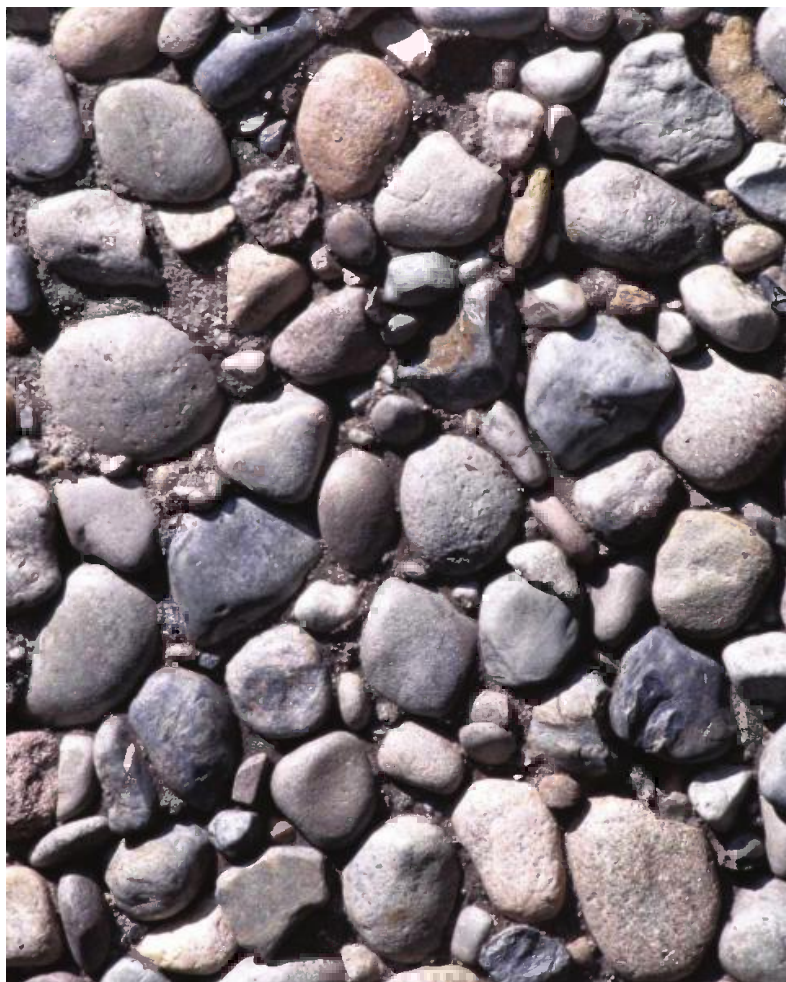


A DESCRIPTION OF SOME OREGON ROCKS AND MINERALS



\$5.50

4-H 3401L

Reprinted August 2006



OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

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A DESCRIPTION OF SOME OREGON ROCKS AND MINERALS

Introduction

Many settlers came to Oregon because of the wealth that minerals, mainly gold, offered. The search for gold in southwestern and northeastern Oregon is largely responsible for the early settling of those areas. In more recent years, the search for minerals in Oregon has not been as hectic nor has it been restricted to the metallic minerals. Instead, a steady, more diversified search has taken place. Today, the value of the annual production of nonmetallic minerals is greater than the value of the metallic minerals of the state. This is true for almost every state in the United States. The search for and utilization of minerals, both metallic and nonmetallic, is still continuing. Mineral wealth still remains to be found or recognized in the state.

The rocks and minerals described in the following text represent some of the more common rocks and minerals found in the state. They do not begin to represent the total number of different minerals and types of rock found in Oregon nor the diverse mineral associations that occur.

GENERAL

The crust of the earth forms a thin skin over the earth and ranges in thickness from about 5 miles (mi) at some places under the oceans to about 30 mi under high mountains. Tremendous forces inside the earth move its crustal surface up, down, and laterally. The crust has been broken into many pieces, called **plates**, that move slowly over the surface because of these forces. In some places, crustal plates collide with each other, and one plate slides under or moves laterally against the other. For example, the collision of two plates has lifted the sedimentary rocks of the Himalaya Mountains as much as 6 miles above sea level where they formed. In other places, such as mid-Atlantic ocean spreading center, the plates move away from each other, and new crust forms as magma (molten rock) wells up to fill the fractures that result from the spreading. This type of geological activity is called **plate tectonics**.

Minerals defined

The earth's crust is composed of rocks and minerals. Minerals are defined as natural inorganic substances, usually crystalline, whose composition can be expressed by a chemical formula and which have physical properties that are definite or variable within limits. A list of the 20 most common elements that make up the earth's crust and are found in many minerals is given in Table 1 (page 2).

Technically, the definition of minerals also includes coal, mineral waters, petroleum, and gas.

Close to 3,000 different minerals have been identified and named. To be a mineral, a substance must have the following qualifications:

1. It must be a natural substance; that is, naturally occurring.
2. It must have been formed by inorganic processes.
3. Its composition should be expressible by a chemical formula.
4. It must be homogeneous; that is, no matter how finely it is divided, each part is like any other part.
5. It is usually crystalline; that is, the molecular structure always has a definite arrangement.

Rocks defined

Rocks are defined as aggregates or mixtures of minerals; rocks also include noncrystalline materials such as the natural glasses, and organic material such as coal. Rocks are found ready-made in nature. They are not homogeneous nor are they crystalline, although they may be made up of crystalline material. The composition of a rock cannot be expressed by a chemical formula except for a few instances in which rocks are made up of a single mineral, as in the case of limestone.

As a help in the identification of rocks and minerals, the following relatively simple classifications are presented. A thorough knowledge of the various divisions of each is essential to ready identification and will help the reader to understand the various geologic processes an area has undergone.

Table 1. The 20 most common elements in the earth's crust in the order of their abundance (after Mason, 1966)

Element	Symbol	Weight percent
Oxygen	O	46.60
Silicon	Si	27.72
Aluminum	Al	8.13
Iron	Fe	5.00
Calcium	Ca	3.63
Sodium	Na	2.83
Potassium	K	2.59
Magnesium	Mg	2.09
Titanium	Ti	0.44
Hydrogen	H	0.14
Phosphorus	P	0.10
Manganese	Mn	0.09
Fluorine	F	0.06
Strontium	Sr	0.04
Barium	Ba	0.04
Sulfur	S	0.03
Carbon	C	0.02
Zirconium	Zr	0.02
Chlorine	Cl	0.01
Chromium	Cr	0.01

MINERALS

Classification

The minerals that have little or no commercial value and that combine to form rocks are called **rock-forming minerals**; those that have commercial value are called **ore-forming minerals**. As this division is based on whether or not the mineral can be sold for profit, many of the same minerals can be found in both classifications. Minerals can also be classified as metallic or nonmetallic minerals. Primary metallic minerals usually have a luster similar to metals. They include minerals from which metals are derived. The nonmetallic minerals do not have a metallic luster but may contain oxides of metals.

Identification

The identification of minerals is dependent on their chemical, optical, and physical properties. Most common minerals can be identified by their physical properties alone, and it is in this manner that they are usually identified in the field.

Physical properties of minerals are:

- | | |
|-------------------------|--------------|
| 1. Form (crystal) | 7. Color |
| 2. Cleavage | 8. Streak |
| 3. Fracture | 9. Magnetism |
| 4. Hardness (H) | 10. Taste |
| 5. Specific gravity (G) | 11. Odor |
| 6. Luster | |

Complete definitions of these terms as well as information for the identification of minerals are contained in most books about minerals and mineralogy.

Rocks

Rocks are usually divided into three main classes: igneous, sedimentary, and metamorphic. This division is based on origin.

Igneous rocks

(From Latin *ignis*—fire)

Igneous rocks have solidified from molten material, called **magma**. If the solidification or, in most cases, crystallization took place at depth, that is, below the surface of the earth, these rocks are termed **intrusive** or **plutonic** rocks. If the solidification occurred on or at the surface of the earth, the rocks are called **extrusive** or **volcanic** rocks. Extrusive flow rocks are called **lavas**.

Igneous rocks can be classified by their textures and contained minerals (see Table 2). Texture depends upon size, shape, and relationship of the minerals of the rock to each other. Common textural terms and their definitions are listed below.

1. Granitoid or granitic—composed of minerals of approximately the same size that can be seen with the unaided eye.
2. Porphyritic (pronounced “pore-fuh-rit´ic”)—composed of a fine-grained or glassy groundmass surrounding mineral crystals that are large enough to be identified with the unaided eye.
3. Aphanitic (compact, stony)—composed of mineral grains that are so small they cannot be distinguished from each other with the unaided eye.
4. Glassy—composed of glass rather than crystals.
5. Fragmental—composed of fragments of igneous material. These rocks are sometimes referred to as **pyroclastic** (fire-broken) rocks. Rocks composed of angular fragments produced by explosions or movement on a fault are called **breccia** (pronounced “bretch´ee-uh”).

Textural terms imply the manner in which igneous rocks solidify. The slower the cooling, the greater the opportunity for crystal growth. Slow cooling, then, results in a granitic or coarse-grained texture. If slow crystal growth is interrupted and then later renewed, or, if after a period of crystal growth, the remaining liquid is cooled so rapidly that only minute crystals are formed, a porphyritic texture results. If the magma cools quickly, crystals discernible only under the microscope are formed, and the texture is then aphanitic. A glassy texture is formed when the solidification of the magma is so rapid that few, if any, crystals have time to form. Explosive extrusion of molten or chilled materials results in a fragmental or pyroclastic texture.

The speed of solidification of magma indicates the conditions under which cooling took place. Slow cooling generally takes place where heat is dissipated slowly at great depths or where the cooling mass is large. Porphyritic rocks form during a period of slow cooling followed by a period of fast cooling. This process may take place around the borders of a large intrusive mass, where small portions of the mass are intruded into fractures of the bordering crust, or where the partially cooled mass is extruded onto the surface of the earth. Extrusive rocks

are generally fine-textured because the pouring out of the magma onto the surface of the earth allows a greater cooling area as well as rapid heat loss to the atmosphere. Cooling rapid enough to form glass may take place by rapid extrusion of magma to the surface of the earth or locally along the edges of a flow or intrusive. Glassy rocks occurring in large masses are extrusive rocks. Fragmental rocks usually are extrusive rocks because the explosive eruption that forms them can take place only at or near the surface of the earth.

Classification of igneous rocks by the mineral content depends upon the amount and the presence or absence of a few minerals, commonly called **essential minerals**. These diagnostic minerals are (1) feldspars, (2) quartz, and (3) olivine. Identifying characteristics of these minerals are found in the section dealing with mineral descriptions.

Other minerals, called **accessory minerals**, may be present, but these accessory minerals do not determine or change the class into which the rock is placed. However, the accessory mineral commonly provides the adjective describing the rock. For instance, a rock containing the essential minerals that classify it as a granite may have mica as an accessory mineral. The rock, then, is called a **mica** or **micaceous granite**. Some of the essential and accessory minerals may occur together, while some cannot form as companion minerals. For instance, feldspars will occur with any minerals; quartz will occur with feldspars, amphiboles, and pyroxenes; olivine will occur with feldspars, amphiboles, and pyroxenes but not with quartz. A classification of some of the more common rocks based on the texture and mineral content is found in the igneous rock chart (Table 2).

Table 2. Classification of igneous rocks

	Quartz present			Little or no quartz present		
	Potassium feldspar	Potassium and plagioclase feldspar	Plagioclase feldspar	Sodic plagioclase feldspar	Calcic plagioclase feldspar	Olivine; little or no feldspar
Intrusive (coarse-grained)	Granite	Granodiorite	Quartz diorite	Diorite	Gabbro	Peridotite
Extrusive (fine-grained)	Rhyolite	Dacite		Andesite	Basalt	—
Extrusive (glassy)	Obsidian			Tachylite		

Sedimentary rocks

(From Latin *sedimentum*—settled)

The forces of nature constantly attack the land on which we live. As long as the land is above the level of the sea and the mountains stand above the general level of the land, erosion gradually wears down these surfaces and transports the material to a base level, which is approximately the level of the sea. The products formed from erosion of the land are called **sediments**. Consolidated sediments form sedimentary rocks. Included in the sedimentary rock classification (see Table 3) are organic materials such as limestone and coal. Most limestone is formed from beds of shells or materials high in calcium deposited by living organisms, and coal is formed from the alteration of vegetable tissue.

The tearing down and transporting of rocks and soil on the earth's surface is called **erosion**. Erosion is accomplished mainly by water, wind, ice, gravity, and chemical alteration. Of these, erosion by running water is by far the most destructive. As most major streams empty into the sea, the ultimate resting place of sediments is the sea. The carrying of sediments to the sea is an irregular and frequently interrupted process. Even in a stream bed, material is constantly being dropped and picked up owing to the change of velocity and therefore the carrying power of currents within the stream. Sediments on their way to the sea frequently are deposited temporarily to form such features as gravel bars, flood plains, terraces, and lake beds. Sediments deposited on the continents are called **continental sediments**. Sediments deposited in the sea are called **marine sediments**.

Besides rock substances, streams also carry organic material such as wood, which sinks when it becomes waterlogged. Also, as water supports the growth of many kinds of animal and plant life, it is inevitable that when the animals and plants die, their bodies sink to the bottom and, like the waterlogged wood, are incorporated into the sediments. Under favorable conditions, this organic material is replaced by mineral matter and retains its original form and structure. In relatively recently deposited material, the hard parts of the original plant or animal are protected from decay by exclusion of the air and are consequently preserved. The preservation from prehistoric time of any recognizable organic structure or impression of a plant or an animal is called a **fossil**. As the seas support abundant plant and animal growth, many marine sediments contain fossils. The ocean floor is also relatively quiet, and fossils have a better chance of being preserved there.

Moving water tends to sort material it is transporting by size and weight. The stronger the current, the larger and heavier particles it is able to transport. The result of this is that most sedimentary deposits are layered or, as geologists call it, **bedded**. Another result of this action, especially in marine waters, is that the coarsest materials are found nearest the shoreline, and material becomes finer and finer away from the shore. It is in the latter zone, where there is little or no deposition of land-derived material, that the large deposits of limestone consisting almost entirely of limy organic materials form.

The classification of sedimentary rocks is based on the sources from which the sediments have been derived. Sediments formed from fragmental materials resulting from the breaking up of rocks are called **clastic** sediments. All others, such as coal, limestone, chalk, iron-bearing beds, phosphate rocks, salt, and gypsum, are termed **nonclastic** sediments. Clastic sediments are named according to the size of the particles that make up the bulk of the material. Nonclastic

sediments are formed, in general, from organic sources or are chemical precipitates. Included in Table 3 is a classification of clastic sediments according to size. A general classification of sedimentary rocks is in the sedimentary rock classification chart (Table 3). A description of individual sediments is included in the section describing the sedimentary rocks.

When describing sedimentary rocks, significant properties should be addressed. The following are the most important.

