Chapter 5: Mineral Resources of the Western 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 West, they are also used in nearly every aspect of our lives. The minerals found in the rocks of the West 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, and, in turn, is also a major component of many rocks. Most minerals present in nature are not composed of a single element, though there are exceptions such as gold. Elements such as copper (Cu), lead (Pb), zinc (Zn), and even silver (Ag), gold (Au), and diamond (C) are not rare, but they are usually widely dispersed through the rocks and occur at very low average concentrations. Eight elements make up (by weight) 99% of the Earth’s crust, with oxygen being 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 for silicates (e.g., feldspar, quartz, and garnet) to be some of the most common minerals in the Earth’s crust and to also be found throughout the West.

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, many metallic minerals occur in the crust in amounts that can only be measured in parts per million (ppm) or parts per billion (ppb). A mineral is called an ore when one or more of its elements can be profitably removed, and it is almost always necessary to process ore minerals in order to isolate the useful element. For example, chalcopyrite (CuFeS₂), 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 (CaSO₄·2H₂O). 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 (CaCO₃), 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 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 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 also 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 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.

Mineral Formation

Mineral deposits in the West range in age from over one billion years old to just a few thousands or tens of thousands of years, and their occurrence is related to different processes that operate in different geologic environments. Economically recoverable mineral deposits are formed by geologic processes that can selectively concentrate desirable elements in a relatively small area. These processes may be physical or chemical, and they fall into four categories:

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 most states.
Magmatic processes separate minor elements of magma from the major elements and concentrate them in a small volume of rock. This may involve the early crystallization of ore minerals from the magma while most other components remain molten, or late crystallization after most other components have crystallized. Magmatic processes responsible for the formation of mineral deposits in the West are usually associated with igneous intrusions (formed during mountain building events, rifting, and volcanic activity), which can range in composition from granite (felsic) to gabbro (mafic). Metamorphism may also cause recrystallization of minerals and concentration of rare elements. Under conditions of extreme high-temperature metamorphism, minerals with the lowest melting temperatures in the crust may melt to form small quantities of pegmatite magmas.

Hydrothermal processes involve hydrothermal solutions that dissolve minor elements dispersed through large volumes of rock, transport them to a new location, and precipitate them in a small area at a much higher concentration. Hydrothermal solutions are commonly salty, acidic, and range in temperature from over 600°C (~1100°F) to less than 60°C (140°F). Some of these fluids may travel very long distances through permeable sedimentary rock. Eventually, the hydrothermal fluids precipitate their highly dissolved load of elements, creating concentrated deposits.

Sedimentary processes gather elements dispersed through large volumes of water and precipitate them in a sedimentary environment, such as sedimentary layers on the ocean floor or layers of sediment on lakebeds. Sedimentary mineral deposits form by direct precipitation from the water.

Weathering and erosion break down large volumes of rock by physical and chemical means and gather previously dispersed elements or minerals into highly concentrated deposits. Residual weathering deposits are mineral deposits formed through the concentration of a weathering-resistant mineral, while other minerals around it are eroded and dissolved. In contrast, mineral deposits formed by the concentration of minerals in moving waters are called placer deposits. In the Western US, placer deposits occur in rivers and streams that carry lighter sediment downstream but leave behind heavy minerals such as gold. Placer deposits can also occur on coastal beaches. The erosion of areas of small, low-grade gold veins and the subsequent concentration of the gold as stream sediment while the other minerals were carried downstream produced hundreds of placer deposits that were mined throughout the Western US during the 19th century. Mining of these deposits continues today.

Minerals in the West
The history of the Western States is driven in large part by the promise of mineral wealth. The rush for gold began in the 1840s, when much of the territory that would become California was ceded to the United States by Mexico. Gold discoveries in California resulted in Americans from the east and immigrants from around the world flocking to the area. The idea of acquiring wealth by finding gold became a backdrop for new communities and towns. As an area became either overcrowded or mined out, these gold seekers moved to new areas, eventually finding silver and gold in Nevada, and then gold and other
Mineral Resources

Review

What are hydrothermal solutions?

