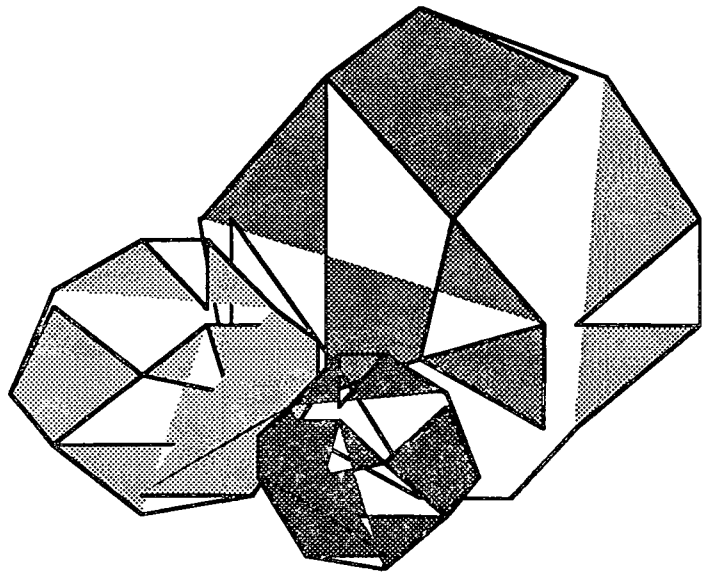


4-H Leader Guide

A Description of Some Oregon Rocks and Minerals



4-H 3401L
July 1987



OREGON STATE UNIVERSITY EXTENSION SERVICE

This publication was prepared by Lawrence L. Brown, Bureau of Mines, Albany, Oregon, in cooperation with Michael H. Holroyd, Extension specialist, 4-H and youth development. The original publication was developed by Hollis M. Dole of the State of Oregon Department of Geology and Mineral Industries and was first printed in 1950.

Extension Service, Oregon State University, Corvallis, O. E. Smith, director. This publication was produced and distributed in furtherance of the Acts of Congress of May 8 and June 30, 1914. Extension work is a cooperative program of Oregon State University, the U.S. Department of Agriculture, and Oregon counties.

Oregon State University Extension Service offers educational programs, activities, and materials without regard to race, color, national origin, sex, or disability as required by Title VI of the Civil Rights Act of 1964, Title IX of the Education Amendments of 1972, and Section 504 of the Rehabilitation Act of 1973. Oregon State University Extension Service is an Equal Opportunity Employer.

CONTENTS

| | <u>PAGE</u> |
|---|-------------|
| Introduction | 1 |
| General | |
| Minerals defined | 2 |
| Rocks defined | 2 |
| Minerals | |
| Classification | 2 |
| Identification | 2 |
| Rocks | |
| Classification | 3 |
| General | 3 |
| Igneous rocks. | 3 |
| Sedimentary rocks | 4 |
| Metamorphic rocks | 8 |
| Mineral descriptions | |
| Minerals from which metals are derived | 9 |
| Nonmetallic minerals | 20 |
| Rock-forming minerals | 25 |
| Rock descriptions | |
| Igneous rocks | 30 |
| Introduction | 30 |
| Extrusive igneous rocks | 30 |
| Flow rocks (lavas) | 30 |
| Pyroclastic rocks | 33 |
| Intrusive igneous rocks | 34 |
| Sedimentary rocks | 36 |
| Clastic sedimentary rocks | 36 |
| Unconsolidated clastic sediments | 38 |
| Nonclastic sedimentary rocks | 40 |
| Chemical precipitates | 40 |
| Organic rocks | 41 |
| Metamorphic rocks | 43 |
| Introduction | 43 |
| Foliate metamorphic rocks | 43 |
| Nonfoliate metamorphic rocks | 44 |
| 20 Most Common Elements in Earth's crust | 46 |
| Bibliography | 47 |
| references | 47 |
| Additional Reading | 48 |
| Oregon Dept. of Geology Publications list | 50-51 |
| Glossary | 52-56 |
| Index | 57-61 |

CHARTS

| | <u>PAGE</u> |
|---|-------------|
| Igneous Rock Chart | 5 |
| Classification Of Sedimentary Rocks | 7 |
| Classification Of Clastic Sediments According To Size | 8 |
| Metamorphic Rocks | 10 |

A DESCRIPTION OF SOME OREGON ROCKS AND MINERALS

By Hollis M. Dole

Revised 1976 and 1985 by Lawrence L. Brown

Introduction

In the pioneer days many of the early settlers came to Oregon because 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. This is true for almost every state in the United States. The search for and utilization of minerals, both metallic and nonmetallic, is still continuing. There is still mineral wealth to be found or recognized in the state.

Every year many people of Oregon visit different parts of at 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 landforms contribute greatly to that grandeur.

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

Knowledge gained by studying the information contained and collecting and studying samples of the rocks and minerals described will add greatly to the pleasure and enjoyment of travel not only around Oregon, but everywhere. It will give a greater understanding and appreciation of our environment.

G e n e r a l

The crust of the earth forms a thin skin over the earth and ranges in thickness from about 5 miles at some places under the oceans to about 30 miles under high mountains. It is 4000 miles to the earth's center. Tremendous forces are available inside the earth to move its crustal surface up and down and laterally. The crust has been broken into many segments that have been and are very slowly moving over the surface by these forces. The segments are called plates. In places crustal plates are in collision with each other with one plate sliding under the other. In other places they are spreading away from each other. New crust is being added in mid-ocean spreading zones where molten rocks are welling up to fill the fractures that result from the spreading. For example, the rocks at the top of the Himalaya Mountains are sedimentary rocks that have been uplifted 6 miles above sea level where they formed. Two plates are in collision. This type of geological activity is referred to as plate tectonics.

Minerals defined

The earth's crust is composed of rocks and minerals. Minerals are defined as natural inorganic substances, usually crystalline, whose composition can be expressed by a chemical formula and which have physical properties that are definite or variable within limits*. Close to 3000 different minerals have been identified and named. 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.
4. It must be homogeneous, that is, no matter how finely it is divided, each part is like any other part.
5. It is usually crystalline, that is, the molecular structure always has a definite arrangement.

Rocks defined

Rocks are defined as aggregates or mixtures of minerals; rocks also include noncrystalline materials such as the natural glasses and organic material such as coal. Rocks are found ready-made in nature. They are not homogenous 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 an area has undergone.

M i n e r a l s

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.

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

Physical properties of minerals are:

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

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

R o c k s

Classification

GENERAL

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

IGNEOUS ROCKS (Ignis -- like fire, containing fire)

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 the relationship of the minerals of the rock to each other. 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 the size that can be identified with the eye.
3. Felsitic (aphanitic, compact, stony) -- The mineral grains are so small that they cannot be distinguished from each other by eye.
4. Glassy -- The rock has a glassy appearance; few, if any, mineral crystals are present, and the rock then is not made 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 solidification 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 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 a 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 the earth or locally along the edges of the flow or intrusive. When in large masses, glassy rocks could only be extrusive rocks. Fragmental rocks usually are extrusive rocks because the explosive eruption which forms them can take place only at or near the surface of the earth.

Classification of igneous rocks by the mineral content depends upon the amount and the presence or absence of a few minerals, commonly called essential minerals. These diagnostic minerals are:

1. Feldspars
2. Quartz
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 feldspars, amphiboles, and pyroxenes but not with quartz. A classification of some of the more common rocks based on the texture and mineral content is found in the igneous rock chart.

SEDIMENTARY ROCKS (Settled, settling)

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

IGNEOUS ROCK CHART

| | | 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 |
| MINERALS | ESSENTIAL MINERALS | Quartz present | Quartz absent | Quartz present | Quartz absent | Olivine and Quartz absent | Olivine present | Olivine present | |
| | ACCESSORY MINERALS None, one or more may be present | Mica ----- Amphibole | Mica ----- Amphibole | Black Mica ----- Amphibole Pyroxene ----- Amphibole | Black Mica ----- Pyroxene ----- Amphibole | Pyroxene ----- ----- Amphibole | Pyroxene ----- ----- Amphibole | Pyroxene ----- ----- Black Mica | |
| CHARACTERIZING | | ROCK NAME | | | | | | | |
| USUAL OR CHARACTERISTIC TEXTURE | Granitic | Granite | Syenite | Quartz diorite ----- grano- diorite | Oiorite | Gabbro | Olivine gabbro | Peridotite ----- dunite (olivine only essential mineral) | INTRUSIVE ROCKS |
| | Porphyritic with fine granitic groundmass | Granite porphyry | Syenite porphyry | Quartz diorite porphyry | Oiorite porphyry | Olabase | Olivine diabase | In medium-sized mass. Slow cooling at depth followed by faster cooling closer to surface. | |
| | Felsitic or porphyritic with fine-grained groundmass. Large mineral grains not common. | Rhyolite | Trachyte | Oacite | Andesite | Basalt | Olivine Basalt | In flows or near surface intrusive of small size. Rapid cooling. | |
| | Fragmental or pyroclastic | Rhyolite tuff ----- Rhyolite agglomerate or Breccia | Trachyte tuff ----- Trachyte agglomerate or Breccia | Oacite tuff ----- Oacite agglomerate or Breccia | Andesite tuff ----- Andesite agglomerate or Breccia | Basalt tuff ----- Basalt agglomerate or Breccia | Olivine basalt agglomerate ----- Olivine basalt agglomerate | Explosive eruptions at surface. Rapid cooling. | |
| | Glassy | ← VOLCANIC GLASSES → Obsidian, perlite, pumice | | | | | | | |
| Usual or comparative color | Light-colored rocks | | Intermediate-colored rocks | | Dark-colored rocks | | | | |

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 or materials high in calcium deposited by animal life, 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 of 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 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 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 in that area the sediments accumulated are almost entirely limey organic materials.