1. Color
2. Size of grains. If several sizes are present, the rock should be classified according to the size of the dominant grains, and the minor grain size should be used as an adjective; for instance, “a bouldery sandstone” or “a sandy shale.”
3. The degree of roundness of the grain. Three degrees of roundness are commonly used: (a) well-rounded, (b) subrounded, and (c) angular.
4. The material that cements the grains together. The most common cementing materials are silica, calcite, and oxides of iron.
5. Fossils. If fossils are present, the descriptive term “fossiliferous” is used.
6. Mineral content

Table 3. Classification of sedimentary rocks

A. Clastic rocks (composed of fragments)		
Texture	Composition	Rock name
Coarse-grained (over 2 mm)	Rounded fragments of any rock type	Conglomerate
	Angular fragments	Breccia
Medium-grained (0.06 mm to 2 mm)	Quartz with smaller amounts of other minerals	Sandstone
	Quartz with at least 25 percent feldspar	Arkose
	Quartz, dark rock and mineral fragments, clay	Graywacke
Fine-grained (0.004 mm to 0.06 mm)	Quartz and clay minerals	Siltstone
Very fine-grained (less than 0.004 mm)	Quartz and clay minerals	Shale
B. Chemical precipitates and organic material		
Texture	Composition	Rock name
Banded calcite	Calcium carbonate (CaCO ₃)	Travertine
Surface crusts	Carbonates and sulfates of sodium	Evaporites
Fine-grained	Diatom shells (SiO ₂)	Diatomite
Fine-to coarse-grained	Calcium carbonate (CaCO ₃)	Limestone
Loosely cemented fossils and fossil fragments	Calcium carbonate (CaCO ₃)	Coquina
Opaque and noncrystalline	Highly altered plant remains and clay	Coal

Metamorphic rocks

(From Greek *meta*—change + *morphe*—form)

The third great class of rocks, metamorphic rocks (see Table 4), is formed by physical and chemical changes in rocks of the other two classes; often, the original nature of the rock is not readily apparent. In metamorphic rocks, the physical and chemical changes result in formation of new minerals, in recrystallization of old minerals, and in the alignment of mineral and rock grains to give the rock a banded or layered appearance together with a tendency to break along certain planes.

The principal factors that cause metamorphism are heat, pressure, recrystallization, cementation, and addition of new material. The processes that cause metamorphism usually take a long period of time and result from a variety of conditions. Therefore, as a rule of thumb, it might be said that the metamorphic rocks are generally the oldest of the rock types found within an area. This criterion of age must be used with caution, however.

The metamorphic rock most easily recognized as such is the rock that has a parallel arrangement of mineral grains. When a crude banding of the mineral grains is seen, the rock is called **gneiss**. Sometimes the alignment of crystal grains of the rock is so well developed that it will split readily into thin flaky slabs or sheets. This means that new minerals that are flat and platy or needle-shape have formed. The ability to break along certain planes is termed **schistosity**. When most of the mineral grains of a platy metamorphic rock are large enough to be identified with the naked eye, the rock is called a **schist**. If it is fine grained, is nearly uniform in composition, and has only one or possibly two readily identifiable minerals, it is called a **phyllite**. When the rock breaks readily into thin or thick sheets with smooth sides and is so fine grained that minerals cannot be identified in hand specimens, it is called **slate**.

Slates and phyllites are usually formed from sedimentary rocks; schists and gneisses can be formed from both sedimentary rocks and igneous rocks. Hornfels, which is very dense and fine grained, is formed from shales that have been metamorphosed by intrusives; argillites are very low-grade metamorphosed shales that have not developed schistosity. Metamorphic rocks that have formed by recrystallization may not have a schistose or gneissic appearance. The most common example of metamorphism due to recrystallization is the conversion of limestone to marble. Quartzite, which forms by the cementation of quartz sand by silica to the point that the rock will break as readily across the quartz grains as it will through the cementing material, is an example of a metamorphic rock formed by cementation followed by interlocking crystal growth.

A few minerals are typical of metamorphism and, when identified in a rock, are indicators that the rock may be a metamorphic rock. A few of the typical minerals are garnet, mica, talc, graphite, chlorite, and amphiboles. Metamorphic rocks can be readily divided into two classes: the “leaflike” foliates (those rocks that will split along certain planes or have an alignment of mineral grains) and the nonfoliates (those rocks that show no mineral alignment and are massive). A few of the rocks in each type are listed in the chart on metamorphic rocks (Table 4).

Table 4. Classification of metamorphic rocks.

A. Foliated rocks (have a planar structure)

Texture	Composition					Rock name	
Fine- to very fine-grained						Slate	
Coarse-grained	Chlorite	Mica	Quartz	Feldspar	Amphibole		Schist
Coarse-grained with alternating layers of light and dark minerals							Pyroxene

MINERAL DESCRIPTIONS

Minerals from which metals are derived

Bauxite—an ore of aluminum

(Pronounced “box´-ite”; from original locality at Baux, France) (Mitchell, 1979)

In the strict sense of the word, bauxite is not a mineral but a rock, as it is a mixture of hydrated aluminum oxides such as gibbsite (for George Gibbs, an early mineralogist), boehmite (pronounced “bow´-mite,” for Johannes Boehm, a German geologist), and diaspore (from Greek for “to scatter,” in allusion to its decrepitating when heated), together with some iron oxide, titanium oxide, and silica. **Bauxite** is a generic term for rocks rich in hydrous aluminum oxides. With increasing hydrous iron oxide content, bauxite grades to laterite (from Latin *later*, meaning brick).

Bauxite occurs in oolitic and earthy masses. Colors range from white to tan to brown. Pure bauxite minerals sometimes have delicate tints. Low silica content as well as high aluminum oxide determine whether or not bauxite may be utilized as an ore of aluminum. The bauxite found in northwestern Oregon is high in iron oxides, and so it has been categorized as high-iron bauxite or ferruginous bauxite.

Bauxite often has rounded grains ranging from shot to marble size set in a claylike groundmass. In this form, it is oolitic, with shot-size grains, or pisolitic (pronounced “pies-o-lit´-ic;” from the Greek word for pea), with larger than shot-size grains, and is readily recognized. However, some bauxite does not have this texture but is granular, both porous and compact, and difficult to distinguish from clay. In Oregon, the shotlike material usually occurs as the upper horizon of the deposits, but locally this horizon has been eroded away. Usually, the soil derived from the breaking down of basalt to form laterite in which the high-iron bauxite occurs is a deep brick red that stains everything it contacts. This deep-red soil is a prospecting aid and, when found over wide areas, should be investigated.

The laterite of northwestern Oregon was formed by the chemical weathering of basalt. The basalt was decomposed by exposure to air and water, and water percolating through this “rotted” rock carried most of the silica and other minerals away, leaving aluminum, iron, and titanium oxides in relatively high percentages.

In Oregon, possible commercial deposits of high-iron bauxite have been found in the northwestern part of the state (Libbey and others, 1945).

The lower Columbia River area has aluminum plants in which aluminum metal is produced from aluminum oxide that is produced by treating bauxite in plants located in the Midwest and South. Most bauxite mined in the United States currently comes from Arkansas, Alabama, and Georgia. A large amount of the original bauxite comes from overseas, and the aluminum oxide must be shipped a long distance across the country to these plants in the Pacific Northwest.

Aluminum is used extensively in airplanes, railroad cars, machinery, packaging material, electric appliances, cooking utensils, electrical conductors, building construction, foundry and metalworking, and chemicals. The properties that make it so desirable are its light weight, high electrical and thermal conductivity, ductility, and resistance to atmospheric corrosion. About 10 percent of all bauxite

produced is not smelted and refined to aluminum. Instead, it is processed into abrasives, ceramics, heat-resistant materials, pharmaceuticals, and cements.

Chalcopyrite, CuFeS_2 —an ore of copper

(Pronounced “kal-ko-pie’-rite”; from Greek *chalcos*—copper + similarity to pyrite)

This mineral is a chemical combination of the elements copper, iron, and sulfur. Its brassy-yellow color often leads to its being mistaken for gold or pyrite. Gold is softer and heavier than chalcopyrite, while pyrite, which is usually whiter in color, frequently has striations (minute parallel lines) on the sides of its crystals. Also, chalcopyrite often has a bluish iridescence or sheen caused by oxidation.

In the period 1852–1947, Oregon produced \$4.6 million in copper (U.S. Bureau of Mines Minerals Yearbook 1947, p. 1,490), with chalcopyrite as the principal ore mineral. Production since then has been very small. The areas of greatest copper production were southwestern Oregon, the central Cascades, the Blue Mountains, and the Willows. Chalcopyrite is also found as a common accessory mineral in many quartz and gold-bearing veins in these same areas.

Chromite, FeCr_2O_4 —an ore of chromium

(Pronounced “krow’-mite”; denotes “containing the element chromium,” based on Greek *chroma*—color)

The most readily identifiable characteristic of chromite is its brown streak. This distinguishes it from magnetite (magnetic iron oxide) with which it is most likely to be confused, as both are black, heavy minerals. Chromite is not as hard or magnetic as magnetite. Occasionally, minute emerald-green crystals or sugary grains of a chrome-rich garnet (uvarovite, named for Count Sergei Uvarov, an early Russian nobleman and scholar) are found on chromite.

Chromite is the main ore of chromium, which is a component of certain hard steels, rustless steel, tools requiring maintenance of a keen edge, stainless steel, and many automobile parts, and which is used in chromium plating and various chemicals. Bricks that are used to line furnaces requiring high temperatures sometimes contain chromite. Certain paints contain chromium as a pigment.

The large chromite deposits of the world are found in South Africa, Russia, Turkey, Zimbabwe, the Philippine Islands, India, and Finland. In times of international stress when the shipping lanes are closed, domestic sources of chromite must be used; under peacetime conditions, however, domestic chromite cannot compete with foreign chromite. During both world wars, Oregon was a prominent contributor to the nation’s supply of this very strategic mineral. For instance, during World War II, Oregon produced chromite that was valued at nearly \$1 million (Libbey, 1948). At the present time, however, there is no production of chromite in Oregon. Southwestern Oregon chromite deposits are described by Ramp (1961).

Chromite has always been found associated with serpentinite and peridotite. In Oregon, large areas of serpentinite are found in Curry, Josephine, and Grant counties. Other sources of chromite in Oregon are the beach sands and beach terraces of Coos and Curry counties. Undoubtedly, these sands were derived from erosion of serpentinite and peridotite areas. After streams had brought the sands to the ocean, ocean currents concentrated the heavy minerals, including chromite, along the shoreline. Deposits of chromite also occur off the coast of Oregon.

**MINERALS
FROM WHICH
METALS ARE
DERIVED**

Cinnabar, HgS—an ore of mercury (quicksilver)

(Pronounced “sin´-a-bar”; from Latin *cinnabaris*, traced to Persian *zinjifrah*—dragon’s blood)

The scarlet streak and blood-red to scarlet color are the most diagnostic features for the identification of cinnabar. The mineral most likely to be confused with cinnabar is hematite—red iron oxide. Sometimes, the color of these minerals is nearly the same; and, when impure, the apparent hardness and weight of each is about equal. The streak of hematite is red-brown, however, and it is this property that helps identify it.

Cinnabar is a chemical combination of mercury and sulfur. It is the principal ore of mercury, the only common metal that is liquid at ordinary temperatures. Mercury is obtained from the roasting of cinnabar, which, when heated to a temperature above 580°C, releases mercury as a vapor that is then collected by condensing in water-cooled pipes.

Mercury is used in electrical apparatus; for the production of caustic soda and chlorine; and in paints, instruments, dental supplies, and chemicals of many kinds.

In this country, mercury has been produced in Nevada and California, with imports from Algeria, Spain, and Mexico. During World War II, it was not possible to obtain mercury from these sources. Domestic sources were then needed, and Oregon, along with California and Nevada, produced the bulk of the nation’s supply. Cinnabar is found in many localities in Oregon. The principal producing areas have been the Bonanza Mine, east of Sutherlin; the Ochocos, east of Prineville and east of Ashwood; and in southwestern Malheur County. Cinnabar occurs as veins and disseminated specks in rocks of various kinds and ages but is most frequently found in areas of fairly recent igneous intrusions. Some of the more important deposits are concentrated in major fault zones. Favorable prospecting areas are the Western Cascades, the Ochocos, and the volcanic rocks of southeastern Oregon.

Galena, PbS—an ore of lead

(Pronounced “ga-lee´-nah”; from Latin *galena*, a name given to lead ore)

Galena is identified by its metallic luster, its lead-gray color and streak, its relatively great weight, and its hardness (H = 2.5–3). In massive pieces, the edges are square or steplike; when a piece is broken, the fragments tend to cleave into cubes or rectangles, always with square corners. Galena has perfect cubic cleavage.

Galena is a chemical combination of lead and sulfur and is the main ore of lead. Frequently, galena has sufficient silver mixed with it to make it an ore of silver. Lead is one of the basic metals of industry and as such has a wide variety of uses. About 75 percent of all lead is used to manufacture storage batteries. Smaller amounts of lead metal are used for ammunition, cable covering, solder, and various lead alloys. Lead oxides are used in ceramics, glasses, and corrosion-resistant paints. A small amount of lead is still used in gasoline.

In the United States, the areas of greatest lead production are southeastern Missouri, the Tri-State area (southwestern Missouri, southeastern Kansas, and northeastern Oklahoma), and the western states (principally Idaho, Utah, Arizona, Colorado, and Montana). Of the states, Missouri is consistently the greatest producer, followed by Idaho and Utah. Oregon’s production of lead is sporadic. Although galena is a common accessory mineral in many of the gold and copper

veins in Oregon, the bulk of the production has come from the Cascades, especially in the Bohemia and the North Santiam mining districts.

Garnierite—an ore of nickel

(Pronounced “gar’-ni-er-ite”; named for Jules Garnier, a French engineer who discovered the mineral in New Caledonia)

Garnierite is a generic name for nickel-magnesium hydrosilicate; that is, it is composed of nickel, magnesium, silicon, oxygen, and water. It is a mixture of several magnesium and nickel hydrosilicates and, in that sense, is not a single mineral (Pecora, Hobbs, and Murata, 1949). It has been formed by the weathering (chemical alteration) of a peridotite that released the nickel from the primary minerals followed by combination of the nickel with silica and water. This natural process takes a very long time and is thought to progress best in a humid tropical climate. It also demands that the lands being weathered are at a low elevation and are porous, so that the water seeps through the rock rather than mechanically tearing it down. Garnierite ranges in color from light yellow-green to dark green. It occurs as fillings in fractures, cracks, and rock pores associated with chalcedony and limonite and is always in an area of a reddish clay soil, the result of “rotting” of the rock. The “rotting” rock is called “saprolite” from the Greek word “sapos”—meaning rotten.

The last producing nickel mine in the United States operated from 1954 to 1986 at the garnierite-laterite deposit on Nickel Mountain in Douglas County near Riddle, Oregon (Pecora and Hobbs, 1942). Other areas in southwest Oregon, including Red Flats in Curry County and Woodcock Mountain in Josephine County (Ramp, 1978), are potential producers of nickel from nickeliferous laterites.

Gibbsite, $\text{Al}(\text{OH})_3$ —an ore of aluminum

(Pronounced “gib’-site”; named for George Gibbs, an early mineralogist whose collection was added to Yale University early in the 19th century)

Gibbsite is a chemical combination of aluminum oxide and water and is one of the minerals usually included in bauxite. Because it is similar in appearance to some of the clay minerals, it is sometimes difficult to recognize. When disseminated in clay or the high-iron bauxites of Oregon, gibbsite sometimes occurs as small, white, rounded fragments that are quite brittle. A freshly fractured surface looks somewhat like porcelain. Usually it is harder than kaolin and much softer than feldspar or quartz. An unusual occurrence of gibbsite is found on the Salem Hills in Marion County, where it occurs as residual nodules, some of which have pink-, yellow-, or cream-color bands. When the nodules are cut and polished, the result is very attractive. The identification of the gibbsite nodules is complicated by a red clay that covers the exterior, and they can readily be mistaken for clay-covered boulders of vesicular basalt. The nodules sometimes are the size of large boulders, and usually their surfaces are badly pitted or extremely rough. Gibbsite also occurs as small veins and linings in cavities in the high-iron bauxite.

