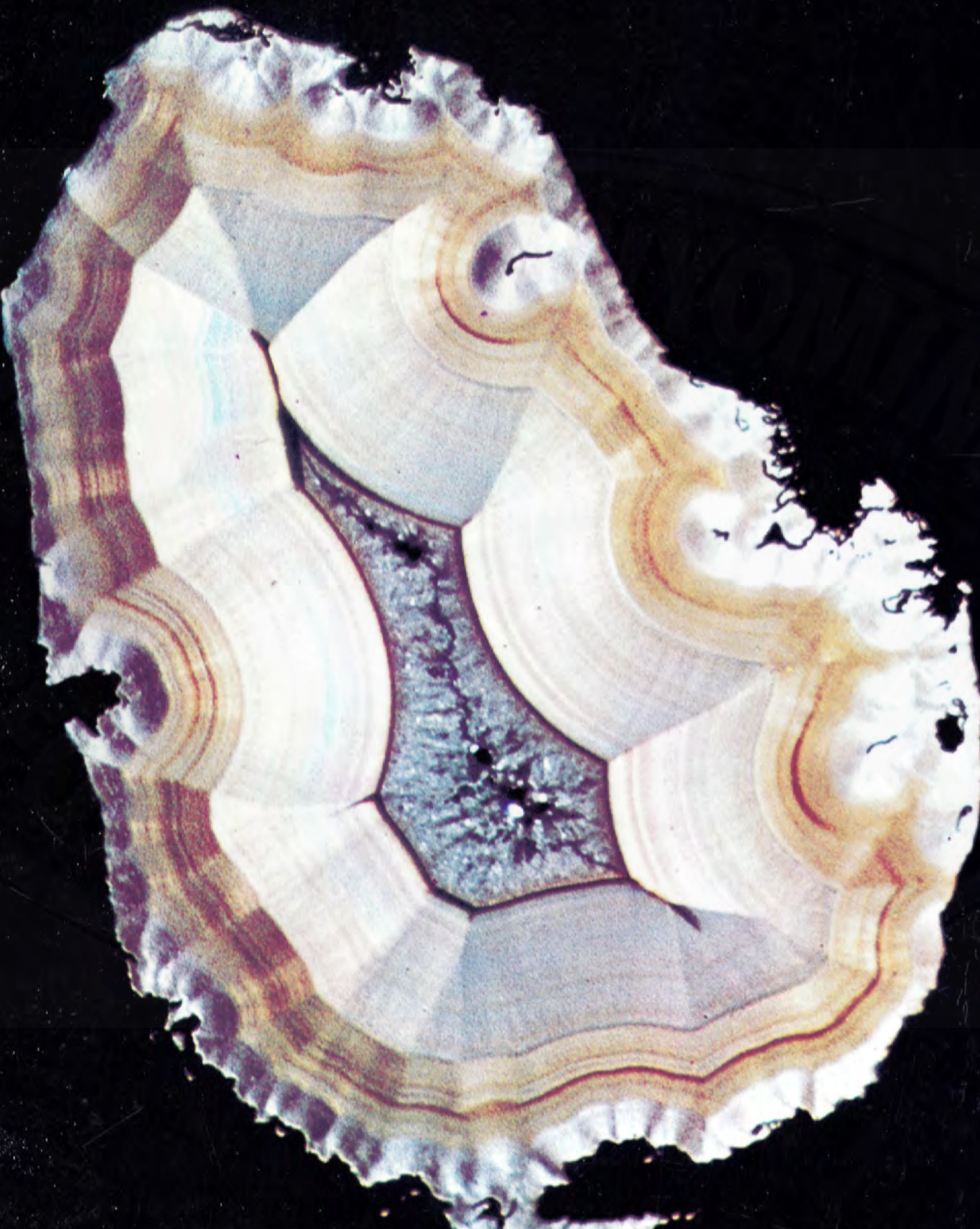
Minerals and Rocks of Wyoming



Bulletin 56
by
Forrest K. Root

Wyoming Geological Survey
Laramie, Wyoming
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THE GEOLOGICAL SURVEY OF WYOMING

Daniel N. Miller, Jr., State Geologist

BULLETIN 56

MINERALS AND ROCKS OF WYOMING

By
FORREST K. ROOT

LARAMIE, WYOMING
JULY, 1972
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COVER PHOTOGRAPH

Rainbow or iris agate from the Wiggins Formation near Dubois. From the Collection of Mr. and Mrs. Paul Westedt, Cheyenne.
Photo Courtesy of Wyoming Travel Commission.

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Foreward

Since time's beginning, man has exhibited keen interest in minerals and rocks, sometimes because of their usefulness and value, sometimes because of their interesting shape or color. Regardless of the reason, most people are curious about minerals and rocks. How are they formed? Why the differences in color? Which minerals are valuable? How can you tell?

In this booklet Dr. Forrest K. Root, Staff Geologist with the Wyoming Geological Survey, has described most of the common minerals and rocks of Wyoming. From his descriptions the reader can ascertain something about the geological origin and chemical make-up of a specimen, its geographic distribution and, in some cases, an understanding about its value as a resource or gem stone. Interesting facts about minerals and rocks are presented in a non-technical fashion, thus the reader will have no problem following the relationships and classification systems used by geologists.

The Geological Survey of Wyoming is pleased to present this information for the readers' use and enjoyment. Hopefully it will lead to a better acquaintance with one of the most interesting aspects of Wyoming's geologic past.

Daniel N. Miller, Jr.
State Geologist

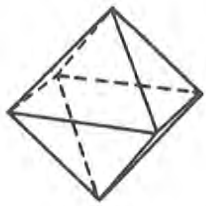
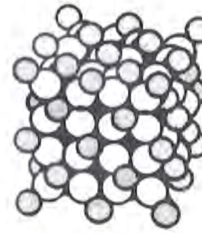
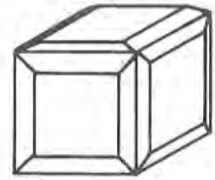
Introduction

This booklet is designed for students beginning studies of geology and mineralogy, and for nonexpert mineral enthusiasts who wish to add to the enjoyment of their hobby by acquiring a better understanding of the occurrence, physical properties and uses of Wyoming minerals and rocks.

In the booklet, minerals and rocks are discussed in the context of their distribution, both in space and time as it is represented by the geological or rock record. Thus, a short summary of the geological history of Wyoming is presented as a preface to discussion of individual minerals and rocks.

The most important and most interesting rocks and minerals of the State, their uses and sites where they may be collected are described. Some suggestions on equipment and collecting procedures are also offered.

It is the author's hope that the information presented will lead the reader toward greater appreciation of the complexity, the beauty and the limitations of the solid Earth materials with which and on which man conducts the activities of civilized life.

Minerals

What are They?

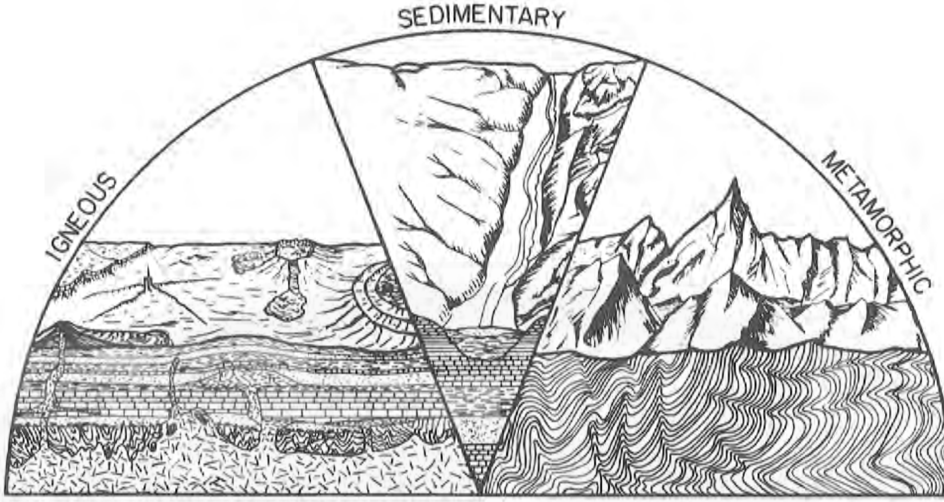
A mineral is a naturally occurring, homogeneous, solid substance which has well-defined chemical composition, internal structure and physical properties.

Individual mineral species may be distinguished from one another because of the unique set of physical, chemical and structural characteristics each possesses. These unique attributes may include physical properties or chemical compositions which make the minerals valuable to man as raw materials for industry, construction and agriculture, or physical beauty which lends itself to artistic expression in jewelry, architecture or sculpture.

The composition of a mineral can always be expressed by a chemical formula, whether the mineral is a naturally occurring single element such as native gold (Au) or a combination of chemical elements (a chemical compound) such as quartz (SiO_2). Within the three dimensional internal framework or crystal structure of many minerals, it is possible for a particular ionic position to be occupied equally well by different chemical elements having similar ionic sizes and properties. Where elements may substitute for one another within a mineral's crystal structure, the formula of the mineral must be expressed as a range of chemical compositions between certain limits (example, olivine $(Mg, Fe)_2SiO_4$, in which magnesium (Mg) and iron (Fe) ions freely substitute for one another in the mineral structure).

When one speaks of the mineral resources of an area, the word "mineral" takes on a much broader meaning. In this context, "mineral" includes all natural materials within the crust of the Earth which are presently or potentially useful to man. Coal, petroleum and natural gas, although chemically and structurally heterogeneous, are commonly thought of as minerals in this economic sense.

A small number of individual mineral species form the bulk of the rocks exposed on the earth's surface. In this booklet, the role of minerals as the major components of the common rock types will be stressed, along with their economic and aesthetic values.



Rocks

How They Are Formed

Geologic processes act through time to combine grains of different minerals and organic material into aggregates or mixtures called rocks. In a chemical sense, a rock must be thought of as a mixture whose component parts all retain their own separate identities.

Different minerals may be combined together in almost any proportion to form a rock. Certain mixtures of minerals and organic matter are much more common in nature than others, however, and these form the common rock types.

All rock types fall into one of three major groups, on the basis of the processes which formed them. Igneous rocks are those formed by the crystallization or solidification of molten rock material from deep within the earth. Sedimentary rocks are deposited by a wide variety of mechanical and chemical processes operating at the surface of the earth, including running water, wind, glacial ice, chemical precipitation and the life processes of organisms. Metamorphic rocks are formed by heat and extreme pressures acting together or separately on any pre-existing rock to alter its original character. The temperatures and pressures necessary for the production of metamorphic rocks are most frequently found at significant depths below the surface of the earth.

The creation and destruction of rock material is continually taking place within and upon the earth. The cyclical processes which act to destroy old and generate new rocks are illustrated in Figure 1.

SUMMARY OF THE GEOLOGIC HISTORY OF WYOMING

Each mineral and rock is the product of geologic conditions in effect at the time and place of its formation. Changes in the geologic environment in the past are reflected in the types of rocks and minerals that were formed. Thus, understanding of the formation and occurrence of Wyoming's rocks and minerals is dependent on a general knowledge of the state's geologic history.

The map on the back cover of this book illustrates the division of Wyoming into a number of distinct geologic provinces. These provinces include:

1—Mountainous areas or uplifts, most of which have an exposed core of very ancient metamorphic and igneous rocks.

2—Basin areas, which contain thick, layered sequences of sedimentary rocks younger than the rocks exposed in the mountain ranges.