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

CLASSIFICATION OF SEDIMENTARY ROCKS

| | Unconsolidated | Consolidated | Common Constituents | Remarks |
|--------------------------------|------------------|--------------------------------|---|-----------------------------------|
| <u>Clastic</u> (mechanical) | Mud or Clay | Shale | Clay minerals, quartz | Well bedded |
| | Sand | Sandstone | Quartz, feldspar | Poor to no bedding |
| | Gravel | Conglomerate | Rounded, coarse rock fragments | |
| | Talus | Breccia | Angular rock fragments. (Found at base of mountains or sea cliffs) | |
| | Till | Till | Rock fragments of all sizes (Deposits of glaciers) | Usually 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 | |
| (chemical) | Saline mud | Salt beds | Common salt, gypsum, nitrates | Chemical precipitate |
| | Iron rich mud | Iron-bearing beds | Limonite and clay | Bedding may or may not be present |
| | Minerals springs | Travertine Siliceous sinter | Calcite Silica | |

| PARTICLE SIZE INCREASES | SIZE RANGE | NAME | | DEGREE OF FINENESS |
|---|------------------|---------|-------------------------|-------------------------|
| | Coarser and 2mm* | Boulder | Gravel | Coarse-grained clastics |
| | | Cobble | | |
| | | Pebble | | |
| 2mm to 1/16 mm | Granule | Sand | Medium-grained clastics | |
| 1/16 mm and finer | Silt | | Fine-grained clastics | |
| *mm = Millimeter. One inch is equal to 25.4 mm. A U.S. five cent piece is about 2 mm thick, a little more than 2 centimeters in diameter, and weighs about 5 grams. | | | | |

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 adjectives. For instance, "a bouldery sandstone" or "a sandy shale."
3. The degree of roundness of the grain. Three degrees of roundness commonly used are: a) well rounded, b) subrounded, c) 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.

METAMORPHIC ROCKS (Meta = change; Morph = form)

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 criterion of age must be used with caution, however.

The metamorphic rock most easily recognized as such, is the rock that has a parallel arrangement of mineral grains. When a crude banding of the mineral grains is seen, the rock is called gneiss. Sometimes the alignment of crystal grains of the rock is so well developed that it will split readily into thin flaky slabs or sheets. 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 specimens 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 very low grade 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 conversion of limestone to 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). A few of the rocks in each type are listed in the chart on metamorphic rocks.

M i n e r a l D e s c r i p t i o n s

Minerals from which metals are derived

BAUXITE (box'-ite) From original locality at Baux, France - an ore of aluminum

In the strict sense of the word, bauxite (box'-ite, from original locality at Baux, France (Mitchell, 1978) -- an ore of aluminum) is not a mineral but a rock, as it is a mixture of hydrated aluminum oxides such as gibbsite (for George Gibbs an early mineralogist) and boehmite (bow'-mite, for Johannes Bohm a german geologist) and diaspor (from Greek - to scatter, in allusion to its decrepitation when heated), together with some iron oxide, titanium oxide, and silica.

METAMORPHIC ROCKS

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

It is a generic term for rocks rich in hydrous aluminum oxides. With increasing hydrous iron oxide content, it grades to laterite (from Latin-later, brick). Bauxite occurs in oolitic and earthy masses. Colors range from white to tan to brown. Pure bauxite minerals sometimes have delicate tints. Low silica content as well as high aluminum oxide determines whether or not bauxite may be utilized as an ore of aluminum. The bauxite found in northwestern Oregon is high in iron oxides, and so 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 shot-like 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, possible 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. There is still interest in these areas and Oregon may at some time become 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.

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.

Aluminum is used extensively in airplanes, railroad cars, machinery, packaging material, 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.

Chalcopyrite (kal'-ko-pie'-rite) from Greek chalcos (copper) and similar to pyrite (CuFeS₂) -- an ore of copper

This is a chemical combination of the elements copper, iron, and sulfur. Its brassy-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 the sides of crystals. Also chalcopyrite often has a bluish iridescence or sheen caused by oxidation.

In the period 1852-1947 Oregon produced \$4,646,443 in copper¹. the principal ore mineral of which was chalcopyrite. Production since then has been very small. The areas of greatest copper production were: southwestern Oregon, the central Cascades, the Blue Mountains, and the Wallowa's. Chalcopyrite is also found as a common accessory mineral in many quartz and gold-bearing veins in these same areas. Copper production today is sporadic.

Chromite (krow'-mite) from composition, contains chromium (FeCr₂O₄) --an ore of chromium

The most readily identifiable characteristic of chromite is its brown streak. This distinguishes it from magnetite (magnetic iron oxide) with which it is most likely to be confused as both are black, heavy minerals. 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 uvarovite (for count Sergei Uvarov an early Russian nobleman and scholar).

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, 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 South Africa, Russia, Turkey, Zimbabwe (Rhodesia), the Philippine Islands, India and Finland. In times of international stress, when the shipping lanes are closed, domestic sources of chromite must be employed, but under peacetime conditions domestic chromite cannot compete with foreign chromite. During both world wars, Oregon was a prominent contributor to the nation's supply of this very strategic mineral. For instance, during World War II, Oregon produced chromite which was valued at nearly \$1,000,000 (Libbey, 1948)*. At the present time, there is no production of chromite in Oregon. However, Oregon chromite will always be an important factor in the natural resources of our nation.

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.

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

*See bibliography in back of this paper.

Cinnabar (sin'-a-bar) from Medieval Latin cinnabaris, with a history traced to Persian, Zinjifrah-Dragon's Blood (HgS) -- an ore of mercury (quicksilver)

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

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

More than 60 percent of the nation's present supply of mercury is produced from one mine in Nevada, the rest is imported from Algeria, Spain, and Mexico. 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. Cinnabar is found in many localities in Oregon. 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 western Cascades, the Ochocos, and in the volcanic rocks of southeastern Oregon.

Galena (ga-lee'-nah) from Latin galena a name given to lead ore (PbS) -- an ore of lead

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 step-like and when the piece is broken the fragments will tend to cleave into cubes or rectangles, always with square corners. It has perfect cubic cleavage.

Galena is a chemical combination of lead and sulfur 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. Oregon's production of lead is sporadic. Although galena is a common accessory mineral in many of the gold and copper veins in Oregon, the bulk of the production has come from the Cascades, especially in the Bohemia and the North Santiam mining districts.

Garnierite (gar-neer'-ite) named for Jules Garnier, A French engineer who discovered the mineral in New Caledonia -- an ore of nickel

Garnierite is a generic name for nickel-hydrosilicates; that is, it is composed of nickel, silicon, oxygen, and water. It is a mixture of several nickel-hydrosilicates and in that sense is not a single mineral (Pecora, Hobbs, and Murata, 1949). It has been formed by the weathering (chemical alteration) of a peridotite 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 "rotting rock" is called sapprolite from the Greek word sappros-rotten.

The only producing nickel mine in the United States is operating at the garnierite-laterite deposit on Nickel Mountain in Douglas County near Riddle, Oregon. Other areas in southwest Oregon, including Red Flats in Curry County and Woodcock Mountain in Josephine County, are potential producers of nickel from nickeliferous laterites.

Gibbsite (gib'-site) named for George Gibbs an early mineralogist whose collection was added to Yale University early in the 19th century. $(Al(OH)_3)$ --an ore of aluminum

Gibbsite is a chemical combination of aluminum oxide and water, and is one of the minerals usually included in bauxite. Because it is similar in appearance to some of the clay minerals, 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 some of which are banded. The colors of the bands are pink, yellow, and cream and when cut and polished the results 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 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.

Gold ore -- gold an Old English word for the metal

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 contains one ounce per ton of rock under ordinary conditions is considered to be very good ore. 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.

Often times pyrite (a mineral composed of iron and sulfur) and chalcopyrite (a copper and iron sulfide) 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 melt by molten lead which is added as litharge in the original smelting operation.

When gold 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 at the surface of the earth by dredges, large mechanical shovels, or by hydraulicking, panning, or sluicing, it is termed placer mining. The largest production of gold in Oregon is by placer mining methods. In 1940, the year of Oregon's maximum production of gold to date, \$2,505,195 was recovered by placer methods and lode production reported by the Bureau of Mines, was \$1,463,875. Total recorded production of gold in Oregon in the period 1852-1965 was valued by the U.S. Bureau of Mines at \$130,000,000. Production since that time generally has been small and sporadic, amounting to only a few thousands of dollars per year even through the value of an ounce of gold has risen about 10 times higher than it was in 1940. At present only a few small mines are in operation.

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

Hematite (hem'-a-tite) from Greek - haimatitis - blood red an allusion to its color (Fe_2O_3) -- an ore of iron

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 black flaky pieces. This last type is called specular hematite because of its very shiny reflective surfaces.

Hematite can best be identified by its streak, which is blood red. 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 and more brown 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.

Ilmenite (ill'-men-ite) from the Ilmen Mountains in Russia where it was first found (FeTiO_3) -- an ore of titanium

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 may be associated with magnetite. As an accessory mineral it occurs as very small disseminated grains, usually fairly well formed. Ilmenite is a common constituent of black sands. Oregon Metallurgical Company in Albany is one of the few producers of titanium metal and alloys in the United States.

Limonite (lie'-mo-nite) from Greek -leimon-meadow in allusion to its occurrence in bogs and swamps. ($2\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$) -- an ore of iron.

