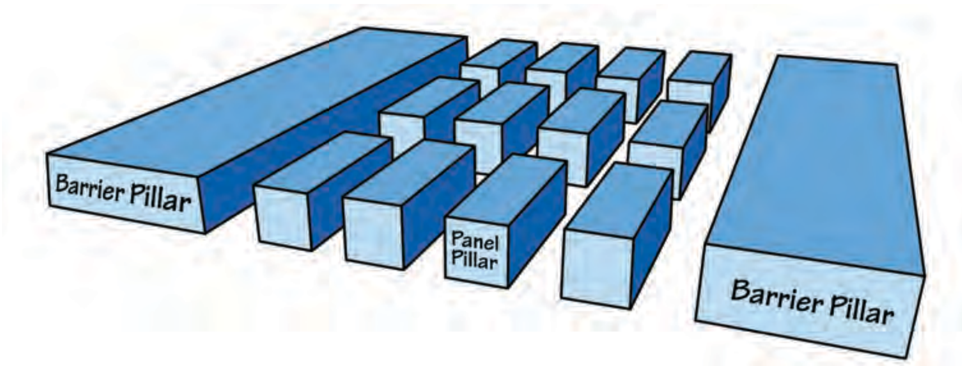


Figure 5.4: In pillar and room mining, the mine is divided up into smaller areas called "panels." The panels are separated from one another by extra-large (barrier) pillars that are designed to prevent total mine collapse in the event of the failure of one or more regular-sized (panel) pillars.

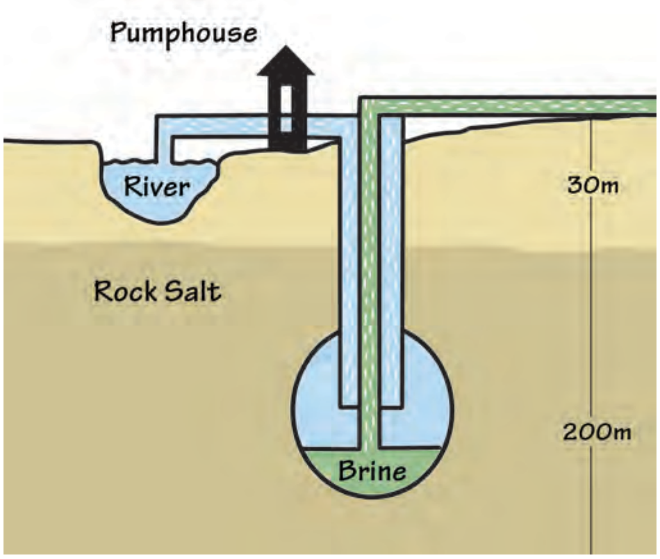


Figure 5.5: An example of solution mining that involves the pumping of fresh water through a borehole drilled into a subterranean salt deposit.

Gypsum, ($CaSO_4$-H_2O) another evaporite mineral, is mined in Michigan and is currently the only mineral resource exploited in all parts of the Central Lowland, especially Iowa. Iosco and Kent Counties in Michigan both lie on the **Michigan Formation**, the source of their gypsum. Iowa is typically the second or third largest producer of gypsum in the country. Deposits are found along the Des Moines River Valley running from north central to the southeastern corner of the state. The Fort Dodge Beds are mined in Webster County, the Saint Louis Formation in Marion County, and the Wapsipinicon Formation in Des Moines County. Gypsum is used in plaster and wallboard. It is the mineral assigned the value of 2 on the Mohs scale of mineral hardness, meaning that it is softer than a fingernail.

Region 2

Michigan Formation • *a ring-like stratum in the rock of the Michigan Basin, where most of the state's gypsum is mined.*

5 Mineral Resources

Regions 2–3

inland basin • *a depression located inland from the mountains, and formed by the buckling (downwarping) of the Earth's crust.*

Mississippian • *a subperiod of the Carboniferous, spanning from 359 to 323 million years ago.*

The Michigan Formation

The bedrock of Michigan's Lower Peninsula forms a basin where older rocks can be imagined curving up from below to cup the younger strata in the center. This produces some formations that appear as rings on geologic maps. For example, the Michigan Formation, where most of the state's gypsum is mined, can be found in a nearly continuous band around, but at least 64 kilometers (40 miles) from, the center of the Lower Peninsula. The formation of Michigan's *inland basin* is described in Chapter 1: Geologic History.