The gibbsite of northwestern Oregon is the result of laterization (a form of chemical weathering) of basaltic lavas of Miocene age. The greatest known concentration of gibbsite in Oregon is in the areas of the high-iron bauxite. However, small gibbsite particles may be found in areas in which volcanic tuffs or agglomerates show some alteration to clay.

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Gold ore, Au

(*Gold* is an Old English word for the metal, from Indo-Germanic word for “bright, shiny,” related to “yellow”)

An ore deposit is defined as a mineral deposit that can be worked at a profit. Gold ore, then, is a deposit containing sufficient gold to pay for both the mining and recovery of the gold and also to give a profit to the operator. Because mining and milling costs vary for nearly every locality and type of ore, the minimum mineral content of the ore deposit required for a profitable mining operation varies considerably.

Gold-bearing rock that contains 1 ounce of gold per ton of rock under ordinary conditions is considered to be very good ore. There are 29,166.66 troy ounces in 1 short ton avoirdupois. Therefore, if the gold in the above example is disseminated evenly throughout the rock, only 1 part in approximately 29,000 is gold. Consequently, it is clear that visible gold is not necessary for rock to be gold ore, and some orebodies currently being mined profitably contain only 0.05 ounce of gold per ton of rock.

Pyrite (a mineral composed of iron and sulfur) and chalcopyrite (a copper and iron sulfide) are often mistaken for gold. Gold can be recognized by its yellow color, softness (it can readily be scratched by a knife), malleability (ability to be pounded into thin pieces), and weight (it is over twice as heavy as iron). It is this last characteristic that makes prospecting by panning possible. If gold is suspected in a rock, the most reliable way it can be verified is by fire assaying, a laboratory method whereby the rock is smelted and the precious metals are extracted from the melt by molten lead that is added as litharge in the original smelting operation.

The mining of gold ore from igneous or metamorphic rocks is termed **lode mining**. This type of mining is by surface or underground methods. If the ore is extracted from sand, gravel, or sedimentary rocks at the surface of the earth by dredging with large mechanical shovels, hydraulicking, panning, or sluicing, it is termed **placer mining**. The largest production of gold in Oregon is by placer mining methods. In 1940, the year of Oregon’s maximum production of gold to date, when the value of gold was \$35/oz, \$2.5 million was recovered in Oregon by placer methods, and lode production reported by the Bureau of Mines was \$1.5 million. Total recorded production of gold in Oregon in the period 1852–1965, when the price of gold ranged from \$16 to \$35/oz, was valued by the U.S. Bureau of Mines at \$130 million. Production since that time in Oregon generally has been small and sporadic, amounting to only a few millions of dollars per year, even though the value of an ounce of gold has risen over 10 times higher than it was in 1940.

Gold mining in Oregon has been from the following counties: Baker, Grant, Jackson, Josephine, Malheur, Douglas, Union, Jefferson, Curry, Coos, Harney, Lane, Crook, Wheeler, Morrow, Umatilla, and Wallowa. The principal lode mines were in Baker, Grant, Jackson, Josephine, Curry, and Wallowa counties. Some gold is derived from black sands found along the coast, principally in Coos and Curry counties. Most lode gold found in Oregon occurs in quartz veins either within or adjacent to granitic intrusive masses. Usually, these veins contain minor amounts of pyrite. Other common minerals found in the veins are chalcopyrite, barite, calcite, and galena.

Higher metal prices and improved extraction techniques have made low-temperature, hot-spring type (epithermal) deposits in central and southeastern

Oregon containing small amounts of gold usually associated with mercury more attractive exploration targets.

Hematite, Fe_2O_3 —an ore of iron

(Pronounced “hem’-a-tite”; from Greek *haima*—blood, an allusion to its color)

Because of its red color when crushed, this mineral is sometimes referred to as **red iron oxide**. It is found in many different forms: as a reddish clay; in massive dark-red or dark-gray masses that are often fibrous or mammillary; in small, rounded concretionary grains cemented together; and in steel-gray, dark-brown, or black flaky pieces. This last type is called **specular hematite** because of its very shiny reflective surfaces.

Hematite can best be identified by its streak, which is blood red. It is also heavy, and the specular and mammillary varieties are quite hard. The mineral it is most apt to be mistaken for is cinnabar. Hematite is usually a little duller and browner in color than cinnabar, and the streak of cinnabar is scarlet.

Although hematite is one of the most important and widespread ores of iron, it has not been found in commercial quantities in Oregon. A few scattered boulders of massive steel-gray hematite were found in Columbia County in the area of the limonite deposits, but the source of these boulders was never found. This material was probably formed by alteration of limonite. Specular hematite is sometimes found as a gangue (waste) mineral in veins and occasionally is seen in metamorphic rocks, especially in the Willowa Mountain region. A compact, dark-colored variety of hematite is carved and polished to make jewelry.

Ilmenite, FeTiO_3 —an ore of titanium

(Pronounced “ill’-mu-nite”; from the Ilmen Mountains in Russia where it was first found)

Ilmenite is an iron titanium oxide. It is steel gray to black in color. It can be distinguished from magnetite by its not being magnetic and from chromite by its black streak. Ilmenite is found as an accessory mineral in almost every type of rock and may be associated with magnetite. As an accessory mineral, it occurs as very small disseminated grains that are usually fairly well formed. Ilmenite is a common constituent of black sands. Oregon Metallurgical Company in Albany is one of the few producers of titanium metal and alloys in the United States.

Limonite, $2\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$ —an ore of iron

(Pronounced “lie’-mu-nite”; from Greek *leimon*—meadow, in allusion to its occurrence in bogs and swamps)

Limonite is a generic term for minerals of iron oxide chemically combined with water. In Oregon, it is commonly found in yellowish-brown earthy deposits. In this form, it is quite soft. The brown to black varieties are much harder and usually contain a higher percentage of iron. As a gangue mineral in veins, limonite occurs in small flakes, has a silky luster, is quite hard, and is brownish black.

The known deposits in Oregon that have any large tonnages have probably been formed by percolating water taking iron into solution and then precipitating it elsewhere under swampy conditions. The iron originally may have been in chemical combination with some of the minerals of a basaltic lava. Search for this type of deposit should be in areas of basalt flows, particularly flows of an age in which chemical weathering was prominent.

The only production of iron in Oregon was during the period 1867–1894 from limonite found in the hills just west of Lake Oswego. Pig iron and cast iron pipe

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were produced from these ores in a plant at Lake Oswego, where the first blast furnace of the Pacific Coast was built (Libbey, 1940). Limonite ores west of Scappoose have long been known and have been investigated several times. These limonite deposits were mined to produce industrial pigments. In 1942, the U.S. Bureau of Mines after extensive examination estimated that the iron-ore deposits in this area contained approximately 4 million tons of iron ore that averaged about 40 percent metallic iron (Bartell, 1949). Another potential source of iron in Oregon is from the high-iron bauxite of Columbia and Washington counties.

Magnetite, Fe_3O_4 —an ore of iron

(Pronounced “mag-ni-tite”; from an ancient term attributed to the locality Magnesia, a district in Greece)

Magnetic iron ore is a heavy, black, magnetic material with a metallic to dull luster and a black streak. When it is polarized—like a magnet with north and south poles—it is called **lodestone** and is naturally magnetic like a magnet.

Magnetite is a common accessory mineral in igneous rocks in sufficient amounts sometimes to become an ore of iron. It is usually the most abundant constituent of black sands concentrated in streams and on beaches. It can be distinguished from the other black minerals, ilmenite and chromite, by its response to a hand magnet.

Manganite, $\text{MnO}(\text{OH})$

(Pronounced “man-ga-nite”; denotes “containing manganese”)

Psilomelane, $\text{BaMn}^{+2}\text{Mn}_8^{+4}\text{O}_{16}(\text{OH})_4$

(Pronounced “si-lom-e-lane”; from Greek *psilos*—smooth and *melan/melas*—black)

Pyrolusite, MnO_2

(Pronounced “pie-row-loo-site”; from Greek *pyros*—fire and *louein*—to wash, because it was used to rid molten glass of brown and green tints)

These minerals are all manganese oxides and frequently occur together. It is sometimes difficult to distinguish between them, and therefore they are treated together in this description. Usually, psilomelane is the hardest (H = 5–7), manganite follows closely (H = 4), and pyrolusite is the softest (H = 2–2.5). The color of each is dark steel gray to iron black. Both manganite and psilomelane can and usually do alter to pyrolusite to some extent. All can alter to an earthy, heterogeneous mixture of oxides called **wad**. The best clue to the identity of the manganese oxides is the fact that even with the most casual handling they soil the hands, leaving a black, sooty stain.

Manganese oxides are seldom primary ores. They form from percolating waters or hot vapors leaching rocks containing very minor amounts of manganese. Under certain conditions, the manganese is precipitated. When the conditions causing precipitation are confined to a definite zone over a long period of time, deposits of ore are formed. When the precipitation is not confined to a zone, the manganese will form a stain along joints and other minute openings in rock, causing a blue-gray discoloration. Oftentimes the precipitate makes a dendritic or treelike pattern that is mistaken for fossil fern or leaf impressions.

Although Oregon has many localities in which manganese minerals are found, production has been negligible. The counties in which most prospects are located are Jackson, Josephine, Coos, Douglas, Curry, Baker, Crook, Grant, and Harney. Manganese oxides occur in a variety of rocks, complicating prospecting for the minerals.

Manganese is used mainly as an alloying material in the making of hard steels. Compounds of the element are used in dry-cell batteries and in paints.

Molybdenite, MoS_2 —an ore of molybdenum
(Pronounced “mo-lib’-du-nite”; from Greek *molybdos*—lead)

Molybdenite is a combination of the elements molybdenum and sulfur. It has a silvery, bluish-white luster and a bluish lead-gray color. It is most likely to be mistaken for graphite, as it is very soft and easily leaves a greenish, lead-gray mark on paper or on the hands. It differs from graphite in its metallic luster, whereas the luster of graphite is submetallic. Molybdenite is most commonly found as granitic rocks and in veins associated with galena. Occasionally it forms in foliated masses as much as $\frac{3}{4}$ inch in size; in a deposit near Gold Hill in Jackson County, masses of molybdenite several inches in diameter have been found. In metamorphic rocks, molybdenite is a common minor mineral and is often associated with scheelite, a tungsten mineral.

Prospects in which molybdenite has been found occur mainly in the Wallowa Mountains region. Other areas are in Baker and Jackson counties. There has been no production of molybdenite in Oregon. The largest deposit of molybdenum in the United States and probably in the world is at Climax, Colorado. In this deposit, there is sufficient molybdenum to supply the world for a great many years. Molybdenite also is obtained as a by-product from the mining of the porphyry copper ores of the Southwest. The main use of molybdenum is in the making of steel alloys. Various proportions of molybdenum, chromium, tungsten, manganese, and nickel added to iron form steels having special properties and uses.

Pyrite, FeS_2
(Pronounced “pie’-rite”; the name from Greek *pyrites lithos*—stone which strikes fire, in allusion to the sparking produced when iron is struck with a lump of pyrite)

Pyrite is composed of iron and sulfur. It is the most common sulfide mineral in nature, occurring in almost every rock type and associated with a great many ore minerals. It is pale brass-yellow and has a conchoidal fracture, a blackish streak, and a metallic luster. It is usually found in cubic or pyritohedral crystals but can occur as octahedral crystals. Pyrite is frequently mistaken for gold, hence its common name **fool’s gold**; but it is easy to distinguish from gold because of its brittleness and streak. Gold can occur as an impurity in pyrite “like worms in an apple.” Pyrite is found throughout Oregon.

Pyrrhotite, Fe_{1-x}S
(Pronounced “peer’-uh-tite”; from Greek word for reddish)

Pyrrhotite is composed of iron and sulfur. It is really a solid solution of sulfur in iron sulfide. It is of commercial importance because it frequently contains nickel and cobalt minerals in amounts sufficient to be classed as an ore of these elements. It is readily identified, for it is the only sulfide mineral that is magnetic. The color of pyrrhotite is between bronze-yellow and copper-red; however, it tarnishes readily and shows colors varying from steel gray to dull gray. When found in masses of any size, pyrrhotite is usually associated with the basic igneous rocks such as gabbro. It commonly occurs with chalcopyrite, pyrite, and magnetite in massive volcanogenic sulfide deposits.

Deposits of pyrrhotite in Oregon are relatively rare; however, it is a fairly common accessory in the metallic ore veins, especially copper. Masses of nickel-bearing pyrrhotite have been found in southwestern Oregon, mainly

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in Jackson County. Disseminated pyrrhotite occurs on Pigeon Butte south of Corvallis.

Most of the nickel used in the United States comes from the Sudbury, Ontario, Canada, region. Ore from this area consists chiefly of pyrrhotite, pentlandite (a nickel iron sulfide), and chalcopyrite.

Sphalerite, $(\text{Zn}, \text{Fe})\text{S}$ —an ore of zinc

(Pronounced “sval’-ur-ite”; from Greek *sphaleros*—treacherous, in allusion to its deceptive similarity to more easily smelted ore)

Sphalerite is a chemical combination of zinc and sulfur with variable amounts of iron that is responsible for its color. The color ranges from almost colorless and transparent through pale yellow to honey brown to very black and opaque (**black jack**—a miners’ name). It is very brittle and shows perfect cleavage, has a resinous to adamantine luster, and forms tetrahedral crystal groups that resemble octahedrons. Sphalerite is a major source of cadmium and indium.

In Oregon, sphalerite is found associated with other sulfide minerals, such as galena, chalcopyrite, and pyrite, in the Cascade Mountains in the Bohemia, Quartzville, and North Santiam mining districts. It is also found in many areas of northeastern and southwestern Oregon but never has been a major mineral product.

Stibnite, Sb_2S_3 —an ore of antimony

(Pronounced “stib’-nite”; from Greek word for the mineral)

Stibnite is a chemical combination of antimony and sulfur. It is the main ore of antimony. Stibnite can be recognized readily from the following properties: it is fairly soft; it can be scratched by a fingernail ($H = 2$); it forms in steel-gray, fan-shape groups of bladed crystals whose sides are usually vertically furrowed; and it can be fused in the flame of a match or candle, coloring the flame greenish blue. Stibnite is usually found in quartz veins and may occur with the ore minerals cinnabar, sphalerite, and galena. Sometimes good gold values are associated with stibnite.

Although Oregon has produced some stibnite, the quantity is small. Production has been sporadic, and it would be difficult to estimate the total. Of the five mines in the state that have production records, two are located in southwestern Jackson County, one in central Baker County, one near the Baker-Union county line, and one near the Baker-Malheur county line. Prospects are also found in eastern Grant County and in the western and southern parts of the Bohemia mining district of Lane County.