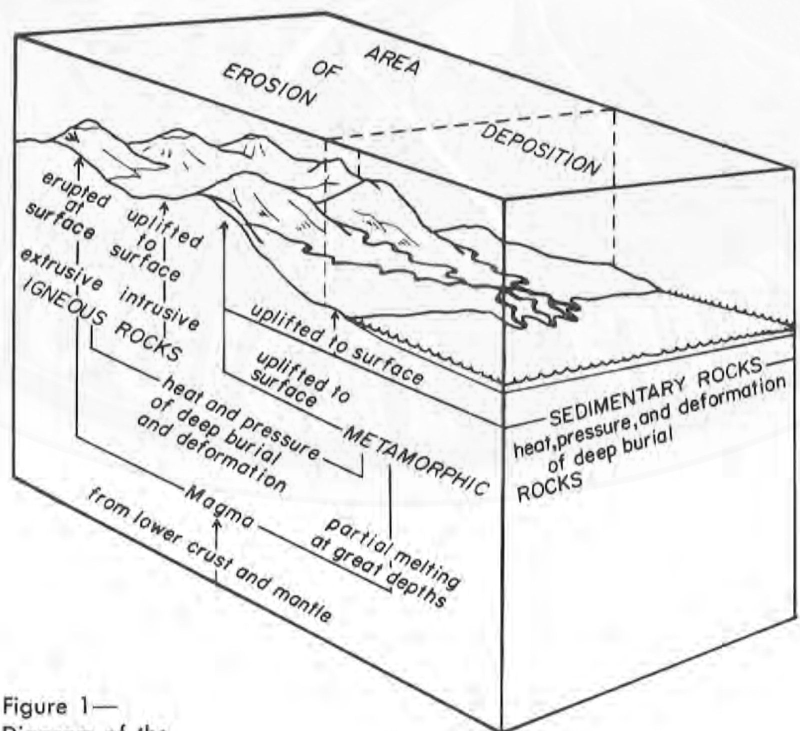


Figure 1—Diagram of the earth's rock cycle

GEOLOGIC TIME CHART OF WYOMING

MILLIONS OF YEARS BEFORE THE PRESENT

TIME	ERA	PERIOD	EPOCH	EVENTS IN WYOMING
0	CENOZOIC 65 M.Y.	QUATERNARY	HOLOCENE	PRESENT CLIMATE
3			PLEISTOCENE	ICE AGE GLACIERS
12		TERTIARY	PLIOCENE	TETONS FORMED TERRESTRIAL DEPOSITION
26			MIOCENE	INTENSE VOLCANIC ACTIVITY IN YELLOWSTONE AREA TEMPERATE CLIMATE
38			OLIGOCENE	TERRESTRIAL DEPOSITION OF GREAT AMOUNTS OF VOLCANIC ASH WARM TEMPERATE CLIMATE
58			EOCENE	GREEN RIVER LAKE AND TERRESTRIAL DEPOSITION SUBTROPICAL CLIMATE
65			PALEOCENE	TERRESTRIAL DEPOSITS TROPICAL CLIMATE
135	MESOZOIC 160 M.Y.	CRETACEOUS		TRANSGRESSION AND REGRESSION OF SEAS ROCKY MOUNTAINS BEGIN TO RISE ABUNDANT CEPHALOPODS
180		JURASSIC		SEAS WITHDREW, BROAD FLOOD PLAINS MANY DINOSAURS
225		TRIASSIC		FLUCTUATION OF SHORE LINE WIDE TIDAL FLATS, MILD CLIMATE
270	PALEOZOIC 375 M.Y.	PERMIAN		SHALLOW SEAS IN WESTERN WYOMING INVERTEBRATES COMMON
		PENNSYLVANIAN		LOCAL UPLIFT IN SOUTHCENTRAL AND SOUTHERN PART OF STATE
350		MISSISSIPPIAN		ENTIRE STATE SUBMERGED IN WARM TROPICAL SEAS
400		DEVONIAN		SEAS IN NORTHWESTERN AND WESTERN WYOMING
440		SILURIAN		PROBABLY EMERGENT RECORD INCOMPLETE IN WYOMING
500		ORDOVICIAN		STATE INUNDATED BY SHALLOW WARM WATERS
600		CAMBRIAN		SEAS TRANSGRESSED FROM WEST ACROSS ENTIRE STATE
	PRECAMBRIAN 4 BILLION YEARS LONG			LONG INTERVAL OF EROSION AT CLOSE OF ERA
				LAND REDUCED TO BROAD PLAINS OF LOW RELIEF
1000				MOUNTAIN BUILDING
				ALGAE GROWING IN ANCIENT SEAS
				WIDESPREAD SEAS
2000				CONTINENTS IN EXISTENCE
4500	FORMATIVE ERA			FORMATION OF THE EARTH

TABLE 1—Geologic Time Chart of Wyoming

3—The high plateau of Yellowstone National Park and the Absaroka Mountains, which is a thick accumulation of lava, volcanic ash and sediments derived from the erosion of these materials.

Wyoming's landscape of mountain ranges, basins and volcanic plateaus is the result of a very long and eventful geologic history. The rocks now seen on the Wyoming land surface range in age from very recent to over 2.8 billion years old. All that we know about the events of this long geologic history comes from examination of the geologic rock record, for each rock layer contains some evidence of the geologic conditions existing at the time of its formation. When these fragments of evidence are placed in their correct positions relative to time, a sequence of events or a geologic history is developed.

It is impossible to discuss history without using time as a reference. The scale that geologists use to locate the relative positions of geologic events in time is divided into long units of time called eras, which are subdivided into shorter units called periods and epochs (see Table 1).

We are presently living in the Cenozoic Era of geologic time. Looking back in time, the earth has passed through the Mesozoic Era (which saw the flourishing and eventual extinction of the dinosaurs), the Paleozoic Era (the time when land plants and animals with backbones first appeared) and a span of time longer than all the other eras combined called the Precambrian, which stretches back to the very formation of the earth approximately five billion years ago.

Precambrian Time

Much less is known about the geologic events of Precambrian time than those of the more recent eras. It is evident, however, that some of the Precambrian rocks which we now see exposed in the mountain ranges of Wyoming were originally deposited as sedimentary rocks and then subjected to varying intensities of metamorphism. Other Precambrian rocks were obviously emplaced as igneous rocks, intruding the sedimentary sequence or interbedded within it as lava flows.

The ancient age of the Precambrian metamorphic and igneous rocks of Wyoming has been determined by measuring the amounts of certain radioactive elements and their known decay or daughter products present within the rocks. Since the rates at which radioactive elements decay and are converted to their daughter products are known, the amount of time which has passed since a given rock or mineral was formed can be determined. Most of the Precambrian rocks in Wyoming range between 1.3 and 2.8 billion years in age.

Before the beginning of the Paleozoic Era, multiple episodes of uplift and erosion had stripped the Precambrian land surface down to a nearly featureless plain (a peneplain). The earliest sediments of the Paleozoic Era were laid down as seas slowly encroached across this peneplain.

Paleozoic Era

During much of the Paleozoic Era, Wyoming formed part of a very broad, low-relief, marine continental shelf which deepened westward into Idaho. The shelf received marine sediments during parts of all of the periods of the Paleozoic, beginning in the Cambrian, but deposition of sediments was interrupted numerous times by periods of erosion as minor upwarping of the shelf or adjustments in sea level caused the seas to retreat.

Late in the Mississippian Period, the broad continental shelf of the Rocky Mountains area started to break up into distinct mountain uplifts and basins. These ancient forerunners of the Rocky Mountain System are called the Ancestral Rockies. They continued to rise and be eroded well into the Pennsylvanian Period. Stability returned to the area in the Permian Period, and seas again covered most of the state.

Mesozoic Era

Wyoming remained relatively stable through the early part of the Mesozoic Era. The eroded cores of the Ancestral Rockies were buried under marine sediments of the Triassic and Jurassic Periods. During Triassic and Jurassic time, the marine trough in western Wyoming and Idaho continued to deepen and receive increasing quantities of sediment. A general retreat of the seas is evident late in the Jurassic Period, and rocks of this age contain abundant evidence of land-dwelling life (dinosaur bones of the Morrison Formation).

With the beginning of the Cretaceous Period, the geography of Wyoming changed drastically. The deep, sediment-filled trough in Idaho began to be uplifted into a mountain range and subjected to erosion. On the eastern flank of this uplift, thick sequences of Cretaceous sandstones, shales and coals were laid down as the episode of mountain building known as the Laramide Orogeny began. Marine conditions became restricted to the eastern part of the state as alluvial floods of gravel, sand and mud poured eastward from the newly raised highlands in Idaho.

Beginning late in Cretaceous time, the individual mountain ranges of the Wyoming Rockies began to rise and intermontane basins started to collect the debris eroded from them. The intense deformation during the Laramide Orogeny spanned nearly 40 million years of Late Mesozoic and Early Cenozoic time.

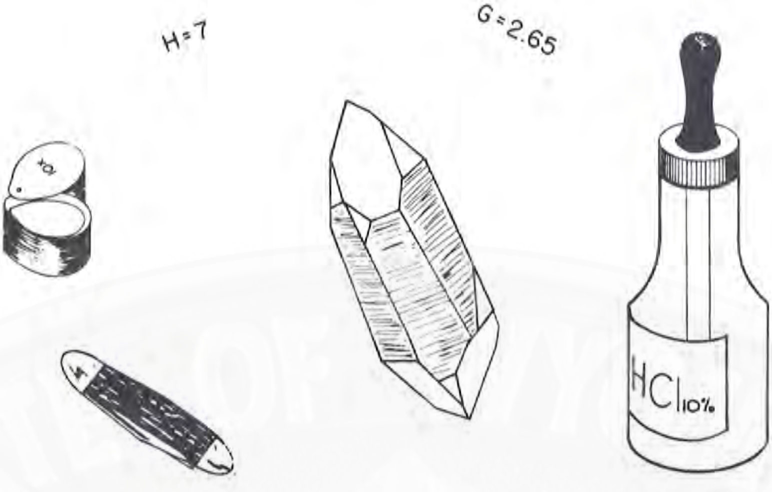
Cenozoic Era

The mountains and basins of Wyoming were well defined when the Cenozoic Era began. Nonmarine sedimentary rocks were deposited in the state during all epochs of the Tertiary Period.

Early in the Tertiary, several large lakes formed in the basins of southwestern Wyoming. Lake sediments deposited in these basins hold a unique assemblage of minerals and fossil life including oil shale, trona and excellently preserved fossil fish. So much sediment accumulated in many Wyoming basins during the Tertiary Period that some mountain ranges were virtually buried.

Volcanic activity began in the Yellowstone Park-Absaroka Mountains area early in the Tertiary Period. Enormous thicknesses of volcanic rocks and sediments derived from erosion of the rocks were laid down. Volcanic ash carried by the winds also contributed significantly to the sediment deposited in basins many miles from the volcanic source.

Renewed regional uplift toward the end of the Tertiary Period caused the removal of much of the Tertiary sedimentary cover and re-exposed some of the topography produced by the Laramide Orogeny. In later Cenozoic time (the Pleistocene Epoch), mountain glaciation altered the forms of many mountain peaks and ridges and deposited ice-borne debris down many mountain valleys.



Physical Properties of Minerals

Every mineral has physical characteristics which usually allow identification by simple methods easily applied to hand size specimens in the field. Accurate observation of these properties provides a systematic and efficient approach to the identification of unknown minerals.

The physical properties most useful in field identification of minerals are (1) color, (2) luster, (3) fracture and cleavage, (4) hardness, (5) streak, (6) specific gravity, (7) crystal form and (8) reaction to dilute hydrochloric acid.

In rare cases, a single unique characteristic possessed by a mineral distinguishes it from all others on first examination. More typically, a combination of several properties must be used to identify an unknown specimen.

Color

In the several thousand years of man's life on Earth, of which we have knowledge, certain minerals have held strong attraction for his aesthetic senses, even becoming objects of or accessories to religious worship in some civilizations. Most of these minerals have unique qualities of color tone or intensity. Jade and turquoise are two well known examples treasured by American Indian civilizations.

Color can sometimes be an important means of mineral identification. In the metallic minerals, color is usually fairly constant for a particular mineral. The bright brass yellow of chalcopyrite is unmistakable, for example, as is the warm yellow color of gold (Plate I-1).

