

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
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A DESCRIPTION OF SOME OREGON ROCKS AND MINERALS

By

Hollis M. Dole

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A DESCRIPTION OF SOME OREGON ROCKS AND MINERALS

By
Hollis M. Dole

Introduction

In the pioneer days many of the early settlers came to Oregon because of the attraction of the wealth that minerals, mainly gold, offered. The search for the gold found in southwestern and northeastern Oregon is largely responsible for the early settling of those areas. In later years 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 the nonmetallic minerals is much greater than the value of the metallic minerals of the state. For instance, in 1973 the mineral production value was \$83,000,000, of which the nonmetallic minerals accounted for \$70,000,000. The search for and utilization of minerals, both metallic and nonmetallic, is still continuing, and the recent recognition of the high-iron bauxite of northwestern Oregon is proof that there is still mineral wealth to be found or recognized in the state.

Every year many people of Oregon visit different parts of the state on pleasure trips. Most of these trips are prompted by the same desire that attracts the thousands of tourists that each year come to Oregon; that is, to view the scenic beauty of the state. Oregon's scenic wealth is truly one of her greatest natural resources.

The accompanying sets of minerals and rocks were prepared by this department to present for study some of the more common rocks and minerals found in the state. These sets do not begin to represent the great number of different minerals and rock types that are found in Oregon nor do they represent all the diverse mineral associations that occur. However, it is thought that they do represent the rocks and minerals most commonly found, and if a good knowledge of these specimens is obtained the enjoyment of pleasure trips will be increased through the ability to identify the more common rocks and minerals as they occur in nature.

The department offers a service to qualified persons, whereby a limited number of rocks and minerals found in this state will be identified or assayed free of charge in exchange for certain information. Persons interested should inquire of the department for details.

General

The crust of the earth is defined as that part of the solid earth that comes under the observation of man. It has a thickness of 5 or 10 miles. This definition is based on the fact that rocks thought to have been buried to that depth have been exposed by erosion.

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*. Then, to be a mineral it must have the following qualifications:

1. It must be a natural substance, that is, it is found ready-made in nature.
 2. It must be formed by inorganic processes.
 3. Its composition should be expressible by a chemical formula and, although it may vary, it is within definite limits.
-

* Legal definition of mineral includes coal, mineral waters, petroleum, and gas.

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 large aggregates 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 in a few instances in which rocks are made up of a single mineral.

As a help in the identification of rocks and minerals the following classifications are presented. These classifications are made as simple as possible with the hope that they will be readily understood. A thorough knowledge of the various divisions of each is essential to ready identification and is a help in understanding the various geologic processes on an area has undergone.

Minerals

Classification

The minerals that have no commercial value and 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 minerals and nonmetallic minerals. Primary metallic minerals usually have a lustre similar to metals. They are minerals from which metals are derived. The nonmetallic minerals do not have a metallic lustre.

Identification

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

Physical properties of minerals are:

- | | |
|---------------------|--------------|
| 1. Color | 7. Hardness* |
| 2. Lustre | 8. Streak |
| 3. Cleavage | 9. Magnetism |
| 4. Fracture | 10. Taste |
| 5. Form | 11. Odor |
| 6. Specific gravity | |

Complete definitions of these terms as well as tables for the identification of minerals are contained in Bulletin 16 of this department, "Field Identification of Minerals for Oregon Prospectors and Collectors".

*Usually abbreviated (H).

Rocks

Classification

GENERAL

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

IGNEOUS ROCKS

Igneous rocks have solidified from molten matter, called magma. If the consolidation took place at depth, that is, below the surface of the earth, these rocks are termed intrusive or plutonic rocks. If the consolidation took place 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 texture and by their contained minerals.

The texture depends upon size, shape, and interrelation of the minerals of the rock. Common textural terms and their definitions are:

1. Granitoid or granitic – Most of the minerals making up the rock are of approximately uniform size and can be seen with the unaided eye.
2. Porphyritic – A fine-grained or glassy groundmass that encloses mineral grains of a size that can be identified visibly.
3. Felsitic (aphanitic, compact, stony) – The mineral grains are so small that they cannot be distinguished visibly.
4. Glassy – The rock has a glassy appearance; few, if any, mineral crystals are present, and the rock then is not made up of mineral grains.
5. Fragmental – Made up of fragments of igneous material. These rocks are sometimes referred to as pyroclastic (fire-broken) rocks.

Textural terms imply the manner in which igneous rocks consolidate. The slower the cooling the greater the opportunity for crystal growth. Slow cooling, then, would result in a granitic texture. If slow crystal growth is interrupted and if later the growth is renewed, or, if after a period of crystal growth the molten matter is cooled so rapidly that only very minute crystals are formed, a porphyritic texture results. If the molten matter is cooled fast, crystals discernible only under the microscope are formed and the texture is then felsitic. A glassy texture is formed when the solidification of the molten matter is so rapid that few crystals have time to form. Explosive extrusion of molten or chilled materials results in a fragmental or pyroclastic texture.

The speed of consolidation of the magma indicates the conditions under which cooling took place. Slow cooling can take place only at great depth where heat is dissipated slowly or where the cooling mass is so large that the relative heat loss is gradual and consequently slow. This means that granitic rocks are formed at depth and usually in a large mass. Porphyritic rocks form during a period of slow cooling followed by a period of fast cooling. This may take place around the borders of a large intrusive mass, or where small portions of the mass are intruded into fractures of the bordering crust, or where the partially cooled mass is extruded on the surface of the earth. Extrusive rocks are generally felsitic because the pouring out of the molten matter on the surface of the earth allows greater cooling area as well as rapid heat loss to the atmosphere. Extremely rapid cooling to form a glass may take place by rapid extrusion of magma to the surface of

IGNEOUS ROCK CHART

CHARACTERIZING MINERALS	Dominant Feldspar ORTHOCLASE		Dominant Feldspar PLAGIOCLASE				Feldspars ABSENT	USUAL MANNER OF CONSOLIDATION OF MAGMA AND SPEED OF COOLING
	Quartz present	Quartz absent	Quartz present	Quartz absent	Olivine and Quartz absent	Olivine present	Olivine present	
	ROCK NAME							
ACCESSORY MINERALS None, one or more may be present	Mica ----- Amphibole	Mica ----- Amphibole	Black mica ----- Pyroxene ----- Amphibole	Black mica ----- Pyroxene ----- Amphibole	Pyroxene ----- Amphibole	Pyroxene ----- Amphibole	Pyroxene ----- Black mica	INTRUSIVE ROCKS
Granitic	Granite	Syenite	Quartz diorite ----- grana- diorite	Diorite	Gabbro	Olivine gabbro	Peridotite ----- dunite (olivine only essen- tial mineral)	
Porphyritic with fine granitic groundmass	Granite porphyry	Syenite porphyry	Quartz diorite porphyry	Diorite porphyry	Diabase	Olivine diabase	In medium-sized masses. Slow cooling at depth followed by faster cooling closer to surface.	
Felsitic or porphy- ritic with fine- grained groundmass. Large mineral grains not common.	Rhyolite	Trachyte	Dacite	Andesite	Basalt	Olivine basalt	In flows or near- surface intrusives of small size. Rapid cooling.	
Fragmental or pyroclastic.	Rhyolite tuff ----- Rhyolite agglomerate	Trachyte tuff ----- Trachyte agglomerate	Dacite tuff ----- Dacite agglomerate	Andesite tuff ----- Andesite agglomerate	Basalt tuff ----- Basalt agglomerate	Olivine basalt agglomerate ----- Olivine basalt agglomerate	Explosive eruptions at surface. Rapid cooling.	
USUAL OR CHARACTERISTIC TEXTURE	VOLCANIC GLASSES							EXTRUSIVE ROCKS
	Obsidian, perlite, pumice		Scoria, tachylite					
Usual or comparative color		Light-colored rocks		Intermediate-colored rocks		Dark-colored rocks		

the earth or locally along the edges of a flow or intrusive. When in large masses, glassy rocks could only be extrusive rocks. Fragmental rocks are extrusive rocks because the explosive eruption which forms them can take place only near or at 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
3. Olivine

Identifying characteristics of these minerals are found in the section dealing with mineral descriptions.

Other minerals, called accessory minerals, may be present, and usually are, but these accessory minerals do not determine or change the class in which the rock would fall. However, the accessory mineral commonly provides the adjective describing the rock. For instance, a rock containing the essential minerals that would classify it as a granite may have mica as an accessory mineral. The rock, then, would be called a mica granite. Some of the essential and accessory minerals may occur together while some cannot form as companion minerals. For instance: the feldspars will occur with any of the minerals; quartz will occur with the feldspars, amphiboles, and pyroxenes; olivine will occur with the 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 opposite page 5.

SEDIMENTARY ROCKS

There is a constant struggle between the forces of nature and the lands 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, the forces of nature strive to tear down these surfaces and transport the material to a base level, which is approximately the level of the sea. The products formed from the tearing down of the land are called sediments. Consolidated sediments form the sedimentary rocks. Both consolidated and unconsolidated materials are considered as rocks. Included in the sedimentary rock classification are organic materials such as limestone and coal. Most limestone is formed from beds of shells, and coal is formed from the alteration of vegetable tissue.