Zircon, ZrSiO_4 —an ore of zirconium and hafnium

(Pronounced “zur’-con”; from Arabic *zarquun*, from Persian *zar*—gold and *gun*—color)

Zircon is a chemical combination of the elements zirconium, oxygen, and silicon. When found in sands, it is usually in small, clear, pointed rectangular crystals. It is quite hard ($H = 7.5$) and has a specific gravity almost twice that of quartz. Therefore, it is frequently found associated with the heavier, dark-color minerals. Generally, zircon fluoresces a distinctive bright golden yellow under ultraviolet light, probably because of the presence of a small quantity of the element hafnium. Zircon is a common accessory mineral in igneous rocks, especially those that are high in quartz.

A process for obtaining metallic zirconium and hafnium from zircon sands was developed by the U.S. Bureau of Mines at their Northwest Electro-develop-

ment Laboratory at Albany, Oregon, now the Albany Research Center. Metallic zirconium is used in nuclear power plants; in the making of special steel alloys, vacuum tubes, flashbulbs, and pyrotechnics; and in construction for chemical plants. Hafnium, which is very expensive, is used for control rods in nuclear power plants.

Nonmetallic minerals

(Minerals lacking the properties of metallic minerals)

Agate, SiO₂

(Pronounced “ag’-it”; from the locality in the ancient river Achates, now Carabi, in Sicily)

Agates are rather common “pretty stones.” Chemically, they are composed of the same elements that combine to form quartz; that is, silicon and oxygen. Agates are very finely crystalline and therefore are technically the form of quartz called **chalcedony** (pronounced “kal-said’-o-nee”). The bands so commonly seen in agates are edges of layers deposited in irregular cavities when the agate was being formed. The different bands and colors represent impurities and different periods of deposition in the filling of the cavity. The waviness of the lines is due to the irregularities in the cavity. The “moss” commonly seen is due to fernlike growths of some mineral, such as manganese oxide or iron oxide minerals.

The formation of agates requires solutions rich in silica. Therefore, they are more likely to be found in areas of more siliceous rocks such as rhyolites and dacites. Agates are not confined to rhyolite and dacite areas in Oregon, but many of the best collecting localities are found in rocks of this type. Agates are found in practically every locality in the state. A few of the areas known for their quality and abundance are the coast; the Agate Desert northwest of Medford; Antelope Valley in north-central Oregon; and the “thunder egg” localities of Wasco, Jefferson, Harney, Crook, Deschutes, Malheur, and Lake counties. The Richardson Ranch in Jefferson County is one of the most famous agate localities in the U.S. Oregon has long been known as a source of quality agates, and there are many people who come to the state each year just for collecting purposes. Thousands of “rock hounds” in the state have as their hobby the collecting, cutting, and polishing of local stones. Also, many residents of the state owe their livelihood to the sale of agates, both as raw cutting material and as the finished product. Oregon’s annual production of rough and cut gems has been estimated to be on the order of approximately \$1 million. The Oregon State Rock is the **thunder egg**, an agate-filled nodule.

Asbestos

(Pronounced “as-bess’-tuss”; from the Greek for inextinguishable, after the misconception that once ignited it could not be extinguished)

Asbestos is a name applied to certain fibrous minerals. The minerals that are included under the name **asbestos** are tremolite, anthophyllite, and crocidolite of the amphibole group and chrysotile of the serpentine group. The main identifying characteristic of these minerals is that they can be separated without much difficulty into fine threads or fibers. Although the color of the individual fibers is usually light, when asbestos occurs in masses or aggregates, it varies from grayish yellow through brown to green. The minerals that are classified as asbestos differ in composition, but all are essentially silicates of calcium, magnesium,

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and iron. Asbestos may be formed by the alteration of mafic igneous rocks such as peridotite. It occurs in veins and lenticular (lens-shape) masses. Sometimes numerous veins varying from a fraction of an inch to as much as 2 inches in width will be closely spaced over a considerable area.

In Oregon, the production of asbestos has been very small, probably not exceeding a few tons. Areas in which prospects have been found are in the serpentine and greenstone belts of Josephine, Jackson, Grant, and Baker counties.

The main uses of asbestos are as fire-resistant material or a binding agent for cement pipes. Lining for automobile brakes and roofing are some of the important materials also manufactured from it. Chrysotile asbestos can be woven into textiles and yarn. Domestic production of asbestos is mainly from Arizona, California, and Vermont. The United States does not produce a sufficient quantity to meet the demands of industry, so the bulk of asbestos used in this country is imported, mainly from Canada. Due to concerns over health hazards associated with some forms of asbestos, new materials that can be substituted for asbestos are being sought.

Barite, BaSO₄

(Pronounced “bear-ite”; from Greek *barus*—heavy, in allusion to its relatively high specific gravity)

As indicated by its name, barite is a barium sulfate mineral. Barite is one of the heaviest of the light-color minerals. Its specific gravity (heft) is less than magnetite and a little greater than chalcopyrite. It is usually gray to white in color, and its hardness is about that of calcite.

The barite found in Oregon is usually an accessory mineral in sulfide deposits. Elsewhere, it is found under a variety of conditions and associations. Barite occurs both in beds and in veins. It is one of the most common gangue minerals in lead, copper, silver, and zinc deposits and is often found in limestone and sandstone as a cementing mineral. Barite has never been produced commercially in Oregon. It is found in lenses and pods of probable mining width in the Almeda and Silver Peak Mines of Josephine and Douglas counties and also in one prospect between these mines. These occurrences usually have pyrite disseminated throughout the barite.

Most of the ground barite produced in the United States is used as a weighting substance in oil-well drilling muds. Other major uses for barite are in the manufacture of paint, rubber, glass, and chemicals. Principal producing states are Arkansas, Missouri, Georgia, Tennessee, Nevada, Arizona, and California. Although many countries produce barite, Canada, the United Kingdom, and Germany are the only ones that produce in quantities approaching the production of the United States.

Calcite, CaCO₃

Pronounced “kal-site”; from Latin *calx*—lime)

Calcite is a combination of the elements calcium, carbon, and oxygen. It can occur in almost any color, but off-white is most common. The clear, transparent crystals are called **Iceland spar**. Calcite is used as the standard for the hardness of 3 in the Mohs scale of mineral hardness. Calcite effervesces (“fizzes”) readily in cold dilute hydrochloric acid, a property that easily and definitely identifies it. The fibrous variety is sometimes mistaken for fibrous gypsum, but gypsum is not as hard as calcite, nor does it effervesce in acid. The massive or granular variety

of calcite can be mistaken for quartz, but as a pocket knife cannot scratch quartz and can easily scratch calcite, this simple test will differentiate the two.

Calcite is one of the most common minerals found in nature. It is a common deposit around mineral springs; it is found in veins formed by deposition from cold descending solutions and by hot ascending solutions; it forms from the alteration of igneous rocks; and it may be formed in sedimentary rocks due to the recrystallization of seashells. The rocks limestone and marble are principally calcite.

Gypsum, $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$

(Pronounced “jip’-sum”; from Greek *ipsos*—plaster, an ancient name for gypsum and its calcined product)

Gypsum, like calcite, occurs in a variety of forms. The clear, colorless variety that will cleave readily into flakes is **selenite**. The fibrous variety is **satin spar**. The massive, fine-grained variety that is used for carvings is **alabaster**. The earthy variety which is a combination of gypsum and impurities, mostly clay, is **gypsite**. Rock gypsum is the massive form that usually makes up the large industrial deposits. All varieties have the same chemical composition: calcium, sulfur, oxygen, and water, making up a hydrous calcium sulfate. Gypsum can be recognized easily by its softness and lack of reaction with hydrochloric acid. It is the mineral representing a hardness of 2 on the Mohs scale of hardness. Frequently, the mineral crystallizes to form distinctive “swallowtail” twins.

Gypsum is widespread. It is the most common sulfate mineral found in nature. The large deposits are usually associated with sedimentary beds and have formed by precipitation from water that has been cut off from the sea. Therefore, it is commonly associated with various salts. It is found in lesser quantities around mineral springs, in veins, and as a gangue in mineral deposits.

No gypsum has been produced in Oregon since about 1924. An unknown but presumably substantial quantity was produced from ancient sediments in the area north of Huntington on the Snake River from about 1890 to 1924 (Wagner, 1946). Other deposits in this same area have been investigated, but the production has been very limited, if any. These deposits are a continuation of a gypsum-bearing horizon found farther east in Idaho. Another deposit consisting of gypsite in volcanic tuff occurs in southwestern Crook County near Bear Creek. It is possible that this deposit was formed by the action of sulfuric acid, resulting from the weathering of sulfides on limestone rather than precipitation from saline waters.

Gypsum is one of the basic minerals of our building industry. Its main use is in the making of plaster and various prefabricated boards such as wallboard. The states that are the principal producers of crude gypsum are Michigan, Texas, California, Iowa, and Oklahoma.

Realgar

(Pronounced “ree-al’-gar”; from Arabic *rahj al-ghar*—powder of the mine)

Orpiment, As_2S_3

(Pronounced “or’-pih-ment”; from Latin *auripigmentum*—golden paint, in allusion to its color and early use)

Both these minerals are sulfides of arsenic and usually occur together. Realgar will change to orpiment by alteration. Realgar and orpiment are both easily recognized by their distinctive colors: realgar is red, usually with an orange tint

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due to alteration; orpiment is lemon yellow. Orpiment is sectile (can be cut with a knife) and has good cleavage and a pearly or resinous luster. Both minerals are quite soft ($H = 1.5\text{--}2$). These minerals are fairly common accessories in mineral veins that were formed from solutions of intermediate temperatures. Examples of minerals formed in veins under these conditions are stibnite, galena, and silver. Therefore these minerals are sometimes associated with realgar. Realgar and orpiment are also found as volcanic sublimation products and as products from hot springs.

In Oregon, realgar and orpiment are found as fillings in cracks along slickensides and in the matrix of the pellet clay at Hobart Butte in Lane County. In this deposit, they are thought to have been derived from the hydrothermal solutions that altered the pyroclastic rocks to clay (Allen and others, 1948). These minerals as found at this locality have no economic value. The use of natural realgar and orpiment has now largely been replaced by the manufacture of synthetic minerals. Realgar was at one time used in the manufacture of fireworks, and orpiment is used as a pigment, in dyes, and in a preparation used for the removal of hair from hides.

Rhodonite, MnSiO_3

(Pronounced “row´-duh-nite”; from the Greek *rhodon*—rose, in allusion to its characteristic color)

Rhodonite is a manganese silicate. It is usually light pink in color but may vary from greenish or yellowish to light brownish red. Rhodonite is very tough and is difficult to break, even though its hardness ($H = 5.5\text{--}6.5$) is less than that of quartz. It can be told from rose quartz by its specific gravity, which is considerably greater. Other identifying features of rhodonite are its peculiar sugary texture and a usual thin coating of black manganese oxides occurring along fractures and exposed faces.

Rhodonite occurs in veins and as an accessory mineral in deposits of other manganese minerals. In Oregon, it has been found in irregular veins several feet in width. Some of the localities where occurrences have been recorded are on Evans Creek in Jackson County and near the Oregon Caves Highway in southern Josephine County.

Because it is tough, rhodonite takes a good polish. Consequently, it has been used as a gem material and for ornamental stone. There has also been some demand for rhodonite in the making of welding rods for the working of manganese steel.

Sulfur, S

(Pronounced “sul´-fer”; from Latin *sulfur*, an old name akin to Sanskrit *sulvere*)

Sulfur is an element; that is, it cannot be decomposed or divided into other components. Sulfur combines with most of the metallic elements to form sulfides. When in combination with oxygen and a metal, it forms sulfates of the metal. The yellow color of native sulfur is characteristic. It also has a low melting temperature (108°C) and burns with a bluish flame, giving off choking fumes of sulfur dioxide. Contrary to popular belief, sulfur is tasteless and odorless. Sulfur is associated with sedimentary rocks, especially in gypsum and limestone areas, and in areas of recent volcanism.

Except for a few spots of sulfur in coal beds, there is record of only one occurrence in Oregon: the Crater Lake volcanic area 1 mile northeast of Weaver Mountain on the headwaters of Castle Rock Creek. It is thought that this deposit was the result of phases from a solfatara (a volcanic vent from which sulfur gases emanate) condensing in clay. This deposit is evidently small and is probably only of academic interest.

Most native sulfur produced in the United State comes from Texas and Louisiana. In Louisiana and Texas, the sulfur occurs several hundred feet below the ground in beds as much as 100 feet thick. The sulfur is underlain by beds of gypsum and salt. An unusual mining method called the Frasch process sometimes is used in its extraction. Superheated steam and compressed air are pumped into the ground through wells having triple-walled casings. The steam melts the sulphur, and the air pressure forces the now-liquid material to the surface through the third hole of the well casing.

A very important use of sulfur in the Northwest is in the manufacture of paper pulp. Every year, hundreds of tons are used in Oregon. Total consumption of sulfur for this purpose in the United States is over 500,000 long tons. It is also used in the manufacture of chemicals, fertilizer and insecticides, explosives, paint and varnish, and rubber. The most important (60 percent) use of sulfur is in the production of sulfuric acid, most of which is used to produce superphosphate fertilizers. About 20 percent is used in the manufacture of pulp paper.

Talc, $\text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2$
(Probably from Arabic *talq*)

The more compact varieties of talc and the talc that contains many impurities are usually referred to as **soapstone**. In this form, talc is often dark green or greenish gray in color. The purer varieties of talc are light in color, varying from silvery white through apple green to bright green. Talc and soapstone, as the latter name implies, have a soapy or greasy feel. Talc is also identified by its softness and can easily be scratched with a fingernail. It is the standard for the hardness of 1 on the Mohs scale of hardness. Talc is a mineral composed of magnesium oxide, silicon dioxide, and water. It frequently contains as impurities other minerals such as quartz, dolomite, chlorite, and amphibole. Talc is a secondary mineral; that is, it has been formed by the alteration of pre-existing minerals. It is thought that solutions emanating from intrusive bodies at moderately high temperatures alter mafic rocks such as serpentine and gabbro to talc; also, emanations from siliceous bodies acting on dolomite (calcium, magnesium carbonate) produce talc.

Favorable prospecting areas in Oregon are in the Siskiyou and Blue Mountains, where granitic rocks intrude serpentine and peridotite. Soapstone occurs in many of these areas, and one Jackson County commercial deposit of carving material has been developed (Peterson and Ramp, 1978; Ferns and Ramp, 1988). The states producing talc and similar materials are California, North Carolina, Vermont, Georgia, Washington, Montana, New York, Maryland, Pennsylvania, and Virginia.

The bulk of the production of talc and similar materials is used by the ceramics, paint, paper, roofing, plastic, cosmetics, and rubber industries. Contrary to popular belief, only a small percentage of the total is used for the making of talcum powder and other toilet preparations.

Rock-forming minerals

The following are typical minerals that, in combinations with other minerals, compose many of the common rocks. As constituents of rocks, they have no commercial value. Occasionally, however, segregations consisting principally of an individual mineral will form and, if marketing and other conditions are favorable, may prove to be of value. If this happens, the minerals are classified as industrial or nonmetallic minerals.