Limonite is a generic term for minerals of iron oxide chemically combined with water. In Oregon it is commonly found in yellowish-brown earthy deposits. 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 then precipitating it elsewhere under swampy conditions. The iron originally may have been in chemical combination with some of the minerals of a basaltic lava. Search for this type of deposit would be in areas of basalt flows and especially flows of an age in which chemical weathering was prominent.

The only production of iron in Oregon was during the period 1867-1894 from limonite found in the hills just west of Oswego. Pig iron and cast iron pipe were produced from these ores in a plant at Oswego where the first blast furnace of the Pacific Coast was built (Libbey, 1940). Limonite ores west of Scappoose have long been known and have been investigated 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 ever used for treatment of this ore, pig iron would be one of the co-products. Even if this process is not used, these deposits contain a valuable potential reserve of iron.

Magnetite (Mag'-ni-tite) from an ancient term attributed to the locality Magnesia, a district in Greece ($\text{FeO} \cdot \text{Fe}_2\text{O}_3$) -- an ore of iron

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

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

Manganite (man'-ga-nite) from the composition - contains manganese ($\text{MnO}(\text{OH})$)

Psilomelane (sil-om'-e-lane) from Greek - psilos = smooth and melan = black ($\text{BaMn}^{+2} \text{Mn}^{+4}_2 \text{O}_{16} (\text{OH})_4$)

Pyrolusite (pie-row-lu'-site) from Greek - pyros = fire and louein = to wash because it is used to rid glass of brown and green tints. (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, psilomelane is the hardest (H = 5-7), manganite follows closely (H = 4), and pyrolusite is the softest (H = 2-2.5). Color of each is dark steel gray to iron black. Both manganite and psilomelane 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. Often times 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 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 prospecting for the minerals.

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

Molybdenite (mo-lib'-de-nite) from composition molybdenum from greek word molybdos-lead (MoS_2) --- an ore of molybdenum

Molybdenite is a combination of the elements molybdenum and sulfur. 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. 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 added to iron form steels having special properties and uses.

Pyrite (Py'-rite) the name from Greek Pyrites lithos "stone which strikes fire" (FeS_2) in allusion to the sparking produced when iron is struck with a lump of pyrite.

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

Pyrrhotite (peer'-ho-tite) from Greek for redness (purros) ($\text{Fe}_{(1-x)}\text{S}$)

Pyrrhotite is composed of iron and sulfur. It is really a solid solution of sulfur in iron sulfide. It is of commercial importance because it frequently contains nickel and cobalt minerals in amounts sufficient to be classed as an ore of these elements. It is readily identified for it is the only 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.

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 sulfide), and chalcopyrite.

Sphalerite (Sfa'-ler-ite) from greek - sphaleros "treacherous" in allusion to its similarity to more easily smelted ore. $(\text{Zn}, \text{Fe}) \text{S}$ -- an ore of zinc

Sphalerite is a chemical combination of zinc and sulfur with variable amounts of iron which is responsible for its color. The color ranges from almost colorless and transparent through pale yellow to honey brown to very black and opaque (black jack-a miners name). It is very brittle and shows perfect cleavages, has a resinous to adamantine luster and forms tetrahedral crystals groups which resemble octahedrons. Sphalerite is a major source of cadmium and indium, elements which occur as trace elements in the sphalerite.

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

Stibnite (stib'-nite) from Greek - stimmi and Latin - stibi, old names applied to the mineral (Sb_2S_3) -- an ore of antimony

Stibnite is a chemical combination of antimony and sulfur. 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, sphalerite, and galena. Sometimes good values in gold are associated with stibnite.

Although Oregon has produced some stibnite the quantity is small. Production has been sporadic and it would be difficult to estimate the total. Of the five mines in the state that have production records, two are located in southwestern Jackson

County, one in central Baker County, one near the Baker-Union county line, and one near the Baker-Malheur county line. Besides the above counties, prospects are found in eastern Grant County and in the western part of the Bohemia District of Lane County.

Zircon (zir'-con) from Arabic zarqun, from Persian zar-gold and gun-color ($ZrSiO_4$) an ore of zirconium and hafnium

Zircon is a chemical combination of the elements zirconium, oxygen, and silicon. When found in sands it is usually in small, clear, pointed rectangular crystals. It is quite hard (H = 7.5) and has a specific gravity almost twice that of quartz. Therefore, it is frequently found associated with the heavier dark-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 and hafnium from zircon sands was developed by the U.S. Bureau of Mines at their Northwest Electro-development Laboratory at Albany, Oregon, now the Albany Research Center. Among the uses of metallic zirconium at present is in nuclear power plants, in the making of special steel alloys, and in vacuum tubes, flash bulbs, pyrotechnics and materials of construction for chemical plants. Hafnium is very expensive, it is used for control rods in nuclear power plants.

Nonmetallic Minerals (minerals used mostly as they are)

Agate (ag'-it) from the locality in the ancient river Achates now Carabi, in Sicily (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 impurities and different periods of deposition in the filling of the cavity. The waviness of the lines is due to the irregularities in the cavity. The "moss" commonly seen is due to fernlike growths of some mineral, such as manganese oxide or iron oxide minerals.

The formation of agates requires solutions rich in silica. Therefore 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 "thunderegg" localities of Wasco, Jefferson, Harney, Crook, Deschutes, Malheur, and Lake Counties. The Priddy 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. The Oregon State Rock is the thunderegg, an agate filled nodule.

Asbestos (as-bess'-tuss) from the Greek for inextinguishable, after the misconception that once ignited it could not be extinguished.

Asbestos is a name applied to certain 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.

Barite (bay'-rite) from Greek barus = heavy, in allusion to its relatively high specific gravity ($BaSO_4$)

As indicated by its name, barite is a compound containing the element barium; it is barium sulfate. 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 in sulfide 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 mineral. Barite has never been produced commercially in Oregon. It is found in lenses and pods of probable mining

width in the Almeda and Silver Peak mines of Josephine and Douglas Counties and also in one prospect between these mines. These occurrences usually have pyrite disseminated through the barite.

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

Calcite (kal'-site) from Latin calx = lime (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 or 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.

Gypsum (gyp'-sum) from Greek gypsos = plaster, an ancient name for gypsum and its calcined product. ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$)

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

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 further east in Idaho. Another deposit consisting of gypsite in volcanic tuff occurs in southwestern Crook County near Bear Creek. It is possible that this deposit was formed by the action of sulfuric acid, resulting from the weathering of sulfides, on limestone rather than precipitation from saline waters.

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

Realgar (ree-al'-gar) from Arabic - Rahj Al Ghar = powder of the mine

Orpiment (or'-pih-ment) from Latin - auripigmentum = golden paint, in allusion to its color and early use. (As_2S_3)

Both these minerals are sulfides 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 distinctively 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.

Rhodonite (row'-doe-nite) from the Greek for rose-rhodon, in allusion to its characteristic color. ($MnSiO_3$)

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 usual thin coating of black manganese oxides occurring along fractures and exposed faces.

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

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

Sulfur (sul'-fur) from Latin sulfur, an old name akin to Sanskrit-Sulvere. (S)

Sulfur is one of the 103 known elements, that is, substances which cannot at will be decomposed, or divided into others. Sulfur combines with most of the metallic elements to form sulfides. When in combination with oxygen and a metal it forms sulfates of the metal. The yellow color of native sulfur is characteristic. Other identifying features are: it melts at low temperature ($108\text{ }^\circ\text{C.}$) and burns with a bluish flame giving off choking fumes of sulfur dioxide. Contrary to popular belief, sulfur is tasteless and odorless. Sulfur is found associated with sedimentary rocks especially in the gypsum and limestone areas and in areas of recent volcanism.

Excepting a few spots of sulfur 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 phases from a solfatara (a volcanic vent from which sulfur gases emanate) condensing in clay. This deposit is evidently small and is probably only of academic interest.

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

A very important use of sulfur in the Northwest is in the manufacture of paper pulp. Every year hundreds of tons are used in Oregon. Total consumption of sulfur for this purpose in the United States is over 500,000 long tons. Other important industrial uses are found in the manufacture of chemicals, fertilizer and insecticides, explosives, paint and varnish, and rubber.

Talc - probably from Arabic - Talq. $[Mg_3Si_4O_{10}(OH)_2]$

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, 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. The states producing talc and similar materials are California, North Carolina, Vermont, Georgia, Washington, Montana, New York, Maryland, Pennsylvania, and Virginia.

The bulk of the production of talc and similar materials is used by the paint, rubber, roofing, ceramics, and insecticide industries. Only a small percentage of the total is used for the making of talcum powder and other toilet preparations.

Rock-forming Minerals

The following are typical minerals that, in combinations with other minerals, compose many of the common rocks. As constituents of rocks they have no commercial value 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.

Amphibole group (am'-fi-bole) - from greek amphibolos-ambiguous, in allusion to the great variety of composition and appearance by this group of minerals

This is a name applied to a large 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. Common Amphibole minerals are: hornblende, actinolite, tremolite, and anthophyllite. A finely fibrous, compact, dense variety of actinolite is nephrite jade.

Feldspar group (feld'-spar) from Swedish names for field-feldt and stone-spar in reference to the spar in tilled fields overlying granite.

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 may show a peculiar minute "gridiron" or "grating" pattern. The 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. Plagioclase feldspars are albite, oligoclase, andesine, labradorite, bytownite, and anorthite.

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.

Garnet group (gar'-net) from Latin granatum = pomegranate, the seeds of which garnets were thought to resemble.

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 or red 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. Common garnet minerals are grossularite, almandite, spessartite, and pyrope. A very fine grained variety of green grossularite found in southwestern Oregon is a pseudojade called Oregon jade. Some sandpapers are coated with crushed, sized, garnet. It is also used for sandblasting.