The tearing down and transporting of the earth's surface is called erosion. Erosion is accomplished mainly by water, wind, ice, 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 a very irregular and much interrupted process. Even in a stream bed, material is constantly being dropped and picked up owing to the change of the currents, and therefore the carrying power, within the stream. Sediments on their way to the sea frequently are temporarily deposited to form such features as gravel bars, flood plains, stream or wave-built terraces, and lake beds. These 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 they sink to the bottom and, like the waterlogged wood, are incorporated in the sediments. Under favorable conditions this organic material will be replaced by mineral matter and will retain its original form and structure. In relatively recent material the hard parts of the original plant or animal are often prevented 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 an abundant plant and animal growth most marine sediments contain fossils. The abundance of fossils in marine sediments is also due to the fact that there is very little movement

on the bottom of the sea. The less the movement the less the grinding action of the sediments and therefore the better the chance of preservation.

In all water-laid deposits, there is a tendency for the currents to sort the material as to size and weight of particle. The stronger the current the larger and heavier particle it is able to transport. The result of this is that most sedimentary deposits are layered or, as the geologist calls it, bedded. Another result of this action, especially in marine waters, is that the coarsest materials are found nearest the shoreline and gradually grade out to a zone of little to no deposition of land-derived material. It is in the latter zone that the large deposits of limestone form. This is because the deposition of material is almost wholly due to accumulated organic material.

The classification of sedimentary rocks is based on the sources from which the sediments have been derived. Sediments formed from fragmental material resulting from the breaking up of rocks are called clastic sediments. All others, such as coal, limestone, chalk, iron-bearing beds, phosphate rock, salt, and gypsum are termed nonclastic sediments. Clastic sediments are named according to the size of the particles which make up the bulk of the material. The size range of the particles is an arbitrary figure. Nonclastic sediments are formed, in general, from some form of life or are chemical precipitates. Following is a commonly used classification of clastic sediments according to size. A general classification of sediments and sedimentary rocks is charted on the opposite page.

Particle size increases	Size Range	Name		Degree of fineness
	Coarser and 2 mm*	Boulder	Gravel	Coarse-grained clastics
		Cobble		
		Pebble		
	2 mm to 1/16 mm	Granule Sand		Medium-grained clastics
	1/16 mm and finer	Silt Clay		Fine-grained clastics
	*One inch is equal to 25.4 mm.			

A description of individual sediments will be found in the section describing the sedimentary rocks.

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

1. Color

2. Size of grains. If several sizes are present the rock should be classified as to the size of the dominant grains, and the minor grain size 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 commonly

used are: 1. well rounded, 2. subrounded, 3. angular.

4. The material which 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.

CLASSIFICATION OF SEDIMENTARY ROCKS

	Unconsolidated	Consolidated	Common Constituents	Remarks
<u>Clastic</u> (mechanical)	Mud or cloy	Shale	Cloy minerals, quartz	Well
	Sand	Sandstone	Quartz, feldspar	bedded
	Gravel	Conglomerate	Rounded, coarse rock fragments	Poor to no bedding
	Talus	Breccia	Angular rock fragments. (Found at base of mountains or sea cliffs)	Usually
	Till	Till	Rock fragments of all sizes. (Deposits of glaciers)	not bedded
<u>Nonclastic</u> (organic)	Ooze	Limestone	Calcite, fossils	Organic accumulations
	Organic mud	Marl	Fresh water fossils	Bedding may or may not be present
	Peat	Coal	Partially decomposed vegetation	
<u>(chemical)</u>	Saline mud	Salt beds	Common salt, gypsum, nitrates	Chemical precipitate
	Iron rich mud	Iron-bearing beds	Limonite and cloy	
	Mineral springs	Travertine Siliceous sinter	Calcite Silica	Bedding may or may not be present

METAMORPHIC ROCKS

The third great class of rocks is formed by profound physical and chemical changes in rocks of the other two classes; usually the original nature of the rock is not readily recognized. 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 which cause metamorphism are: heat, pressure, recrystallization, cementation, and addition of new material. These are the result of hot water and vapors (mainly from intrusions of igneous masses), extremely deep burial by sediments and lavas (vertical pressure), and intense folding to form mountain ranges (lateral pressure). Cementation may also be the result of percolating waters of moderate temperatures. The processes which cause metamorphism usually take a long period of time and result from a variety of conditions. This is especially so for the formation of widespread areas of metamorphic rocks. Therefore, as a rule of thumb, it might be said that the metamorphic rocks are the oldest of the rock types found within an area. This criteria 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. Usually, then, new minerals that are flat and platy or needle shaped have formed. This ability to break along certain planes is termed schistosity. When most of the mineral grains of a platy metamorphic rock are sufficiently large to be identified with the naked eye the rock is called schist. If it is fine-grained, nearly uniform in composition, and only one, or possibly two minerals are identifiable it is called 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 specimen it is called slate.

Slates and phyllites are usually formed from sedimentary rocks, schists are formed from both sedimentary rocks and extrusive igneous rocks, and gneisses are usually formed from intrusive igneous rocks. Hornfels are formed from shales that have been metamorphosed by an intrusive; argillites are metamorphosed shales that have not developed schistosity. Metamorphic rocks that have formed by recrystallization usually do not have a schistose or gneissic appearance. The most common example of metamorphism due to recrystallization is the alteration of limestone to marble. Thorough recrystallization of a limestone results in marble. Cementation of a 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 forms quartzite. This is an example of a metamorphic rock formed by cementation.

There are a few minerals that are typical of metamorphism and, when these minerals are recognized, the possibility that the rock belongs to the metamorphic class should be investigated. A few of the typical minerals are: garnet, mica, talc, graphite, chlorite, and the needlelike amphiboles. Metamorphic rocks can be readily divided into two classes: the foliates (those rocks that will split along certain planes or have an alignment of mineral grains) and the nonfoliates (those rocks which show no mineral alignment and are massive). On the opposite page are listed a few of the rocks in each type.

Mineral Descriptions

Metallic Minerals

1. Bauxite (box'-ite)

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 and noncrystalline diaspore, together with some iron oxide, titanium oxide, and silica. 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 determines whether

METAMORPHIC ROCKS

	<u>Metamorphic Product</u>	<u>Source Rock (Igneous)</u>
Foliate Metamorphic Rocks	Granite gneiss	Granite
	Diorite gneiss	Diorite
	Gabbro gneiss	Gabbro
	Mica schist	Rhyolite
	Hornblende schist	Andesite
	Hornblende schist	Basalt
	Chlorite schist	
Non-Foliate Metamorphic Rocks	Serpentine	Peridotite
	Soapstone	
	Metavolcanics	Rhyolite
		Andesite
		Basalt
		Volcanic tuff
		<u>Source Rock (Sedimentary)</u>
Foliate Metamorphic Rocks	Conglomerate gneiss or schist	Conglomerate
	Quartz schist	Sandstone
	Mica schist	Shale
	Phyllite	or
	Slate	Mud
	Marble gneiss or schist	Impure limestone
Nonfoliate Metamorphic Rocks	Quartzite	Sandstone
	Argillite	Shale or Mud
	Hornfels	
	Marble	Limestone
	Anthracite coal	Coal
	Graphite	

or not bauxite may be utilized as an ore of aluminum. The bauxite found in northwestern Oregon is high in iron oxides, and so the material has been called high-iron bauxite or ferruginous bauxite.

Bauxite often has rounded grains from shot size to marble size set in a claylike groundmass. In this form it is oolitic (shot size grains) or pisolitic (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 is then difficult to distinguish from clay. In Oregon the shotlike material usually occurs as the upper horizon of the deposits, but in places 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 the 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, commercial deposits of high-iron bauxite so far have been found only in the northwestern part of the state. Deposits were first recognized, by this department, in Washington County in 1944. In 1945 Bulletin 29, "Ferruginous Bauxite Deposits in Northwestern Oregon" was issued describing the geology and outlining areas in Washington, Multnomah, Columbia, Polk, and Marion Counties. In the September, 1948, issue of The Ore.-Bin a discovery in Clackamas County was described. Since the initial discoveries by the department of high-iron bauxite, Alcoa Mining Company has done extensive exploration work, mainly in Washington and Columbia Counties. Interest in these areas is still keen and undoubtedly Oregon will at some time be a major domestic source of aluminum ore. Most bauxite mined in the United States comes from Arkansas, with minor amounts from Alabama, Georgia, and Virginia. Imports are mainly from the Guionos.

In the lower Columbia River area there are three plants for the reduction of aluminum metal from aluminum oxide which is produced by treating bauxite in plants located in the Middle West and South. 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 Northwest. Because of this, the discovery by the department of aluminum ore so close to the reduction plants takes on an added importance.

Aluminum is used extensively in airplanes, railroad cars, machinery, electric appliances, cooking utensils, electrical conductors, building construction, foundry and metal working, and chemicals. The properties that make it so desirable are: its light weight, its high electrical and thermal conductivity, its ductility, and its resistance to atmospheric corrosion.