Amphibole group

(Pronounced “am-fi-bowl”; from Greek *phibolos*—ambiguous, in allusion to the great variety of composition and appearance in this group of minerals)

This name is applied to a large group of minerals having similar properties and chemical compositions. The different minerals are composed mainly of various proportions of the following elements: magnesium, calcium, iron, silicon, and oxygen. The amphiboles may occur as stout crystals but are usually long bladed or fibrous in form. The color is generally a shade of dark green to black. Amphiboles are distinguished from pyroxenes by the fact that the crystal sides do not form right angles as the pyroxenes do. Minerals of the amphibole group are common in most igneous and metamorphic rocks. They are especially common in the granitic rocks in which they occur as black, slender crystals or needles. They alter quite readily and often form a brown stain in the rock; on weathering out of the rock, they may give the surface a pitted appearance. Common amphibole minerals are hornblende, actinolite, tremolite, and anthophyllite. Nephrite jade is a finely fibrous, compact, dense variety of actinolite.

Feldspar group

(Pronounced “feld-spar”; from German *feld*—field and *spat*—stone-spar, in reference to the spar in tilled fields overlying granite)

The feldspar group is divided into two main classes, which in turn are subdivided. All divisions are based on physical and optical properties as well as on chemical composition. The feldspars are aluminum silicates of potassium, sodium, or calcium. The percentages of these three elements determine the name of the mineral and the class to which it belongs. The feldspar in which potassium is dominant is called **alkali feldspar**; feldspar in which varying proportions of sodium and calcium are dominant is termed **plagioclase feldspar**.

Feldspar occurs in rocks as rectangular or lath-shape crystals. Alkali feldspar is generally flesh pink to dull white in color but may be red or green. Striations (parallel lines due to repeated crystals) are absent. One mineral (microcline) of the alkali class may show a peculiar minute “gridiron” or “grating” pattern. The most common minerals belonging to the alkali class are orthoclase and microcline. Plagioclase feldspar is generally white to gray in color and usually shows prominent striations. The striations can best be observed by turning the rock back and forth slightly so as to get reflections from the sides of the individual crystals. Plagioclase feldspars, which include albite, oligoclase, andesine, labradorite, bytownite, and anorthite, may alter to soft clay coatings that can mask the cleavage surfaces so that they no longer reflect light. The colored, transparent plagioclase called **sunstone** is now the state gemstone.

In rocks, the feldspars are most often confused with quartz. Identifying characteristics of feldspar are hardness (feldspar, H = 6; quartz, H = 7), striations, color, cleavage, and alteration.

Feldspars may form economic deposits. Alteration under proper conditions may produce clay or bauxite. Occasionally, segregations of feldspar (usually of the alkali class) and quartz form dikes. Masses of feldspars found in these dikes are sometimes mined and utilized as raw material for common household cleaners. They make excellent abrasives, as the hardness is just under that of glass and therefore will not scratch it. Feldspar is used primarily in the production of glass (65 percent) and ceramics (30 percent), including pottery, porcelains, dinnerware, and glazes. Smaller amounts are used as fillers in paint and plastics.

Garnet group

(Pronounced “gar´-net”; from Latin *granatum*—pomegranate, the seeds of which garnets were thought to resemble)

Garnet is the name of a group of minerals having similar optical and physical properties. The most common of the garnets are aluminum silicates with calcium, magnesium, iron, or manganese. The most common colors are brown to red, but garnets varying in color from black to green also occur. Because garnets are quite hard (H = 6.5–7.5), they are a common constituent of sand; as a general rule, the pink or red grains seen in sands are garnets. Garnets occur as accessory minerals in igneous rocks and are a common and often major constituent of some metamorphic rocks. Common garnet minerals are grossularite, airnandite, spessartite, and pyrope. A very fine-grained variety of green grossularite found in southwestern Oregon is a pseudojade called “Oregon jade.” Garnet is used primarily as an abrasive in garnet sandpaper and in grit for sandblasting.

Mica group

(Pronounced “my´-cah”; from Latin *micare*—to shine)

The primary characteristic of this group of minerals that permits ready identification is the ease with which the minerals may be split into very thin, elastic plates or leaves. The color varies from water-clear to black. Other physical properties that help in identification are hardness (H = 2.5–3.5) and pearly to vitreous luster. The chemical composition of the micas is very complex. They are essentially aluminum silicates containing water and various amounts of potassium, magnesium, and iron.

The field identification of the different micas is based on their colors. The three varieties most commonly seen and their identifying colors are as follows:

- (1) Muscovite (pronounced “muss´-co-vite”; from Muscovy Glass, a name used when the mineral was first described from the Russian province of Muscovy)—usually almost colorless or light shades of green and yellow
- (2) Phlogopite (pronounced “flog´-o-pite”; from Greek for *firelike*, in allusion to its reddish tinge)—brown to brownish red, often displaying a golden copperlike sheen. Phlogopite is often mistaken for gold, especially when found in sands or soils. It can be readily differentiated from gold, however, as mica tends to float when agitated with water, whereas gold sinks quickly.
- (3) Biotite (pronounced “by´-o-tite”; for Jean Baptiste Biot, French physicist)—usually black to dark green in color. Altered biotite may be mistaken for phlogopite.

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The micas are some of the most common of the accessory rockforming minerals of igneous rocks. Almost all the coarse-grained, light-color igneous and metamorphic rocks, especially the granites, contain abundant mica, particularly biotite. Muscovite is very common in schists and at times makes up a high percentage of that rock. Some of the mica used in industry is recovered from this source. Large pieces of mica are found in pegmatites in **books** or **sheaves**.

The principal use of mica is in plaster wallboard joint cements. Lesser amounts are used in paint, plastics, roofing materials, rubber, and well-drilling muds.

Olivine, $(\text{Mg,Fe})_2\text{SiO}_4$
(Pronounced “oll’-i-veen”; named in allusion to its olive-green color)

Olivine is the dominant mineral in rocks of the peridotite group and is common in basalts. It is a chemical combination of magnesium, iron, silicon, and oxygen. The distinguishing feature of olivine is its olive-green color. The mineral alters quite readily to a brownish or reddish color. It occurs as scattered grains or in segregated masses and in the latter form has a sugary or granular texture. It is quite rare to find olivine associated with quartz in igneous rocks. The ore minerals magnetite and chromite are common associates and may make up portions of a rock high in olivine. All these materials have comparatively high specific gravities; when a rock containing these materials is ground up by natural processes and the resulting sand-size pieces are carried to the sea by streams, these heavier materials are separated from the lighter by a natural concentrating process. The concentration can be carried still further by action of waves and shore currents. The black sands of river and ocean beaches, therefore, frequently contain olivine and associated minerals. Selective concentration may be used to separate these minerals from each other fairly efficiently.

Dunite (pronounced “done’-ite”) is an igneous rock that is composed of at least 90 percent olivine. These rocks readily alter to serpentine. The principal serpentine areas of Oregon are found in the southwestern and northeastern parts of the state in the Siskiyou and Blue Mountains regions. Olivine also occurs in some gabbros and basaltic lavas.

Most olivine is used in blast furnaces to help form slag in iron smelting. Olivine also is used for foundry sands and in the making of refractories. The gemstone peridot is olivine, as are the green sand beaches of Hawaii.

Pyroxene group

(Pronounced “peer’-ox-ene”; from Greek *pyro*—fire and *xenos*—stranger; mineral was incorrectly believed to be out of place in igneous rocks)

The pyroxenes form another very important group of rockforming minerals. As in the case of other mineral groups, the pyroxene “family” consists of separate minerals that have their own names. The chemical composition of these minerals varies widely, but they are all silicates (combinations of the elements silicon and oxygen) with varying amounts of magnesium, iron, aluminum, and calcium. The most common pyroxene is the mineral augite. Other common minerals of the group are enstatite, hypersthene, diopside, pigeonite, and aegirine. A less common member of the group, jadeite, is precious jade.

Most pyroxenes are green or dark colored and occur as stout crystals with the crystal sides at right angles to each other. This last characteristic differentiates pyroxenes from amphiboles. Otherwise, these two groups are quite similar in appearance. The hardness of pyroxene is from 5 to 6, but occasionally it is

apparently less, due to alteration. A rock containing a high percentage of pyroxene is heavier than the ordinary light-color rock as a result of the fairly high specific gravity of these minerals. Pyroxenes alter readily, and a common product is red or brown iron oxide as well as chlorite and serpentine. Pyroxenes may also alter to amphiboles.

The pyroxenes are common accessory minerals in igneous rocks, especially the dark-color ones. They occur with amphiboles in light-color rocks but usually in a subordinate role. In basalts, gabbros, diabases, and peridotites, the pyroxenes often make up a large percentage of the rock. Because of the ease with which they alter, pyroxenes are not found in sedimentary and metamorphic rocks as frequently as in igneous rocks.

Quartz, SiO₂

(Pronounced “kworts”; from German *quarz*, possibly originally Slavic) (*See also* agate)

Quartz is the most common mineral and can be found in some form in almost any locality. It is the essential component of many igneous rocks and the dominant mineral in many sedimentary and metamorphic rocks. Juvenile or original quartz is formed from magmas; secondary quartz is formed by the chemical decomposition of complex silicates followed by solution and later precipitation or crystal growth from solution. Quartz is found in small grains disseminated in rocks, in large masses adaptable to mining, as the principal gangue mineral in many ore deposits, and in veins of various sizes. The many varieties of quartz are given different names, and certain of these are classed as gems.

The combination of the elements silicon and oxygen is termed **silica**, and the crystalline variety of silica is called **quartz**. The individual crystals vary in size from microscopic to several feet in length. The color of quartz is usually white or clear, but it may be any shade of the rainbow. The color varieties are usually valuable as gem materials. In rocks, quartz occurs as irregular, clear to dull-white grains and frequently looks like glass. The hardness of quartz is greater than glass; that is, it will scratch glass; it is the standard of the hardness of 7 on the Mohs scale of hardness. When broken, the edges do not conform to crystal boundaries but tend to take on a concave pattern; this is termed **conchoidal** (shell-like) fracture and is typical of quartz.

Besides being a gem material, quartz is used in the manufacture of glass, silicon carbide, and silicon metal and alloys (ferrosilicon) (45 percent); as molding sand (30 percent); and as a natural abrasive (10 percent). Oregon has at least three developed deposits that have been or are supplying quartz or quartz sand suitable for various uses. One is in Jackson County near the town of Rogue River, another is in North Bend in Coos County, and the third is Quartz Mountain in Douglas County. The Rogue River and Quartz Mountain deposits are massive lenses of quartz. The North Bend deposit is a dune sand that is used to produce glass bottles in Portland. Other similar deposits are known to exist but have not yet been developed.

Tourmaline. General formula:



(Pronounced “tour-ma-lean”; from Singhalese *turamali*, a term originally applied to zircon and other gems by jewelers of Ceylon)

Tourmaline is most commonly found in granites and associated pegmatites. In the latter, it may develop into crystals several inches wide and as much as

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1 foot long. Tourmaline is a complex silicate of boron and aluminum with variable amounts of magnesium, iron, or the alkali metals.

There are several varieties of tourmaline; the colors vary from blue, green, and red to brown and black. Gem varieties are colored and may display different colors within the same crystal. The large tourmaline crystals always are three-, six-, or nine-sided, and the sides are always deeply striated. As an accessory mineral, tourmaline often occurs as minute crystals, and the above characteristics may not be well displayed. Tourmaline has a hardness equal to or a little greater than quartz. The fracture of tourmaline is ragged, and the common black variety, when broken, looks like bright coal.

The most common occurrence of tourmaline is in pegmatites and granites. The best prospecting areas in Oregon are in the granite areas of the Siskiyou, Blue, and Wallowa Mountains. Tourmaline also occurs in metamorphic rocks and can be associated with economic mineral deposits such as tin, titanium, lithium, and even base and precious metals.

Zeolite group

(Pronounced “zee’-o-lite”; “water stone,” from Greek *zein/zeo*—to boil, because of its behavior before flame)

Zeolites form a large family of hydrous silicates of sodium, calcium, barium, potassium, and strontium, usually colorless to white, which show close similarities in composition, association and occurrence. Zeolites are secondary minerals that may form crystals in cavities in lava flows. Large amounts of zeolites formed from the alteration of air-fall tuffs in lake beds also occur as bedded deposits, and many rocks that appear to be tuffs or andesites have been completely altered to zeolite minerals. There are about 50 named zeolite minerals.

Natural zeolites have been used for water purification. Synthetic (not naturally occurring) zeolites are also compounded for that use. The zeolite mineral clinoptilolite is currently being mined by Teague Mineral Products in Malheur County for use as pet litter, odor-control products, fungicide carrier, and ammonia absorbent in aquariums. Several other uses for zeolite are being tested by Teague.

Fine crystal specimens of zeolite minerals are found in many different localities around the state. Oregon probably has some of the largest bedded zeolite deposits in the world (Sheppard and Gude, 1987).

ROCK DESCRIPTIONS

Igneous rocks

Introduction

The classification of igneous rocks is dependent upon the essential minerals present in the rock, the percentage of these minerals, and the texture of the rock (see Table 2, page 5). The crystallization of magma is probably more or less a continuous process, and there may be consistent and usually gradual changes in the mineral content and texture of igneous rocks. Consequently, the variation from one rock type to another is frequently gradational. The name applied to an igneous rock therefore is arbitrary and depends upon established limits.

In the descriptions of the rocks on the following pages, it is recognized that the identification of certain minerals and the percentage of these minerals present is sometimes very difficult, if not impossible, without the help of laboratory equipment. This is especially true of the extrusive rocks. Therefore, textures and various “rule-of-thumb” methods will be stressed in this publication. It must be emphasized that the mineral content is the dominant factor in the classification of igneous rocks, and a person trying to identify a rock should make every effort to identify as many minerals as possible. After minerals in the rock are identified, the classification given in the igneous rock chart (Table 2) should be consulted to determine the name of the rock.

Extrusive igneous rocks: flow rocks (lavas)

Basalt

(Pronounced “ba-salt”; from Latin *basaltes*, earlier Latin/Greek *basanites*—touchstone)

Basalt is one of the most common rocks to be found in Oregon. It is black to dark gray to brown in color, usually fine-grained (but may have relatively large crystals called **phenocrysts** in it), and fairly dense. The most commonly recognized mineral in basalt is plagioclase feldspar, which occurs as small, light-color, often lath-shaped crystals. Olivine is a common constituent but is not always present; however, when it is recognized, the classification of the rock as basalt is fairly certain. Glass is frequently present in basalt and sometimes occurs as small, clear to black, rounded fragments with conchoidal fracture and glassy luster. Most basalts contain some magnetite, and occasionally enough is present so that very small chips of the rock can be picked up by a magnet.

Large areas of Oregon are covered with basalt that was erupted from volcanic vents and fissures as lava flows. When the molten lava poured from the vents, it contained some gas. As the lava cooled, bubbles of gas formed and tended to collect sometimes near the bottoms but more frequently near the tops of the flows. After the lava cooled completely, the gas escaped, but the bubble holes, called **vesicles**, remained. Lava which contains numerous vesicles is called **vesicular lava**; if the lava has the composition of basalt, it is called **vesicular basalt**. If the vesicles are later filled with a secondary mineral, the fillings are called **amygdules**, and the rock is called **amygdaloidal basalt**.

Basalt is used in Oregon primarily in road building and as riprap. A special type of weathering of basalt, termed **laterization**, has resulted in the formation of the high-iron bauxite of northwestern Oregon. The limonite deposits of this area also have formed from weathering of basalt.