Hot water enriched in salts such as sodium chloride (NaCl), potassium chloride (KCl), and calcium chloride (CaCl₂) is called a hydrothermal solution, or simply “brine.” The brine is as salty or even saltier than seawater, and 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.

minerals in Washington and Oregon. And finally, in the late 19th century, they headed to the Klondike and Alaska in search of new strikes. The minerals that early prospectors sought in rivers and streams are still being mined in many regions of the West.
Many Western mineral deposits are the products of several different concentration processes, sometimes operating tens or hundreds of millions of years apart. There are a variety of geologic environments in which these mineral-concentrating processes have operated over the past billion years to produce the abundance and diversity of mineral deposits found in the West today (Figure 5.2), including passive continental margins (Arctic Coast of Alaska), volcanic island arcs (Aleutian Islands), mountain-building events (Sierra Nevada, Cascades, Brooks Range), and basins formed by rifting events (Basin and Range of Nevada).

Mineral Resources of the Basin and Range

Region 1

The Basin and Range region covers most of Nevada, some parts of eastern California, and a small part of southeastern Oregon. This province is defined by an alternating pattern of north-south trending faults and mountains with valleys in between. The Basin and Range, with its dry mountains and valleys, was initially seen as a barrier for those trying to reach the California gold fields. The little precipitation that does occur there quickly evaporates, flowing into short-lived lakes on the valley floors or sinking into the ground to become groundwater. These climate patterns have created abundant evaporite minerals such as salt; the geologic history of the region has also created the opportunity for large-scale mining of metallic minerals such as gold and silver, as well as of industrial materials, such as sand and gypsum (See Figure 5.2).

Metallic Minerals

The primary metallic minerals mined in the Great Basin (Figure 5.3) are gold and silver. In 1849, Mormon prospectors found placer gold in streams leading into the Carson River. However, these prospectors were on their way west to California, so it wasn’t until 1859, with the discovery of silver in Nevada’s Comstock Lode, that mining began in earnest. The mining boom brought prospectors who worked the mines, settlers who started farms and ranches to feed the miners, and shopkeepers who kept them

Figure 5.2: Mineral resources of Washington, Oregon, Nevada, and California.
supplied. Between 1860 and 1880, the Comstock District produced more than six million tons of ore.

Gold mining in the Great Basin produces 79% of the gold in the United States today. The Carlin Unconformity in Eureka and Elko Counties, Nevada, is one of the several sedimentary rock-hosted gold regions in the Great Basin. The Unconformity is associated with a period of collision between a terrane and the North American plate about 350 million years ago, generating higher crustal temperatures and pressures and producing numerous hot springs. The hot springs acted as hydrothermal solutions, precipitating gold from the bedrock. The belt of gold mineralization is found primarily in material from the late Eocene (~36–40 million years ago). Originally, placer deposits were found, but in 1960 mining began on a large scale in both open pit and underground mines (Figure 5.4). Slightly south of the Carlin Unconformity is the Battle Mountain-Eureka
Trend (here “trend” refers to an alignment of deposits), which has a similar geologic structure. Historically, mines in the area produced significant amounts of silver as well as gold.

Copper has been mined in several areas of the Great Basin. It is usually extracted in association with the other metals, like gold and silver. In White Pine County, Nevada, ore bodies produced by hydrothermal processes are being mined. The deposits are low-grade and include gold and silver as secondary products.

Non-metallic Resources
In the northwest corner of the Basin and Range there are several mines that produce opals, which are used as gemstones (Figure 5.5). Opal is silica
Mineral Resources

How is gold mined?

Gold can be extracted using a wide variety of methods.

Placer mining searches stream bed deposits for minerals moved from their original source by water. Placer deposits can be mined in several different ways: panning, which uses a small, hand-held pan to manually sort the gold from sand and rock fragments, sluicing, in which water is sent through a man-made stepped channel that traps particles of gold, or dredging, where a large machine uses mechanical conveyors or suction to pull loads of material from the river bottom and then dump smaller fragments into a sluice box.