Mica group (my'ca) from Latin micare meaning to shine

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) from Muscovy Glass, name used when the mineral was first described from the Russian province of Muscovy -- Usually almost colorless or light shades of green and yellow.

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

Biotite (by'-o-tite) for Jean Baptiste Biot, French physicist -- Usually black to dark green in color. Altered biotite may be mistaken for phlogopite.

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."

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

Olivine (ol'-i-veen) in allusion to its olive-green color. $[(Mg,Fe)_2SiO_4]$

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 materials 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.

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 the making of refractories and for foundry sands. 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. The gemstone peridot, is olivine.

Pyroxene group (pie'-rox-ene) from Greek for fire - pyro and stranger-xenos --- it was incorrectly believed to be out of place in igneous rocks.

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 of magnesium, iron, aluminum, and calcium. The most common pyroxene is the mineral augite. Other common minerals of the group are enstatite, hypersthene, diopside, pigeonite, and aegerine. One of the group, jadeite, is precious jade.

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 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, diabases, and peridotites the pyroxenes often make up a large percentage of the rock. Because of the ease with which they alter, pyroxenes are not found in sedimentary and metamorphic rocks as frequently as in igneous rocks. It is not uncommon to find pyroxene altered to amphibole.

Quartz (kwarts) from Saxon -- querkluffertz meaning cross-vein ore, the word was condensed. (SiO₂) (See also agate p. 20)

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

The combination of the elements silicon and oxygen is termed silica, and the crystalline variety of silica is called quartz. The individual crystals vary in size from microscopic to several feet in length. The color of quartz is usually white or clear but it may be any shade of the rainbow. 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 (shell like) 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 can supply 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 adaptable, after suitable beneficiation, as a source of glass sand.

Tourmaline (tur'-ma-lene) Singhalese - turamali, a term originally applied to zircon and other gems by Jewelers of Ceylon.

General formula (Na,Ca)(Mg,Fe⁺², Fe⁺³, Al, Li)₃
Al₆(BO₃)₃(Si₆O₁₈)(OH, F)₄

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

There are several varieties of tourmaline; the color varies from blue, green, and red, to brown and black. Gem varieties are colored and may display different colors within the same crystal. The large tourmaline crystals always are three-, six-, or nine-sided, and the sides are always deeply striated. As an accessory mineral, tourmaline 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 Wallowa Mountains.

Zeolite group (ze'-o-lite) -- water stone -- from Greek zein-"to boil" because of its behavior before flame.

A large family of hydrous silicates of sodium, calcium, barium, potassium and strontium, usually colorless to white, which show close similarities in composition, association and occurrence. They are secondary minerals forming best in cavities in lava flows. There are about 50 named zeolite minerals.

Many rocks which appear to be tuffs or andesites or others have been completely "altered" to zeolite minerals.

Natural zeolites have been used for water purification. Synthetic (man made) zeolites are compounded for that use now.

Very fine specimens of zeolite minerals are found in many different localities around the state.

R o c k D e s c r i p t i o n s

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 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 set up.

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 in the igneous rock chart should be consulted and the name of the rock determined.

Extrusive Igneous Rocks

Flow Rocks (Lavas)

Basalt (ba-salt')

Basalt is one of the most common rocks to be found in Oregon. It is black to dark gray to brown 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 frequently present and sometimes occurs as small, clear to black, rounded

fragments with conchoidal fracture and vitreous lustre. Most basalts contain some magnetite 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 and fissures 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.

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 metalliferous mineral veins, especially veins containing cinnabar, but areas of andesite flows are usually not considered as favorable prospecting areas.

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. Banding 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 area associated with the feeders to the flows. Agates are frequently found in the beds of the streams draining the rhyolite areas, and the state rock, the "thunderegg," is found in and near rhyolite flows.

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

Perlite (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, may expand or "pop" to

several times its original size. By utilizing this principal 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, was mined for a time and a plant for processing the raw material was built at the mine.

Pyroclastic Rocks

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 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). The volcanic cones that have been the main sources of pumice in southcentral Oregon in late geologic time are Mt. Mazama, Newberry Crater, and Devel'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 as a lightweight aggregate. The Chemult-Tumalo area and in general the Bend area of Deschutes County, is an active area of pumice mining. Lump pumice is produced from one locality near Newberry Crater and is used as an abrasive.

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 1-1/4 inches. Similar but finer material is called ash while material larger than 1-1/4 inches is called dribblet or spatter. 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, brown, 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.

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.

Tuff ('tuf)

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 the 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 eighty and ninety 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 shortage of silica. This is called a basic rock. The peridotites are ultra basic rocks as the magmas from which they formed were very deficient in silica.

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 white or pink but may be cream colored or light green. 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 crystallization and 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.

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, Baker, and Wallowa Counties.

Gabbro (gab'-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.

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 a real extent, contrasts sharply with its surroundings. In the weathering of some peridotites certain minerals are sometimes etched into relief, giving the rock a very rough outer surface of red to tan color. Prospectors often refer to outcrops of this kind as "buckskin rock."

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

SEDIMENTARY ROCKS

Clastic Sedimentary rocks

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 a 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 of the shale indicates that the material was laid down either in very quiet water or a great distance from the source or both.

* See table on page 8

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

Sandstone

Sandstone is formed from consolidation of particles larger than those 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 Wallowa 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.

Conglomerate (con-glom'-er-at)

Breccia (bret'-chia)

Conglomerates are cemented gravels. The bulk of the particles that compose them is greater than 2mm in diameter and may range in size up to several feet through. Usually there is a great diversity in the size range but it is not uncommon to find material that is well sorted, that is, all about the same size. The material of conglomerates is predominately rock fragments rather than mineral grains. The fragments usually show some rounding and may be well rounded. Conglomerates represent rapid erosion by streams and waves and deposition near the source of the rock material. Fossils are not commonly found in these coarse rocks 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 as large a 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 mud flows, 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. However, some conglomerates are cemented so hard that when broken they will break across the pebbles.

Unconsolidated Clastic Sediments

Clay

Clay is an earthy aggregate. The term has a double meaning. When used to describe the size of a particle it refers to material less than 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 families.

Clay, as used when referring to size of particle, can be conveniently divided into two classes: a transported clay and residual clay. Transported clay is a finely ground or weathered rock that has been carried by water or wind, often great distances, before being deposited. It bears no relation to the underlying rock. It is a heterogeneous mixture of mineral grains, usually of varied composition. It implies slow deposition, either in quiet waters or from the air. When water deposited, it has probably formed on flood plains, in lakes, or at a 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 being clay-sized particles.

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

It is impossible to tell whether a clay is of fire clay grade unless it is subjected to a firing test. However, there are some preliminary tests 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 will not absorb a great quantity of water; this is indicated by its feel. When placed in water, flint clays do not lose their original shape, nor do they flake off or quickly turn the water milky as do the plastic clays. 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.

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 bulk. Some are known that will increase 15 times their 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.

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 sands.

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

Nonclastic Sedimentary Rocks

Chemical Precipitates

Travertine (trav'-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).

Sodium carbonate

The chemical composition is given in the heading rather than the rock name. This is because the material 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 from 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-grained 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 Harney Counties. The main minerals of these salts are natron (nay'-tron) -- common washing soda $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$, trona (tro'-na) $\text{Na}_3(\text{CO}_3)(\text{HCO}_3) \cdot 2\text{H}_2\text{O}$, and thermonatrite (therm-o-nay'-trite) $\text{Na}_2\text{CO}_3 \cdot \text{H}_2\text{O}$.

Organic Rocks

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. No coal is being mined in Oregon at the present time.

Diatomite (dy-at'-o-mite)

Diatomite is mainly composed of siliceous shells (skeletons, frustules) 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 very fine grained volcanic ash.

The main uses of diatomite are: as a filtering medium, as a filler, for insulation, and for fine abrasives. It also makes good kitty litter and in Christmas Valley it is mined and sold for this use. In determining its use, the shape of the diatom shells is important as well as the purity of the diatomite. The chief producing states in the United States are California, Kansas, Oregon, Nevada, and Washington. The greatest production in Oregon came 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.

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 warm 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.

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 Valley, 12 miles northwest of Paisley in Lake County. A chemical analysis of this material gave 61.5 percent calcium carbonate and 30.1 percent magnesium carbonate (Wagner, 1947).

Parts of the Marquam Limestone Quarry in southwestern Clackamas County contain porous masses of shells and shell fragments. This deposit was formed in an ancient sea; however, it is not typical of rocks of this classification 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 times.

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 Willowa Mountains, and are exposed near the base of the Pueblo Mountain escarpment. It is thought that extensions of these or similar rocks form the "basement" 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

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.

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.

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 of 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.

Nonfoliate Metamorphic Rocks

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.

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.

Quartzite (kwarts'-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 may not be possible to detect the original quartz grains. The rock has the hardness of quartz (H = 7) and on fresh surfaces has a vitreous luster.

Because quartzite is much harder than most rocks and 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.

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 luster, 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 further 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.