2. Chalcopyrite (kal'-ko-pie'-rite) (CuFeS_2)

This is a chemical combination of the elements copper, iron, and sulphur. Its yellow color often leads one to mistake it for gold or pyrite. Gold is softer and heavier than chalcopyrite and pyrite is usually whiter in color and frequently has striations (minute parallel lines) on its sides. Also chalcopyrite often has a bluish iridescence or sheen caused by oxidation.

In the period 1852-1947 Oregon produced \$4,646,443 in copper,¹ the principal ore mineral of which was chalcopyrite. The areas of greatest copper production are: southwestern Oregon, the central Cascades, the Blue Mountains, and the Wallowas. Chalcopyrite is also found as a common accessory mineral in many quartz and gold-bearing veins in these same areas.

3. Chromite (krow'-mite) (FeCr_2O_4)

The most readily identifiable characteristic of chromite is its brown streak. This distinguishes it from

¹U. S. Bur. Mines Minerals Yearbook 1947, p. 1490.

magnetite (magnetic iron oxide) with which it is most likely to be confused as both ore black, heavy minerals. Other distinguishing characteristics are: chromite is not as hard as magnetite nor is it as magnetic. Occasionally, minute emerald-green crystals or sugary grains are found on chromite; this is a chrome-garnet and is the mineral uvorovite.

Chemically, chromite is a combination of iron oxide and chromic oxide. Standard metallurgical grade chromite contains a minimum of about 48 percent chromic oxide and a ratio of chromic oxide to iron oxide of about 3.0 to 1.

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 in cutlery, many automobile parts, and 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 Turkey, Rhodesia, the Philippine Islands, and New Caledonia. In times of international stress, when the shipping lanes are closed, domestic sources of chromite must be employed, but under peacetime conditions domestic chrome cannot compete with foreign chrome. 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 which was valued at nearly \$1,000,000 (Libbey, 1948).^{*} At the present time (1949) production of chromite in Oregon is sporadic. However, Oregon chromite will always be an important factor in the natural resources of our nation, and it would be to the advantage of this country to maintain some production from these mines.

Chromite has always been found associated with serpentine and peridotite. This fact should be kept in mind and these areas should be the first to be investigated. In Oregon large areas of serpentine are found in Curry, Josephine, and Grant Counties. Another source of chromite in Oregon is in the beach sands and beach terraces of Coos and Curry Counties. Undoubtedly these sands were derived from erosion of serpentine and peridotite areas. After streams had brought the sands to the ocean, ocean currents concentrated the heavy minerals along the shore line. Chromite is one of the heavy minerals of these sands.

4. Cinnabar (sin-a-bor) (HgS)

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 blood red, however, and it is this property that helps identification.

Cinnabar is a chemical combination of mercury and sulphur. 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, that is, cinnabar is heated to a temperature above 1076° F. and the mercury comes off as a vapor which is then collected by condensing in water-cooled tile pipes.

Mercury is used in pharmaceuticals, as a detonator for high explosives, as a catalyst, in thermometers, antifouling marine paints, chemicals of many kinds, in electrical apparatus, and in many other industrial uses. In recent years a small dry cell using mercury as one of its components has been developed. This battery has several times the life of an ordinary dry-cell battery of equal size.

Most of the nation's present supply of mercury is imported from Spain, Italy, Mexico, and Japan.[†] During World War II it was not possible to obtain mercury from these sources. Domestic sources were needed and Oregon, along with California and Nevada, produced the bulk of the nation's supply. Consistently,

^{*} See bibliography in back of this paper.

[†] Op. cit., p. 775 (1947).

Oregon ranks among the top three states in the United States in the production of mercury. In the 10-year period, 1937 through 1946, the quicksilver produced from Oregon ores was valued at \$7,591,000.¹ Cinnabar is found in many localities in Oregon and the reader is referred to the map issued by the department showing the distribution and approximate production of the mercury mines of the state. This map sells for 30 cents postpaid and can be obtained from the department's office at Portland and the field offices at Grants Pass and Baker. The principal producing areas have been: the Cascades, 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. Favorable prospecting areas would be in the western Cascades, the Ochocos, and in the volcanics of southeastern Oregon.

5. Galena (go-lee'-nah) (PbS)

Galena is identified by its metallic lustre, 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 and when the piece is broken the fragments will tend to break into cubes or rectangles, always with square corners.

Galena is a chemical combination of lead and sulphur and is the main ore of lead. Frequently, galena has mixed with it sufficient silver to make it an ore of silver. Lead is one of the basic minerals of industry and as such has a wide variety of uses. Its principal uses are as red lead and litharge, cable coverings, as plates in storage batteries, in gasoline, and in paints.

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). By states, Missouri is consistently the greatest producer and is followed by Idaho and Utah.² Oregon's production of lead is sporadic. Usually a few thousand pounds are produced each year as a by-product of smelting ores, but there have been many years when there has been no recorded production. In the period 1852-1947 the value of Oregon's lead production was \$80,237.³ 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 district.

6. Garnierite (gar-neer'-ite)

Garnierite is a nickel-hydrasilicate; that is, it is composed of nickel, silicon, oxygen, and water. It is really a mixture of two or possibly three nickel-hydrasilicates and in that sense is not a single mineral (Pecora, Hobbs, and Murata, 1949). It has been formed by the weathering (chemical alteration) of peridotite which 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 stand at a low elevation 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 only locality where garnierite is mined for an ore of nickel is the South Pacific island of New Caledonia. Most of the production of nickel in the world comes from the sulphide ores of that metal. Domestic production of nickel is very small and is a by-product from the mining of ores of other metals and reclamation of scrap metal. Therefore, any nickel deposits found in the United States are of national importance. The occurrence of a deposit of garnierite on Nickel Mountain in Douglas County, Oregon, northwest of the town of Riddle, has been investigated by private companies and various government agencies. It has been estimated (Pecora and Hobbs, 1942) that this deposit contains "...over 6,000,000 tons of material, 1 to 2 percent of which is probably nickel. Eighty thousand tons have been proved to contain 2 to 3 percent of nickel, and 75,000 tons have been proved to contain 1 to 2 percent of nickel." The possibility of other areas in southwestern Oregon containing nickel-silicates is being investigated by the department and to date the work has shown that about 1 percent nickel is found in the laterite of the Red Flat locality of west-central

¹Op. cit., p. 37 (1940 Rev. of 1939); p. 38 (1941); p. 75 (1943); p. 60 (1946).

²Op. cit., p. 668 (1946).

³Op. cit., p. 1490 (1947).

Curry County and in the Woodcock Mountain area just west of Kerby in Josephine County.

7. Gibbsite (gib-site) $(\text{Al}(\text{OH})_3)$

Gibbsite is an ore of aluminum. It 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 its recognition is sometimes difficult. When disseminated in clay or the high-iron bauxites of Oregon, gibbsite sometimes occurs as small, white, rounded fragments which are quite brittle. On fresh fracture the surface is somewhat like porcelain. Usually it is harder than kaolin and is much softer than feldspar or quartz. An unusual occurrence of gibbsite is found on the Salem Hills in Marion County. Here it occurs as residual nodules (loose fragments) some of which are bonded. The colors of the bonds are pink, yellow, and cream and when cut and polished the result is very attractive. The recognition of the gibbsite nodules is complicated by a red clay which covers the exterior; they can readily be mistaken for clay-covered boulders of vesicular basalt. The nodules sometimes are the size of a large boulder and usually the surface is 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 the 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.

8. Gold ore

An ore deposit is defined as a mineral deposit that can be worked at a profit. Gold ore, then, would be in a deposit containing sufficient gold to pay for the mining and recovery of the gold and also pay the operator a profit. Because mining and milling costs will vary for nearly every locality and type of ore, the minimum mineral content of the rock would also vary if it is to be mined profitably.

Gold-bearing rock which assays \$35 a ton under ordinary conditions is considered to be pretty good ore. As gold sells for \$35 a troy ounce, this would mean that ore of this quality would contain one ounce of gold per ton of rock. There are 29,166.66 troy ounces in one short ton avoirdupois. Therefore, if the gold in the above example were disseminated evenly throughout the rock, only one part in approximately 29,000 would be gold. Consequently, it can readily be seen that visible gold is not necessary for rock to be gold ore. For this reason it is quite unlikely that any gold will be seen in the samples of the accompanying sets.

Oftentimes pyrite (a mineral composed of iron and sulphur) and chalcopyrite (copper, iron sulphide) are mistaken for gold. Gold can be determined not only from its yellow color but more reliably by its softness (it can readily be scratched by a knife), its malleability (ability to be pounded into thin pieces), and its weight (it is over twice as heavy as iron). It is this last characteristic that aids in its detection when prospecting by panning. If gold is suspected in a rock the most reliable way it can be determined is by fire assaying, a laboratory method whereby the rock is smelted and the precious metals are extracted from the rock by molten lead.

When ore is mined from igneous or metamorphic rocks it is termed lode mining. Usually this type of mining is by underground methods. If the ore is extracted from sedimentary rocks found on the surface of the earth by dredges, large mechanical shovels, or by hydroulicking, 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, \$2,505,195 was recovered by placer methods whereas the lode production was \$1,463,875.¹ In recent years the percentage produced by placer mines has been even greater. Total recorded production of gold in Oregon in the period 1852-1947 is valued by the U.S. Bureau of Mines at \$127,831,628.²

¹Op. cit. p. 424 (Rev. of 1940).