Gold that is trapped in layers of rock may be excavated through underground mining, where tunnels or shafts are used to locate the ore, or by open pit mining, which is used when deposits are relatively close to the surface.

that lacks a crystalline structure, so it is not technically a mineral. These opal deposits formed over a period of 16 million years, in the silica-rich water of a wet, lush basin. The basin’s forests were periodically buried under layers of volcanic ash and debris from pyroclastic flows. Over time, hot groundwater picked up silica-rich deposits that slowly replaced the carbon molecules in the buried trees. When the area was uplifted during the formation of the Basin and Range, erosion exposed the opal deposits.
In many places, salt deposits have formed where land-locked lakes evaporated. Because these **playas** capture all the salt and saline compounds that are washed out of the surrounding mountains, the deposits have become quite thick (and commercially viable). They are currently mined in southern Nevada and the southeast part of California. Gypsum also forms as an evaporite, and is found in similar settings.

### Mineral Resources of the Columbia Plateau

#### Region 2

The Columbia Plateau covers a vast area of eastern Washington, northern Oregon, and southwestern Idaho. This region is the result of one of the world’s largest accumulations of lava, with over 500,000 square km (193,000 square miles) covered by flood **basalts**. The majority of these flows occurred from 17 to 14 million years ago. Mineral resources within the Columbia Plateau are often hidden under these prodigious flows, so they tend to be found within river canyons or in **accreted terranes** that rise above the flood basalt. These terranes were brought to North America on the Pacific plate, when the coast was near the border of Idaho and eastern Washington and Oregon. As the Pacific plate **subducted** underneath the North American plate, the terranes were welded onto the growing plate. Some elevated portions of these terranes were not covered by the lava flows, allowing them to be accessed for their mineral resources (See **Figure 5.2**).

#### Metallic Resources

In the Columbia Plateau, gold is the most common metallic resource. In the Blue Mountains of Oregon, which are part of an exposed terrane surrounded by the basaltic flow, placer and **lode** gold was mined near John Day and Baker City. In the southwest corner of the region, intense volcanic and hot spring activity led to the hydrothermal formation of fine-grained gold deposits in Oregon’s Owyhee Uplands.

#### Non-metallic Resources

The primary mineral resources found in the Columbia Plateau are glacial deposits of sand, **gravel**, and stone. These are used as building materials, and are also shipped outside the region for use elsewhere. Due to the large quantity of glacial deposits in the region, commercial-size quarries can be found in just about every county in Washington and Oregon that lies within the Columbia Plateau.
Mineral Resources of the Northern Rocky Mountains
Region 3

In the far northeast corner of Washington State is a small arm of the Rocky Mountain system. The Rocky Mountains formed about 70 million years ago when an oceanic plate began subducting under the North American plate. The angle of subduction was significantly shallower than usual, causing the Rockies to form much farther inland.

Metallic Resources

Metallic resources are limited in this region. In Ferry County, Washington, mining operations began in the Kettle River-Buckhorn Mountain area. The mine is an underground facility designed to maintain as small a footprint as possible in order to minimize environmental impact. In the year 2013, the mine had a gold equivalent production (wherein silver production is converted to a gold equivalent) of 42 million grams (150,000 ounces).

The other metallic mining operation lies in Pend Oreille County, Washington. This mine accesses a lead-zinc ore body that is located in a narrow belt of sedimentary, volcanic, and metamorphic rocks.

Non-metallic Resources

Non-metallic resources in this region include sand, gravel, and stone. These materials are used as building materials for roads and other infrastructure in the region and are also shipped outside the region. Commercial-size quarries are found in the area.