THE 20 MOST COMMON ELEMENTS IN THE EARTH'S CRUST
IN THE ORDER OF THEIR ABUNDANCE (After Mason)

| <u>Element</u> | <u>Symbol</u> | <u>Weight Percentage</u> |
|---------------------------|---------------|--------------------------|
| Oxygen | O | 46.60 |
| Silicon | Si | 27.72 |
| Aluminum | Al | 8.13 |
| Iron | Fe | 5.00 |
| Calcium | Ca | 3.63 |
| Sodium | Na | 2.83 |
| Potassium | K | 2.59 |
| Magnesium | Mg | 2.09 |
| Titanium | Ti | 0.44 |
| Hydrogen | H | 0.14 |
| Phosphorous | P | 0.118 |
| Manganese | Mn | 0.100 |
| Flourine | F | 0.070 |
| Sulfur | S | 0.052 |
| Strontium | Sr | 0.045 |
| Barium | Ba | 0.040 |
| Carbon | C | 0.032 |
| Chlorine | Cl | 0.020 |
| Chromium | Cr | 0.020 |
| Zirconium | Zr | 0.016 |
| All others (+72 elements) | | <u>.317</u> |
| | | 100.000 |

BIBLIOGRAPHY

- Allen, V. T.,
1948 Fahey, J. J., and Axelrod, J. M.
Mansfieldite, a new arsenate, the aluminum analogue of scorodite, and the mansfieldite-scorodite series: Am. Mineralogist, vol. 33, nos. 3 and 4, p. 124.
- Bartell, A. O.,
1949 Northwestern Oregon iron ores:
Raw Materials Survey News Letter, pp. 3-5, February, 1949.
- Libbey, F. W.
1940 Oswego Iron: Geol. Soc. Oregon Country News Letter,
Vol. 6. no. 22, pp. 194-197.
- 1948 Oregon's mining industry: Oregon Dept. Geology and Min,
Industries Ore.-Bin, vol. 10, no. 2, p.10.
- Mitchell, Richard S.
1979 "Mineral Names," What Do They Mean, Van Nostrand and
Reinhold Company, New York.
- Pecora, W. T. and Hobbs, S. W.
1942 Nickel deposit near Riddle, Douglas County Oregon: U.S.
Geol. Survey Bulletin. 931-1, p.205.
- Pecora, W. T., Hobbs, S. W. and Murata, K. J.
1949 Variations in garnierite from the nickel deposit near
Riddle, Oregon: Econ. Geology, vol. 44, no. 1, pp. 12-23.
- Wagner, N. S.
1944 Travertine deposits near Durkee, Baker County, Oregon:
Oregon Dept. Geology and Min. Industries unpublished
report.
- 1946 Gypsum mine on the Snake River below Huntington, Oregon:
Oregon Dept. Geology and Min. Industries unpublished
report.
- 1947 Ten-mile Ridge Claims, Lake County Oregon: Oregon Dept.
Geology and Min. Industries Unpublished Report.
- Williams, Howel
1942 Geology of Crater Lake National Park, Oregon: Carnegie
Inst. Washington Pub. 540, p. 70.

ADDITIONAL READING

- Alt, David D. & Hyndman, Donald W.
1978 Roadside Geology of Oregon, Mountain Press Publishing Co., 279
WestFront St., Missoula, MT 59801
- Baldwin, Ewart M.
1964 Geology of Oregon, U. of O. Book Store.
- Bateman, Alan M.
1951 The Formation of Mineral Deposits, John Wiley and Sons, Inc., New
York
- Bates, Robert I. & Jackson, Julia A.
1980 Glossary of Geology, American Geological Institute, Falls Church,
Virginia.
- Dana, Edward S. (Ford, W. E.)
1958 Dana's Textbook of Mineralogy, John Wiley and Sons, Inc. New York,
fourth edition.
- Deer, W. A., Howie, R. A. and Zussman, J.
1966 An Introduction to the Rock Forming Minerals, John Wiley and Sons,
Inc., New York.
- Fleischer, Michael
1983 Glossary of Mineral species, The Mineralogical Record, Tucson, AZ
85740 (P.O. Box 35565)
- Leet, L. D. and Judson, S.
1965 Physical Geology, Prentice-Hall, Inc., Englewood Cliffs, New Jersey
- Lindgren, Waldemar
1933 Mineral deposits, fourth ed., McGraw-Hill Book Company, Inc.,
New York.
- Palache, C., Berman, H., and Frondel
Dana's System of Mineralogy, seventh edition,
1944 Vol. I
1951 Vol. II
1962 Vol. III
John Wiley and Sons, Inc., New York
- Pearl, Richard M.
1973 Handbook for Prospectors, fifth ed., McGraw-Hill Book Company, Inc.,
New York
- Pettijohn, F. J.
1957 Sedimentary Rocks, second ed., Harper and Brothers, New York.

- Pough, Frederic H.
1953 A Field Guide to Rocks and Minerals, Houghton Mifflin Co., Boston.
- Ransom, Jay Ellis
1974 Gems and Minerals of America -- A Guide to Rock Collecting, Harper and Row, New York.
- Shelton, John S.
1966 Geology Illustrated, W. H. Freeman, San Francisco, California.
- Sinkankas, John
1964 Mineralogy for Amateurs, Van Nostrand Reinhold Co., New York
- Sorrell, Charles A.
1973 Rocks and Minerals, A Guide to Field Identification, Golden Press, New York.
- Turner, F. J.
1960 Igneous and Metamorphic Petrology, second ed., McGraw-Hill Book Company, Inc., New York.
- Twinhofel, W.H.
1950 Principals of Sedimentation, second ed., McGraw-Hill Book co., Inc., New York.
- U.S. Bureau of Mines
1968 A Dictionary of Mining, Minerals and Related Terms, Supt. of Documents, Washington D.C.
- 1980 Mineral Facts and Problems, 1980 and 1985 editions, Bulletins 671
& and 695, Supt. of Documents, Government Printing Office, Washington
1985 D.C. 20402
- annually:
Minerals Yearbook, published each year. Supt. of Documents,
Washington D.C.
- Williams, H., Turner, F. J., and Gilbert, C. M.
1954 Petrography, W.H. Freeman and Company, San Francisco, California

AVAILABLE DEPARTMENT PUBLICATIONS

GEOLOGICAL MAP SERIES

| | Price | No. copies | Amount |
|---|---------|------------|--------|
| GMS-4: Oregon gravity maps, onshore and offshore. 1967 | \$ 3.00 | | |
| GMS-5: Geologic map, Powers 15-minute quadrangle, Coos and Curry Counties. 1971 | 3.00 | | |
| GMS-6: Preliminary report on geology of part of Snake River canyon. 1974 | 6.50 | | |
| GMS-8: Complete Bouguer gravity anomaly map, central Cascade Mountain Range, Oregon. 1978 | 3.00 | | |
| GMS-9: Total-field aeromagnetic anomaly map, central Cascade Mountain Range, Oregon. 1978 | 3.00 | | |
| GMS-10: Low- to intermediate-temperature thermal springs and wells in Oregon. 1978 | 3.00 | | |
| GMS-12: Geologic map of the Oregon part of the Mineral 15-minute quadrangle, Baker County. 1978 | 3.00 | | |
| GMS-13: Geologic map, Huntington and part of Olds Ferry 15-min. quadrangles, Baker and Malheur Counties. 1979 | 3.00 | | |
| GMS-14: Index to published geologic mapping in Oregon, 1898-1979. 1981 | 7.00 | | |
| GMS-15: Free-air gravity anomaly map and complete Bouguer gravity anomaly map, north Cascades, Oregon. 1981 | 3.00 | | |
| GMS-16: Free-air gravity anomaly map and complete Bouguer gravity anomaly map, south Cascades, Oregon. 1981 | 3.00 | | |
| GMS-17: Total-field aeromagnetic anomaly map, south Cascades, Oregon. 1981 | 3.00 | | |
| GMS-18: Geology of Rickreall, Salem West, Monmouth, and Sidney 7½-min. quads., Marion/Polk Counties. 1981 | 5.00 | | |
| GMS-19: Geology and gold deposits map, Bourne 7½-minute quadrangle, Baker County. 1982 | 5.00 | | |
| GMS-20: Map showing geology and geothermal resources, southern half, Burns 15-min. quad., Harney County. 1982 | 5.00 | | |
| GMS-21: Geology and geothermal resources map, Vale East 7½-minute quadrangle, Malheur County. 1982 | 5.00 | | |
| GMS-22: Geology and mineral resources map, Mount Ireland 7½-minute quadrangle, Baker/Grant Counties. 1982 | 5.00 | | |
| GMS-23: Geologic map, Sheridan 7½-minute quadrangle, Polk/Yamhill Counties. 1982 | 5.00 | | |
| GMS-24: Geologic map, Grand Ronde 7½-minute quadrangle, Polk/Yamhill Counties. 1982 | 5.00 | | |
| GMS-25: Geology and gold deposits map, Granite 7½-minute quadrangle, Grant County. 1982 | 5.00 | | |
| GMS-26: Residual gravity maps, northern, central, and southern Oregon Cascades. 1982 | 5.00 | | |
| GMS-27: Geologic and neotectonic evaluation of north-central Oregon: The Dalles 1°x2° quadrangle. 1982 | 6.00 | | |
| GMS-28: Geology and gold deposits map, Greenhorn 7½-minute quadrangle, Baker/Grant Counties. 1983 | 5.00 | | |
| GMS-29: Geology and gold deposits map, NE¼ Bates 15-minute quadrangle, Baker/Grant Counties. 1983 | 5.00 | | |
| GMS-30: Geologic map, SE¼ Pearsoll Peak 15-minute quadrangle, Curry/Josephine Counties. 1984 | 8.00 | | |
| GMS-31: Geology and gold deposits map, NW¼ Bates 15-minute quadrangle, Grant County. 1984 | 5.00 | | |
| GMS-32: Geologic map, Wilhoit 7½-minute quadrangle, Clackamas/Marion Counties. 1984 | 4.00 | | |
| GMS-33: Geologic map, Scotts Mills 7½-minute quadrangle, Clackamas/Marion Counties. 1984 | 4.00 | | |
| GMS-34: Geologic map, Stayton NE 7½-minute quadrangle, Marion County. 1984 | 4.00 | | |
| GMS-35: Geology and gold deposits map, SW¼ Bates 15-minute quadrangle, Grant County. 1984 | 5.00 | | |
| GMS-36: Mineral resources map of Oregon. 1984 | 8.00 | | |
| GMS-37: Mineral resources map, offshore Oregon. 1985 | 6.00 | | |
| GMS-39: Geologic bibliography and index maps, ocean floor and continental margin off Oregon. 1986 | 5.00 | | |
| GMS-40: Total-field aeromagnetic anomaly maps, Cascade Mountain Range, northern Oregon. 1985 | 4.00 | | |