Andesite

(Pronounced “an´-duh-site”; named for the Andes Mountains, where it occurs in great abundance)

Andesite, like basalt, is a very common type of lava in Oregon. It is especially common in the High Cascades. Andesite is sometimes difficult to distinguish accurately from basalt without laboratory assistance. However, typical andesite is usually lighter in color than typical basalt. A distinguishing feature used by some petrographers is the presence or absence of olivine: if olivine is present, the rock is probably basalt; if it is absent, the rock is probably andesite. Like basalt, andesite is fine-grained but may contain a few minerals recognizable in hand specimens. The dominant mineral of andesite is feldspar. Dark-colored minerals (normally pyroxenes) usually make up about a third of the rock.

Andesite is used in building roads and as riprap. Platy andesite also is used sometimes as building stone. Occasionally, it is the host rock for metalliferous mineral veins, especially veins containing cinnabar, but areas of andesite flows are usually not considered as favorable prospecting areas.

Rhyolite

(Pronounced “rye´-o-lite”; from Greek *rhein*—to stream, flow)

Although rhyolite is found in eastern and southeastern Oregon, it is not as common a rock as basalt or andesite. Rhyolite is usually light in color; pink and red shades may predominate, but the color can vary from tan to dark purple. Banding or flow structure is common and often gives the rock the appearance of a sedimentary rock. Quartz and alkali feldspar are minerals commonly found in rhyolite; other minerals include plagioclase feldspar, biotite, and amphibole (usually hornblende). The texture of a rhyolite is usually extremely fine-grained. If it is so fine-grained that no minerals can be determined, the term **aphanatic** may be applied to it.

Rhyolites are extruded as flows, the same as andesites and basalts. As a rule, the areal extent of an individual flow of rhyolite is more restricted than are flows of basalt or andesite because rhyolite magma is much more viscous. Rhyolite is therefore likely to form mounds or domes.

Metallic-mineral veins are sometimes associated with rhyolites. Several of the cinnabar deposits of south-central and southeastern Oregon areas may be associated with feeders to rhyolite flows. Agates are frequently found in the beds of the streams draining the rhyolite areas; and the state rock—the thunder egg—is found in and near rhyolite flows.

Obsidian

(Pronounced “ob-sid´-i-yun”; from *Obsius*, name of its supposed discoverer)

Obsidian is the most common of the volcanic glasses. Its usual color is black to smoky or reddish brown, and thin chips are generally translucent. It breaks with a conchoidal fracture. Seldom are any mineral grains seen, but white chalky-appearing segregations called **crystallites** that are considered the start of crystal growth are not uncommon. If the volcanic glass has a vitreous luster, it is called **obsidian**; if it has a greasy or pitchlike luster, it is called **pitchstone**.

Volcanic glass forms from magma that cools so rapidly that mineral crystals are unable to form. The composition of the magma determines the type of glass formed. Magmas having a rhyolitic composition are more viscous and will cool more rapidly than those having a basaltic composition; consequently rhyolitic glasses are more common than basaltic glasses. The rhyolitic glass is called **obsidian**, and the basaltic glass is called **tachylite** (pronounced “tack-i-lite”).

Obsidian flows usually cover relatively small areas. Many masses of obsidian also contain various amounts of stony, fine-grained lava. Volcanic glass also may be found as a thin rind or layer on the margins of intrusive masses and occasionally at the surface of lava flows where the cooling has been particularly rapid.

Masses of obsidian occur in Oregon at Glass Buttes in northeastern Lake County, near Paulina Lake in Deschutes County, and on the south slope of the South Sister at the summit of the Cascades. There are probably many other occurrences, especially in eastern and southeastern Oregon, but the masses noted above are the largest and most easily accessible. Western Indians prized obsidian for making arrowheads and spear points and bartered it widely.

Perlite (pronounced “pur-lite”) is a special type of volcanic glass. This glass gets its name from the many curved, concentric fracture lines that develop in it. They give the rock the appearance of being composed of many small, onionlike shells or pearls. This structure is referred to as **perlitic**, and the name of perlitic obsidian is given to the rock. In recent years, the name has been contracted to **perlite**. Because perlite contains a small amount of water, when it is heated, it may expand or “pop,” forming pumicelike particles several times their original size. This characteristic makes it possible to produce a very lightweight aggregate that makes an excellent plaster sand. Because it is light in weight, it is easy to apply, and its use reduces the weight of plaster in buildings. Perlite is also used in acoustical tile, pipe insulation, and roof insulation boards. The small white beads in potting soils are expanded perlite grains that are added as soil conditioner.

Deposits of perlite are found in several places in central, eastern, and southeastern Oregon. One deposit, just south of Maupin in Wasco County, was mined for a time, and a plant for processing the raw material was built at the mine. Good deposits have also been identified in Lake, Baker, and Malheur counties.

Extrusive igneous rocks: pyroclastic rocks

Pumice

(Pronounced “pum-iss”; from Latin *pumex*, related to “foam”)

Pumice is light-color rock froth. It has formed from the explosive volcanic eruption of a magma having a high gas content. The emission of gas-rich magma from the throat of the volcano is very rapid, and the magma is often thrown some distance into the air. Consequently, chilling of the molten material is fast, and a glass is formed. Accompanying the ejection of the molten rock is a rapid escape of the entrapped gas, resulting in the formation of a great many minute, thin-walled bubble holes in the glass. Because the cellular structure of the pumice tends to give it buoyancy, it is not only lightweight but will actually float on water. Most pumice has a composition ranging between those of andesite and rhyolite. The only difference between obsidian and pumice is the presence of bubble holes. In other words, pumice is formed by explosive eruption and rapid consolidation of a gas-rich magma and obsidian by rapid consolidation of a gas-poor magma.

Deposits of pumice are fairly common in central Oregon, and large areas of Deschutes and Klamath counties are blanketed with it, in some places to a depth of more than 100 feet (Williams, 1942). The volcanic cones that have been the main sources of pumice in south-central Oregon in late geologic time are Mount Mazama, Newberry Crater, and Devil's Hill. Mount Mazama is the name given to the mountain peak whose caldera is now occupied by Crater Lake.

Pumice is used as a lightweight aggregate in concrete blocks. The Chemult-Tumalo area and the Bend area of Deschutes County in general is an active area of pumice mining. A small amount of pumice is sold to the textile and garment industry for the production of stone-washed products. Lump pumice has been produced from one locality in Newberry Crater.

Cinders

(Pronounced "sin'-ders"; from Old German/English *sintar*—dross, slag)

Cinders are unconsolidated, very porous masses of glassy lava that have been explosively ejected from a volcanic vent. They range in size from a fraction of an inch to approximately 1¼ inches. Similar but finer material is called **ash**, while material larger than 1¼ inches is called **dribblet** or **spatter**. **Bombs** are similar to cinders but have been modified during their flight through the air. Bombs have no definite size range; they are frequently 2 to 4 inches in diameter but may be almost any size. Cinders are generally colored in dark shades: dull red, brown, and black predominate. Frequently they have microscopically thin, iridescent crusts or rinds that are probably due to thin coatings of iron oxides.

The vesicles or pores of cinders are not as small as those of pumice, and they are more irregular and abundant than those of vesicular lava or scoria, a highly porous lava. Also, cinders are glassy, whereas vesicular lava and scoria are partially crystalline.

Many of the smaller volcanic cones of the High Cascades and of central Oregon—for example, Black Butte—have ejected great quantities of cinders. They are a very common product of the last stages of volcanism in Oregon.

Where available, cinders are used for railroad ballast and for road metal. Cinders are also used to produce lightweight concrete or "cinder" blocks.

Tuff

(Pronounced "tuf"; from Old Italian *tufa*)

Tuff is a compacted mass of fine volcanic ejecta and is a common rock type in the areas of volcanic rocks. A combination of pumice or cinders of about pea size or less in a matrix of ash is most common, but tuff can contain crystals, rock fragments, and volcanic ash or dust. Some volcanic ejecta may still be hot enough when they come to rest that individual particles partially melt or fuse together. These are called **welded tuffs** and may be quite dense and hard. Tuff deposits frequently are bedded, indicating either deposition by water or different periods of explosive volcanic action. When deposited by water, tuff usually contains some admixed sediment. If the percentage of sediment in the tuff is appreciable, it should be indicated in the name by applying a suitable adjective, such as sandy tuff or silty tuff. If the sediment predominates, the word **tuffaceous** should be used as the adjective; i.e., tuffaceous sand or tuffaceous silt.

Tuff is usually light in color; grays predominate, but shades of red are not uncommon. Although it is generally not a hard rock, in the sense that granite or basalt is hard, tuff "sets" (hardens) upon exposure to the air, and this quality among others makes it adaptable as a building block. Nails can be driven into

tuff building blocks as into wood. Some of the buildings erected in Baker many years ago were made of a tuff that occurs extensively in nearby Pleasant Valley. Today these buildings are as strong or stronger than buildings constructed of other materials at comparable times. Blocks of tuff are obtained for construction simply by sawing out the size and shape desired.

Intrusive igneous rocks

Intrusive igneous rocks are generally coarse grained; they have crystallized below the surface of the earth, sometimes at depths of several miles, and have been later exposed at the surface by uplift and erosion. In other words, the covering over these rocks was eroded away after the magma crystallized.

Most of the rock-forming minerals in these rocks are silicates, which means that silica is incorporated in varying amounts into their crystal structures. The intrusive rocks described below, from granite through peridotite, contain a decreasing amount of total silica. In granites, which are classified as silicic rocks, more silica is present than is used in the silicate minerals, leaving quartz in the rock. In the magma that formed diorite, little excess silica was in the magma, and consequently little or no quartz is present in the rock, which is an intermediate rock. In the magma from which gabbro was formed, there was a deficiency of silica; therefore, no quartz is present, and the minerals that form are the result of a shortage of silica. Because many of the minerals in a gabbro contain magnesium and iron, this type of rock is called a **mafic** rock. The peridotites are called **ultramafic** rocks, because the magmas from which they formed were even lower in silica content and higher in iron and magnesium content than mafic magmas.

Granite

(Pronounced “gran´-it”; from Latin *granum*—grain)

The term **granite** is often misused. In common usage, granite refers to any coarse-grained, light-color rock. As a matter of fact, few of the coarse-grained rocks found in Oregon are true granites; they are mostly diorite or granodiorite. To be a granite, a rock must be composed principally of quartz and orthoclase feldspar, with quartz making up 20 to 40 percent of the rock. Orthoclase, the dominant feldspar of granite, is commonly white or pink but may be cream color or light green. Other minerals do not have to be present but usually are. The most common of these minerals are mica, hornblende, and augite. Usually biotite is more common in granite, and hornblende is found in diorite. Granite is the sub-surface equivalent of rhyolite, in that it cooled below the earth’s surface. Because it cooled more slowly, it is more coarse-grained than rhyolite.

Areas of granite are found in the larger intrusives in the Siskiyou, Blue, and Wallowa Mountains. The Wallowa Mountains probably contain more true granite than any of the others.

Diorite

(Pronounced “dye´-o-rite”; from Greek *diorizein*—to distinguish)

Diorite can be most readily distinguished from granite by its minor amount or complete lack of quartz. The dominant feldspar in diorite is also different from the dominant feldspar in granite. In diorite, plagioclase feldspar makes up more than 50 percent of the rock, while in granite, the dominant feldspar is orthoclase, with plagioclase occurring only in minor amounts. As a rule, diorites are darker

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in color than granites, due to the higher percentage of dark minerals, which normally make up about 35 percent of the diorites. The extrusive equivalent of diorite is andesite.

Granodiorite is intermediate between granite and diorite in percentage of quartz and plagioclase feldspar. A granodiorite will have a plagioclase-orthoclase ratio of approximately 2:1 and a quartz content as high as 15 percent.

Quartz diorite is intermediate in composition between granodiorite and diorite. It contains more quartz and orthoclase than a normal diorite but less than a granodiorite.

Diorite, granodiorite, and quartz diorite are the common intrusive rocks of the Siskiyou, Blue, and Willowa Mountains. Diorite also is found in the areas of the metalliferous veins in the western Cascades and in some of the thicker sills of the Coast Range.

In the past, building and monumental stone has been quarried in Jackson and Baker counties from these coarse-grained intrusives.

Gabbro

(Pronounced “gab´-bro”; from Italian)

Gabbro is a dark-color, coarse-grained rock. Approximately half of the average gabbro is composed of dark-color minerals (mainly pyroxene); most of the remainder is plagioclase feldspar which often takes needlelike forms. Olivine is not an essential mineral of gabbro but is commonly present; when it does occur, the rock is called an **olivine gabbro**. The nearest rock to an extrusive equivalent of gabbro is basalt.

Gabbro is fairly common in the Cascade Mountains and the Coast Range. Large masses of gabbro are found in southwestern Oregon near the margins of the granitic intrusives and especially in areas near serpentine and peridotite. In eastern Oregon, gabbro is found in the Blue Mountains.

Peridotite group

(Pronounced “per-id´-o-tite”; from French)

The peridotite group includes rocks whose only essential mineral is olivine; pyroxene is usually present and occasionally is the dominant mineral. The ore minerals chromite, magnetite, pyrrhotite, and ilmenite frequently are present in appreciable amounts. Light-color minerals may make up as much as 10 percent of these rocks but are more likely to be absent. Olivine, commonly in rounded masses and having a sugary texture, may compose as much as 90 percent of the mass of certain rocks included in this group. As may be inferred from the minerals, the peridotites are dense, greenish-black rocks. Rocks of this group are considerably heavier than granite and diorite.

Peridotites alter readily. The most common product is serpentine. Other common alteration products are talc and iron oxides. The iron oxides stain the surface a brick-red color that, in outcrops of sizable areal extent, contrasts sharply with its surroundings. In the weathering of some peridotites, certain minerals are sometimes etched into relief, giving the rock a very rough outer surface of red to tan color. Prospectors often refer to outcrops of this kind as **buckskin rock**.

Large areas of southwestern Josephine and southeastern Curry counties are composed of peridotite. Other counties in which peridotite is found over a considerable area are Douglas, Jackson, Grant, and Baker counties.

Sedimentary rocks

Clastic sedimentary rocks

Shale

Shales are formed by the consolidation of rock particles and mineral grains of very small size. Before consolidation, shales were muds, silts, or clays. Shales are always laminated and are usually thin bedded. Because the material was deposited in successive thin layers, the rock has a tendency to break along the planes of these layers. Consolidation to form shale has taken place through compaction due to the weight of overlying materials or cementation from percolating waters. Shales are frequently light in color but can be found in almost any color. The presence of organic material produces dark-gray to black shales. If any quantity of sand-size grains are present, the material is a sandy shale. If fossils are present, and they frequently are, the material is a fossiliferous shale. The small size of particles of the shale indicates that the material was laid down either in very quiet water or a great distance from the source or both.

Great thicknesses of shale are found in western Oregon, most of which represent deposition in marine waters. Shale is also found in many other localities of the state and is one of the most common of the sedimentary rock types.