Mineral Resources of the Sierra-Cascade Mountains
Region 4

The Cascade-Sierra Mountains form a nearly uninterrupted barrier along the western edge of the United States. Interestingly, these two ranges have very little in common. The Sierra Nevada are composed of granitic intrusions (plutons) that once formed the molten core of an arc-shaped chain of volcanoes during the Mesozoic. Erosion wore away the volcanoes, leaving the granite exposed (Figure 5.6). Then, less than five million years ago, these granitic blocks began to rise along their eastern edge, tilting to the west in the process. The modern Sierra, as a result, have a gently sloping west side and...
a very steep east side. The Sierra are all that remains of an ancient volcanic arc, but the Cascades form an active volcanic arc that stretches from British Columbia to northern California. Thirteen major volcanic centers are strung along this arc. Between these large volcanoes lie thousands of short-lived volcanoes. In the North Cascades, the geologic picture is more complicated, as modern volcanoes are superimposed on a series of accreted terranes.

Metallic Resources
Gold formation in the Sierra Nevada occurred within saturated sediments. Hydrothermal fluids were heated at depth, causing them to rise through the overlying rock. The fluids cooled as they rose to the surface, concentrating metals like gold. This gold, in the foothills of the western Sierra Nevada, was the source of the California Gold Rush of 1848–1849. The initial find at a mill on Sutter’s Creek led to thousands of prospectors arriving from around the world in hopes of striking it rich. Eventually, the gold that was relatively easy to find was depleted, and miners either moved on to other gold fields or began looking for less convenient gold sources.

Gold is still mined in the Sierra Nevada today, but on a much smaller scale. In California’s Amador, El Dorado, Placer, and Nevada counties, there are several small operations that employ 20 or fewer employees. In addition, there are several designer mines that make jewelry out of gold-intruded quartz (Figure 5.7). The quartz is cut and polished so the gold veining shows.

In the southern Cascades, in and around Jackson County, Oregon, a number of small gold mines were developed after the 1850s. Many of these were placer...
claims that brought in dredges to move and process larger amounts of material from the riverbeds. Most of these claims were abandoned by the 1920s. Today, small placer claims are still worked along the rivers and streams that flow from the Cascades to the Pacific Ocean.

In the northern Cascades, silver, copper, and gold mining was a prominent industry in the late 19th and early 20th centuries. One of the largest copper mines in the country, the Howe Sound Holden Mine in Holden, Washington, produced $66 million worth of ore before it was shut down in the 1950s as mineral prices dropped. Today, the US Forest Service and Rio Tinto mining group are engaged in a multi-million-dollar project to remediate environmental problems at the Holden Mine area, including the disposal of old mining waste and dismantling the old buildings (Figure 5.8).

Other metals, including silver and zinc, have been found throughout the Sierra Nevada and Cascade Range, but not in quantities that currently make them commercially viable.

**Non-metallic Resources**

In the Sierra Nevada and Cascade Range, gravel, stone, and sand are quarried for use in building roads, houses, and other infrastructure. In addition, pumice and volcanic cinders are quarried in the volcanic southern Cascade Range. These deposits are notable for having a lower density and higher porosity than most other rocks (Figure 5.9); this makes them commercially valuable for use as a lightweight yet strong construction material. Pumice can also be used as lightweight aggregate, insulators, absorbents, and abrasives. Pumice and cinders are quarried in Deschutes County, Oregon, near the town of Bend. Further south in Klamath County, Oregon, pumice is also quarried commercially.
Near the Canadian border in the northern Cascades, the Twin Sisters **dunite** contains one of only two **olivine** mines in the United States. Dunite is olivine-rich **ultramafic mantle** rock, and is rarely found at the surface. Olivine has a high **heat** tolerance, making it ideal for use in foundries when casting objects and when lining kilns, furnaces, incinerators, and reactors. It is also a good material for sandblasting and for other abrasive uses. In Whatcom County, olivine is
Figure 5.9: A close-up of a pumice stone, revealing its highly porous and vesicular texture. These gas bubbles make the rock so lightweight that it is able to float. Field of view is 2.7 centimeters (1 inch) across.

mined mostly for abrasive purposes, although a small amount of foundry-grade material is also produced.