OTHER MAPS

| | | | |
|---|---|--|--|
| Reconnaissance geologic map, Lebanon 15-minute quadrangle, Linn/Marion Counties. 1956 | 3.00 | | |
| Geologic map, Bend 30-minute quad., and reconnaissance geologic map, central Oregon High Cascades. 1957 | 3.00 | | |
| Geologic map of Oregon west of 121st meridian (U.S. Geological Survey Map I-325). 1961 | 6.10 | | |
| Geologic map of Oregon east of 121st meridian (U.S. Geological Survey Map I-902). 1977 | 6.10 | | |
| Landforms of Oregon (relief map, 17x12 in.) | 1.00 | | |
| Oregon Landsat mosaic map (published by ERSAL, OSU). 1983 | \$8.00 over the counter; \$11.00 mailed | | |
| Geothermal resources of Oregon (map published by NOAA). 1982 | 3.00 | | |
| Geological highway map, Pacific Northwest region, Oregon/Washington/part of Idaho (published by AAPG). 1973 | 5.00 | | |
| Mist Gas Field Map, showing well locations, revised 4/85 (DOGAMI Open-File Report 0-84-2, ozalid print) | 5.00 | | |
| Northwest Oregon, Correlation Section 24. Bruer & others, 1984 (published by AAPG) | 5.00 | | |

BULLETINS

| | | | |
|--|-------|--|--|
| 33. Bibliography of geology and mineral resources of Oregon (1st supplement, 1937-45). 1947 | 3.00 | | |
| 35. Geology of the Dallas and Valsetz 15-minute quadrangles, Polk County (map only). Revised 1964 | 3.00 | | |
| 36. Papers on Foraminifera from the Tertiary (v.2 [parts VI-VIII] only). 1949 | 3.00 | | |
| 44. Bibliography of geology and mineral resources of Oregon (2nd supplement, 1946-50). 1953 | 3.00 | | |
| 46. Ferruginous bauxite deposits, Salem Hills, Marion County. 1956 | 3.00 | | |
| 53. Bibliography of geology and mineral resources of Oregon (3rd supplement, 1951-55). 1962 | 3.00 | | |
| 61. Gold and silver in Oregon. 1968 | 17.50 | | |
| 65. Proceedings of the Andesite Conference. 1969 | 10.00 | | |
| 67. Bibliography of geology and mineral resources of Oregon (4th supplement, 1956-60). 1970 | 3.00 | | |
| 71. Geology of selected lava tubes, Bend area, Deschutes County. 1971 | 5.00 | | |
| 77. Geologic field trips in northern Oregon and southern Washington. 1973 | 5.00 | | |
| 78. Bibliography of geology and mineral resources of Oregon (5th supplement, 1961-70). 1973 | 3.00 | | |
| 81. Environmental geology of Lincoln County. 1973 | 9.00 | | |
| 82. Geologic hazards of Bull Run Watershed, Multnomah and Clackamas Counties. 1974 | 6.50 | | |
| 83. Eocene stratigraphy of southwestern Oregon. 1974 | 4.00 | | |
| 85. Environmental geology of coastal Lane County. 1974 | 9.00 | | |
| 87. Environmental geology of western Coos and Douglas Counties. 1975 | 9.00 | | |
| 88. Geology and mineral resources, upper Chemco River drainage, Curry and Josephine Counties. 1975 | 4.00 | | |
| 89. Geology and mineral resources of Deschutes County. 1976 | 6.50 | | |
| 90. Land use geology of western Curry County. 1976 | 9.00 | | |
| 91. Geologic hazards of parts of northern Hood River, Wasco, and Sherman Counties. 1977 | 8.00 | | |
| 92. Fossils in Oregon. A collection of reprints from the <i>Ore Bin</i> . 1977 | 4.00 | | |
| 93. Geology, mineral resources, and rock material of Curry County. 1977 | 7.00 | | |
| 94. Land use geology of central Jackson County. 1977 | 9.00 | | |
| 95. North American ophiolites (IGCP project). 1977 | 7.00 | | |
| 96. Magma genesis. AGU Chapman Conference on Partial Melting. 1977 | 12.50 | | |
| 97. Bibliography of geology and mineral resources of Oregon (6th supplement, 1971-75). 1978 | 3.00 | | |
| 98. Geologic hazards of eastern Benton County. 1979 | 9.00 | | |
| 99. Geologic hazards of northwestern Clackamas County. 1979 | 10.00 | | |
| 100. Geology and mineral resources of Josephine County. 1979 | 9.00 | | |
| 101. Geologic field trips in western Oregon and southwestern Washington. 1980 | 9.00 | | |
| 102. Bibliography of geology and mineral resources of Oregon (7th supplement, 1976-79). 1981 | 4.00 | | |

SHORT PAPERS

| | | | |
|---|------|--|--|
| 21. Lightweight aggregate industry in Oregon. 1951 | 1.00 | | |
| 24. The Alameda Mine, Josephine County. 1967 | 3.00 | | |
| 25. Petrography of Rattlesnake Formation at type area, central Oregon. 1976 | 3.00 | | |
| 27. Rock material resources of Benton County. 1978 | 4.00 | | |

AVAILABLE DEPARTMENT PUBLICATIONS (continued)

| | Prices | No. copies | Amount |
|--|-------------------------------------|------------|--------|
| MISCELLANEOUS PAPERS | | | |
| 1. A description of some Oregon rocks and minerals. 1950 | \$ 1.00 | _____ | _____ |
| 5. Oregon's gold placers. 1954 | 1.00 | _____ | _____ |
| 8. Available well records of oil and gas exploration in Oregon. Revised 1982 | 4.00 | _____ | _____ |
| 11. Collection of articles on meteorites (reprints from <i>Ore Bin</i>). 1968 | 3.00 | _____ | _____ |
| 15. Quicksilver deposits in Oregon. 1971 | 3.00 | _____ | _____ |
| 18. Proceedings of Citizens' Forum on Potential Future Sources of Energy. 1975 | 3.00 | _____ | _____ |
| 19. Geothermal exploration studies in Oregon. 1976. 1977 | 3.00 | _____ | _____ |
| 20. Investigations of nickel in Oregon. 1978 | 5.00 | _____ | _____ |
| SPECIAL PAPERS | | | |
| 1. Mission, goals, and programs of the Oregon Department of Geology and Mineral Industries. 1978 | 3.00 | _____ | _____ |
| 2. Field geology. SW Broken Top quadrangle. 1978 | 3.50 | _____ | _____ |
| 3. Rock material resources. Clackamas, Columbia, Multnomah, and Washington Counties. 1978 | 7.00 | _____ | _____ |
| 4. Heat flow of Oregon. 1978 | 3.00 | _____ | _____ |
| 5. Analysis and forecasts of the demand for rock materials in Oregon. 1979 | 3.00 | _____ | _____ |
| 6. Geology of the La Grande area. 1980 | 5.00 | _____ | _____ |
| 7. Pluvial Fort Rock Lake. Lake County. 1979 | 4.00 | _____ | _____ |
| 8. Geology and geochemistry of the Mount Hood volcano. 1980 | 3.00 | _____ | _____ |
| 9. Geology of the Breitenbush Hot Springs quadrangle. 1980 | 4.00 | _____ | _____ |
| 10. Tectonic rotation of the Oregon Western Cascades. 1980 | 3.00 | _____ | _____ |
| 11. Theses and dissertations on geology of Oregon: Bibliography and index. 1899-1982. 1982 | 6.00 | _____ | _____ |
| 12. Geologic linears of the northern part of the Cascade Range. Oregon. 1980 | 3.00 | _____ | _____ |
| 13. Faults and lineaments of the southern Cascades. Oregon. 1981 | 4.00 | _____ | _____ |
| 14. Geology and geothermal resources of the Mount Hood area. 1982 | 7.00 | _____ | _____ |
| 15. Geology and geothermal resources of the central Oregon Cascade Range. 1983 | 11.00 | _____ | _____ |
| 16. Index to the <i>Ore Bin</i> (1939-1978) and <i>Oregon Geology</i> (1979-1982). 1983 | 4.00 | _____ | _____ |
| 17. Bibliography of Oregon paleontology. 1792-1983. 1984 | 6.00 | _____ | _____ |
| OIL AND GAS INVESTIGATIONS | | | |
| 3. Preliminary identifications of Foraminifera. General Petroleum Long Bell #1 well. 1973 | 3.00 | _____ | _____ |
| 4. Preliminary identifications of Foraminifera. E.M. Warren Coos County 1-7 well. 1973 | 3.00 | _____ | _____ |
| 5. Prospects for natural gas. upper Nehalem River basin. 1976 | 5.00 | _____ | _____ |
| 6. Prospects for oil and gas. Coos Basin. 1980 | 9.00 | _____ | _____ |
| 7. Correlation of Cenozoic stratigraphic units of western Oregon and Washington. 1983 | 8.00 | _____ | _____ |
| 8. Subsurface stratigraphy of the Ochoco Basin. Oregon. 1984 | 7.00 | _____ | _____ |
| 9. Subsurface biostratigraphy. east Nehalem Basin. 1983 | 6.00 | _____ | _____ |
| 10. Mist Gas Field: Exploration and development. 1979-1984 | 4.00 | _____ | _____ |
| 11. Biostratigraphy of exploratory wells. western Coos, Douglas, and Lane Counties. 1984 | 6.00 | _____ | _____ |
| 12. Biostratigraphy of exploratory wells. northern Willamette Basin. 1984 | 6.00 | _____ | _____ |
| 13. Biostratigraphy of exploratory wells. southern Willamette Basin. 1985 | 6.00 | _____ | _____ |
| 14. Oil and gas investigation of the Astoria basin. Clatsop and north Tillamook Counties. 1985 | 7.00 | _____ | _____ |
| MISCELLANEOUS PUBLICATIONS | | | |
| Mining claims (State laws governing quartz and placer claims) | 1.00 | _____ | _____ |
| Back issues of <i>Ore Bin</i> | 50c over the counter; \$1.00 mailed | _____ | _____ |
| Back issues of <i>Oregon Geology</i> | 75c over the counter; \$1.00 mailed | _____ | _____ |
| Colored postcard: Geology of Oregon | 0.10 | _____ | _____ |