²Op. cit. p. 1490 (1947).

At present there are few operating gold lode mines in Oregon. This is due to several factors, one of which was the War Production Board Limitation Order L-208 closing most gold mines during World War II. This was a blow from which few mines have been able to recover.

Gold mining in Oregon is limited to the following counties, named in order of their 1940 production:¹ Baker, Grant, Jackson, Josephine, Malheur, Douglas, Union, Jefferson, Curry, Coos, and minor amounts from Harney, Lane, Lincoln, Morrow, Umatilla, and Wallowa. The principal lode mines are found 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.

9. Hematite (hem'-a-tite) (Fe_2O_3)

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, often fibrous or mammillary; in small, rounded concretionary grains cemented together; and in steel gray, dark brown, or brownish-black flaky pieces. This last type is called specular hematite because of its very shiny surfaces.

Hematite can best be identified by its streak, which is blood red. Other identifying characteristics are: it is 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 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 Wallowa Mountain region.

10. Ilmenite (ill'-men-ite) (FeTiO_3)

Ilmenite is an iron, titanium oxide. It is steel gray to black in color. It can be distinguished from magnetite as it is not magnetic and from chromite by its black streak. Ilmenite is found as an accessory mineral in almost every type of rock and is usually associated with magnetite. As an accessory mineral it occurs as very small disseminated grains, usually fairly well formed. Hematite is a common constituent of black sands.

11. Limonite (lie'-mo-nite) ($2\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$)

Limonite is iron oxide chemically combined with water. In Oregon it is commonly found in yellowish-brown to ocher-yellow earthy deposits. When 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 lustre, is quite hard, and is brownish black in color.

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

The only production of Oregon iron was in the period 1867-1894 from limonite found in the hills just

¹Op. cit. p. 424 (Rev. of 1940).

west of Oswego. Pig iron and cast iron pipe were produced from these ores in a plant at Oswego where the first blast furnace on the Pacific Coast was built (Libbey, 1940). Limonite ores west of Scappoose have long been known and have been investigated by many people. In 1942 the U. S. Bureau of Mines after extensive examination estimated that the iron-ore deposits in this area contained approximately 4,000,000 tons of iron ore that would average about 40 percent metallic iron (Bartell, 1949). A potential source of iron in Oregon is from the high-iron bauxite of Columbia and Washington Counties. If the Pedersen alumina extraction process is used for treatment of this ore, pig iron will be one of the products. Even if this process is not used, these deposits contain a valuable potential reserve of iron.

12. Mongonite (mon'-go-nite) ($\text{MnO}(\text{OH})$)

Psilomelone (sil-om'-e-lone) (MnO_2)

Pyrolusite (pie-row-lu'-site) (MnO_2)

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, psilomelone is the hardest ($H = 5-7$), mongonite follows closely ($H = 4$), and pyrolusite is the softest ($H = 2-2.5$). Color of each is dark steel gray to iron black. Both mongonite and psilomelone can alter to pyrolusite and usually do 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 tree-like pattern and this has been mistaken for fossil fern or leaf impressions.

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

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. For a more thorough discussion of manganese the reader is referred to Department Bulletin No. 17, "Manganese in Oregon".

13. Molybdenite (mo-lib'-de-nite) (MoS_2)

Molybdenite is a combination of the elements of molybdenum and sulphur. It has a bluish-white lustre and a bluish lead-gray color. It is most likely to be mistaken for graphite, as it is very soft and easily leaves a lead-gray mark on paper or on the hands. It differs from graphite in its ability to cleave into thin flakes like mica, and it has a metallic lustre whereas the lustre of graphite is submetallic. Molybdenite is most commonly found as disseminated flakes or scales in granitic rocks and in veins associated with galena. Occasionally it forms in foliated masses as much as three-fourths of an inch in size, and in a deposit near Gold Hill 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 Mountain 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. The ore reserves at Climax, which have been outlined by drilling, are estimated at 260 million tons.¹ Molybdenite is also 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 to iron form steels having special properties and uses.

14. Pyrrhotite (peer'-ho-tite)

Pyrrhotite is composed of iron and sulphur. It is really a solid solution of sulphur in iron sulphide. 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 sulphide 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 veins.

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 in Jackson County. 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 sulphide), and chalcopyrite.

15. Stibnite (stib'-nite) (Sb_2S_3)

Stibnite is a chemical combination of antimony and sulphur. It is the main ore of antimony. The mineral can be readily recognized from the following properties: it is fairly soft; it can be scratched by the finger nail ($H = 2$); it forms in steel-gray, fan-shaped 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, zinc, and lead. Sometimes good values in gold ore 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. During the 5-year period 1942 through 1946 production was valued at \$44,309.² 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-Molheur county line. Besides the above counties, prospects are found in eastern Grant County and in the western part of the Bohemia District of Lane County.

The United States uses more antimony than it produces. Chief contributors to our national supply are China, Bolivia, and Mexico. Domestic production is largely from Idaho with minor amounts coming from Nevada, Oregon, and Washington.³ Antimony is a very important metal to our industries and, because most of our supply must be imported, a local source is of great national importance. The main uses of antimony are in the production of battery plates, anti-friction bearings, type metal, flameproofed textiles, and in paints and lacquers. A more complete treatment of antimony is found in the department's publication, G.M.I. Short Paper 13, "Antimony in Oregon."

16. Zircon (zir'-con) (ZrSiO_4)

Zircon is a chemical combination of the elements zirconium, oxygen, and silicon. When found in sands

¹ U.S. Bur. Mines Minerals Yearbook 1946, p. 799.

² idem, 1944, p. 71; 1946, p. 60.

³ idem, 1946, pp. 128-136.

it is usually in small, clear, boot-shaped 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-colored 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 from zircon sands has recently been developed by the U. S. Bureau of Mines at their Northwest Electro-development Laboratory at Albany, Oregon. Among the uses of metallic zirconium at present is the making of special steel alloys, in vacuum tubes, flash bulbs, and pyrotechnics.

Nonmetallic Minerals

1. Agate (og-it) (SiO_2)

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. 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 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.

The formation of agates requires solutions rich in silica. Therefore when prospecting for them, areas of the more siliceous rocks such as rhyolites and dacites would be favorable. Agate areas of Oregon are not confined to the rhyolite and dacite areas but many of the best 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, Horney, Crook, Deschutes, Molheur, and Lake counties. The Friday Ranch in Jefferson County is one of the famous agate localities of the nation. 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. There are thousands of "rock-hounds" in the state who have as their hobby the collecting, cutting, and polishing of local stones. Also, there are many who owe their livelihood to the sale of agates, both as a raw cutting material and as the finished product. It is very difficult to arrive at an accurate value for Oregon's production of rough and cut gems but it has been estimated that it is on the order of \$1,000,000 annually (Doke, 1947).

2. Asbestos (os-bess-tuss)

Asbestos is a name applied to certain minerals that will separate into fibers. The minerals which are included under the name asbestos are tremolite, anthophyllite, and crocidolite of the amphibole group, and chrysotile of the serpentine division. The main identifying characteristic of these minerals is their ability to be separated without much difficulty into fine threads or fibers. Although the color of the individual fibers is usually light, when found in masses or aggregates it varies from grayish yellow through brown to green. The minerals which are classified as asbestos differ in composition but all are essentially silicates of calcium, magnesium, and iron. Asbestos may be formed by the alteration of basic igneous rocks such as peridotite. It occurs in veins and in lenticular (lens-shaped) masses. Sometimes numerous veins varying from a fraction of an inch to as much as two inches in width will be closely spaced over 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 use of asbestos is in the making of fire-resistant material; lining for automobile brakes, pipe covering, and roofing are some of the important materials manufactured from it. Chrysotile asbestos can be woven into textiles and yarn. Domestic production of asbestos is mainly from Arizona, California, Georgia, North Carolina, 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.

3. Barite (bay'-rite) (BaSO_4)

As indicated by its name, barite is a compound of the element barium; it is barium sulphate. Barite is one of the heaviest of the light-colored 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 of sulphide deposits. Elsewhere, it is found under a variety of conditions and associations. Barite occurs in large amounts in beds and is also found in veins. It is one of the most common gangue minerals in lead, copper, and zinc deposits, and is found in limestone and sandstones often as a cementing material. 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 through the barite.

Of the 372,610 short tons of ground barite produced in the United States in 1946, 82 percent was used as a weighting substance in oilwell drilling muds.¹ Other major uses for barite are in the manufacture of paint, rubber, gloss, 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.

4. Calcite (kal'-site) (CaCO_3)

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 Mohs scale of mineral hardness. When crystal sides can be seen they usually are of the form of a rhombohedron. Calcite effervesces 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 pocketknife 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 sea shells. The rocks limestone and marble are principally calcite.