Many nonmetallic minerals, however, appear in a wide range of colors. In these cases the color of the mineral is not, by itself, sufficient evidence for identification. Quartz can be colorless, white, gray, purple, yellow, pink or even black. Such variation in color in a single mineral species may be due to different kinds and amounts of impurities included within the crystal structure.

Luster

Luster describes the appearance of a mineral's surface in reflected light. Minerals such as pyrite, galena and chalcopyrite have the appearance of metals and so are said to have metallic luster.

Several terms are used to describe the luster of the nonmetallic minerals.

Vitreous luster means the mineral has the appearance of glass (example, quartz). Adamantine luster is seen in minerals which strongly refract light (example, diamond). Other words sometimes used to describe the luster of nonmetallic minerals include resinous (sphalerite), greasy (serpentine) and silky (asbestos). Minerals which have a luster between metallic and vitreous may be described as submetallic (example, chromite).

Cleavage and Fracture

The manner in which a mineral breaks is often its most distinctive physical property. If a mineral breaks along definite parallel planes, such planes are almost always parallel to planes of weakness in the mineral's internal crystal structure. Minerals which break in this manner are said to show cleavage. For example, the mica minerals have perfect cleavage in one direction or plane. Other minerals have cleavage in more than one direction (example, feldspar, which has two cleavage directions nearly at right angles to one another, and calcite, which breaks into rhombohedral forms bounded by three different cleavage planes. See Plate I-3).

A mineral which does not break along planar surfaces may still exhibit a characteristic form or habit along the break. This type of breakage, irregular and unrelated to planes in the mineral's structure, is known as fracture. Quartz exhibits a type of fracture called conchoidal, which simply means that the surface of the break is smooth and curved like the interior surface of a seashell (Fig 2). Some other common types of fracture are described as fibrous, splintery and hackly (jagged with sharp edges).

Hardness

The relative hardness of a mineral can be measured by observing how easy or difficult it is to scratch the mineral surface with a knife or some other tool whose hardness is already known. Hardness is measured against an arbitrary scale of ten minerals called Moh's Scale of Hardness.

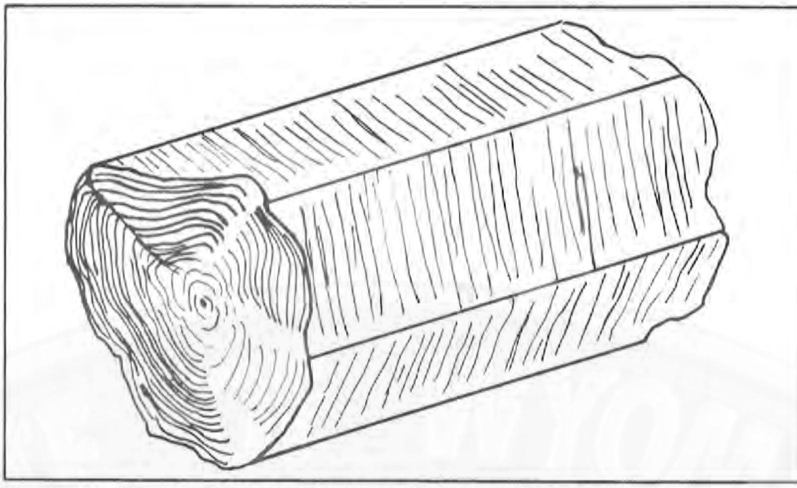


FIGURE 2—Conchoidal fracture in quartz

Moh's Scale of Hardness	Common Tools for Measuring Hardness
1. Talc	
2. Gypsum	Fingernail
3. Calcite	Copper Penny
4. Fluorite	
5. Apatite	Knife Blade
6. Feldspar	Window Glass
7. Quartz	Steel File
8. Topaz	
9. Corundum	
10. Diamond	

The correct determination of a mineral's hardness may be difficult if the mineral is weathered or occurs in a granular or splintery form.

Streak

Streak is the color of a mineral in fine, powdered form. It is best observed by rubbing a mineral specimen across hard, white, unglazed porcelain or by scraping up a fine powder on the mineral surface with a knife blade.

Some minerals exhibit streak colors quite different from the color of the massive hand specimen. For example, the iron mineral hematite may be black, gray, or reddish-brown in the hand specimen, but invariably gives a bright, brick-red streak.

Specific Gravity

Specific gravity is a number that expresses the ratio of the weight of a given volume of a substance to the weight of an equal volume of water. Accurate measurements of specific gravity are not practical in the field; therefore, the rock and mineral collector must develop a good feel for the relative weights of rock and mineral specimens. Among the metallic minerals, galena (specific gravity 7.5) will feel heavy, but graphite (specific gravity 2.3) will seem light. Among minerals with a nonmetallic luster, the range of specific gravities is much lower, and a mineral like corundum (specific gravity 4.02) will feel very heavy.

Crystal Form

Under certain favorable geologic conditions, most minerals will form in geometric shapes called crystals. Crystals are external expressions of the orderly internal atomic arrangement which all minerals possess. The most common mineral crystal forms are the cube, the prism, the pyramid, the rhombohedron, the octahedron, the dodecahedron and the scalenohedron (Fig. 3). Some minerals such as quartz occur regularly in distinctive crystal forms which lead readily to their identification (Plate I-2). Although cleavage and crystal form are both related to the internal atomic structure, a mineral which exhibits good crystal form will not necessarily show cleavage.

Reaction to Acid

One family of minerals, the carbonates, reacts with acid solutions to produce a gas (CO_2). The release of the gas is visible as bubbling or effervescence when acid is dropped onto the mineral surface. A drop of dilute hydrochloric acid (10% solution) will cause calcite ($CaCO_3$, the most common of the carbonate minerals) to effervesce rapidly. Other carbonate minerals react much more slowly to the dilute acid and may require heating or stronger acid to produce an observable reaction.

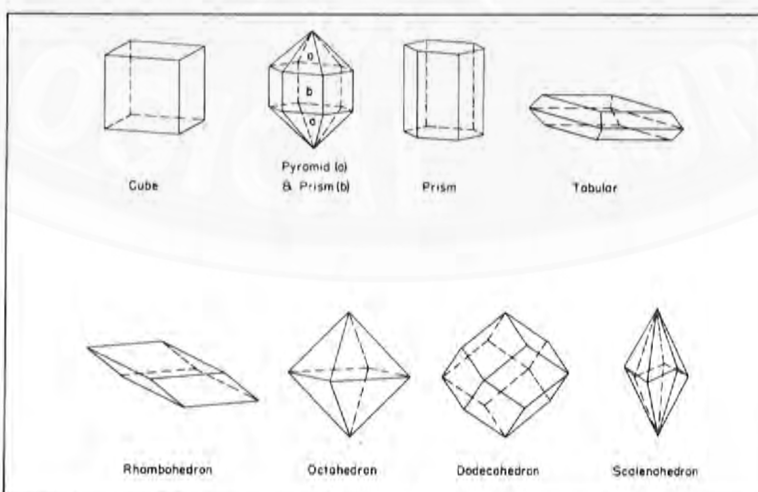


FIGURE 3—Crystal forms of some common minerals

Wyoming Minerals

Of the thousands of individual mineral species which occur in nature, less than a dozen minerals and mineral groups make up most of the Earth's outer shell or crust. The common rock-forming minerals of the Earth are: quartz, the feldspars, the micas, the amphiboles, the pyroxenes, olivine, garnet, calcite, dolomite, gypsum-anhydrite and the clays.

As the granular constituents of rocks, these minerals provide the basic framework of the Earth's crust. Rarer minerals occur either as minor constituents widely scattered among the rock-forming minerals or in higher concentrations formed locally where unusual geologic conditions have produced an environment well suited to their formation or concentration. Such unusual conditions account for the formation of mineral veins rich in chemical elements such as gold, silver, and copper, which are very minor components of the crust as a whole.

Another geological environment which also seems to favor the crystallization of relatively rare minerals is sometimes found in the closing stages of crystallization of large igneous rock masses. Very coarse grained igneous rock bodies called pegmatites may be produced by crystallization from the water rich silicate melt remaining near the end of such episodes. In some cases, pegmatites are enriched in otherwise scarce chemical elements such as beryllium, lithium, tin and the rare earth elements.

In this booklet, the rock-forming minerals are discussed first. The less common minerals are grouped in the sections following according to their most typical geologic association.

Rock-Forming Minerals

Quartz

(Silicon Dioxide)

Quartz is one of the most important rock-forming minerals. It occurs as a major constituent in a wide variety of igneous, metamorphic and sedimentary rock types. The mineral is the major constituent of most sands and sandstones.

The physical appearance of quartz varies more widely, perhaps, than any other mineral. Coarsely crystalline varieties may be transparent (rock crystal), milk-white (milky quartz), purple (amethyst), pink (rose quartz), yellow (citrine) or smoky gray to brown (smoky quartz).

Some coarsely crystalline varieties are colored by the inclusion of other minerals. Rutilated quartz contains needle-like crystals of the titanium mineral rutile. Aventurine contains small, brilliant flakes of hematite, mica or chlorite.

All of the coarsely crystalline varieties are widely used in jewelry and ornamental materials. Rock crystal is commonly used in optical and electric equipment.

The finely crystalline varieties of quartz are also varied in color. Finely crystalline quartz made up of fibrous or elongated crystals tends to be translucent and have a waxy luster. All such varieties are lumped together under the encompassing term "chalcedony". Colors and patterns of color variations distinguish the many varieties of chalcedony; all are popular for jewelry and other decorative uses. Agate is chalcedony finely banded in alternating layers of different color. Moss agate is unbanded but has irregular, dendritic markings. Other color varieties are carnelian (red), sard (brown) and chrysoprase (green). Common opal is similar in appearance to much chalcedony, but differs in having small amounts of water irregularly combined with silica in the mineral structure. Precious opal exhibits an internal play of colors, breaking light into flashes of red, blue, green and yellow.

Chalcedony and opal are commonly found as the mineral material in petrified wood. Chalcedonic quartz of all varieties is most frequently found lining or filling cavities in rocks. The erosion of such rocks may result in concentration of hard, erosion-resistant chalcedony nodules as pebbles or boulders in streams or surface gravel. Nodules which are hollow inside are called geodes. The central cavity of a geode may be lined with coarsely crystalline quartz, chalcedony, or any of a large number of other minerals.

Some finely crystalline quartz is granular rather than fibrous in form or habit. These varieties tend to be dull in luster, totally opaque to light and, therefore, less used for ornamental stone. Some variety names given to dull, granular, finely crystalline quartz are: flint (dark gray to black), chert (white to light gray), jasper (red, yellow, or brown) and prase (green).

Physical Properties

(Bold face type indicates those physical properties which are most useful in identification of a particular mineral).

Color	Usually colorless or white, but may take on wide range of colors
Luster	Vitreous
Cleavage	None
Fracture	Conchoidal (fig. 2)
Hardness	7
Specific Gravity	2.65
Crystal Form	Most commonly a six-sided prism terminated by rhombohedral faces. Prism faces commonly show horizontal striations (fig. 2)

Occurrences in Wyoming

Large, iron-stained, well-formed quartz crystals are abundant in Precambrian pegmatites located three miles north of the Colorado-Wyoming border, along U. S. Highway 287. These crystals are exceptional for their sharply defined form, but are useless for cutting and faceting because of the iron oxide which coats all of the crystal faces.