Separate price lists for open-file reports, geothermal energy studies, tour guides, recreational gold mining information, and non-Departmental maps and reports will be mailed upon request.

OREGON GEOLOGY

910 State Office Building, 1400 SW Fifth Avenue,
Portland, Oregon 97201

Second Class Matter
POSTMASTER: Form 3579 requested

| | | | |
|---|---------------------|---|---------------|
| PUBLICATIONS ORDER | | OREGON GEOLOGY | |
| Fill in appropriate blanks and send sheet to Department. Minimum mail order \$1.00. All sales are final. Publications are sent postpaid. Payment must accompany orders of less than \$50.00. Foreign orders: Please remit in U.S. dollars. | | <input type="checkbox"/> Renewal <input type="checkbox"/> New Subscription <input type="checkbox"/> Gift <input type="checkbox"/> 1 Year (\$6.00) <input type="checkbox"/> 3 Years (\$15.00) | |
| NAME _____ | NAME _____ | ADDRESS _____ | ADDRESS _____ |
| ADDRESS _____ | ADDRESS _____ | ZIP _____ | ZIP _____ |
| Amount enclosed \$ _____ | If gift: From _____ | | |

GLOSSARY

- Acicular - Needlelike; refers to the growth of a mineral in long and slender crystals.
- Adamantine - The word used to describe a very high lustre, like the lustre of a diamond. It is a metallic lustre on a translucent material.
- Amorphous - Without form, non-crystalline, cannot have crystal faces.
- Amygdule - A rounded mass of mineral formed in a gas cavity in a volcanic rock, a rock which solidified before all the gas bubbled out.
- Botryoidal - Descriptive of a mineral surface, which is rounded like the surface of a compact mass of grapes.
- Cleavage - The tending of a mineral crystal to break readily along certain parallel planes.
- Crystalline - Atoms arranged in definite order or pattern. The outward expression of the order is the smooth faced polyhedral form called a crystal.
- Decrepitation - The explosive shattering of mineral grains on heating, commonly observed during blowpipe testing or in the open- and closed-tube tests.
- Detrital - Descriptive of a form of occurrence for minerals, in gravels that came from a mineral deposit. Hard or heavy minerals, like diamonds and gold, are often found in detrital deposits.
- Dike - An intrusive, more or less vertical, thin sheet of igneous rock that cuts across other rocks.
- Druse - A crystal-coated surface of rock, commonly used interchangeably (but erroneously) with vug.
- Ductile - Able to be drawn into a wire, a characteristic of some of the metals.
- Flourescence - A luminescence originating in substances that are being irradiated by rays of invisible light, like ultraviolet light or x-rays.
- Foliated - Made up of thin leaves, like a mica schist.
- Gangue - the minerals of no value that are associated in veins with ore minerals.
- Geode - A rounded concretionary rock mass, hollow and lined with crystals.

- Geology - The study of the earth (geos) and its life as recorded in the rocks.
- Habit - The general shape of a crystal, sometimes long and thin, other times short and flat. Often an indication of the temperature and pressure conditions under which a crystal formed.
- Hackly - The fracture characteristic of metals in rock, like gold and copper. Drawn to points as the rock breaks, the metal grains catch the skin as the finger is scraped across a hackly surface.
- Hardness - The resistance that a smooth surface of a mineral offers to scratching. Moh's standard scale of hardness is used.
- Hydrothermal - A self-explanatory word, "hydro" meaning water, and "thermal" meaning heat. Hydrothermal solutions, from which so many minerals are deposited, are solutions of hot water escaping from subterranean sources, possibly of molten rock. Hydrothermal solutions may have the temperatures of superheated steam or be as cool as bath water.
- Isomorphous - "Iso" means equal and "morph" means form - minerals in which two or more elements can replace each other to any extent without notably changing the appearance of the crystal.
- Lithophysae - Rounded nodular areas in obsidian which represent centers where crystallization of the molten rock began before it cooled into glass. Usually contracted and cracked, creating crystal-coated surfaces.
- Lustre - The appearance of a mineral in ordinary reflected light. (adamantine, vitreous, greasy, resinous, waxy, pearly, silky, dull)
- Magma - The name given to molten rock under the surface of the earth. Magma becomes lava if it escapes to the surface at a volcano.
- Magmatic - Changes in the rocks or minerals that form as a result of magma movements. Magmatic segregations are mineral deposits created directly as a result of the separation of one part of a mass of molten rock in one spot. Some iron deposits are thought to have formed in this way, by a separation and concentration of magnetite crystals from a mass of magma.
- Malleable - Can be flattened out by pounding, a characteristic of the native metals.

- Metamorphism - Changes in the rocks brought about, in the general usage of the word, by heat and pressure acting in the rocks below the immediate surface. Contact metamorphism is the result of heat and hydrothermal solutions accompanying and preceding intrusions of magma, with pressure playing no important part.
- Mineral - A natural compound with a chemical composition and physical properties that are either uniform or variable within definite limits.
- MOHS Scale - A standard of ten minerals by which the hardness of a mineral may be rated. The scale includes, from softest to hardest and numbered from one to ten: talc, gypsum, calcite, fluorite, apatite, orthoclase, quartz, topaz, corundum, and diamond.
- Native - Uncombined with other elements, native metals are those that are found as minerals, like gold, silver, and copper.
- Nodule - A small, irregularly rounded knot, mass, or lump of a mineral or mineral aggregate, normally having a warty or knobby surface and no internal structure and usually of contrasting composition from the enclosing rock.
- Ore - A mineral occurring in sufficient quantity and containing enough metal to permit its recovery and extraction at a profit. The term is also applied to rock containing such a mineral or metal, as "gold ore" and "copper ore."
- Outcrop - A place where bed rock is exposed on the surface without any soil capping to conceal it.
- Paleontology - A division of geology that concerns itself with prehistoric life and the fossilized remains of that life found in the rocks.
- Pegmatite - A very coarse granite, usually forming dikes that cut granite or the gneisses and schists that border granite masses. They represent the last liquid portion of the crystallizing granite magma. They are coarse because the liquid residue at the time of their crystallization contained a high percentage of water and other volatile elements that did not go into the make-up of the common minerals of granite, and which were for that reason concentrated in the residue. They are interesting mineralogically because minerals of the rarer elements are found with the coarse quartz, feldspar, and mica that principally compose the pegmatite.
- Petrography - A division of geology that concerns itself with the mineral make-up of rocks. It is usually carried on with the assistance of the "petrographic microscope" and thin, transparent slices of rock, known as "thin sections," ground to 3/1000 inch thickness.

- Petrology - A division of geology that concerns itself with the origin of rocks, trying to understand and explain some of the unusual mineral combinations that have been found as rock masses of considerable volume.
- Phosphorescence - A luminescence originating in substances that have been irradiated with ultraviolet light or X-rays, but which persists after the source of the stimulation has been removed.
- Placer - A deposit of heavy minerals in stream beds, in which the valuable substances have been concentrated as the lighter-weight minerals have been carried away by the stream.
- Plumose - A feathery mineral growth, composed of a compact mass of slender branching crystals. A common appearance of some of the sulphosalt minerals.
- Polarized light - Light that has been forced to vibrate in a single plane rather than in all planes. Limited polarization takes place when light is reflected from polished non-metallic surfaces. Light escaping from a Nicol prism (made from calcite) or coming through a green tourmaline or sheet of Polaroid is almost completely polarized.
- Primary - A mineral deposit that formed directly from hot molten rocks or from hot water solutions.
- Pseudomorph (False Form) - A substance with the crystal form of some other mineral, forming as the result of the alteration of the original mineral without loss of the original shape. Pseudomorphs may form by a breakdown and rearrangement of the same atoms (a paramorph), by a slight change in composition, by a coating over another crystal, or by a complete replacement by an entirely different mineral.
- Refraction - The bending of light as it passes from air into transparent substances. Each mineral has a very definite ability to bend light, differently in different crystal directions as a rule. The determination of the "index of refraction" is a method of mineral identification. A petrographic microscope and considerable training are required to make this a useful tool for mineral recognition.
- Reniform - A descriptive term for rounded mineral surfaces, meaning kidney-like. It is coarser than botryoidal and finer than mammillary.
- Secondary enrichment - A mineral deposit that has been altered, and enriched in valuable metals like copper, as a result of the weathering of the surface portion of the vein. The dissolved metals seep downward and reach the fresh unweathered section of the vein, where they react chemically with the lower-grade minerals to form new compounds richer in copper.