The main use of calcite crystals is for prisms in precision optical instruments. To qualify for this use the crystal must be free from internal strain or blemishes and in most cases be perfectly clear. During World War II, when there was a great demand for optical-grade calcite, a project was undertaken by the department in the Owyhee River area of northeastern Malheur County to explore for optical calcite. This project was unsuccessful in developing a commercial source. The main difficulty, as is always the case, lay in the mining; as soon as the crystal was extracted, internal strains immediately developed. In recent years synthetic crystals of various compounds have been produced, consequently the demand for calcite crystals is low. Demand never was great, however; under normal times it seldom exceeded more than a few hundred pounds per year.

¹ op. cit., p. 169, (1946).

5. Gypsum (gyp'-sum) ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$)

Gypsum, like calcite, occurs in a variety of forms. The clear, colorless variety that will cleave readily into flakes is called selenite. The fibrous variety is called 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 sometimes called gypsite or rock gypsum. It is this last type that usually makes up the large industrial deposits. All varieties have the same chemical composition - calcium, sulphur, oxygen, and water, i.e., hydrous calcium sulphate. Its recognition is made easy because it is quite soft and it does not react with hydrochloric acid. It is the mineral representing a hardness of 2 on Mohs scale of hardness. Frequently the mineral crystallizes to form distinctive "swallowtail" twins.

Gypsum is widespread. It is the most common sulphate 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.

There has been no production of gypsum in Oregon since about 1924. An unknown quantity, but presumably substantial, 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 sulphuric acid, resulting from the weathering of sulphides, 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 which were the principal producers of crude gypsum in 1946 are, in order, the following: Michigan, New York, Texas, California, Iowa, Nevada, Ohio, and Virginia.¹

6. Realgar (ree-al'-gar) (AsS)

Orpiment (or'-pih-ment) (As_2S_3)

Both these minerals are sulphides of arsenic and usually occur together. Realgar by alteration will change to orpiment. They are easily recognized by their distinctive colors: realgar is red, usually with an orange tint due to alteration; orpiment is lemon yellow. Other distinctive physical properties of orpiment are: it is sectile, it has good cleavage, and the lustre is pearly or resinous. Both are quite soft ($H = 1.5-2$). These minerals are fairly common accessories in mineral veins which 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, Fahey, and Axelrod, 1948). As found in this locality, these minerals have no economic value.

The use of natural realgar and orpiment has now largely been replaced by the manufacture of the synthetic minerals. Realgar was at one time used in the manufacture of fireworks, and orpiment is used as a pigment, in dyeing, and in a preparation for the removal of hair from skins.

¹ op. cit., p. 590, (1946).

7. Rhodonite (row-doe-nite) (MnSiO_3)

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 ($H = 5.5-6.5$) 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 thin coating of black manganese oxides 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 as much as 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. Rhodonite also has had some demand in the making of welding rods for the working of manganese steel.

8. Sulphur (sul-tur) (S)

Sulphur is one of the 96 known elements, that is, substances which cannot at will be decomposed, or divided into others. Sulphur combines with most of the metallic elements to form sulphides. When in combination with oxygen and a metal it forms sulphates of the metal. The yellow color of native sulphur is characteristic. Other identifying features are: it melts at a low temperature (108°C.) and burns with a bluish flame giving off choking fumes of sulphur dioxide. Contrary to popular belief, sulphur is tasteless and odorless. Sulphur is formed as a sublimation product due to volcanic activity; by bacterial action breaking down hydrogen sulphide and sulphates (common constituents in hot spring waters) and by the decomposition of metallic sulphides. Sulphur is found associated with sedimentary rocks especially in the gypsum and limestone areas and in areas of recent volcanism.

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

Most native sulphur produced in the United States comes from Texas and Louisiana. In 1936, Texas produced 77 percent of the total production of 3,859,642 long tons, and Louisiana produced nearly 23 percent.¹ Other states that usually have some production are California, Colorado, and Nevada. In Louisiana and Texas the sulphur occurs several hundred feet below the ground in beds as much as 100 feet thick. The sulphur is underlain by beds of gypsum and salt. An unusual mining method is sometimes 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 sulphur in the Northwest is in the manufacture of paper pulp. Every year hundreds of tons are used in Oregon. Total consumption of sulphur for this purpose in the United States in 1946 was 305,000 long tons.² Other important industrial uses are found in the manufacture of chemicals, fertilizer and insecticides, explosives, paint and varnish, and rubber.

9. Talc ($\text{H}_2\text{Mg}_3(\text{SiO}_3)_4$)

The more compact varieties of talc and the talc that contains many impurities is usually referred to as soapstone. In this form the color of the material is often dark green or greenish gray. The purer varieties of talc are light in color, varying from silvery white through apple green to bright green. Talc and soapstone,

¹op. cit., p. 1137, (1946).

²op. cit., p. 1140, (1946).

as the latter name implies, have a soapy or greasy feel. Talc is also identified by its softness; it can be easily scratched with the fingernail. It is the standard for the hardness of 1 on Mohs scale of hardness. Talc is a mineral composed of magnesium oxide, silicon dioxide, and water in chemical combination. 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 basic rocks such as serpentine and gabbro to talc; also, that 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 granitics are found intruded into serpentine and peridotite. There are records of many samples of soapstone from these areas, but so far a commercial deposit has not been developed. In 1946 the states producing talc and similar materials were California, North Carolina, Vermont, Georgia, Washington, Montana, New York, Maryland, Pennsylvania, and Virginia. Total production amounted to 457,066 short tons which was valued at \$6,445,344. Besides the above there were 18,449 tons of talc and similar materials having a value of \$400,267 imparted into this country. Principal importers were Italy, Canada, and France.

Seventy-seven percent of the sales of talc and similar materials was used by the paint, rubber, roofing, ceramics, and insecticide industries in 1946. Only 4 percent of the total was used for the making of talcum powder and other toilet preparations.

Rock-forming Minerals

The following are typical minerals that, in combination with other minerals, compose many of the common rocks. As constituents of rocks they have no commercial value but occasionally segregations consisting principally of an individual mineral will form and, if marketing and other conditions are favorable, they may prove of value. If this should happen they would be classified as an industrial or a nonmetallic mineral.

1. Amphibole group (am'-fi-bole)

This is a name applied to a group of minerals having similar properties and chemical compositions. The different minerals are mainly composed 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 varying 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; or on weathering out of the rock they may give the surface a pitted appearance.

2. Feldspar group (feld'-spar)

The feldspar group is divided into two main classes and these classes are further divided. 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 the last three elements named determine the name of the mineral and the class to which it belongs. The feldspar in which potassium is dominant is called the alkali or orthoclase class, and if sodium and calcium are dominant it is termed the soda-lime class or the plagioclase feldspars.

In rocks, the feldspar group occurs as lath-shaped grains. The alkali class 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 shows a peculiar minute "gridiron" or "grating" pattern. The

¹ op. cit., pp. 1150-1158, (1946).

most common minerals belonging to the alkali class are orthoclase and microcline. The feldspars of the soda-lime class are white to gray in color and usually show 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 which make up the lath-shaped grains. The feldspars alter readily to a soft chalk-white substance which often masks the cleavage surfaces so that they no longer reflect light. Because of this, many grains should be observed, especially if alteration is noted.

In rocks, the feldspars are most often confused with quartz - a serious mistake and one to guard against. Identifying characteristics of feldspar are: hardness (feldspar, $H = 6$; quartz, $H = 7$), striations, color, and alteration.

Feldspars may form economic deposits. By alteration, clay may be formed and, under certain conditions, 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 a 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. Finely ground feldspar is also used in the making of glazes for dishes and in enamels for bathtubs, stoves, and other household appliances.

3. Garnet (gar'-net)

Garnet is a name for 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 color most commonly seen is red to pink, but it may vary from black to green. Because garnets are quite hard ($H = 6.5-7.5$) they are common constituents of sands. As a general rule, the pink grains seen in sands are garnets. Garnets occur as accessory minerals in igneous rocks; they are common and often are a major constituent of some metamorphic rocks.

4. Mica group (my'-ca)

The characteristic of this group of minerals that permits its ready identification is the ease with which the minerals may be split into very thin elastic plates or leaves. No matter what the color is, and it may vary from water-clear to black, the minerals of this group always have this property. Other physical properties that help in their identification are: hardness ($H = 2.5-3.5$) and pearly to vitreous lustre. 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:

Muscovite (mus'-co-vite) - Usually almost colorless or light shades of green and yellow.

Phlogopite (flog'-o-pite) - Color is brown to brownish red, often displaying a golden copper-like sheen. Phlogopite is often mistaken for gold, especially when found in sands or soils. It can be readily differentiated, as the mica will tend to float when agitated with water whereas gold will sink quickly.

Biotite (by'-o-tite) - Usually black to dark green in color.

The micas are some of the most common of the accessory rock-forming minerals of igneous rocks. Most all the coarse-grained light-colored 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".

United States production of sheet and punch (pegmatite) mica in 1946 amounted to 1,078,867 pounds valued at \$217,955. Production of ground (schist) mica the same year amounted to 62,113 short tons valued at \$2,516,018. Imports of all kinds of mica amounted to 13,945 short tons valued at \$7,118,877. Principal states producing mica are North Carolina and South Dakota. Imports were made principally from Brazil, India, and Argentina.¹

Mica is used mainly in the electrical appliance and electronic industries and in the manufacture of roofing materials.