Mineral Resources of the Inland Basin

Region 3

Because the Inland Basin is represented in a relatively small area in the Midwest and its rocks are not particularly rich in minerals, this region contains little in the way of exploitable mineral resources. The ancient seas of the **Mississippian** era, during which the rocks formed, provided some evaporite minerals, but they are commercially viable to mine in only a few places. Rock salt is mined in northeastern Ohio, beginning in Cuyahoga, Lake, Wayne, and Summit Counties, and sometimes going deep under Lake Erie. Farther south, Licking County also produces salt. The only other mineral resource produced in the Inland Basin of the Midwest is in Martin County, Indiana, where gypsum is mined (*Figure 5.6*).

Mineral Resources

Region 3

Jurassic • *the geologic time period lasting from 201 to 145 million years ago.*

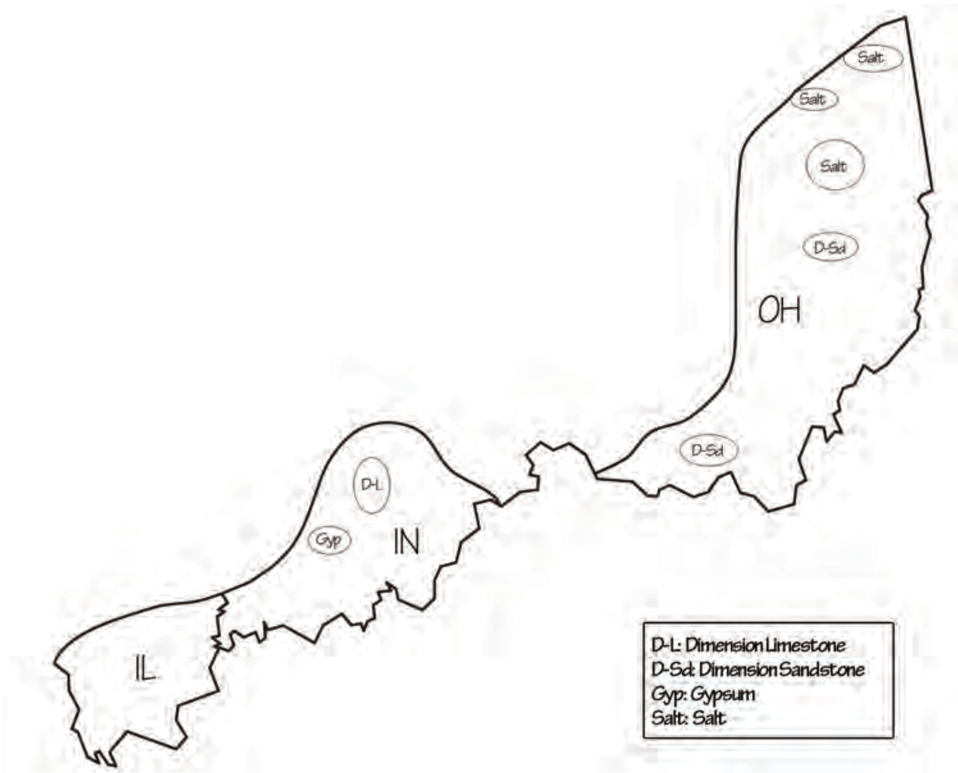


Figure 5.6: Principal mineral-producing localities in the Inland Basin, associated primarily with Paleozoic deposition of sand, carbonate sediments, and occasionally evaporates in the warm shallow continental seas filling the Appalachian Basin (see Chapter 1: Geologic History and Chapter 2: Rocks).

Mississippian rocks in Illinois host Illinois' state mineral: fluorite (CaF_2). During the **Jurassic**, more than 100 million years after the limestone bedrock was laid down, geothermally heated water full of dissolved chemicals was forced through existing cracks. Fluorite crystals precipitated onto the walls of these cracks, forming Illinois' famous deposits. Fluorite is mined primarily to be converted into hydrogen fluoride (HF), a chemical with a wide range of applications. While colorful and translucent, fluorite is too soft to see extensive use as a semiprecious gemstone.

Resources

Books

Skinner, Brian J., 1989, *Mineral Resources of North America*, vol. A, The Geological Society of America: Denver, CO.

State-based Resources

USGS Minerals Yearbook, Volume II – Area Reports: Domestic, State and Territory chapters, http://minerals.usgs.gov/minerals/pubs/state/index.html#pubs. (State-by-state information about mineral mining and production.)