PLATE I-1 Placer gold from the Medicine Bow Mountains, Albany County (From the collection of Don Mitchell, Laramie)

PLATE I-2 Quartz crystals from near Marshall, Albany County (From the collection of Jay Sundberg, Rawlins)

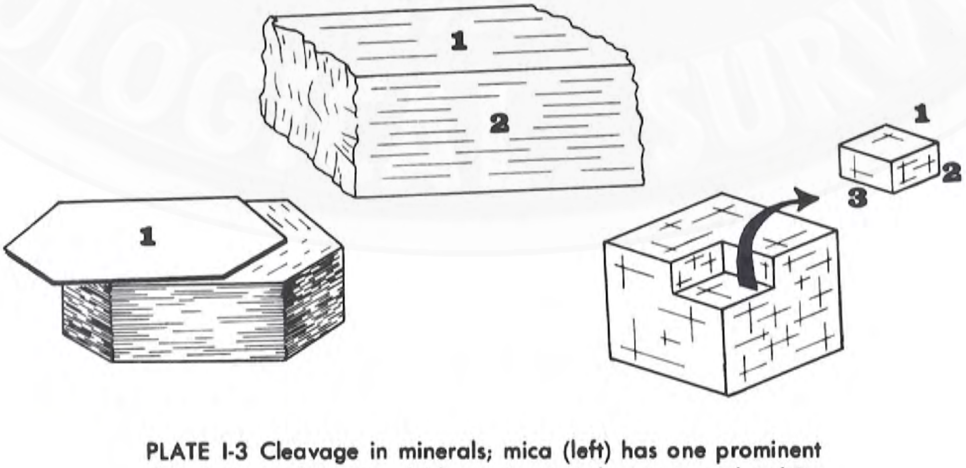


PLATE I-3 Cleavage in minerals; mica (left) has one prominent direction of cleavage, feldspar (center) has two and calcite (right) has three

PLATE II-1 Agate from the Wiggins Formation, the Absaroka Mountains (From the collection of Gilford Alexander, Cheyenne)

PLATE II-2 Small agate-filled limb casts from the Absaroka Mountains (From the collection of Gilford Alexander, Cheyenne)

PLATE II-3 Polished agate from the Wiggins Formation, Absaroka Mountains (From the collection of Gilford Alexander, Cheyenne)

PLATE II-4 Sweetwater agate pebbles, tumble polished (From the collection of Jay Sundberg, Rawlins)

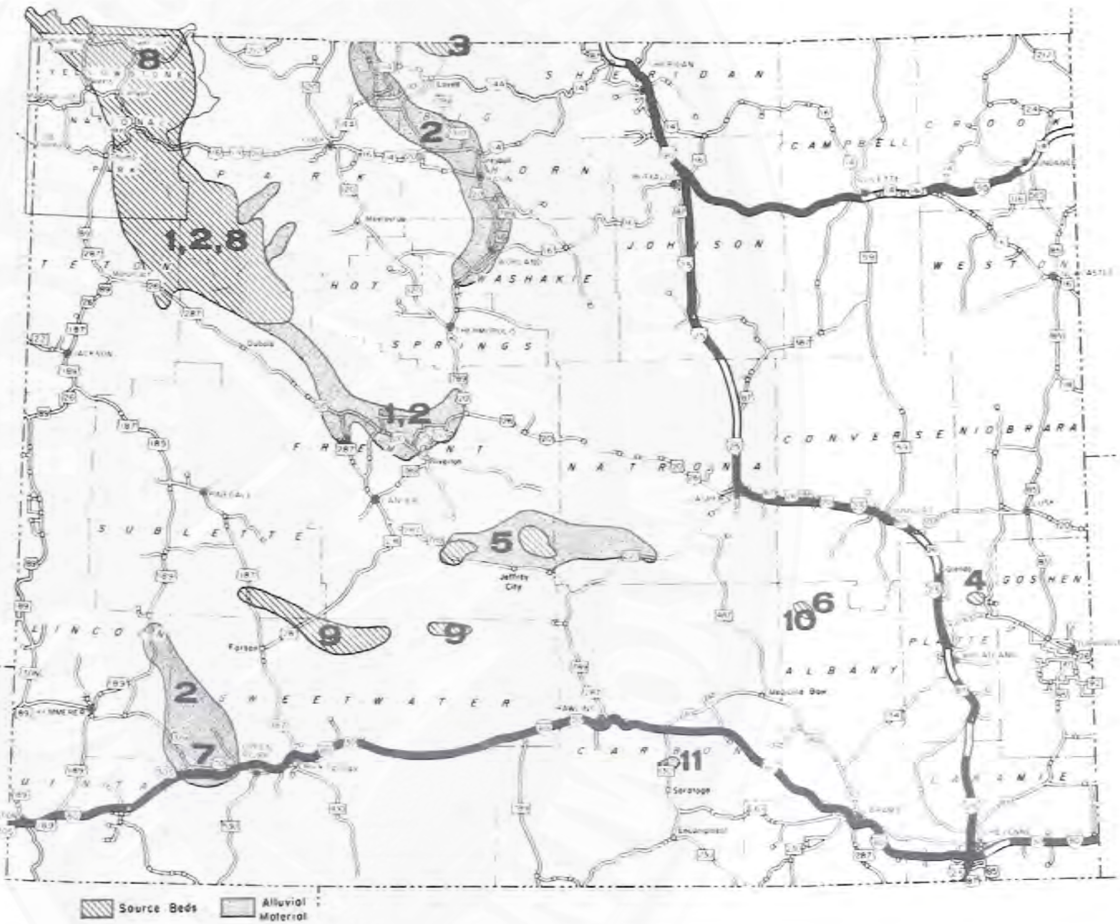
PLATE II-5 Agate collected near Hartville, Platte County (From the collection of Mr. and Mrs. Paul Westedt, Cheyenne)

PLATE II-6 Agate from the Wiggins Formation of the Absaroka Mountains. Eye-like markings (right) are the result of stalactitic growth of the agate within a cavity (left)(From the collection of Gilford Alexander, Cheyenne)

EXPLANATION

1. Iris or rainbow agate
2. Wood cast agate
3. Dryhead agate
4. Guernsey agate
5. Sweetwater agate
6. Marshall or Medicine Bow agate
7. Goniobasis agate
8. Wiggins petrified wood
9. Eden Valley petrified wood
10. Shirley Basin petrified wood
11. Saratoga Valley petrified wood

10 0 10 20 30 MILES
SCALE



Modified from Keenan, 1964.

FIGURE 4—
Principal agate and petrified wood sites in Wyoming

Clear, well-formed rock crystal has been found in the Encampment area of Carbon County and near Marshall in the northern Laramie Mountains (Plate I-2). Encrusting and cavity-filling masses of weakly colored amethyst have been collected from scattered localities in the dissected volcanic plateau of northwestern Wyoming.

Opportunities for collecting high quality specimens of coarse crystalline quartz are rare in Wyoming. The finely crystalline varieties, however, are abundant and have widely diverse forms.

Both banded and moss agate varieties are common in Wyoming (Fig. 4). Several special varieties of banded agate are found. Rainbow or iris agate, as shown on the cover, will diffract ordinary light into the colors of the rainbow when thinly sliced. Iris agate is found along the Wind River near Riverton, and as wood-cast agate in the Wiggins Formation of the Absaroka Mountains (wood-cast agate is chalcedony which has filled and taken external form of cavities created by the rotting and removal of buried limbs, roots and tree trunks. In contrast, petrified wood is formed by mineral replacement of the organic material as it lies in the earth, with retention of at least some of the internal features characteristic of the wood).

The Wiggins Formation of the Absaroka Mountains contains many agate-filled casts of tree trunks and limbs (Plates II-2 and III-5). Most of this material is gray to white, displaying either concentric or horizontal banding. In some cases, mineral growth within the voids is stalactitic, producing elongated fingers of protruding agate. When cut, this type of agate may display spectacular eye-like markings (Plate II-3).

Dryhead agate is a beautiful red and white banded or fortification agate found along the Big Horn River northeast of Lovell. This area is an extension of the famous Dryhead Creek agate grounds of Montana. Agate similar to Dryhead is found in Tertiary gravels of eastern Wyoming and Nebraska, probably transported from eroded source beds on the Hartville Uplift.

Agate occurs as seams in Mississippian age limestones at Hartville in Platte County. Both white moss agate and cream-colored banded agate have been taken from these deposits, which were mined commercially in the early part of the century (Plate II-5).

A brown to cream colored moss agate is found in place at one privately owned location near Tensleep in Big Horn County. This variety has been called Spanish Point agate.

The most abundant variety of agate indigenous to Wyoming is the Sweetwater moss agate. The Sweetwater is a dark, gray-blue agate with small clusters or dendrites of black manganese oxide impurities (Plate II-6). Some of the best localities are along Sage Hen Creek northeast of Jeffrey City in Fremont County. However, small agate pebbles are very common along the Sweetwater River, which is paralleled by U. S. Highway 287 for about 35 miles through southeast Fremont County.

PLATE III-1 Marshall (White Moss) agate found near Marshall, Albany County (From the collection of Jay Sundberg, Rawlins)

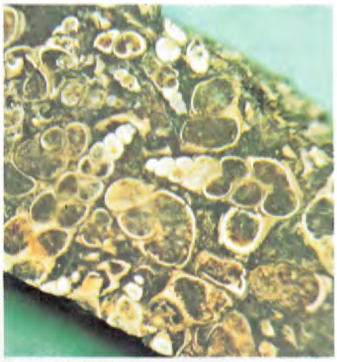


PLATE III-2 Goniobasis agate (From the collection of Mr. and Mrs. Paul Westedt, Cheyenne)

PLATE III-3 Petrified wood from the Wiggins Formation, the Absaroka Mountains (From the collection of Gilford Alexander, Cheyenne)

PLATE III-4 Petrified tree trunk in standing position in the Wiggins Formation of the Absaroka Mountains (Photo courtesy of J. D. Love, Laramie)

PLATE III-5 Agatized twig, seed cluster, and cone from the Wiggins Formation, Absaroka Mountains. (Photo courtesy of J. D. Love, Laramie)

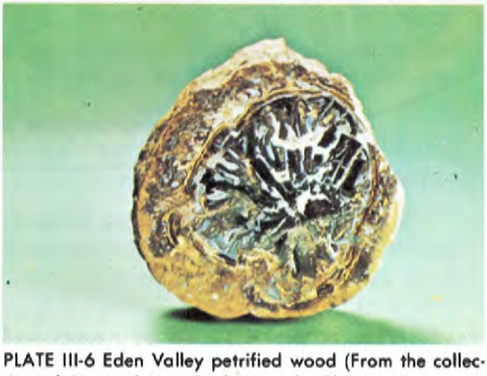


PLATE III-6 Eden Valley petrified wood (From the collection of Mr. and Mrs. Paul Westedt, Cheyenne)

PLATE IV-1 Naturally polished jade boulders or slicks (From the collection of Jay Sundberg, Rawlins)

PLATE IV-2 Dark green jade with white quartz crystals (From the collection of Jay Sundberg, Rawlins)

PLATE IV-4 Apple green jade boulder, weight, 62 pounds (From the collection of Jay Sundberg, Rawlins)

PLATE IV-3 Snowflake jade (From the collection of Jay Sundberg, Rawlins)

PLATE IV-5 Black jade (From the collection of Jay Sundberg, Rawlins)

PLATE IV-6 Jade boulders with weathering rinds (From the collection of Jay Sundberg, Rawlins)

White moss agate is found in seams in the Casper Formation near Marshall in Albany County (Plate III-1). The same material is found in gravels west of the Laramie Range in northern Albany County.

Goniobasis agate is a dark brown siliceous rock containing shells of the fossil snail *Goniobasis* (Plate III-2). This rock is found capping buttes along Interstate 80 between Green River and Granger in Sweetwater County.

Petrified wood is wood whose original organic material has been replaced by mineral matter, generally cryptocrystalline quartz or sometimes opal. Most Wyoming petrified wood formed when forests of the Tertiary Period were buried under sudden influxes of volcanic ash. Very fine petrified forests may be seen in Yellowstone National Park at Specimen Ridge and Amethyst Mountain, and in the Absaroka Mountains. The Wiggins Formation of the Absaroka Mountains contains much petrified wood, some in an upright or standing position, and even petrified cones and seed clusters (Plate III-3, 4 and 5). Some of the most beautiful petrified wood in the state is found northeast of Farson in Sweetwater County. This is the famous Eden Valley wood, which is generally black or dark gray in color (Plate III-6). Petrified wood is also found along the old Casper road about 35 miles north of Medicine Bow and on the flats along Wyoming State Highway 130 between Saratoga and Walcott.