5. Olivine (ol-i-veen) $((\text{Mg,Fe})_2\text{SiO}_4)$

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 and then it usually has 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, chromite, ilmenite, and pyrrhotite are common associates and may make up several percent of a rock high in olivine. All these materials have a comparatively high specific gravity, and when a rock containing these minerals is ground up by natural processes and the sand is carried to the sea by streams, a natural concentrating process is accomplished whereby these heavier materials are separated from the lighter. 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 several percent of olivine and its associates. By selective concentration, man may separate these minerals one from the other fairly well. The olivine sands in the mineral set have been obtained in this manner from sands found along ancient shore lines (wave-built terraces) of southwestern Oregon. These sands, of course, are sediments and so the sample is included in the sets in the sedimentary rock section.

Dunite 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 is used in limited quantities in the making of refractories. In 1946 shipments amounted to 7,649 short tons valued at \$92,868. Other uses of olivine which are being investigated are: with phosphate rock in preparation of a fertilizer, for the production of magnesium chloride and magnesium oxide, and for roofing granules.²

6. Pyroxene (pie-rox-ene)

The pyroxenes form another very important group of rock-forming minerals. As in the case of other mineral groups, the pyroxene "family" consists of separate minerals which 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, in the most common varieties, of magnesium, iron, aluminum, and calcium. The most common pyroxene is the mineral augite.

Most pyroxenes are green or dark colored and occur in stout crystals with the crystal sides almost at right angles to each other. It is this last characteristic that differentiates the pyroxenes from the amphiboles. In other characteristics these two groups are quite similar. The hardness of the pyroxenes is from 5 to 6 but occasionally it is apparently less; this is due to alteration. A rock containing a high percentage of pyroxene

¹ op. cit., pp. 783-796, (1946).

² op. cit., pp. 1293-1294, (1946).

is heavier than the ordinary light-colored 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.

The pyroxenes are common accessory minerals in the igneous rocks, especially the dark-colored ones. They occur with the amphiboles in the light-colored rocks but usually in a subordinate role. In basalts, gabbros, diabbases, 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. It is not uncommon to find pyroxene altered to amphibole.

7. Quartz (kwarts) (SiO_2)

Quartz is a very 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. 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. It is usually the colored varieties that are of value as gem materials. In rocks it occurs as irregular grains, clear to dull white in color, and it 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 7 on 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 fracture and is typical of quartz.

Besides being a gem material, quartz finds use as a natural abrasive, in the manufacture of silicon carbide, as molding sand, in the manufacture of glass, and as poultry grit. Oregon has two known deposits that are furnishing quartz or quartz sand suitable for the above. One of these is in Jackson County near the town of Rogue River and the other is in Eugene. The deposit near Rogue River is a massive lens of quartz several hundred feet wide and many hundred feet long. The Eugene deposit is a quartz sand that marks the shore of the ocean which was in the area around 35 million years ago. Some sands found along the present sea coast are high in quartz and are probably adaptable, after suitable refining, as a source of silica.

8. Tourmaline (tur-ma-lene) ($\text{H}_9\text{Al}_3(\text{B}^\circ\text{OH})_2\text{Si}_4\text{O}_{19}$)

Tourmaline is most commonly found in granites and associated pegmatites. In the latter it often develops into crystals several inches wide and as much as one foot long. Tourmaline is essentially a silicate of boron and aluminum with minor amounts of magnesium, iron, or the alkali metals.

There are several varieties of tourmaline; the color varies from blue, green, and red, to 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 occurs as minute crystals and often the above characteristics are not well displayed. Tourmaline has a hardness about 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.

As the most common occurrence of tourmaline is in pegmatites and granites the best prospecting areas would be in the granite areas of the Siskiyou, Blue, and Willowa mountains.

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. As consolidation of magma is probably more or less of a continuous process there is a constant and usually a gradual change in the mineral content and texture of the product. Consequently, the change from one rock type to another frequently is gradual. It is obvious, then, that the name applied to an igneous rock is arbitrary and depends upon the man-made limits setup.

In the descriptions of the rocks on the following pages it is recognized that the determination of certain minerals and the percentage of these minerals 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. It must be emphasized that the mineral content is the dominant factor in the identification of classes of rocks and every effort should be made to identify as many minerals as possible. After the identification of the minerals, the classification given opposite page 4 should be consulted and the name of the rock determined.

EXTRUSIVE IGNEOUS ROCKS

Flow Rocks (Lavas)

1. Basalt (ba-salt')

Basalt is one of the most common rocks to be found in Oregon. It is black to dark gray in color, usually felsitic (but may be porphyritic) and fairly heavy. The most commonly recognized mineral in basalt is feldspar. It occurs as small, light-colored, often lath-shaped grains. Olivine is a common constituent but it is not an essential mineral; however, when it is recognized the determination of the rock as basalt is fairly certain. Glass is usually present and sometimes occurs as small, clear to black, rounded fragments with conchoidal fracture and vitreous lustre. Most basalts contain a high percentage of iron minerals and frequently the percentage is sufficiently great so that very small chips of the rock can be picked up by a magnet.

Large areas of Oregon are covered with basalt. It poured out of volcanic vents as lava (magma that flows out on the surface) flows. It is quite unlikely that any one lava flow was very extensive, but instead, many flows from numerous vents at different periods in the geologic past were responsible for the great thicknesses and extensive area covered. When the molten lava poured from the vents it contained some gas. As the lava cooled the gas escaped and, because the lava was somewhat viscous, bubble holes remained. Lava which contains numerous bubble holes, termed vesicles, is called vesicular lava and if the lava has the composition of basalt, it is called vesicular basalt. If the vesicles are later filled with some mineral, the fillings are called amygdules, and the rock is called an amygdaloidal lava.

The main uses of basalt are for road metal and riprap. Seldom in Oregon does it contain metallic mineral veins. A special type of weathering of basalt, termed laterization, however, 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.

2. Andesite (an'-de-site)

Andesite, like basalt, is a very common type of lava in Oregon. It is especially common in the upper Cascade Mountains. This rock is named for the Andes Mountains where it occurs in great abundance. Andesite is very 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 basalt, and if it is absent the rock is andesite. Like basalt, andesite is fine grained (felsitic) or porphyritic and contains few minerals recognizable in hand specimens. The dominant mineral of andesite is feldspar. Dark-colored minerals usually make up about one-third of the rock.

Andesite has issued from volcanic vents in the same manner as basalt. In many instances it appears that a single vent has issued basaltic and andesitic lavas at different periods in its life. Also, separate but nearby vents have simultaneously issued lavas which differed in composition. Consequently, in a thick series of lava flows it is not uncommon to find both basalt and andesite present.

The use of andesite is restricted to road metal and riprap. Occasionally it is the host rock for metaliferous mineral veins, especially veins containing cinnabar, but areas of andesite flows are usually not considered as favorable prospecting areas.

3. Rhyolite (rye'-o-lite)

Although rhyolite is found widespread in eastern and southeastern Oregon, it is not as common a rock as basalt or andesite. Rhyolite is usually light colored; pink and red shades predominate but the color may vary from tan to dark purple. Bonding or flow structure is common and often gives the rock the appearance of a sedimentary rock. Quartz is an essential mineral and occurs as irregular grains. Feldspar, the other essential mineral of rhyolite, and quartz form more than 50 percent of the rock. The texture of the rock is usually felsitic. If no minerals can be determined the term felsite may be used. This term refers to any light-colored felsitic rock, regardless of its composition.

Rhyolites are extruded as flows, the same as andesites and basalts. As a rule, an individual flow of rhyolite is more restricted in area than a flow of the other lavas; this is because the rhyolite magma is more viscous.

Metallic mineral veins are sometimes associated with rhyolites. Several of the cinnabar deposits of southeastern Oregon are associated with the feeders to the flows. Agates are frequently found in the beds of the streams draining the rhyolite areas, and the so-called "thunder eggs" are found in and near rhyolite flows.

4. Obsidian (ob-sid-i-yun)

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

Volcanic glass has formed from the rapid congealing of magma. Cooling has been so rapid that mineral crystals have been 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 tachylyte (tack'-i-lite).

Flows of volcanic glass are usually of small areal size and thickness, and in most places there are various amounts of stony, fine-grained lava mixed with it. Volcanic glass may also 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 are known to occur in Oregon at Glass Buttes in northeastern Lake County, near Paulino 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 it is thought that the masses noted above are the largest and most easily accessible.

Perlite (pur'-lite) is a special type of volcanic glass. This glass gets its name from the many curved concentric lines of fracture that have developed in it. They give the rock the appearance of being composed of many small onion-like 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. Perlite when heated will expand or "pop" to several times its original size. By utilizing this principle a very lightweight aggregate can be produced. This 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 a building.

Deposits of perlite are found in several places in eastern and southeastern Oregon. One deposit, just south of Maupin in Wasco County, is being mined and a plant for processing the raw material has been built at the mine. This property is the means of livelihood for a new, small community of the state.