Sandstone

Sandstone is formed from consolidation of particles larger than those that form shale and smaller than the particles forming conglomerates. Compaction and cementation cause sand grains to become interlocked to form a coherent mass. Common cementing materials in sediments are calcite, silica, and iron oxides. When the cementing material can be determined, it is applied as a descriptive term to the sedimentary rock. Sandstones are composed principally of mineral grains and some rock fragments. Quartz is usually the dominant mineral and sometimes makes up practically all of the rock. Sandstones are usually light gray to buff in color, but various shades of red are also common.

In Oregon, sandstones are most widely exposed in the marine rocks of the western part of the state and often contain both quartz and feldspar grains. A large part of the Coast Range is composed of sandstones that were deposited in seas millions of years ago. Marine sandstones are also widely exposed in the Willamette Mountains and in the area near Suplee in central Oregon. Red sandstones associated with sandstones of other colors are found in the Silvies River region near Burns in southeastern Oregon. Sandstones deposited in lakes or streams are quite common throughout most of eastern Oregon.

Many sandstones of Oregon are suitable for building purposes, and in years past, some have been extensively quarried. Early settlers utilized these materials in construction of their homes, especially the chimneys. No Oregon sandstone quarries are in operation at this time.

Conglomerate

(Pronounced "con-glom-er-ut")

Conglomerates are cemented gravels. Most of the particles that compose them are greater than approximately $\frac{1}{10}$ inch in diameter and may range in size

up to several feet through. Usually there is a great diversity in the size range, but it is not uncommon to find material that is well-sorted; that is, all about the same size. The material of conglomerates is predominately rock fragments rather than mineral grains. The fragments usually show some rounding and may be well-rounded. Conglomerates represent rapid erosion by streams and waves and deposition near the source of the rock material. Fossils are not commonly found in these coarse rocks because the grinding action of the material rolling back and forth destroys most of the organic material before it has a chance to be preserved.

Consolidated angular rock debris is called **breccia**. Breccia deposits can be from the accumulation of rock at bases of cliffs or mountains, from rocks broken by gas and steam explosions, from rocks broken by movement along a fault, or from angular rocks transported by landslides or mudflows. Rocks deposited by glaciers are also usually not rounded, and they are called **glacial till**. Rock composed of angular volcanic fragments is termed a **volcanic breccia**.

Unconsolidated clastic sediments

Clay

Clay is an earthy aggregate. The term has a double meaning. When used to describe the size of a particle, it refers to material less than $\frac{1}{256}$ mm in all dimensions. When used in a mineralogical sense, however, it refers to certain minerals. Usually, clay minerals are clay-size particles, and, conversely, deposits of clay-size particles are commonly composed of minerals of the clay families.

Clay, as used when referring to size of particle, can be conveniently divided into two classes: a transported clay and residual clay. Transported clay is a finely ground or weathered rock that has been carried by water or wind, often great distances, before being deposited. It bears no relation to the underlying rock. It is a heterogeneous mixture of mineral grains, usually of varied composition. It implies slow deposition, either in quiet waters or from the air. When deposited by water, it has probably formed on flood plains, in lakes, or at a considerable distance from a shoreline. This is the most common type of clay deposit. Residual clay is directly related to the underlying rocks. It is formed by chemical weathering and selective removal of certain minerals leaving, among other materials, clay in place. This clay is frequently composed of the clay minerals as well as being clay-size particles.

Commercially, clay is classified according to its physical properties including the manner in which it responds to heating, commonly called **firing** or **burning**. There are many classes of clays, and standards have been set up for each class so that when referring to a particular class, the trained individual knows how that clay will respond under certain conditions. Two of the most widely used classes of clay are common clay and fire clay. Common clay is the raw material used in the manufacture of building brick, building tile, and drain tile. It can be almost any color when raw but, when fired, it is usually some shade of red. It will not stand up under very high temperatures. Fire clay is usually white when raw, but it, too, can be almost any of the light colors. When fired, it is white or nearly so. The finished product can withstand high temperatures and so finds use as linings of furnaces and boilers.

It is impossible to tell whether a clay is of fire clay grade unless it is subjected to a firing test. However, there are some preliminary tests that indicate whether or not it might be a fire clay. If it feels "greasy" and wet, it has absorbed considerable water and is a common clay or plastic fire clay. Flint fire clays will not absorb

a great quantity of water; this is indicated by its feel. When placed in water, flint clays do not lose their original shape, nor do they flake off or quickly turn the water milky as do the plastic clays.

Several large deposits of fire clay occur in Oregon. One, a low-heat-duty, plastic fire clay, is near the town of Willamina in Yamhill County. Another deposit, a flint fire clay, is at Hobart Butte in Lane County. Other deposits are found near Mayger in northern Columbia County and near Molalla in Clackamas County. The deposit at Willamina is of interest in that the raw clay is black but, when fired, turns to a near-white color. The black color is due to included organic material; when the clay is fired, the organic material is consumed.

Common clay is widespread throughout Oregon, and many of the first buildings in almost every town and city of the state were constructed from brick made from local clay deposits.

Bentonite (pronounced “ben-ton-ite”) is a clay of definite mineralogical composition. It is principally composed of the mineral montmorillonite (pronounced “mont-more-ill-un-ite”), essentially a complex hydrous calcium magnesium aluminum silicate. There are two types of bentonite: the swelling and the non-swelling. The nonswelling bentonite can be identified only by special tests. The swelling type, when dropped in water, will increase to as much as 15 times its original size.

Bentonite is formed from the alteration of volcanic ash. As there is ash in almost all the younger rocks in the state, bentonite is a common constituent of many rocks, especially the tuffs and agglomerates. Bentonitic clays are being mined in central Oregon and near Adrian in Malheur County (Geitgey, 1987a). Favorable prospecting areas are in the western part of the Cascade Range and in the areas of the pyroclastic rocks of central and eastern Oregon.

Bentonite has a variety of uses, but the bulk of the material produced is used for mud in drilling oil wells and as a bonding agent for iron ore pellets for smelter feed, for animal feed pellets, and for molds for foundries.

Sand

The name **sand** is given to mineral grains or rock fragments smaller than conglomerates and greater than clay particles. It is commonly found in quantity on beaches and river bars. The grains of sand always show some rounding, indicating transportation and wear. Any type of inorganic material can be ground to form sand-size particles. If, however, the material is transported any distance, the softer materials are soon reduced to finer-size particles. As most sands are the result of considerable mechanical wear, more resistant minerals such as quartz usually are the dominant materials of a sand deposit; and, if the sand is subjected to long periods of abrasive action such as that taking place on the ocean beaches, the result is sand composed entirely of more resistant minerals. As quartz is very resistant to both mechanical and chemical erosion, ancient beach sands are often the source of nearly pure quartz sands.

Sands indicate the mineral content of an area undergoing erosion. Because metallic minerals are heavier than nonmetallic minerals and are concentrated in favorable areas by moving water, sands are a good indicator of the presence of metallic minerals in an area. By panning stream, river, or beach sands, an astute prospector may quickly determine the mineral potential of an area.

The tendency of the metallic minerals and other heavy minerals to be concentrated in placer deposits can, under favorable conditions, form large deposits relatively high in some of the metallic minerals. After additional concentration,

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these deposits may be mined profitably. Gold and platinum are two of the minerals that have been mined from such deposits in Oregon. Other minerals that are concentrated in natural deposits because of their specific gravity are magnetite, chromite, garnet, ilmenite, olivine, and zircon. These last-named minerals make up a fairly high percentage of the “black sands” of the elevated beaches of the coastal region of southwestern Oregon. These black sands represent beaches of the sea preserved from the geological past. By taking advantage of their different specific gravities and magnetic properties, some of the metallic minerals of the black sands have been separated from whole sand and from each other. It is very difficult and costly to make a separation in which only an individual mineral is present, so the most economical method to produce as high a concentration as possible of the desired mineral is used. The product that is obtained is called a **concentrate**, and the objective is to obtain a concentrate that is pure enough to be utilized commercially.

Chemical precipitates and organic material

Travertine

(Pronounced “trav´-er-teen”; from French)

Mineral deposits built up around springs are called **tufa** (pronounced “toof´-a”). If this material is mainly calcium carbonate (the same combination of elements that are found in limestone), it is called **travertine**. As hot water is capable of carrying more mineral matter in solution than cold water, mineral deposits are generally more common around hot springs than around cold springs. Travertine usually has a banded structure due to different periods of deposition. It may vary in color from white to brown, the latter color being the most common. It has the same physical properties as limestone.

Oftentimes spring deposits of fairly large size are formed. The travertine deposits near Durkee, Oregon, are an example. These are found over an area several acres in extent (Wagner, 1945).

Evaporites

Oregon has a group of minerals, called **evaporites**, composed of sodium carbonate and water in various proportions. The constituents of these minerals were precipitated from lake waters carrying elements that were leached from rocks over and through which they had flowed. After reaching lake basins, the water eventually evaporated, and minerals were left. As the basins in which these minerals formed had no drainage outlet, minerals slowly accumulated in them over the passing years. If the concentration of minerals in the lake was quite large before the lake dried up, beds of evaporites may have formed. If the lake existed for only a few months out of each year, there were insufficient minerals to form beds, and the minerals that did form were mixed with fine-grained clastic sediments. After the lake dried up, water from below coming to the surface, either due to capillary attraction or to springs, dissolved some of the minerals from the clastic sediments and precipitated them at the surface, thereby concentrating them in localized areas. Deposits that evidently formed in this manner are found in south-central Oregon in Lake and Harney counties. The main minerals of these salts are natron (pronounced “nay´-tron”)—common washing soda, $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$; trona (pronounced “tro´-na”), $\text{Na}_3(\text{CO}_3)(\text{HCO}_3) \cdot 2\text{H}_2\text{O}$; and thermonatrite (pronounced “therm-o-nay´-trite”), $\text{Na}_2\text{CO}_3 \cdot \text{H}_2\text{O}$.

Diatomite

(Pronounced “dye-at´o-mite”; from Greek *diatomos*—cut in half)

Diatomite is mainly composed of siliceous shells (skeletons, frustules) of very minute single-celled plants called **diatoms** (pronounced “dye´a-toms”). Several million shells occur in a cubic inch of a good-grade diatomite. When the diatoms die, the shells sink and, over a period of time, accumulate to form a deposit. The purity of the deposit depends upon the quantity of other sediments being deposited along with the shells of the diatoms. Consequently, the purest deposits are formed in quiet lakes and embayments of the sea. When quantities of mud are deposited with the diatom shells, the deposit is called a **diatomaceous shale**. Diatoms flourish in either fresh or salt water and can even be found in large mud puddles. They multiply very rapidly and have an average life span of around 72 hours. The shell, which can only be seen under the microscope, is composed of silica and has a variety of shapes, many of an intricate design. Diatomite, which is usually white or off shades of white and light in weight, will absorb a minor amount of water but does not become plastic (“greasy”) as clay does. It is difficult to distinguish from fine-grained volcanic ash without a microscope.

The main uses of diatomite are as a filtering medium for various beverages and liquids, as a filler, for insulation, and for fine abrasives. It also makes good kitty litter and in Christmas Valley is mined and sold for this use. In determining its use, the shape of the diatom shells is important as well as the purity of the diatomite. The chief producing states in the United States are California, Kansas, Oregon, Nevada, and Washington. Until recently, the greatest production in Oregon came from just west of Terrebonne in northern Deschutes County. Now, however, Eagle Picher is conducting operations in northern Harney and Malheur counties and has a plant near Vale (Brittain, 1986). Other deposits are known in Klamath, Lake, Baker, Grant, and Jackson counties. Minor beds are common throughout most of eastern Oregon.

Limestone

Limestone is composed mainly of calcite (calcium carbonate) and may occur in large masses. The impurities will vary from 30 or 40 percent to a fraction of 1 percent. If there is a preponderance of other rock material in proportion to the amount of calcite present, the rock is described according to the dominant material, and the prefix **calcareous** is applied. Most limestone is formed from the shells and other calcareous parts of animals and plants. These organisms extract calcium carbonate for the building of their hard parts from the waters in which they live. When the animal or plant dies, the hard parts sink to the bottom and slowly accumulate, sometimes to great thicknesses. Over a great period of time, the spaces between the shells are filled by fine fragments of the shells as a result of the grinding action of waves. By compaction due to deposition of more sediments or to folding, the shells are converted to massive limestone. Compaction often results in the complete destruction of the form of the shell, leaving only crystalline calcite; consequently, some deposits of limestone do not contain fossils. Limestone also is formed by the chemical precipitation of calcium and magnesium carbonates on the sea floor.

Conditions that favor the accumulation of quantities of shells with very little addition of other sediments are relatively shallow, warm marine waters with low bordering lands. An environment such as this promotes the rapid growth of calcite-secreting organisms, and streams emptying into the sea carry minor quantities of sediments, the source of impurities.

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The largest deposits of limestone found in Oregon are in Josephine and Jackson counties of southwestern Oregon and in Baker and Wallowa counties of northeastern Oregon. Other deposits from which there has been some production are in Douglas, Polk, and Clackamas counties of western Oregon.

Limestone is one of the basic raw materials of industry, and its availability is very important to the industrial development of a community. The bulk of the limestone mined in Oregon is used in the manufacture of cement. In the past, it also was used in the pulp and paper industry, as agricultural limestone, and in the manufacture of calcium carbide—the source of acetylene gas. Part of the limestone mined near Durkee in Baker County is used in refining beet sugar.

Coquina

(Pronounced “ko-kee´-na”; probably from the diminutive form of *concha*—shell)

Coquina is a mass of loosely consolidated shells and shell fragments that have accumulated on the bottom of lakes and seas. Individual shells are plainly seen, and cementation is not complete.

A deposit of coquina is found on the east side of Summer Lake Valley, 12 miles northwest of Paisley in Lake County. A chemical analysis of this material gave 61.5 percent calcium carbonate and 30.1 percent magnesium carbonate (Wagner, 1947).

Parts of the Marquam Limestone Quarry in southwestern Clackamas County contain porous masses of shells and shell fragments. This deposit was formed in an ancient sea; however, it is not typical of rocks of this classification because cementation and compaction have proceeded to an extent greater than is commonly found in coquina. As a rule, most coquina formed in recent times.

Coquina can be substituted for limestone in many of its uses.

Coal

Coal is altered vegetable tissue, a large percentage of which has been changed to carbon. Coal beds have formed from the compaction of accumulated vegetable matter such as trees and ferns. For the formation of coal, it is necessary that oxygen be kept from the accumulating vegetable material to prevent its rotting, which is accomplished by deposition of the vegetable material in water. The conditions necessary for large quantities of vegetable material to accumulate and be covered by water to prevent decay are best met under warm, humid climates in a swampy environment. Burial and subsequent compaction causes some of the water to be squeezed out and certain chemical changes to take place. The kinds of changes that occur determine the class of coal formed. The types of coal include (1) woody tissue, (2) peat, (3) lignite, (4) bituminous coal, and (5) anthracite coal. The last is considered a metamorphic rock.

Most coal found in Oregon is subbituminous or lignite in grade. The largest known coal deposits in Oregon are found in the Coos Bay area. Coal has been mined in this area since about 1854, and the total production is thought to have been on the order of 3 million tons. The reserves are estimated as many millions of tons. Another coal field occurs in the Eden Valley area of southern Coos County, but very little work has been done in this area. Coal also is found in lesser quantities and in more restricted areas in Marion, Clackamas, and Columbia counties in northwest Oregon, in the northern coast area, and in the Bear Creek Valley of Jackson County. Minor occurrences are also found in many parts of eastern Oregon. Large deposits of lignite coal were explored recently in northern Wallowa County (Brownfield, 1981).