Feldspar

(Potassium, sodium and calcium-aluminum silicates)

The group of closely related minerals called feldspars are the most abundant rock-forming minerals in the earth's crust. Granite and most other igneous rocks include one or more varieties of feldspar as major components. In fact, the classification of igneous rock types is based primarily on the amounts and kinds of feldspar minerals present. Feldspars are also important rock-forming minerals in many metamorphic rocks and some sandstones.

The feldspar minerals are aluminum silicates containing potassium (orthoclase, microcline and sanidine varieties), or sodium and calcium (plagioclase varieties).

These two major feldspar types can usually be distinguished from one another because plagioclase feldspar almost always exhibits very fine striations (shallow, parallel depressions on the cleavage surface) across one of the two prominent cleavage surfaces they display (Fig. 5). The potassium feldspars also have the tendency to cleave along two mutually perpendicular sets of surfaces, but do not exhibit striations on the cleavage surfaces.

Potassium feldspars are used in porcelain, ceramics and glass making. A green variety of microcline, called Amazon Stone, is cut and polished for ornamental purposes. Wyoming feldspar production is all currently from the Bridger Mountains northeast of Shoshoni in Fremont County. This feldspar is almost all used as abrasive filler for household cleansers.

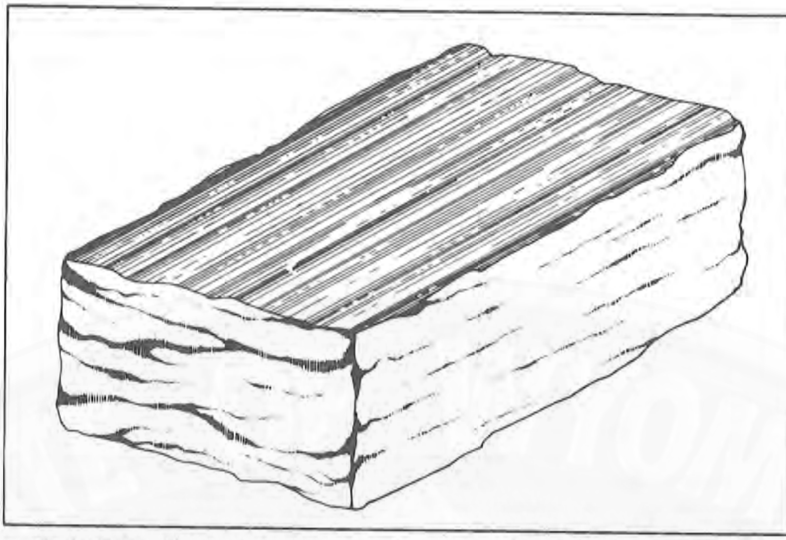


FIGURE 5—Plagioclase feldspar showing striated cleavage surface

Physical Properties

Color	Usually white, gray or pink, but may be green or red
Luster	Vitreous
Cleavage	Good to perfect in two directions which approximate a 90° angle with one another (See Plate I-3)
Hardness	6
Streak	White
Specific Gravity	2.55-2.76
Crystal Forms	Most commonly tabular in the plagioclase feldspars, may be prismatic in the potassium varieties. The plagioclase feldspars commonly show fine striations upon the cleavage faces.

Occurrences in Wyoming

Large crystals of microcline feldspar are abundant in Precambrian pegmatities at many sites in Wyoming. Microcline has recently been mined on Casper Mountain in Natrona County, about one mile west of Casper Mountain County Park, and in the Bridger Mountains northwest of Shoshoni in Fremont County.

Several smaller deposits were once worked in the Laramie Range in Albany and Laramie Counties. One such deposit is exposed in a pit located 500 feet east of US Highway 287, three miles north of the

Wyoming-Colorado state line. Microcline pegmatites are also common in the Haystack Range, nine miles northeast of Guernsey in Goshen County.

Plagioclase feldspar is seen best in the large Precambrian anorthosite mass of the Laramie Range, northeast of Laramie. Anorthosite is an igneous rock composed almost entirely of plagioclase feldspar. Good samples of anorthosite may be obtained in a quarry one-quarter mile south of the Ninth Street-Rogers Canyon Road, 10½ miles northeast of Laramie.

Mica

(Hydrous silicates of potassium, magnesium, iron, sodium and lithium)

The group of minerals called micas is a chemically complex series of hydrous aluminum silicates characterized by perfect cleavage in one direction (Plate I-3). The cleavage in micas is so good that these minerals can easily be split into extremely thin sheets.

Biotite, muscovite and phlogopite, the most common varieties of mica, are found as major constituents in many igneous rocks. Biotite and muscovite are also common in many metamorphic rocks. The best specimens of muscovite (white mica) and biotite (black, brown or dark green mica) are in pegmatites, commonly occurring in thick sheaves of cleavage plates called books. The major use of muscovite mica today is for electrical insulating material. In the past, muscovite was used widely in stove doors and lantern windows because of its transparency and resistance to heat. The lilac-colored lithium-bearing mica, lepidolite, can be used as a source of lithium.

Physical Properties

Muscovite

Color	Transparent
Luster	Vitreous, shiny
Cleavage	Perfect in one direction, flaky
Hardness	2-2½
Streak	White
Specific Gravity	2.7-3.1
Crystal Form	Platy, frequency with hexagonal cross section

Biotite

Color	Black, brown, dark green
Luster	Vitreous
Cleavage	Perfect in one direction, flaky
Hardness	2.5-3.0
Streak	White
Specific Gravity	2.8-3.2
Crystal Form	Tabular to short prismatic with hexagonal cross-section

Phlogopite

Color	Yellow-brown
Luster	Vitreous
Cleavage	Perfect in one direction, flaky
Hardness	2.5-3.0
Streak	White
Specific Gravity	2.86
Crystal Form	Hexagonal plates

Lepidolite

Color	Lilac, gray
Luster	Vitreous
Cleavage	Perfect in one direction, flaky
Hardness	2.5
Streak	White
Specific Gravity	2.8-2.9
Crystal Form	Fine-grained aggregates

Occurrences in Wyoming

Coarsely crystalline biotite and muscovite are found in Precambrian age pegmatites at numerous places in Wyoming. Good specimens may be collected at most of the sites already listed for microcline feldspar. Phlogopite occurs as a minor component in the Tertiary igneous rocks of the Leucite Hills in Sweetwater County. Masses of fine-grained lepidolite occur in the pegmatites of the Bridger Mountains, northeast of Shoshoni, in Fremont County.

Amphiboles

(Hydrous silicates of iron, magnesium, calcium, sodium and aluminum)

Though they vary widely in chemical composition, the group of minerals called amphiboles all share a common internal structure. The amphibole structure allows a wide latitude in ionic substitution, thus the large number of individual mineral species included in the group.

In its importance as a rock-forming mineral, the mineral hornblende is the most significant in the group. Hornblend is an essential mineral constituent of many igneous and metamorphic rocks. Less abundant, but still locally important as rock-formers are the amphibole minerals tremolite and actinolite.

As a group, the amphibole minerals are of little economic value. A special form of tremolite and actinolite called nephrite, however, is highly valued as an ornamental and gem stone. Wyoming is famous for its high quality nephrite, better known as Wyoming jade.

It was not generally realized until the late 1800's that jade, the material used in so much fine sculpture, ornamental work and jewelry in ancient China, was not a single mineral species. The word jade refers to several different minerals used for these purposes in the Orient, which had in common their occurrence in very pure microcrystalline aggregates with particularly fine polishing qualities,

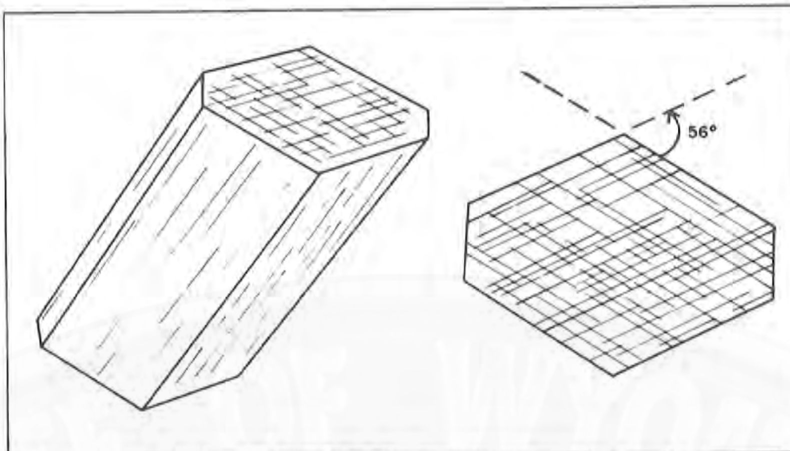


FIGURE 6—Typical amphibole crystal showing major cleavages

color, hardness and transluscence. The two predominant jade minerals, nephrite and jadeite, are so alike in physical appearance that they had been referred to for thousands of years by the one Chinese name Yu, and in the last four hundred years by the English word jade. The Chinese name was used by Europeans until the sixteenth century, when similar rocks from the New World came to be known in Spanish as "piedras hijadas," piedras for stones, hijadas for flank or side. This name derived from the belief held in many cultures that such a stone would bring relief for ailments of the kidneys or other internal organs when placed on one's side. The Spanish word hijadas was adopted by the English and soon corrupted to our word jade.

By all standards, then, "jade" is not correctly used as a mineral name. It is actually a varietal name describing the particular texture and color of certain minerals, much as the word agate describes a form of the mineral quartz. The word nephrite refers to the same kinds of physical properties when exhibited by the amphibole minerals tremolite-actinolite.

All Wyoming jade is nephrite. That is, it is composed of one of the amphibole minerals of the tremolite-actinolite series. Most of the analyzed Wyoming jade is on the tremolite or low-iron end of the series.

The extreme toughness of nephrite is difficult to explain without resorting to instruments allowing a close look at the very unusual texture of the material. In coarsely crystalline form, the mineral tremolite is not particularly hard (5 ½), and has excellent cleavage in two directions (Fig. 6), giving the mineral a strong tendency to brittleness. The explanation of the extreme toughness of the nephrite form of tremolite lies in the very finely interwoven texture of the thousands of tiny, fiber-like crystals which compose the material. In Figure 7, a scanning elec-

FIGURE 7—Scanning electron microphoto of apple-green nephrite from Crooks Mountain, Wyoming (1400x magnification)

tron microscope photograph of the nephrite texture, the individual crystals of tremolite can be seen, but are crossing and tied to one another at many points. Although tremolite is not particularly hard and quite brittle taken one crystal at a time, the interlocking texture of the fine, hair-like crystals in the nephrite form produces one of the toughest gemstone materials known.

The extreme toughness of nephrite leads to its preservation as float jade, water or wind-worn pebbles or boulders sometimes found tens or hundreds of miles from the lode deposit or point of original formation (Fig. 8).

The distribution of float jade depends on the drainage patterns prevailing at the time the material was separated from the lode deposit and, also, on any subsequent redistribution which has occurred as more modern streams resurrected buried deposits.

The external appearance of float jade varies widely, depending on the amount of abrasion by wind and water that the material has undergone (Fig. 8). Jade slicks are float jade blocks which have a high degree of natural polish. More characteristic are float blocks which exhibit brown to red weathering rinds.

It is generally true that the float jade found in Wyoming has been of higher quality than most of the lode deposits discovered to date. This is true for the simple reason that the better qualities of nephrite tend to be tougher and more resistant to destruction by erosion. The natural processes of transportation tend, therefore, to select the better nephrite for preservation and to destroy the lesser quality.

Lode jade deposits in Wyoming are generally located at or very near a contact between dark-colored igneous or metamorphic rocks, such as diabase, diorite and amphibolite, and light colored granite, granite gneiss, or quartz veins.

The reaction between these two contrasting rock types is complex and variable in nature, depending on the temperature, depth of burial and amount of water prevailing at the time and place the rocks came into juxtaposition. In certain conditions, pods or veins of nephrite jade are the result (Fig. 8).