**Mineral Resources of the Pacific Border**

**Region 5**

The Pacific Border is defined by a series of mountain ranges that run along the coast. These mountains include (from north to south) the Olympic Mountains, the Oregon Coast Range, the Klamath Mountains, the California Coast Range, the Transverse Range, and the Peninsular Range. Much of the area formed due to Pacific plate subduction, as sea bottom sediments, basaltic upper crust, and ultramafic lower crust were scraped onto the overriding North American plate and subsequently metamorphosed, uplifted, and finally eroded.

**Metallic Resources**

Placer gold deposits were mined along the coast of Oregon and California. In southern Oregon, gold was originally found near the mouth of the Rogue River, and these beach deposits were extensively mined starting in the 1850s. There are still a few gold mining operations upriver on the Rogue, and gold can still be panned on the beach (*Figure 5.10*).
In the Klamath Mountains of southern Oregon and northern California, sedimentary deposits from the **Devonian** and **Carboniferous** periods form tightly folded **slates**. These slates are riddled with highly siliceous intrusions that contain copper and zinc. These minerals were mined extensively from the 1890s to about 1920.

**Non-metallic Resources**

As cities like Los Angeles and San Francisco began to grow along California’s coast, there was a demand for cheap building materials for roads, buildings, and other infrastructure. As a result, the quarrying of materials, including sand, gravel, and stone, became an important industry, and these materials are produced throughout this region. Large stones are used as breakwaters and jetties to protect coastal infrastructure from battering waves. Interestingly, the famous sandy beaches of Southern California no longer receive sand from the inland mountains. The growth of Los Angeles has interrupted the rivers that used to transport eroded sediments from the mountains to the beaches. As a result, rock is quarried from the mountains, mechanically pulverized into sand-sized grains, and then trucked to the beach.

Salt is produced in the San Francisco Bay—ponds are filled with saltwater from the bay, which is then allowed to evaporate (Figure 5.11). It takes over four years for this process to turn saltwater into harvestable salt. The salt was originally used for paper pulp production, livestock, and food preservation,
but today it is sold as table salt. Bittern, a byproduct of the salt purification, consisting of magnesium chlorides, sulfates, and other chemical compounds, is sold as dust control for construction sites and vineyards.

Further north, **agate** can be found along many beaches in Washington and Oregon. This semi-precious gemstone is collected and used for jewelry and other decorative purposes.

### Mineral Resources of Alaska

#### Region 6

Alaska encompasses a large landmass that contains a wide variety of mineral resources. However, difficulties associated with a lack of transportation and challenging environmental conditions (extreme cold, snow, and darkness) have limited the amount of mining that can occur there. Despite these obstacles, mineral resources continue to play an important role in the state’s development (Figure 5.12).

Alaska can be divided into separate areas, classified mainly by their differing modes of formation (Figure 5.13). Northern Alaska formed as the Yukon-Tanana terrane collided with the North American plate about 200 million years ago. This movement uplifted sections of the Arctic Sea floor, forming the Brooks Range
Mineral Resources

Region 6

Figure 5.12: Mineral resources of Alaska.

Figure 5.13: Common subdivisions of Alaska

Ag = Silver
Au = Gold
Cu = Copper
Gr = Graphite
J = Jade
Mo = Molybdenum
Y = Yttrium
Zn = Zinc
and White Mountains, and leaving behind the Arctic Plain (North Slope) between the Brooks Range and the Arctic Ocean. Major oil and gas development has taken place on the Arctic Plain. Mineral deposits, including zinc, silver, gold, graphite, and jade, are found in and around the Brooks Range and the White Mountains.

Alaska’s Interior lies between the Brooks Range to the north and the Aleutian Arc (and associated Alaska Range) to the south. It consists of sediment-covered crustal material from the Yukon-Tanana terrane. Two major river systems run through the Interior, along with a number of smaller rivers and tributaries, contributing to erosion and depositing sediments throughout. Placer gold mining brought prospectors to the area in the late 19th century, and mining remains an important industry there today.