Pyroclastic Rocks

1. Pumice (pum'-iss)

Pumice is light-colored 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 it 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 there is a rapid escape of the contained gas; this results in the formation of a great many minute, thin-walled bubble holes in the glass. The cellular structure of the rock tends to give it buoyancy and so it is not only lightweight but it will actually float on water. Most pumice has a composition that ranges between that of andesite and rhyolite. The only difference between obsidian and pumice is the presence of bubble holes. In other words, pumice is formed by rapid consolidation of a gas-rich magma and obsidian by rapid consolidation of a gas-poor magma.

Deposits of pumice are fairly common in eastern Oregon, and large areas of Klamath County are blanketed with it, in some places to a depth of more than 100 feet (Williams, 1942). In the Bend area of Deschutes County the mining of pumice is an active industry. The volcanic cones that have been the main sources of pumice in southcentral Oregon in late geologic time are Mt. Mazama, Newberry Crater, and Devil's Hill. Mt. Mazama is the name given to the mountain peak whose caldera is now occupied by Crater Lake.

Pumice is being used to an increasing degree in construction. In 1947 it was estimated that 33,240 short tons of pumice having a value of \$111,380 was produced in Oregon.¹ Most of this came from the Chemult-Tumalo area of Central Oregon. Lump pumice is produced from one locality near Newberry Crater and is used as an abrasive.

2. Cinders (sin'-ders)

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 $1\frac{1}{4}$ inches. Similar but finer material is called ash while material larger than $1\frac{1}{4}$ inches is called dribblet. Bombs are similar to cinders but have been modified during their flight through the air. Bombs, however, have no definite size range; they are commonly 2 to 4 inches in diameter but may be almost any size. Cinders are generally dark shades - dull reds, browns, and blacks predominate. Frequently they have a microscopically thin, iridescent crust or rind which is probably due to coating by 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.

¹Sixth biennial report: Oreg. Dept. Geology and Min. Industries Bull. 38, p. 3, 1948.

Many of the smaller volcanic cones of the High Cascades and of Central Oregon have ejected great quantities of cinders. They are a very common product of the last stages of volcanism in Oregon.

Where available, cinders have been used for railroad ballast and for road metal.

3. Tuff (tough)

Tuff is a common rock type in the areas of volcanic rocks. It is a compacted mass of fine volcanic ejecta. A combination of pumice or cinders of about pea size or less in a matrix of ash is the more ordinary type seen, but tuff can also be composed wholly of volcanic ash or dust. It frequently is bedded, indicating either deposition by water or different periods of explosive volcanic action. When deposited by water it 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 light colored; grays predominate but shades of red are not uncommon. Although it is 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. Like pumice building blocks, nails can be driven into the tuff as into wood. Some of the buildings erected in Baker thirty and forty 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

The intrusive rocks are coarse-grained rocks; they have consolidated below the surface of the earth, sometimes at distances of several miles, and have been later exposed at the surface by uplift and erosion. In other words, the covering over these rocks has been carried away after the magma consolidated.

The intrusive rocks described below represent, from granite through peridotite, rocks containing a decreasing amount of total silica. In the magma which formed granite there was an excess of silica, consequently quartz formed. This is referred to as an acid rock. In the magma which formed diorite the excess of silica was very slight if at all; consequently, little or no quartz is present in the rock. This 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 which formed are the result of a lack of silica. This is called a basic rock. The peridotites are ultrabasic rocks as the magmas from which they formed were very deficient in silica.

1. Granite (gran-it)

The term granite is greatly misused. In common usage, granite refers to any coarse-grained light-colored 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 pink but may be light green or cream colored. Other minerals do not have to be present but they usually are. The most common of the accessory minerals are mica, hornblende, and augite. Usually biotite is more common in granite and hornblende in diorite. Granite is the subsurface equivalent of rhyolite. The difference between the two lies in the manner of consolidation which is reflected in the texture.

The areas of granite are the areas of the larger intrusives, which here in Oregon are found in the Siskiyou, Blue, and Wallowa mountains. The Wallowa Mountains probably contain more true granite than any of the others.

2. Diorite (dye'-o-rite)

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, plagioclase occurring only in minor amounts. As a rule, diorites are darker colored than granites; this is 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 two to one and a quartz content as high as 15 percent.

Quartz diorite is intermediate 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 Wallowa mountains. Diorite is also found in the areas of the metalliferous veins in the Cascade Mountains and in some of the thicker sills of the Coast Range.

In the past, building and monumental stone of these coarse-grained intrusives has been quarried in Jackson, Boker, and Wallowa Counties.

3. Gabbro (gob'-bro)

Gabbro is a dark-colored, coarse-grained rock. Approximately half of the average gabbro is composed of dark-colored minerals (mainly amphibole and pyroxene); most of the remainder is plagioclase feldspar which often takes needlelike forms. Olivine is not an essential mineral of gabbro but it 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 and in some cases probably represents feeders to the overlying flows of basalt. 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 especially common in the Blue Mountains but is not uncommon elsewhere.

4. Peridotite group (per-id'-o-tite)

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-colored 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, the formation of which, in some cases, may be due to late magmatic action accompanying intrusion. Other common alteration products are talc and iron oxides. The iron oxides stain the surface a brick red color which, 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. 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 considerable area are: Douglas, Jackson, Grant, and Boker.

CLASTIC SEDIMENTARY ROCKS

1. Shale

Shales are formed by the consolidation of rock particles and mineral grains of very small size. An arbitrary figure of 1/16* millimeter is taken for the maximum size of the bulk of the particles making up rock in this class. Shales before consolidation were muds, silts, or clays. Shales are always laminated and are usually thin bedded. This is the result of the material having been 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 dominantly light colored but can be found in almost any color. If any quantity of sand-sized grains are present, the material is termed a sandy shale. If fossils are present, and they frequently are, the material is termed a fossiliferous shale. The small size of particles in shale indicates that the material was laid down either in very quiet water or a great distance from the source.

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.

2. Sandstone

Sandstone is formed from consolidation of particles larger than those which form shale and smaller than the particles of conglomerates. The arbitrary size range of sand particles is from 1/16 mm to 2 mm. By compaction, sand grains become interlocked to form a coherent mass; cementation is also usually involved in consolidation. Common cementing materials in sediments are calcite, silica, and iron oxides. When the cementing material can be determined it should be 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 common.

In Oregon, sandstones are most widely exposed in the marine rocks of the western part of the state. A large part of the Coast Range is composed of sandstones that were deposited in seas that occupied that area 40 to 50 million years ago. Marine sandstones are also widely exposed in the Willowa Mountains region and in the area near Suplee in central Oregon. Red sandstones associated with sandstones of other colors are found in the Silvies River region north of Burns, in central 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. There are no operating quarries in Oregon sandstones at this time (1949).

3. Conglomerate (con-glom'-er-at)

Breccia (bref'-chia)

Conglomerates are cemented gravels. The bulk of the material that composes them is greater than 2 mm in size and the particles may even be several feet in diameter. 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 predominantly 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

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* See footnote on page 6.

deposition near the source of the rock material. Fossils are not commonly found in these coarse rocks as the grinding action of the material rolling back and forth destroys most of the organic material before it has a chance to be preserved.

Conglomerates are found mainly in western Oregon. They are not uncommon rocks but do not make up a large proportion of the sediments as do sandstones and shales.

Consolidated angular rock debris is called grit if the particle size is just above the sand-sized particle range and breccia if the particle size is still larger. Deposits of the larger angular fragments can be formed from wave erosion at a sea cliff, by landslides or mudflows, and by talus - rock accumulation at the foot of steep mountainous slopes. Deposits from glaciers are usually angular and the special name of till is given to these rocks. When the material that composes a deposit of larger than sand-sized rounded rock is largely of volcanic origin, the term agglomerate rather than conglomerate is used. If it is of angular volcanic material it is termed a volcanic breccia. Agglomerates are very common in Oregon, especially in the Cascade Mountains and eastward. Consolidation to form these types of sediments is usually due to compaction, and mud or clay is the dominant cementing material. Mineral cementation usually plays a minor role.

UNCONSOLIDATED CLASTIC SEDIMENTS

1. 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 1/256 mm in all dimensions. When used in a mineralogical sense it refers to certain minerals. Usually the clay minerals are clay-sized particles and, conversely, deposits of clay-sized particles are commonly composed of minerals of the clay family.

Clay, as used when referring to size of particle, can be conveniently divided into two classes: 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 water deposited, it has probably formed on flood plains, in lakes, or considerable distance from a shore line. This is the most common type of clay deposit. Residual clay is directly related to the underlying rocks. It has 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 clay-sized particles.

Commercially, clay is classified according to its physical properties including the manner in which it responds to its 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 which 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 (see sample in mineral set) will not absorb a great quantity of water; this is indicated by its feel. When placed in water, flint fire clays do not lose their original shape, nor do they flake off or quickly turn the water milky as do the plastic clays. The most common test, however, is the color.

There are four large deposits of fire clay known in Oregon. One is near the town of Willamina in

Yamhill County. This is a low heat duty, plastic fire clay. Another deposit is Hobart Butte in Lane County which is a flint fire clay. The third deposit is found near Mayger in northern Columbia County, and the fourth deposit is the clay found near Molalla in Clackamas County. The deposit at Willamina is of interest in that the raw clay is black but when fired it turns to a near-white color. The black color is due to disseminated organic material; when 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. In 1948 there were twenty brick and tile plants in the state.