Physical Properties

Color	Green to black, more rarely white or brown
Luster	Vitreous to silky
Cleavage	Perfect in two directions which make angles of 56° and 128° with one another (Fig. 6)
Hardness	5½-6
Streak	White
Specific Gravity	2.8-3.5
Crystal Form	Prismatic, may be fibrous (Fig. 6)

Nephrite

Because of its occurrence in finely crystalline aggregates and the possibility of confusion with other minerals, special care must be taken for accurate field identification of Wyoming jade. The following rules are useful in the field.

1. Nephrite is heavier than an average rock of the same size.
2. Nephrite cannot be scratched with an ordinary knife blade.

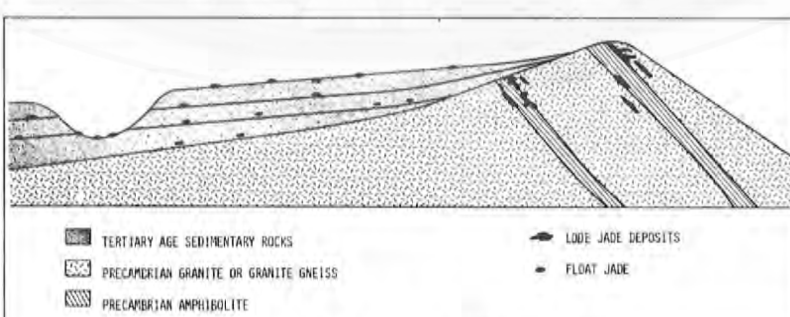


FIGURE 8—Types of Wyoming jade deposits

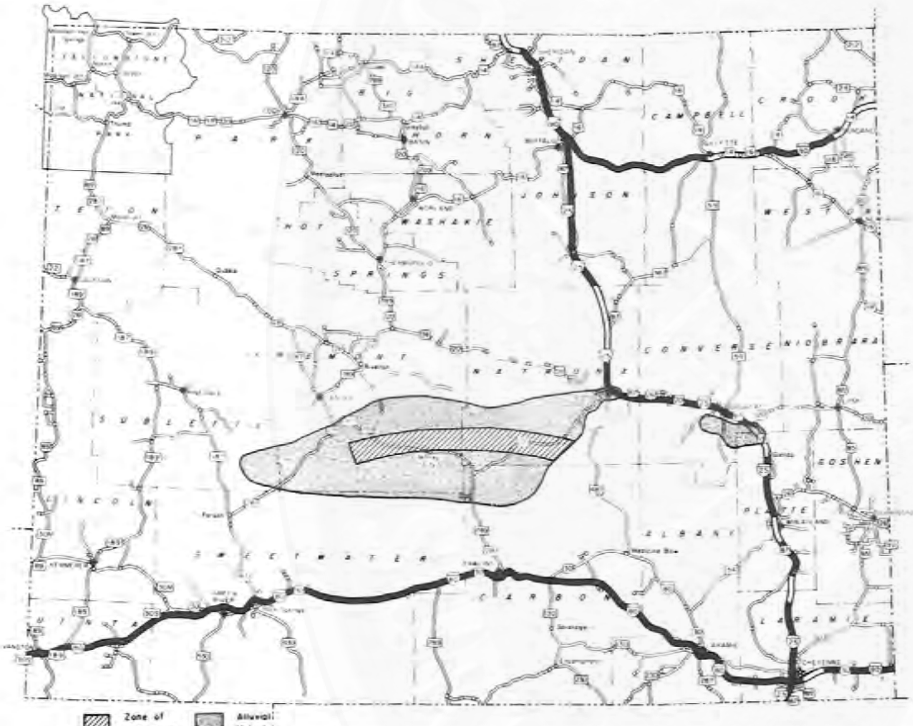


FIGURE 9—
Principal jade occurrence of
Wyoming (Modified from Keenan, 1964)

3. Nephrite has a smooth, almost waxy appearance.
4. If the end is ground off a suspected nephrite jade specimen, the fresh surface should not sparkle or glitter in the sun. If it sparkles, it is not nephrite.

Wyoming jade may be black, olive green, emerald green, or light apple green (Plate IV-1-6). Snowflake jade has a mottled coloration, due to the intermixing of feldspar or other minerals with nephrite. The lighter colors of nephrite are in general the most valued.

Certain identification of nephrite must frequently be based on rather complicated laboratory methods such as X-ray diffraction. Two rocks commonly mistaken for nephrite in Wyoming are green quartzites found in many Precambrian metamorphic rock terrains throughout the state and serpentinites, which are frequently found in the same geologic associations as nephrite. Quartzites can be seen on close inspection to have a granular texture unlike that of nephrite. Serpentinite may be distinguished by its inferior hardness as it can be scratched with an ordinary pocket knife.

Occurrences in Wyoming

Amphiboles are quantitatively important rock-forming minerals in many of the Precambrian rocks of Wyoming's mountain ranges. The hornblende variety is also a common constituent in the Tertiary extrusive and intrusive rocks of the Absaroka Mountains, frequently visible as small black prisms in a fine-grained rock matrix.

Wyoming's most prolific jade collecting grounds have been between the Wind River Mountains and the North Platte River in Carbon, Natrona and Fremont Counties (Fig. 9). Boulders and pebbles of jade have been picked up from Tertiary and younger gravel deposits throughout this district, but pod and vein deposits are restricted to the Precambrian rocks exposed in the low mountain ranges of the area. Areas where alluvial jade has been most abundant and the areas of known pod and vein deposits are located on Figure 9.

The novice jade collector should be forewarned that most of the above-mentioned jade grounds have been so thoroughly explored through the years that little worthwhile material should be expected. However, the effects of rains and snow ordinarily uncover a little more jade each year.

Pyroxene

(Silicates of calcium, iron, magnesium and aluminum)

The pyroxene minerals group is similar in appearance to the amphiboles. They are important components in dark-colored igneous rocks such as basalts, gabbros and andesites, and in some metamorphic rocks.

Pyroxenes have no economic use, except for spodumene, a source of lithium, and jadeite, as an ornamental and gem material (also called jade). No jadeite has been found in Wyoming.

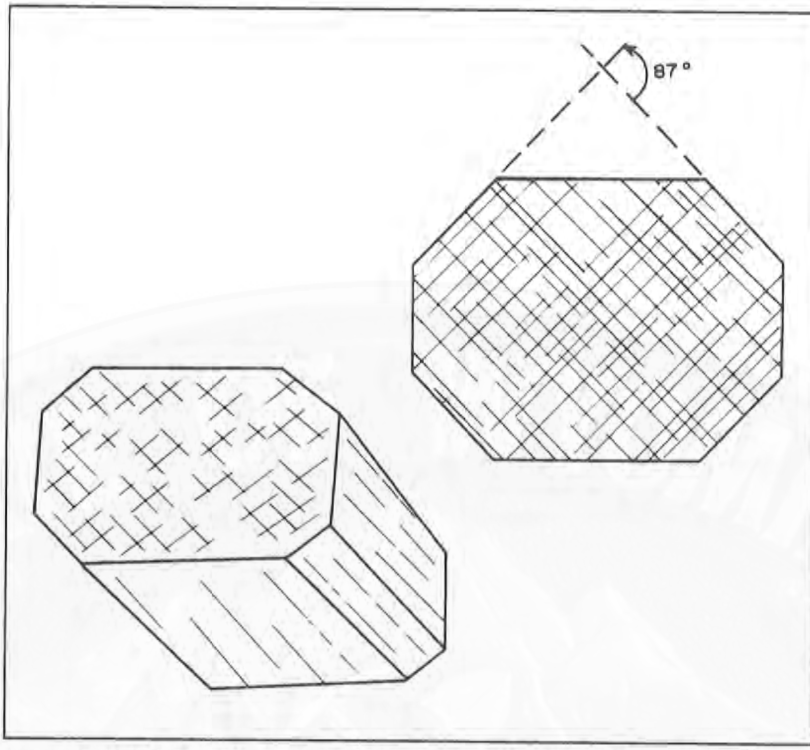


FIGURE 10—Typical pyroxene crystal showing major cleavages

Physical Properties

Color	Green, black or white
Luster	Vitreous
Cleavage	Good to poor in two directions nearly at right angles to one another (see Fig. 10). Cleavage is the best way to distinguish pyroxene from amphibole.
Hardness	6
Streak	White
Specific Gravity	3.2-3.5
Crystal Form	Prismatic

Occurrences in Wyoming

In Wyoming, pyroxenes are found principally in gabbros and pyroxenites of Precambrian age, and in the Tertiary volcanic rocks of the Absaroka Mountains and Yellowstone National Park.

Olivine

(Magnesium and iron silicate)

Olivine is a moderately abundant mineral in many dark-colored igneous rocks. It is also found in some meteorites. The mineral is a magnesium and iron silicate which is formed at extremely high temperatures.

Olivine is rarely put to any economic use. A clear, bright green variety, peridot may be used as a gemstone.

Physical Properties

Color	Olive-green
Luster	Vitreous
Cleavage	None
Fracture	Conchoidal
Hardness	6½-7
Streak	White
Specific Gravity	3.27-3.37
Crystal Form	Prismatic with pyramidal terminations

Occurrences in Wyoming

Olivine is found in some of the dark-colored Precambrian igneous rocks of Wyoming and in some of the Tertiary basalt flows of the Absaroka Mountains.

Garnet

(Silicates with varying amounts of iron, magnesium, aluminum, calcium and manganese)

Garnet is a fairly common mineral in metamorphic rocks and, more rarely, in igneous pegmatites. Garnet is sometimes of gem quality, but quality stones have not yet been reported in Wyoming. The most common use for garnet is as an abrasive.

Physical Properties

Color	Dark red to reddish-brown, brown, green, black
Luster	Vitreous to resinous
Cleavage	None
Hardness	6½-7½
Streak	White
Specific Gravity	3.5-4.3
Crystal Form	Dodecahedrons

Occurrences in Wyoming

Garnet occurs in Precambrian metamorphic rocks in most of the Wyoming mountain ranges. Large numbers of low grade garnets occur in weathered mica schists along the west side of Jelm Mountain, just south of Woods Landing, in Albany County. Garnet is also abundant in the Cooney Hills, 15 miles southwest of Wheatland, in Platte County. Since garnet is a hard and resistant material, the mineral is frequently found in relatively high concentrations in river sands.

Calcite

(Calcium carbonate)

Calcite is one of the most aboundant minerals in sedimentary rocks. It is the predominant mineral in limestones and is frequently found as a cement binding together the grains of sandstones. Most calcium carbonate in limestone has been formed directly or indirectly by the life functions of sea plants and animals, either as shells or tiny crystals organically secreted or precipitated as a fine ooze or mud. Calcite can also be deposited by simple chemical precipitation from calcium-bearing waters. The terraces of mineral matter found around many hot springs are deposited this way.

The largest uses of calcite in the form of limestone are in the manufacture of lime and portland cement. Sugar beet refining also uses large amounts of limestone in Wyoming and other western states. Clear, colorless crystals of calcite are sometimes used in instruments such as microscopes because of special optical properties.

Physical Properties

Color	Usually white, may be yellow, pink, gray, green, or blue
Luster	Vitreous
Cleavage	Perfect along three directions giving rhombohedral cleavage fragments (Plate I-3)
Hardness	3
Streak	White
Specific Gravity	2.72
Crystal Forms	Rhombohedrons, prisms, scalenohedrons and many others
Other Characteristics	Effervesces or bubbles rapidly in cold, dilute hydrochloric acid

Occurrences in Wyoming

In Wyoming, calcite is most abundant in the Paleozoic limestone units (the Madison Formation, the Casper Formation). Calcite crystal masses occur in the Permian Phosphoria Formation at Lime Ridge, at the east end of the Bridger Mountains north of Lysite, in Fremont County. Coarsely crystalline calcite may also be found lining geodes (cavities within solid rock which have been partly or completely filled by mineral material) in the Cretaceous Niobrara Shale in Carbon County and in the volcanic rocks of the Absaroka Mountains. Hot spring terraces in Yellowstone Park (particularly at Mammoth Hot Springs) and at Thermopolis are composed largely of calcite.