Minerals of Wisconsin, Wisconsin Geological and Natural History Survey. http://wgnhs.uwex.edu/wisconsin-geology/minerals-wisconsin/.

Economic Minerals Prominent in the Midwest

Fluorite: The Illinois State Mineral, Illinois Department of Natural Resources. http://dnr.state.il.us/mines/education/indus2.htm.

Gypsum the Commodity, Indian Geological Survey. http://igs.indiana.edu/MineralResources/Gypsum.cfm.

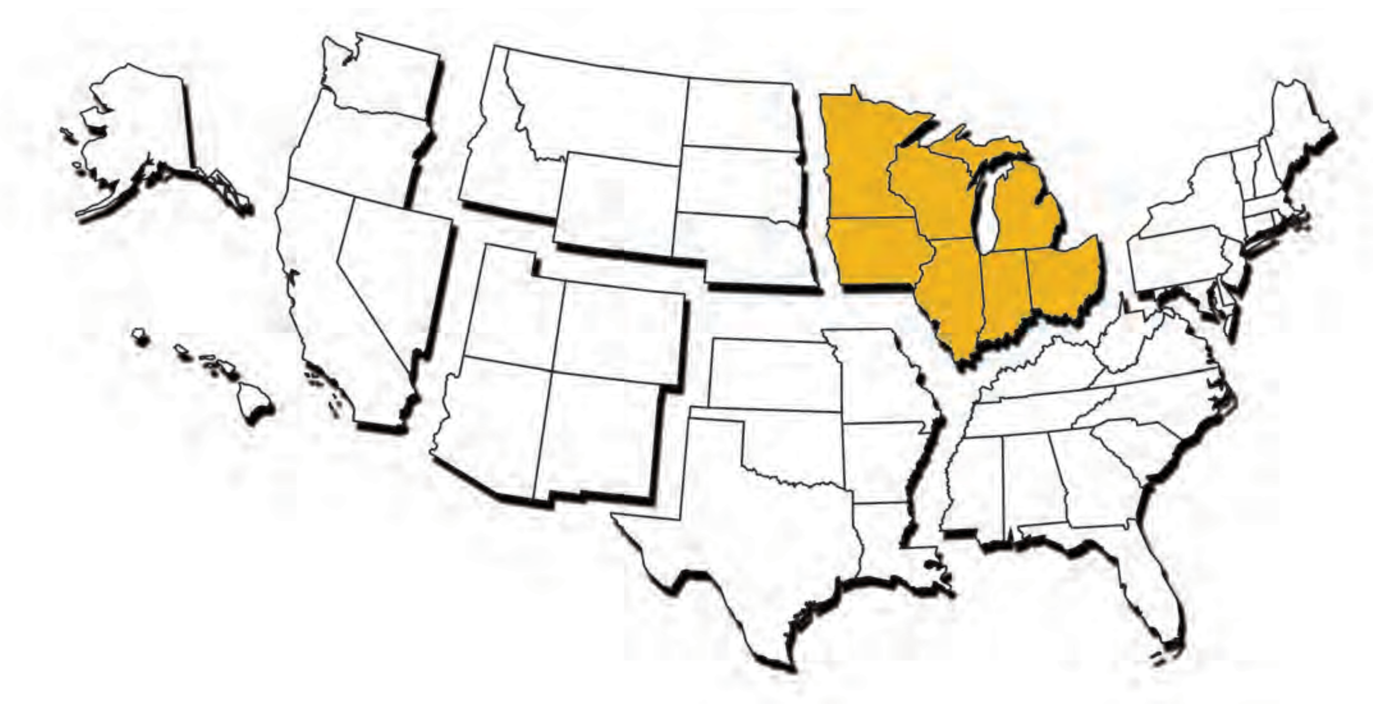
Rock Salt Mining, Michigan State University. http://web2.geo.msu.edu/geomich/saltminingM.html.

Salt Mining, How Stuff Works. http://science.howstuffworks.com/innovation/edible-innovations/salt.htm.

Iron mining. http://wgnhs.uwex.edu/wisconsin-geology/iron-mining.

The **Teacher-Friendly** Guide™

to the Earth Science of the Midwestern US



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On the back cover: Blended geologic and digital elevation map of the Midwest. Each color represents the age of the bedrock at the surface. Adapted from Barton, K.E., Howell, D.G., Vigil, J.F., *The North America Tapestry of Time and Terrain*, US Geological Survey Geologic Investigations Series I-2781, http://pubs.usgs.gov/imap/i2781.