The Aleutian Island Arc lies along the southern edge of the North American plate in Alaska. This area is an active subduction zone, where the Pacific plate subducts beneath the North American plate. As the subducting plate descends and begins to melt, water is released from the oceanic crust; this leads to melting of the overlying mantle and the generation of volcanism. The result is an arc of volcanic islands that stretches 2500 kilometers (1550 miles) from the Alaskan mainland through the Aleutians to Russia’s Kamchatka Peninsula. The arc is relatively young and continues to change as a result of regional volcanism. Some small-scale mineral development has occurred, and exploration of the area’s resources is ongoing.

Southeast Alaska is one of the state’s most geologically complex areas. It consists of a narrow archipelago of about 1100 islands and a thin strip of the Pacific Coast Range mountains, about 965 kilometers (650 miles) long with an average width of 193 kilometers (120 miles). Much of the land is mountainous, rising directly from sea level to great heights, and subsequently carved by recent glaciations. Since the last ice age, the removal of vast quantities of glacial ice from the landscape has allowed the land to rebound, elastically springing back to its former height (before it was compressed by the glaciers). This process, known as isostasy or isostatic rebound (Figure 5.14), has elevated the ocean shelf as much as several hundred meters (yards) above sea level. Physical structures in the area are generally oriented from the northwest to the southeast. The islands have long axes in these directions, forming strips of land that are roughly parallel to each other. Rocks in Southeast Alaska can be subdivided into 10 groups: five terranes that have distinct geologic records and five rock groupings that are depositional, intrusive, or of unknown connection to the terranes. Most of the area is accessible only by plane or ship, making mineral development difficult. There are exceptions, however, such as large gold mining operations in the Juneau area and historical garnet mining near Wrangell.
Mineral Resources of Northern Alaska

**Metallic Minerals**

In the southern part of the Brooks Range, mineral deposits are found in **Paleozoic**-age metamorphosed sedimentary rocks that contain similarly aged basalt **dikes**. In several areas close to the Dalton Highway, small mining
operations extract small quantities of placer gold. Near Coldfoot, larger-scale operations use hydraulic pumps to blast frozen gravel from hillsides that is then washed in large sluice operations (Figure 5.15).

On the western end of the Brooks Range, mineral deposits are found in Paleozoic black shales, creating a sulfide ore zone from which zinc and lead are mined. Because this area is north of the Arctic Circle, extreme winter conditions (with temperatures as low as -51°C [-59°F]) make mining in this area difficult. The placer gold found on the beaches of Seward Peninsula became the center of a gold rush in the late 19th century. The beaches around what eventually became the community of Nome were staked out and mined. Later, dredges were built on the rivers around Nome. Today, the beaches and ocean shelf around Nome are still home to a number of placer mining operations.

**Non-metallic Minerals**
Northeast of Nome on the Seward Peninsula, a graphite mine—the Graphite Creek Deposit—is under development. The graphite here formed through metamorphism and are found primarily near subduction zones, which explains why jade is abundant in a variety of locations along the active plate boundaries of both Alaska and the western continental U.S.

**Jade**
The word “jade” is applied to two minerals that look similar and have similar properties: jadeite (a kind of pyroxene) and nephrite (a kind of amphibole). The two minerals are so similar that they weren’t distinguished from one another until 1863. Both minerals are formed during metamorphism and are found primarily near subduction zones, which explains why jade is abundant in a variety of locations along the active plate boundaries of both Alaska and the western continental U.S.

Late Triassic chromian jade, which contains both pyroxene and amphibole.
metamorphism in the late Jurassic to early Cretaceous. It is generally found as flakes dispersed throughout the host rock, but can also be found in highly concentrated pockets.

Jade found in the Kobuk area has been mined in small amounts since the 1940s, and is used for jewelry and small, carved objects. The jade is found in ultramafic and mafic rocks formed in the middle to early Jurassic periods.