Metamorphic rocks

Introduction

The oldest rocks found in Oregon constitute the main bodies of the Siskiyou, Blue, and Willowa Mountains and are exposed near the base of the Pueblo Mountain escarpment. It is thought that extensions of these or similar rocks form the basement for the rocks that cover the state. Most of the metamorphic rocks in Oregon are found in the areas of these mountains.

Foliated metamorphic rocks

Slate

This type of rock splits readily into smooth-sided plates and has few, if any, mineral grains that can be identified with the unaided eye. It is formed from mud or shale. The colors of slate are all dull shades and vary from red and green to black.

Large areas of semislate are found in southwestern Oregon in the Rogue River area centering around Galice.

Slate is used in the building industry as a roofing and decorative stone and as flagstone.

Schist

(Pronounced "shist"; from Greek *schistos*, describing something that may be split)

Thin, platy minerals occurring in schists tend to be aligned in layers, giving schists a layered or banded appearance. They split readily into thin, flaky slabs of irregular thickness. The mineral grains of schists are generally large enough to be identified by the unaided eye, and the name given to a schist depends on the dominant minerals. For instance, if quartz and mica are readily recognized and abundant, the rock is called a **quartz-mica schist**. Schists represent a metamorphism of greater intensity than that which formed slates. They may have formed from shales or extrusive igneous rocks.

Schists of many kinds are found widespread in Josephine, Jackson, and Curry counties of southwestern Oregon and in parts of Grant, Baker, Willowa, and Malheur counties of northeastern Oregon.

Gneiss

(Pronounced "nice"; from the Sanskrit root meaning "spark")

Gneiss is coarse grained and crudely banded. It may split more readily parallel to the banding than across it, but it does not display the smooth surfaces of slate nor does it split as readily as schist. The banding is usually due to alternating layers of minerals of different colors. Feldspars are commonly present in gneisses but are less common in schists; this fact often helps in differentiating between the two. The same minerals that are found in the coarse-grained igneous rocks are found in gneisses, and many gneisses have undoubtedly formed from these rocks. The gneisses can be named for the type of igneous rock from which they were derived; i.e., **granite gneiss**, **diorite gneiss**, etc. The source rocks, however, cannot always be identified readily.

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Gneisses are not as widespread in Oregon as schists, but they are common. They may be found in the same areas as schists.

Alignment of crystal grains due to flowage just prior to the cooling of a large intrusive gives a banded appearance similar to that found in a gneiss. This type of rock is called a **primary gneiss** and is often found around the edges of a coarse-grained intrusive.

Nonfoliated metamorphic rocks

Argillite

(Pronounced “ar’-jill-ite”; related to Greek word for “white”)

Argillites are rocks similar to slates except they have no schistosity; that is, they have no plane along which they will split more readily than any other. The colors, size of particles, and original material are the same for argillites and slates.

Argillites are widespread in Jackson and Josephine counties in southwestern Oregon and Grant and Baker counties in northeastern Oregon.

Marble

The complete recrystallization of limestone forms marble. Sometimes it is difficult to distinguish between the two. Usually marble has larger crystals, is denser, and is consequently slightly heavier than limestone. If fossils are found in marble, they are often badly distorted. Marble can be scratched easily with a knife and effervesces readily in dilute hydrochloric acid. Like limestone, its principal constituent is the mineral calcite.

Marble can be found in almost any color, but white and off shades of white are the most common. In the Willamette Mountains, there is a beautiful black marble that at one time was quarried for building stone and more recently for making calcium carbide. The greatest production of marble from Oregon for building material and monumental stone has been from Josephine and Willamette counties.

Quartzite

(Pronounced “kwor’-tsite”)

As the name implies, quartzite is a metamorphic rock composed essentially of the mineral quartz. It has formed by solutions high in silica that cement quartz sands to such a degree that it may not be possible to detect the original quartz grains. It also can form by the recrystallization of chert. The rock has the hardness of quartz (H=7) and on fresh surfaces has a vitreous luster.

Because quartzite is much harder than most rocks and is composed of a relatively stable mineral, it does not weather (break down) easily. As a result, quartzite rocks are frequently found as residual or lag materials. Scattered boulders of quartzite of this type are found over a wide area in the lower Columbia River Valley and occasionally in weathered gravels of the lower Applegate River Valley.

Serpentinite

(Pronounced “sur´-pen-tin-ite” or “sur-pen´-tin-ite”)

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Serpentinite is a name applied to a rock composed principally of serpentine minerals. The minerals composing serpentinite have been formed mainly from the alteration of olivine and minerals of the amphibole and pyroxene groups. Serpentinite is readily formed from peridotite and to a lesser extent from gabbro and dolomite. Various amounts of the unaltered or partially altered parent rock are usually found within masses of serpentine. The color of serpentinite is nearly always some shade of green, usually a dark green but sometime bluish, but it may vary from light apple green to almost black. It fractures easily but does not follow any definite pattern. The surface of a fracture is usually smooth, with a pearly luster and a curved surface. Because it fractures easily, serpentinite areas are often sites of large landslides. The rock is quite soft and may be scratched easily with a knife. The darker-color varieties may contain enough magnetite to be attracted by a magnet.

Serpentinite may alter still further to form talc or chlorite. The surface of serpentinite weathers slowly to a reddish or black infertile soil that does not support many varieties of vegetation very well. Consequently, large masses of serpentinite are easily distinguished, because they present color and vegetative cover that are usually in marked contrast to the surrounding area. Southwestern Oregon, especially southwestern Josephine County and southeastern Curry County, has large areas of serpentinite. Masses of considerable size are also found in Grant and Baker counties of northeastern Oregon.

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GLOSSARY

- acicular**—Needlelike; refers to the growth of a mineral in long and slender crystals.
- adamantine**—Very high luster, like the luster of a diamond; may give a metallic luster to a translucent material.
- amorphous**—Without form; noncrystalline; does not have crystal faces.
- amygdule**—A rounded mass of secondary mineral that fills a gas cavity (vesicle) in a volcanic rock.
- botryoidal**—Mineral surface that is rounded like the surface of a compact mass of grapes.
- cleavage**—The tending of a mineral crystal to break readily along certain parallel planes due to its internal structure.
- crystalline**—Atoms arranged in a definite order or pattern. The outward expression of this order is the smooth-faced polyhedral form called a crystal.
- decrepitation**—The breakdown (shattering) of mineral grains on heating commonly observed during blowpipe testing or in the open- and closed-tube tests.
- detrital**—Pertaining to or formed from detritus, which includes mineral grains formed by mechanical disintegration of parent rock. Hard or heavy minerals, like diamonds and gold, are often found in detrital deposits.
- dike**—A tabular-shape intrusive igneous rock body that cuts across bedding of other rocks.
- druse**—A cavity or opening in a vein or rock that is coated with small, projecting crystals; crystals coating such surfaces.
- ductile**—Able to be drawn into a wire, a characteristic of some of the metals.
- fluorescence**—A luminescence originating in substances that are being irradiated by rays of invisible light, like ultraviolet light or X-rays.
- foliated**—A structure in metamorphic rocks caused by alignment of platy and prismatic mineral grains, like a mica schist.
- gangue**—The valueless rocks and minerals in an ore; the material that is separated from ore minerals during concentration.
- geode**—A cavity or rock mass that is hollow and lined with crystals.
- geology**—From the Greek work *geos*, meaning Earth. The study of the Earth and its origins, materials, forms, and processes as recorded in rocks.
- habit**—The general shape of a crystal, sometimes long and thin, other times short and flat. Often an indication of the temperature and pressure conditions under which a crystal formed.
- hackly**—The characteristic of metals or rocks to break with a jagged surface.
- hardness**—The resistance that a smooth surface of a mineral offers to scratching. The property by which minerals are described relative to the Mohs standard scale of hardness, which ranges from 1 to 10, with 1 being the most easily scratched and 10 being the hardest.
- hydrothermal**—“Hydro” means “water,” and “thermal” means “heat.” Hydrothermal solutions, from which many minerals are deposited, are solutions of hot water heated by subterranean sources, possibly molten rock or partially crystallized magmatic bodies.
- isomorphous**—“Iso” means “equal,” and “morph” means “form.” These are minerals in which two or more elements can replace each other to any extent without notably changing the appearance of the crystal. All varieties of an isomorphous series such as the calcite-dolomite-magnesite group have the same crystal form.
- lithophysae**—Rounded nodular areas in obsidian or rhyolite that represent centers where crystallization of the molten rock began before it cooled into glass. Usually contracted and cracked, creating crystal-coated surfaces. Larger lithophysae that are partially or totally filled with silica are called **thunder eggs**.
- luster**—The appearance of a mineral in ordinary reflected light. Examples are adamantine, vitreous, greasy, resinous, waxy, pearly, silky, and dull.

magma—Molten rock. Magma is called **lava** when it flows onto the earth's surface through volcanic or fissure eruptions.

magmatic—Of, related to, or resulting from magma. Magmatic segregations are mineral deposits created directly as a result of the separation of one part of a mass of molten rock in one spot. Some iron and chrome deposits have formed in this way, by a separation and concentration of magnetite crystals from a mass of magma, i.e., the settling of early-formed crystals to the bottom of the magma chamber.

malleable—Can be flattened out by pounding, a characteristic of most native metals.

metamorphism—Changes in rocks brought about by heat, pressure, and time acting on the rocks below the immediate surface of the earth. Contact metamorphism is the result of close proximity to heat and hydrothermal solutions accompanying and preceding intrusions of magma, with pressure playing no important part.

mineral—A naturally occurring element or inorganic compound with chemical composition, internal structure, and physical properties that are either uniform or variable within definite limits.

Mohs scale—A standard set of ten minerals by which the hardness of a mineral may be rated. The scale includes, from softest to hardest and numbered from one to ten: talc, gypsum, calcite, fluorite, apatite, orthoclase, quartz, topaz, corundum, and diamond.

native—Any element found uncombined with other elements in nature. Native metals include gold, silver, copper, iron, mercury, iridium, lead, palladium, and platinum.

nodule—A small, irregularly rounded knot, mass, or lump of a mineral or mineral aggregate normally having a warty or knobby surface and no internal structure and usually of contrasting composition from the enclosing rock.

ore—A mineral deposit occurring in sufficient quantity and containing enough metal to permit its recovery and extraction at a profit. The term is also applied to rock

containing such a mineral or metal, such as gold ore and copper ore.

outcrop—A place where bedrock is exposed at the earth's surface without any soil concealing it.

paleontology—The division of geology that concerns itself with prehistoric life and the fossilized remains of that life found in the rocks.

pegmatite—A very coarse-grained igneous rock, usually forming dikes that cut granite or the gneisses and schists that border granitic masses. Pegmatites represent the last liquid portion of a crystallizing granite magma. They are coarse because the liquid residue at the time of their crystallization contained a high percentage of water and other volatile elements that did not go into the make-up of the common minerals of granite and that were for that reason concentrated in the residue. Pegmatites are interesting mineralogically because minerals of the rarer elements are found with the coarse quartz, feldspar, and mica that principally compose the pegmatite.

petrography—A division of geology that studies the mineral makeup of rocks. Petrographic studies are usually conducted with the assistance of a petrographic microscope and thin, transparent sections of rock.

petrology—A division of geology that studies the origin, occurrence, structure, composition, and history of rocks.

phosphorescence—Luminescence originating in substances that have been irradiated with ultraviolet light or X-rays and continue to emit light after the source of the irradiation has been removed.

placer—A sedimentary deposit of heavy minerals concentrated by running water or wave action in which the valuable, heavier elements or minerals have been left behind as lighter-weight material has been carried away.

plumose—A feathery mineral growth, composed of a compact mass of slender branching crystals. A common structural pattern of sulphosalt minerals.

polarized light—Light that has been filtered to vibrate in a single plane rather than in all planes. Limited polarization takes place when light is reflected from polished nonmetallic surfaces. Light escaping from a Nicol prism (made from calcite) or coming through a green tourmaline or sheet of Polaroid is almost completely polarized.

primary—A mineral deposit that formed directly from hot molten rocks or from hot-water solutions. It has not been altered since original deposition or formation.

pseudomorph—A substance with the crystal form of some other mineral that formed as the result of the alteration of the original mineral without loss of the original shape. Pseudomorphs may form by a breakdown and rearrangement of the same atoms (a paramorph), by a slight change in composition, by a coating over another crystal, or by a complete replacement by an entirely different mineral.

refraction—The bending of light as it passes from air into water or transparent materials. Each mineral has a characteristic ability to bend light differently. The determination of this index of refraction is a method of mineral identification. A petrographic microscope and considerable training are required to make this a useful tool for mineral recognition.

reniform—Rounded mineral surfaces, meaning kidney-shape. This shape is coarser than botryoidal and finer than mammillary.

secondary enrichment—A mineral deposit that has been altered and enriched in valuable metals such as copper as a result of the weathering of the surface portion of the vein. The dissolved metals seep downward and reach the fresh unweathered section of the vein where they react chemically with lower grade minerals to form new compounds richer in copper. Also called **supergene**.

sectile—Can be cut by a knife, like silver and some of the softer metals.

sill—Layer of igneous rock sandwiched (injected parallel) to bedding or schistosity of intruded rock.

streak—The color of the powder of a mineral, determined by scratching on the surface of a white, unglazed porcelain tile.

striations—Parallel lines of furrows or shallow grooves on crystal surfaces.

sublimate—A deposit that has grown or condensed from a vapor, rather than from a solution. Sublimates are often seen in blowpipe testing.

tenacity—The resistance (tensile strength) that a mineral offers to breaking, crushing, bending, or tearing (brittle, malleable, sectile, ductile, flexible, elastic).

vein—A tabular or sheetlike hydrothermal mineral filling of a fault or fracture in a host rock. A vein may cause replacement of the host rock. Veins vary greatly in thickness and may branch, bend, offset, etc.

vitreous—Having the appearance and luster of broken glass.

volatilize—To change into a gaseous state, sometimes without melting (as with ammonium chloride).

vugs—Open cavities in the rocks, often lined with druses of crystals.

volcanism—The phenomena associated with volcanoes, fumaroles, hot springs, and lava flows.

weathering—In the broadest sense, any of the destructive effects of the atmosphere and the exposure of rocks to the temperature extremes of the surface. In a mineral sense, it usually means the chemical effects of water, carbon dioxide, and oxygen attacking and destroying minerals that occur near the surface of the earth. Minerals that form deep in the earth at high temperatures and pressures become unstable under surface conditions and alter to form new compounds.

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This publication was prepared by L.L. Brown, U.S. Bureau of Mines, Albany, Oregon, in cooperation with M.H. Holroyd, Extension specialist, 4-H youth development, Oregon State University, as a 4-H Leader Guide, issued in 1987. The original work was produced by H.M. Dole of the Oregon Department of Geology and Mineral Industries (DOGAMI) and was first printed in 1950 as DOGAMI Miscellaneous Paper 1.

The Oregon Department of Geology and Mineral Industries is publishing this paper because the subject matter is consistent with the mission of the Department. To facilitate timely distribution of information, this report has not been edited to our usual standards.

Open-File Report O-88-6

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Revised 1986. Reprinted August 2006.