- Sectile - Can be cut by a knife, with a shaving curling away, like horn silver and some of the softer metals.
- Sill - Layer of igneous rock sandwiched (implanted parallel) to bedding or schistosity of intruded rock.
- Streak - The color of the powder of a mineral.
- Striations - Parellel lines of furrows on crystal surfaces.
- Sublimate - A deposit that has grown from a vapor, rather than from a solution. Sublimates are often seen in blowpipe testing.
- Tenacity - The resistance that a mineral offers to breaking, crushing, bending, or tearing. (Brittle, Malleable, Sectile, Ductile, Flexible, Elastic.)
- Vein - A more or less upright sheet deposit of minerals, cutting other rocks and formed from solutions, rather than from a molten magma like a dike.
- Vitreous - Having the lustre of broken glass.
- Volatilize - To change into a gaseous state, sometimes without melting (as with ammonium chloride).
- Vugs - Open cavities in the rocks, often lined with druses of crystals.
- Vulcanism - The phenomena associated with volcanoes; fumaroles, hot springs, and lava flows.
- Weathering - In the broadest sense, any of the destructive effects of the atmosphere and the exposure of rocks to the temperature extremes of the surface. In a mineral sense we usually mean the chemical effects of water, carbon dioxide, and oxygen attacking and destroying the minerals that are near the surface of the earth. minerals that formed deep in the earth, at high temperatures, and pressures, become unstable under surface conditions and alter to form new compounds.

I N D E X

MINERALS

A

Accessory . . . 4, 12, 13, 16
 . . . 17, 19-21, 24, 26-29, 35
 Actinolite.26
 Agate20, 21
 Agerine28
 Alabaster22
 Albite.26
 Almandite27
 Amphibole . .21, 25, 26, 28
35, 45
 Andesine26
 Anorthite.26
 Anthophyllite. . . . 21, 26
 Antimony19
 Asbestos21
 Augite28, 35

B

Barite15, 21, 22
 Bauxite.9, 11, 14
17, 26, 31
 Biotite.27, 35
 Boehmite9
 Bytownite.26

C

Calcite. .8, 15, 21, 22, 37
42, 45, 54, 55
 Chalcedony14, 20
 Chlorite9, 25, 45
 Chromite12, 16, 17
28, 36, 40
 Chrysotile21
 Cinnabar.13, 16, 19, 31, 32
 Crocidolite21

D

Diaspore.9
 Diopside.28

E

Enstatite28
 Essential . . . 2, 4, 29, 30
32, 35, 36

F

Feldspar. . 4, 14, 26, 30-32
35, 44, 54
 Ferruginous Bauxite . . . 11

G

Gangue. . 16, 21, 23, 29, 52
 Galena. . 13, 15, 18, 19, 23
 Garnet. . .9, 12, 26, 27, 40
 Garnierite14, 47
 Gibbsite9, 14
 Gold. . 1, 12, 13, 15, 18-20
27, 40, 51-53
 Graphite.9, 18
 Grossularite.27
 Gypsite23
 Gypsum. . . 6, 22-24, 47, 54

H

Hematite.13, 16
 High-iron bauxite . . 11, 14
17, 31
 Hornblende.26, 35
 Hypersthene28

I
Ilmenite. .6, 17, 28, 36, 40

J
Jade.26-28
Jadeite28

L
Laboradorite.26
Limonite. . .14, 16, 17, 31

M
Magnetite . .12, 16, 17, 19
. . .21, 28, 31, 36, 40, 53
Manganite17
Metallic . .1, 2, 13, 17-20
.24, 31, 32, 40, 52
Mica. . . .4, 9, 18, 27, 35
.44, 52, 54
Microcline.26
Molybdenite18
Montmorillonite39
Muscovite27

N
Natron.41
Nephrite.26
Nonmetallic1, 2, 20
.25, 40, 55

O
Oligoclase.26
Olivine . .4, 27, 28, 30, 31
.35, 36, 40
Oregon jade27
Ore-forming2
Orpiment.23, 24
Orthoclase. . . .26, 35, 54

P
Pentlandite19
Peridot28
Pigeonite28
Plagioclase26, 35
Platinum.40
Psilomelane17
Pyrite . .12, 15, 18, 19, 22
Pyroxene . .28, 35, 36, 45
Pyrolusite17
Pyrope27
Pyrrhotite . . .19, 28, 36

Q
Quartz . . .4, 9, 12, 14, 15
.19, 20, 22, 24-26
.28, 29, 32, 34, 35
.37, 39, 44, 45, 54

R
Realgar.23, 24
Rhodonite.24
Rock-forming . . .2, 25, 27
.28, 48
Rock gypsum.23

S
Satin Spar22
Secondary. . .25, 29, 30, 55
Selenite22
Silica . . .8, 9, 11, 14, 20
.29, 34, 37, 42, 45
Specular hematite. . . .16
Spessartite.27
Sphalerite19
Stibnite19, 23
Sulphur.24

T
Talc . . .9, 25, 36, 45, 54
Thermonatrite.41
Tourmaline29, 55
Tremolite.21, 26
Trona.41

U
Uvarovite.12

W
Wad.17

Z
Zeolite.30
Zircon20, 29, 40

ROCKS

A
Acid. 22, 23, 34, 45
Agglomerate 38
Amygdaloidal lava 31
Andesite. 31, 33, 35
Anthracite coal 41
Argillite 44
Ash 33, 34, 39, 42

B
Basalt . . .11, 14, 16, 30, 31
 34-36, 45
Basic.13, 19, 21, 23
 25, 34, 43
Bentonite.39
Bituminous coal.41
Black sand . . . 15-17, 28, 40
Bombs.33
Breccia.37, 38
"Buckskin"36

C
Cinders.33, 34
Clastic. 6, 36, 38, 41
Clay 1, 14, 16, 23
 24, 26, 38, 39, 42
Coal2, 6, 24, 29, 41
Conglomerate37, 38
Coquina.43

D
Diabase.28
Diatomite. 2
Diorite. 34-36, 44
Driblet.33
Dunite28

E
Extrusive. 3, 4, 9, 30, 35, 44

F
Felsite.32
Flow 3, 4, 30-32
Foliate.43

G
Gabbro . . . 19, 25, 34-36, 45
Gneiss9, 44 53
Gneiss, primary.44
Granite. 4, 26, 29
 34-36, 44, 54
Granodiorite35
Grit29, 38

H
Hornfels 9

I
Igneous.3, 4, 8, 9, 13
 15, 17, 19-22, 26-30
 34, 44, 49, 52, 56
Intermediate23, 34, 35
Intrusive. . . 3, 4, 9, 15, 25
 32, 34, 35, 44, 52

L

Laterite11, 14
 Laterization14, 31
 Lava16, 30-34, 53, 56
 Lignite41
 Limestone6, 9, 21-24, 40
42, 43, 45

M

Marble9, 11, 22, 45
 Metamorphic3, 8-10, 15, 16
18, 26-29, 41, 43-45, 49

N

Nonclastic6, 40
 Nonfoliate44

O

Obsidian32, 33, 53
 Olivine gabbro35
 Organic2, 6, 37, 39, 41

P

Peat41
 Peridotite12, 14, 21, 25
27, 36, 45
 Perlite32, 33
 Phyllite9
 Pitchstone32
 Plutonic3
 Primary gneiss44
 Pumice33, 34
 Pyroclastic3, 4, 23, 33, 39

Q

Quartz diorite35
 Quartzite9, 45

R

Rhyolite20, 31-33, 35
 Rock gypsum23

S

Salt6, 24, 30, 41, 42
 Sand .9, 28, 29, 33, 34, 36-40
 Sandstone8, 37
 Schist9, 44, 52
 Scoria34
 Sedimentary .1, 3, 4, 6-9, 15
2-24, 28, 29, 32
36, 37, 40, 48
 Serpentine . . .12, 21, 25, 28
36, 45
 Shale, diatomaceous42
 Silt34
 Slate9, 43, 44
 Sodium Carbonate41

T

Tachylyte32
 Thunderegg20, 21, 32
 Till38
 Travertine40, 47
 Tufa40
 Tuff23, 34
 Tuffaceous34

U

Ultrabasic34
 Unconsolidated6, 33, 38

V

Vesicular basalt14, 31
 Vesicular lava31, 34
 Volcanic3, 13, 14, 23
24, 31-34, 38, 39, 42, 52
 Volcanic breccia38
 Volcanic glass32

ELEMENTS

A

Aluminum . . .9, 11, 14, 26-29
.39, 46, 47
Antimony19
Arsenic.23

B

Barium. 21, 30, 46

C

Calcium . 6, 21-23, 25, 26, 28
. 30, 39, 40, 42, 43, 46
Chromium. 12, 18, 46
Cobalt. 19
Copper. . . 12, 13, 15, 18, 19
.21, 53-55

G

Gold. . . 1, 12, 13, 15, 18-20
. 27, 40, 52-54

H

Hafnium 20

I

Iron. . .6, 8, 9, 11-21, 25-29
. 31, 33, 36, 37
. 46, 47, 53

L

Lead. 13, 15, 18, 21

M

Manganese . . . 17, 18, 20, 24
. 26, 46
Mercury 13
Molybdenum. 18

N

Nickel. 14, 18, 19, 47

P

Platinum. 40

S

Silicon 14, 20, 25
.27-29, 46
Silver. . . 13, 22, 23, 54, 56
Sulphur 24

T

Titanium.9, 11, 16, 46

Z

Zirconium 20, 46