**Mineral Resources of Interior Alaska**

**Metallic Minerals**

Prospectors first came to Alaska’s interior following the Klondike gold rush in the late 19th century. Miners who arrived to the Klondike too late to stake claims, or simply chose to move on, would travel down the Yukon River. Eventually, near Fairbanks, placer gold was found in the creeks and streams that feed into the Yukon and Tanana Rivers. These early claims led to massive dredging operations in the early 20th century (Figure 5.16). Today, two large gold mines are found in this area. The Pogo Mine near Delta Junction is in high-grade gneiss intruded by Cretaceous granitic bodies. Closer to Fairbanks, the Fort Knox Mine is found in a granite body known as the Fort Knox pluton. The gold is found in quartz veins, which are the precipitated remains of hydrothermal fluids that once circulated through the pluton. Although the gold has been concentrated in the quartz veins, the ore must be further processed in order to separate the gold from the quartz.

More recently, at the Pebble Deposit in the Kuskokwim River drainage, copper, molybdenum, and gold have been found in veins and within granitic rocks. In part of the deposit, these minerals are partially exposed at the surface, while other portions are concealed beneath younger volcanic and sedimentary rock.
Non-metallic Minerals
Large amounts of sand and gravel (aggregate) are extracted throughout the area for use in road building and construction. Besides building new roads, aggregate is used to cope with the effects of climate change: as permafrost melts, soil compacts and overlying roads and infrastructure become unstable, requiring solid material to fill in the gaps. Large stone is also quarried for use as rip-rap along riverbanks in populated areas.

Mineral Resources of the Aleutian Arc
Metallic Minerals
Little is known about metallic deposits on the Aleutian Islands, and mining has occurred only in small pockets. On Unga Island, close to the Alaska Peninsula, gold and silver have been found in quartz deposits. Further out in the Aleutians, on Salt Island, the indigenous peoples collected native copper from the basaltic rocks for use as tools (such as awls, needles, and knives) and decoration.

Metallic mineral deposits are more common on the Alaska Peninsula itself, and also in the Cook Inlet. Placer gold deposits have been found on the beaches of the Alaska Peninsula and Kodiak Island, as well as in small creeks throughout the area. Deposits of copper and molybdenum have been found in the Pyramid Mountain area and are being explored for possible development.

In Cook Inlet, small placer deposits led to gold rushes during the early 20th century, and major mining operations started targeting underground deposits.
Along Turnagain Arm, near Anchorage, gold was found in Crow, Hope, and Six-Mile creeks. Placer mines were developed, and some individuals still mine these small claims (*Figure 5.17*). North of Anchorage, in the Talkeetna Mountains, placer gold was found in creeks. As prospectors moved to the headwaters of these creeks they found surface veins of gold, which led to underground mining at Independence Mine. The mine reached peak production in 1941 with a workforce of over 200 men blasting nearly 20 kilometers (12 miles) of tunnels and producing 975,677 grams (34,441 ounces) of gold. In 1942, shortly after the United States entered World War II, the War Production Board decided that gold was non-essential to the war effort. Gold mining throughout the United States was halted as a result—Independence Mine continued to operate, however, because of the presence of scheelite. Scheelite is a source of tungsten, a strategic metal for the war effort, and it was found in the same gold-bearing quartz veins being excavated by the mine. Since the production of scheelite was low, the mine closed in 1943. After the war, the price of gold dropped—mining at Independence was no longer profitable, and the mine closed for good in 1951.

**Non-metallic Minerals**

Non-metallic minerals found in this area are used in the road and building industries. Large amounts of sand and gravel are extracted for use in road building and construction. In the Matanuska Valley and the Anchorage area, rivers and glaciers left large sedimentary deposits that provide an inexpensive source of sand and gravel.

After World War II, the city of Anchorage grew quickly, and it therefore needed building materials. A pumice mine was developed nearby, on volcanic Augustine Island. From 1946 to 1949, pumice was mined and transported by barge to Anchorage to be used as an additive in cement and concrete. The mining ended when Mt. Augustine erupted, destroying the roads and several structures on the island.