One of the clays of a special type is bentonite (ben-ton-ite). This denotes a clay of definite mineralogical composition. It is principally composed of the mineral montmorillonite (mont-more-ill-un-ite), essentially a complex hydrous calcium, magnesium, aluminum silicate. There are two types of bentonite, the swelling and the nonswelling. The nonswelling can be determined only by special apparatus. The swelling type, when dropped in water, will increase greatly in size. Some are known that will increase 15 times the 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. Favorable prospecting areas would be 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, in filtering and decolorizing oil and sugar, and as a bonding agent in making molds for foundries.

2. Sand

Sand is any material, mineral grains, or rock fragments, less than 2 mm and greater than 1/16 mm in size. 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 material can be ground to form sand-sized particles. If, however, the material is transported any distance, the softer materials are soon reduced to finer-sized particles. As most sands are the result of considerable mechanical wear, the more resistant minerals, such as quartz, usually are the dominant materials of a sand, and if the sand is subjected to long periods of abrasive action such as that taking place on the ocean beaches, the result would be sands composed entirely of the more resistant minerals. As quartz is very resistant to both mechanical and chemical erosion, ancient beach sands are often the source of pure quartz sand.

Sands reflect the mineral content of an area undergoing erosion. This is because the minerals are freed from the rock due to differential erosion. Because the metallic minerals are heavier than the nonmetallic minerals and are not carried away as readily by the processes of erosion, sands are a good indication of the presence of some of the metallic minerals in an area. By panning, many valuable clues as to the mineral potentialities of an area may be quickly obtained.

The tendency of the metallic minerals to "hang back" can, under favorable conditions, form large deposits relatively high in some of the metallic minerals, and man by further concentrating them may be able to mine these deposits profitably. Gold and platinum are two of the minerals that have been won from such deposits in Oregon. Other minerals that are concentrated in natural deposits because of their specific gravity are: 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 can be utilized commercially. In every concentrate, therefore, there will be found a certain amount of the whole "black sand".

Included in the mineral sets are concentrates of five minerals that have been obtained from the "black sands" of Oregon. Brief descriptions of these minerals will be found in the section describing the minerals.

NONCLASTIC SEDIMENTARY ROCKS

Chemical Precipitates

1. Travertine (trov'-er-teen)

Mineral deposits built up around springs are called tufa (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 taking more mineral matter into solution than cold, mineral deposits around hot springs are generally more common 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, 1944).

2. Sodium carbonate

The chemical composition is given in the heading rather than the rock name. This is because the sample is a mixture of minerals all principally composed of sodium carbonate and water in various proportions. As it is an aggregate of minerals this material falls into the classification of a rock and would be called a salt. The mineral matter to form this rock is due to precipitation from lake waters. Water entering the lake basin has leached mineral matter from the rocks which it flowed over and through. After reaching the lake basin the water evaporated and the mineral matter was left. As the basins in which these salts have formed have no drainage outlet, there is a slow accumulation of mineral matter with the passing years. If the concentration of minerals in the lake was quite large before the lake was dried up, beds of salts may form. If the lake existed for only a few months out of each year, there will be insufficient salts to form beds and they will then be mixed with fine-grain clastic sediments. After the lake has dried up, water from below coming to the surface, either due to capillary attraction or to springs, dissolves some of the salts from the clastic sediments and precipitates them at the surface, thereby concentrating them in localized areas. Deposits, evidently formed in this manner, are found in south central Oregon in Lake and Horney Counties. The main minerals of these salts are natron (noy'-tron) -- common washing soda, trona (tro'-no), and thermonatrite (therm-o-noy'-trite).

Organic Rocks

1. 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. This is accomplished by covering with water, that is, deposition of the vegetable material in water. The conditions necessary for the formation of large quantities of vegetable material and covering by water to prevent decay are best met under warm, humid climates in a swampy environment. Compaction causes certain chemical changes to take place as well as squeezing out some of the water. The degree of alteration that takes place determines the class of coal formed. The series from vegetable material to the various coals is as follows: (1) woody tissue, (2) peat, (3) lignite, (4) bituminous coal, (5) anthracite coal. The last is considered a metamorphic rock.

Most coal found in Oregon is sub-bituminous 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 be on the order of 3 million tons. The reserves are estimated as many millions of tons. Another coal field is known in the Eden Valley area of southern Coos County but very little work has been done in this area. Coal is also found in lesser quantities and in more restricted areas in Marion, Clackamas, and Columbia Counties as well as in the northern coast area and in the Bear Creek Valley of Jackson County. Very minor occurrences are also found in many parts of eastern Oregon.

2. Diatomite (dy-at-o-mite)

Diatomite is mainly composed of siliceous shells of a very minute single-celled plant called a diatom (dy-a-tom). Several million shells will 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 is usually white or off shades of white. It is very light in weight and easily "rubs off". It will absorb a minor amount of water but does not become plastic ("greasy") as clay does. It is very difficult to distinguish from volcanic ash.

The main uses of diatomite are: as a filtering medium, as a filler, for insulation, and for fine abrasives. 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, Oregon, Nevada, and Washington. Production in Oregon comes mainly from just west of Terrebonne in northern Deschutes County. Other deposits are known in Klamath, Lake, Harney, Malheur, Baker, Grant, and Jackson Counties. Minor beds are common throughout most of eastern Oregon.

3. Limestone

Limestone is impure 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.

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

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 and other building materials, in the pulp and paper industry, as agricultural limestone, and in the manufacture of calcium carbide -- the source of acetylene gas.

4. Coquina (ko-kee'-na)

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 great.

A deposit of coquina is found on the east side of Summer Lake Volley 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 as cementation and compaction have proceeded to an extent greater than is commonly found in coquina. As a rule, most coquina has formed in Recent time.

Coquina has the same use as limestone.

Metamorphic Rocks

INTRODUCTION

The oldest rocks found in Oregon constitute the main bodies of the Siskiyou, Blue, and Wallowa 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" or "foundation" for the rocks that cover the state. Most of the metamorphic rocks in Oregon are found in the areas of these mountains.

FOLIATE METAMORPHIC ROCKS

1. Slate

This type of rock will split 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 will vary from red and green to black.

Large areas of slate 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. There is no commercial production in Oregon.

2. Schist (shist)

Schists split readily into thin flaky slabs of irregular thickness. They are broken with difficulty across the plane of schistosity with a result that irregular frayed edges are left. The mineral grains of schists are generally large enough to be identified by the unaided eye and the nomenclature 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 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, Wallowa, and Malheur Counties of northeastern Oregon.

3. Gneiss (nice)

Gneiss is coarse grained and crudely banded. It will split more readily parallel to the banding than across it but 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 rare 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; therefore, gneisses have undoubtedly formed from these rocks. The gneisses are named for the type igneous rock from which they were derived, i.e., granite gneiss, diorite gneiss, etc.

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. Some of the samples of gneiss in the mineral sets are of this type.

NONFOLIATE METAMORPHIC ROCKS

1. Argillite (ar-jill-ite)

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. Why slates will develop a platy cleavage and argillites will not is not readily understood.

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

2. Marble

The complete recrystallization of limestone forms marble. Sometimes it is difficult to distinguish between the two. Usually marble has larger crystals, is more dense, and consequently heavier than limestone. If fossils are found in marble they are often badly distorted. Marble can be scratched easily with a knife and it effervesces readily in 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 Wallowa Mountains there is a beautiful black marble that at one time was quarried for building stone, and more recently for making lime. The greatest production of marble from Oregon for building material and monumental stone has been from Josephine and Wallowa Counties. At the present there is no production.

3. Quartzite (kworts-ite)

As the name implies, quartzite is a metamorphic rock composed essentially of the mineral quartz. It has formed by solutions high in silica, cementing quartz sands to such a degree that it is seldom possible to detect the original quartz grains. The rock has the hardness of quartz ($H = 7$) and on fresh surfaces a vitreous lustre.

Because quartzite is much harder than most rocks and as it 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.

4. Serpentine (sur'pen-teen)

Serpentine is a name applied to a group of minerals and to a rock composed principally of these minerals. It is in this last sense that it is used in this description. The minerals composing serpentine have been formed mainly from the alteration of minerals of the amphibole-pyroxene groups. Serpentine is readily formed from peridotite and to a lesser extent from basalt and gabbro. Various amounts of the unaltered or partially altered parent rock are usually found within masses of serpentine. The color of serpentine is always some shade of green, usually a dark green 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, has a pearly lustre, and a curved surface. Because it fractures easily, serpentine areas are often sites of large landslides. The rock is quite soft and may be scratched easily with a knife.

Serpentine may alter still farther to form talc or chlorite. The surface of serpentine weathers readily to a reddish soil. Consequently, large masses of serpentine are easily distinguished as they present a color that is usually in marked contrast to the surrounding area in Oregon. Southwestern Oregon, especially southwestern Josephine County and southeastern Curry County, has large areas of serpentine. Masses of considerable size are also found in Grant and Baker counties of northeastern Oregon. Restricted occurrences are common throughout all of Oregon.

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