Aragonite, a mineral which has the same chemical composition as calcite but a different crystal structure, is found as short, prismatic or tabular crystals in the Goose Egg Formation at Red Mountain, near the Wyoming-Colorado border on US Highway 287.

Dolomite

(Calcium-magnesium carbonate)

Dolomite is much like calcite in its occurrence and many of its physical properties. It differs chemically in that it contains nearly equal proportions of calcium and magnesium. The mineral dolomite is the chief constituent of a sedimentary rock type which is also called dolomite or, less frequently, dolostone.

Most dolostone formed when calcite in previously deposited limestones reacted chemically with magnesium-bearing water. Dolomite is used as flux in the manufacture of steel and in certain cements.

Physical Properties

Color	Pinkish-white, white, gray or brown
Luster	Vitreous
Cleavage	Rhombohedral
Hardness	3½-4
Streak	White
Specific Gravity	2.85
Crystal Form	Usually rhombohedra with curved faces
Other Characteristics	Powdered mineral effervesces slowly in cold, dilute hydrochloric acid

Occurrences in Wyoming

In Wyoming, dolomite is found primarily as dolostone, principally in the older Paleozoic formations.

Gypsum

(Calcium sulfate and water)

Gypsum is a common mineral in the sedimentary rocks of Wyoming. It frequently occurs either in thick beds or in stringers and isolated crystals (Plate V-1) in shales. Anhydrite, a mineral similar in appearance and occurrence to gypsum, is calcium sulfate without water. Most gypsum beds were deposited when bodies of salt water became partly or completely isolated from the sea and began to evaporate.

Gypsum is used to make plaster of paris, plaster wall board, cement and also in fertilizers and soil conditioners. The massive, fine-grained form of gypsum called alabaster can be used for sculpting.

Physical Properties

Color	White, tan or transparent
Luster	Vitreous to earthy
Cleavage	Four directions, perfect in one, yielding thin sheets
Hardness	2
Streak	White
Specific Gravity	2.32
Crystal Form	Prismatic or tabular, sometimes in spectacular "fishtail" twin crystals (Plate V-1)

Occurrences in Wyoming

Gypsum beds in Wyoming lie mainly in the Goose Egg, Chugwater and Gypsum Spring Formations. These beds were deposited under evaporative conditions in ancient seas and saline lakes. Gypsum is mined from the Gypsum Springs Formation at Cody and near Greybull and made into wall board.

Clay Minerals

(Hydrous aluminum silicates)

The most important of the clay minerals are kaolinite, illite, chlorite and montmorillonite. All have a characteristic sheetlike crystalline structure. These minerals always occur in very fine-grained aggregates and cannot be distinguished from one another accurately in the field. Clay minerals are major constituents of the consolidated sedimentary rocks called shales and the unconsolidated sediment called clay.

Clay minerals are most often formed by the weathering of feldspars and other silicate minerals at or near the surface. Clays may be carried long distances from their original site of formation by streams and laid down as mud, or they may be concentrated as a residual product in the soil. Clay minerals are sometimes found in association with mineral veins, produced by the reaction of feldspar and other silicates in the wall-rocks with the water of the mineralizing solutions.

Much of the clay found in Wyoming is of the swelling type. That is, it can adsorb large amounts of water and swell to many times its original volume. The property of swelling is best shown by the clay mineral montmorillonite, a principal constituent of bentonite. Bentonite is used in drilling mud, foundry sands, dams and reservoir linings, and in the preparation of Wyoming's siliceous iron ores for the blast furnace. Nonswelling clays are more frequently used in brick, tile and ceramics. Such clays generally contain some combination of the minerals kaolinite, illite and chlorite.

Physical Properties

Color	White, usually obscured by impurities
Luster	Dull, earthy
Cleavage	Not visible because of small grain size
Hardness	2-2½
Streak	White
Specific Gravity	2.60-2.63
Crystal Form	Not visible with the naked eye because of small grain size, but clay minerals occur in plates much like the micas

Occurrences in Wyoming

Wyoming is the nation's leader in bentonite production. Most Wyoming bentonite beds occur in the Cretaceous Mowry and Frontier Formations. The bentonite layers in these formations formed when air-borne ash ejected from volcanic vents to the west dropped into Cretaceous seas reacting with sea water to produce montmorillonite. Bentonite is mined at several sites where the Mowry and Frontier Formations crop out on the margins of the Powder River and Big Horn Basins. Non-bentonitic clay is presently mined for making brick, tile and pipe near Lovell.

Less Common Minerals In The Igneous Rocks

Chromite

(Iron-chrome oxide)

Chromite is a constituent of many dark-colored igneous rocks. The mineral is one of the earliest to form in the cooling of an igneous melt. Most concentrated deposits of chromite probably formed by gravitational settling of early-formed crystals of chromite at the bottom of such melt.

Chromite is the only ore of chromium, a metal used in steel to give it hardness, for plating of automobile parts and for heat-resistant linings in metallurgical furnaces.

Physical Properties

Color	Black
Luster	Submetallic
Cleavage	None
Hardness	5½
Streak	Dark brown
Specific Gravity	4.6
Crystal Form	Octahedron, but rarely visible, usually in massive aggregates

Occurrences in Wyoming

Chromite is found in Precambrian rocks of the northern Laramie Mountains in Converse and Natrona Counties. Deposits on Casper Mountain have been extensively explored by the U. S. Bureau of Mines and found to contain large reserves of presently noncommercial chromite ore. The Deer Creek Mine, 15 miles southwest of Glenrock, produced a small amount of high grade chromite ore in the 1930's.

Diamond

(Carbon)

Diamonds were first discovered around 800 B.C. Because of their durability and unsurpassed brilliance, diamonds are the most valuable gemstones today. Most diamonds are mined in southern and central Africa from lode and placer deposits.

Diamonds are exceedingly rare even in minable occurrrences. The concentration of diamond in a rich kimberlite pipe (the host type of igneous intrusive rock for most primary diamond occurrences) is .2 gm/ton or less. African diamond miners may work their entire life without observing a diamond in place.

Diamonds are extracted from kimberlite by crushing, flotation in heavy liquids and gravity-type concentration. The final recovery process is always by hand-sorting. Industrial diamond (useful only for abrasives) and gemstones are both extracted in this manner.

Kimberlite is a dark igneous rock containing broken fragments of other rock layers which it penetrated. Surface alteration of the kimberlite to serpentine and other hydrous silicate minerals characteristically produces soft, unconsolidated material with blue or yellow coloration. Kimberlites originate at great depths from the mantle, the solid rock layer underlying the crust. Many kimberlite bodies are circular or pipe-shaped in plan.

Not all kimberlite contains diamonds. Pipes in the Laramie Range of southeastern Wyoming, however, have recently been shown to contain microscopic diamonds.

Physical Properties

Color	Pale yellow, colorless, shades of red, orange, green, blue, brown or black
Luster	Adamantine
Cleavage	Perfect in four directions, parallel to the faces of octahedral crystals
Fracture	Conchoidal
Hardness	10
Streak	White
Specific Gravity	3.5
Crystal Form	Commonly octahedral dodecahedral, cubic or tetrahedral. Faces often curved

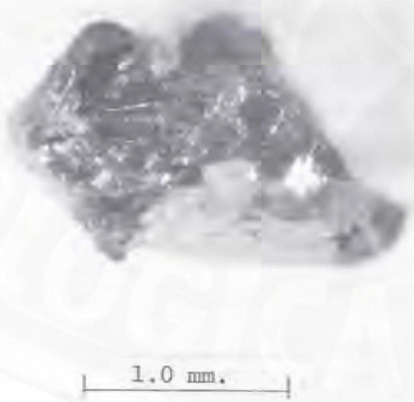


FIGURE 11—Aggregate diamond crystal from the state link kimberlite pipes near Tie Siding (from WGS Report of Investigation no. 12 by M. E. McCallum and C. D. Mabarak)

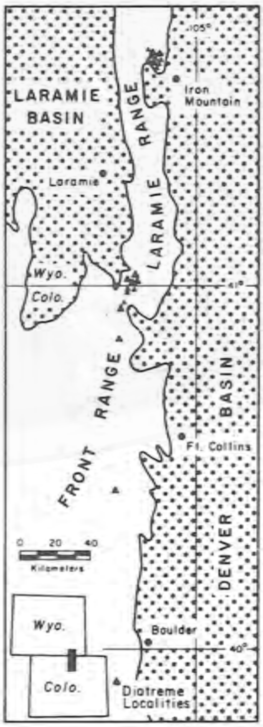


FIGURE 12—Location map of kimberlite pipes. Stippled areas are underlain by sedimentary rock, unshaded areas by Precambrian crystalline rocks (illustration from R. I. 12)

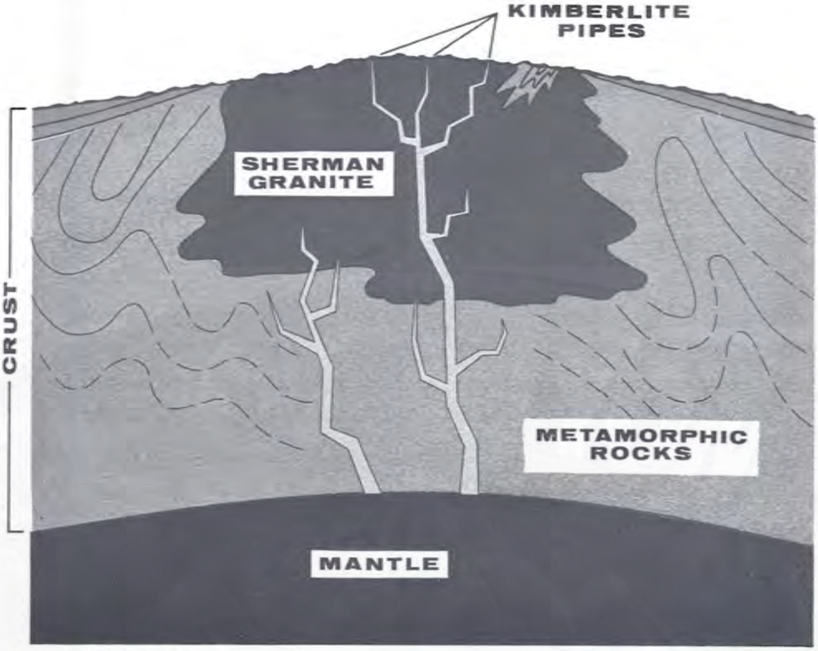


FIGURE 13—Diagram showing emplacement of kimberlite pipes

Occurrences in Wyoming

To date, microscopic diamonds have been found in most of the kimberlite bodies known in the Laramie Range of southeastern Wyoming. (Figs. 11-12). The geologic relationships of the area are diagrammed in Fig. 13. The sampling of these bodies to date is not sufficient to determine the economic feasibility of mining.

Ilmenite

(Iron-titanium oxide)

Ilmenite is found in many dark-colored igneous intrusive rocks. Ilmenite frequently occurs in close association with iron oxides. Ilmenite is also common in some black beach sands and some sandstones formed from ancient beach sands.

Ilmenite can be utilized as a source of titanium, which is used in paint pigments and as a lightweight structural metal.

Physical Properties

Color	Black
Luster	Metallic to submetallic
Cleavage	None
Hardness	5½-6
Streak	Black to brownish red
Specific Gravity	4.7
Crystal Form	Thick, tabular, but usually massive

Occurrences in Wyoming

Ilmenite occurs in great abundance in the southern Laramie Range in Albany County. The ilmenite is closely associated with magnetite in igneous rocks of Precambrian age. Ilmenite-magnetite is mined at Iron Mountain, 22 miles northeast of Laramie, for use mainly as a heavy aggregate in concrete. Ilmenite-bearing black sandstones, formed as beach sands during Late Cretaceous time, are found at many places in Wyoming.