**Mineral Resources of Southeast Alaska**

**Metallic Minerals**

Alaskan gold was first discovered in the southeastern part of the state, as prospectors had been following the gold fields north from California in the 30 years since the finds at Sutter’s Mill in 1848–1849. By the 1870s, gold had been found in small amounts near Wrangell and Sitka. In 1880, a major strike took place in what would become Juneau, the state capital. At the far north of Southeast Alaska, the Kennecott Copper Mine was developed starting in 1900, and produced millions of tons of ore over 27 years of operation (*Figure 5.18*). In addition to copper, the mines also produced a significant amount of silver.

Today, gold is the primary metal mined in Southeast Alaska, although recent discoveries of silver, zinc, and lead in commercial quantities have led to new mines. Southwest of Juneau, on Admiralty Island, a large mine at Green Creek has been developed in schists metamorphosed from volcanic and sedimentary rocks—this mine produces gold, silver, copper, lead, and zinc produced by magmatic and hydrothermal processes.
Non-metallic Minerals

A number of non-metallic minerals are currently mined in Alaska’s southeast. Near Wrangell, a garnet-bearing schist wall has been mined for specimen-grade garnets since the early 1900s (Figure 5.19). The mine is currently owned...
by the local Boy Scout Troop, which collects and sells the garnets to tourists. Further north at Gypsum Creek, a mine produces gypsum from the Paleozoic Iyoukeen Formation. At the southernmost end of the Panhandle, on Prince of Wales Island, Bokan Mountain is being explored for heavy rare earth elements. Surveys have shown that about 40% of the area (by weight) is composed of these rare elements, including dysprosium (used in nuclear reactors and data storage), terbium (used in solid-state devices and fuel cells), and yttrium (used in the production of lasers, electrodes, and superconductors).

Mineral Resources of Hawai‘i
Region 7

The uniform geology of the Hawaiian Islands does not produce the variety of mineral resources seen in many other parts of the world (Figure 5.20). However, human development has spurred demand for building materials, which, in turn, has driven the development of basalt and limestone resources. In ancient times, Hawaiians used dense basalt for tools and implements. Evidence of
quarry sites once used for these purposes can be found throughout the islands. The Hawaiians also used basalt rocks for building hut bases and ceremonial walls (Figure 5.21).

The arrival of Europeans and the subsequent development of the Hawaiian Islands led to an expansion of the construction industry, ultimately requiring more materials. More recently, some companies have been working to develop deposits of extremely weathered soils for their aluminum potential.

The US Geological Survey divides the current utilized mineral resources of Hawai‘i into three categories: crushed stone, construction sand/gravel, and gems.

Crushed stone is Hawai‘i’s largest mineral resource, making up over 85% of the state’s mineral production resources (Figure 5.22). Crushed basalt is used for a variety of purposes in the construction industry, such as in road bases and as an aggregate in concrete, drainage, and stone retaining walls. Sand made of cinder from cinder cones is also sought after as a landscaping material. Limestone from emerged Pleistocene-age reefs, and the coastal carbonate sand dunes that fringe O‘ahu and older Hawaiian islands, has been used to make cement products.

The “gems” mined in Hawai‘i are limited to black and precious corals. Approximately $150,000 a year of this material is taken from the waters off the
Mineral Resources

Figure 5.22: Crushed stone quarry nestled in the hills of O'ahu.

Figure 5.23: Coral bracelet.
It is often thought that the olivine (peridot) sold in stores around the islands is sourced from the local rocks, but collecting and selling olivine is considered disrespectful in traditional Hawaiian custom. It is therefore illegal to extract it from most sites, and the olivine sold in Hawai‘i is actually sourced from locations outside the islands.
Resources

Books


State-based Resources


Gold


The Teacher-Friendly Guide™

to the Earth Science of the

Western US

Edited by Mark D. Lucas, Robert M. Ross, & Andrielle N. Swaby

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