Leucite

(Potassium-aluminum silicate)

Leucite is a rather rare mineral which occurs principally in volcanic and shallow intrusive igneous rocks. It characteristically occurs as well-formed trapezohedral crystals (Fig. 14) within a fine grained volcanic matrix. Leucite may someday be utilized as a source of potassium.

Physical Properties

Color	White to gray
Luster	Vitreous to dull
Cleavage	None
Hardness	5½-6
Streak	White
Specific Gravity	2.42
Crystal Form	Trapezohedra

Occurrences in Wyoming

Leucite is found in abundance in volcanic cones, plugs and flows of Tertiary age in the Leucite Hills, about 20 miles northeast of Rock Springs.

Zeolites

(Hydrous silicates)

The zeolites occur most frequently as cavity fillings in volcanic rocks. Many of the zeolites of Wyoming are found in beds of volcanic ash and sedimentary rocks containing a high volcanic ash percentage.

FIGURE 14—
A trapezohedron, the typical crystal form of the mineral leucite

The principal zeolite minerals in Wyoming are clinoptilolite, heulandite, erionite and thomsonite.

The zeolites have a unique ability to act as molecular filters to remove undesirable chemical substances from waters. Because of this property, zeolites are now used in water softeners and may, in the future, be increasingly used in the treatment of industrial waste waters.

Physical Properties

Color	Generally white
Luster	Vitreous to pearly
Cleavage	None
Hardness	3½-5
Streak	White
Specific Gravity	2.1-2.3
Crystal Form	Prismatic for most Wyoming zeolites

Occurrences in Wyoming

Clinoptilolite, heulandite and erionite are most abundant in Eocene age sedimentary rocks found along the Beaver Rim southeast of Lander. Thomsonite is found as cavity fillings in Tertiary lava flows in the remote Sunlight Creek area of the Absaroka Mountains.

Less Common Minerals In The Sedimentary Rocks

Halite

(Sodium chloride)

Halite or salt is found in sedimentary rocks deposited under evaporative conditions. It is commonly found in association with other evaporative minerals such as gypsum, anhydrite and, in Wyoming, trona. Halite is used by many chemical industries and in food.

Physical Properties

Color	Colorless, white
Luster	Vitreous
Cleavage	Cubic
Hardness	2½
Streak	White
Specific Gravity	2.16
Crystal Form	Cubic
Other Characteristics	Halite is easily identified by its taste

Occurrences in Wyoming

Halite is found in association with trona and other evaporative minerals in the Eocene lake beds of the Green River Basin in southwestern Wyoming. The minerals in these rocks were deposited as evaporation slowly dried up the ancient lakes and caused the precipitation of mineral matter from the lake waters.

The trona and halite beds of the Green River Basin do not crop out on the surface, but their extent has been accurately determined by numerous mineral exploration drill holes. Small amounts of halite do occur at the surface in several small present-day alkali lakes in Albany, Carbon, Natrona, Fremont and Lincoln Counties.

Sulfur

Sulfur is one of the few chemical elements that is found as a mineral in its native state (not combined with other elements). Sulfur is frequently formed by direct precipitation from sulfurous volcanic gases. It can also be formed by the chemical alteration of sulfate minerals such as gypsum, or by deposition from sulfur-bearing waters (hot springs) through the action of bacteria. Sulfur is used in the manufacture of sulfuric acid, paper, gunpowder and rubber.

Physical Properties

Color	Yellow
Luster	Resinous
Cleavage	None
Hardness	1½-2½

Streak	Pale yellow
Specific Gravity	2.05-2.09
Crystal Form	Dipyramidal

Occurrences in Wyoming

Sulfur occurs in many of the hot springs deposits of Wyoming including some along the Yellowstone Highway, three miles west of Cody, and some in altered limestone along Wyoming Highway 120, three and one-half miles northwest of Thermopolis.

A great deal of sulfur is produced in Wyoming from hydrogen sulfide-bearing natural gas. Most of this "sour gas" sulfur production is from gas fields in the eastern and northern Big Horn Basin.

Trona

(Hydrated sodium carbonate and sodium bicarbonate)

Trona (Plate V-2) is a rare sodium mineral found in relative abundance in Eocene sedimentary rocks of the Green River Basin in southwestern Wyoming. The trona beds of the Basin were deposited as large, fresh water lakes began to evaporate, precipitating mineral matter.

Trona is used to produce the industrial chemical soda ash (sodium carbonate) which is vitally important in the glass, paper, soap, petroleum refining and textile industries. Bicarbonate of soda (baking soda) is also produced from trona.

Physical Properties

Color	Yellowish brown to gray, translucent
Luster	Vitreous to earthy
Cleavage	Perfect in one direction
Hardness	2½-3
Streak	White
Specific Gravity	2.14
Crystal Form	Flattened, prismatic
Other Characteristics	Alkaline taste

Occurrences in Wyoming

The Green River Basin trona deposits are not visible at the surface. They are mined underground from depths to 1,500 feet. The four active trona mines in Wyoming are all northwest of Green River in Sweetwater County. Wyoming trona now accounts for about 75 percent of the soda ash consumed in the United States.

In terms of dollar value and numbers of people employed, the trona industry is now the largest of the non-energy mineral industries in Wyoming.

Uranium Minerals

(Uranium oxides, silicates, sulfates, phosphates and vanadates)

Although uranium minerals occur in igneous and metamorphic rocks, in mineral veins and in pegmatites, most uranium ore produced in Wyoming and the United States comes from sandstones of Mesozoic and Cenozoic age. Uranium ore mineral concentrations resulted from groundwater leaching of disseminated uranium from volcanic ash layers, feldspathic sandstones or Precambrian granitic rocks, and the transport of these uranium-bearing groundwater solutions to chemically favorable sites where precipitation occurred.

The uranium minerals are numerous and chemically complex, but can be differentiated into two easily recognizable groups on the basis of color and degree of oxidation. Most Wyoming uranium ores contain black minerals, which are of the unoxidized type. The most common of these minerals are uraninite (uranium oxide) and coffinite (hydrous uranium silicate). In some districts, ore exposed to oxidizing conditions was converted to one or more of the oxidized uranium minerals, which are usually bright yellow to yellow green in color (Plate V-3, 4). Some of the more common of the oxidized uranium minerals are carnotite (potassium uranium vanadate), autunite (calcium uranium phosphate), schroeckingerite (hydrated fluocarbonate-sulfate of sodium, calcium and uranium) and tyuyamunite (calcium uranium vanadate).

All uranium minerals naturally emit beta and gamma rays. Radiation surveys are, therefore, a principal uranium exploration method.

The energy of radioactive uranium is converted to electricity in power plants, drives nuclear ships and submarines, and can be unleashed with massive explosive force in nuclear bombs. In recent years, the demand for uranium for electric power generation has far outstripped the military uses.

Physical Properties

Uraninite

Color	Brown to black
Luster	Submetallic to greasy to dull
Cleavage	None
Fracture	Uneven to conchoidal
Hardness	5-6
Streak	Brownish, black or gray
Specific Gravity	9-9.7
Crystal Forms	Cubes, octahedra, most often massive with no crystals visible

Coffinite

Color	Black
Luster	Dull to adamantine
Cleavage	None
Fracture	Irregular to subconchoidal
Hardness	5-6

Streak	Brown to black
Specific Gravity	5.1
Crystal Form	Tetrahedrons, but most commonly in fine aggregates

Carnotite

Color	Lemon yellow to greenish yellow
Luster	Dull earthy
Cleavage	Perfect in one direction, but rarely seen due to occurrence in very fine powdery form
Hardness	2-3
Streak	Yellow
Specific Gravity	5.03
Crystal Form	Rarely seen in crystals, usually as powdery aggregate

Autunite

Color	Lemon yellow to pale green
Luster	Vitreous
Cleavage	Perfect
Hardness	2-2½
Streak	Yellow
Specific Gravity	3.1-3.2
Crystal Form	Thin tabular

Schroeckingerite

Color	Greenish yellow
Luster	Vitreous
Cleavage	Perfect in one direction
Hardness	2½
Streak	Greenish yellow
Specific Gravity	2.51
Crystal Form	Six-sided tabular or scaly

Tyuyamunite

Color	Yellow to green
Luster	Waxy
Cleavage	Perfect micaceous
Hardness	2
Streak	Yellow
Specific Gravity	3.67-4.35
Crystal Form	Prismatic to tabular, scaly

Occurrences in Wyoming

Uranium minerals occur in economic concentrations in Cretaceous and Tertiary sandstones in the Powder River Basin, the Shirley Basin, the Great Divide-Washakie Basin and the Wind River Basin. Wyoming is considered to have the second largest reserves of uranium ore in the United States (New Mexico is first). The major producing districts in the state (Fig. 15) are Gas Hills (15 miles north of Jeffrey City), Shirley Basin (35 miles south of Casper), Crooks Gap-Green Mountain and the southern Powder River Basin.

Most production in the state is from rocks of Eocene age, but additional production has come from Cretaceous rocks in the Black Hills area of Crook County and from Miocene rocks in the Washakie Basin of Carbon County. Numerous undeveloped occurrences of uranium minerals have been located throughout the state, and it can be expected that many of these will become commercial producers in the future.

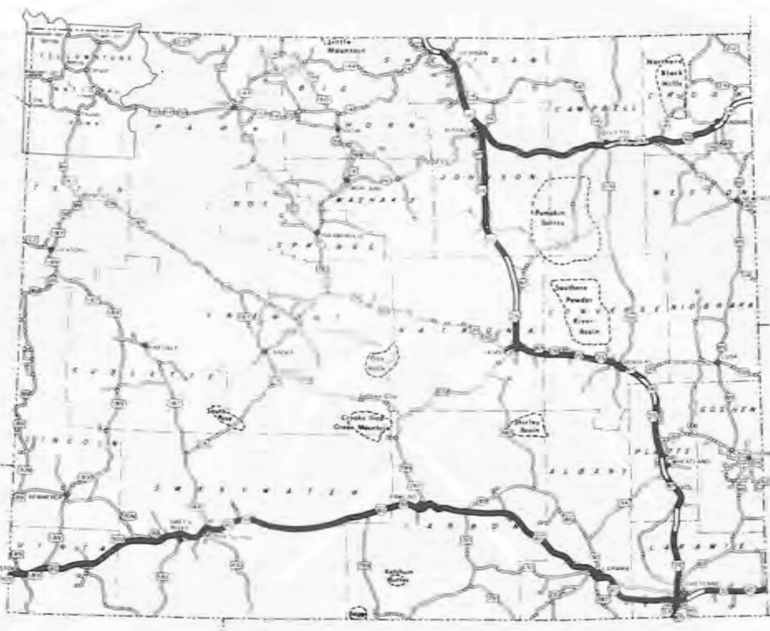


FIGURE 15—Major uranium mining districts of Wyoming

Less Common Minerals In Metamorphic Rocks

Cordierite

(Magnesium-iron-aluminum silicate)

Cordierite is found mainly in metamorphic gneisses and schists (Plate VI-1). Cordierite is used in ceramic parts which must withstand very large changes in temperature, such as industrial oil and gas burner tips. Some cordierite exhibits strikingly different colors when viewed along two different crystallographic directions. This property is called dichroism. Cordierite of good color may be used for gemstones.

Physical Properties

Color	Gray, blue, may show dichroism
Luster	Vitreous
Cleavage	Poor in one direction
Hardness	7-7½
Streak	White
Specific Gravity	2.60-2.66
Crystal Form	Prismatic
Other Characteristics	Cordierite may be difficult to distinguish from quartz

Occurrences in Wyoming

Cordierite-bearing gneisses are found in the Precambrian rocks of the Laramie Range, about 20 miles northeast of Laramie near the Horse Creek road. The cordierite of the Laramie Range contains a large amount of iron, however, which limits its usefulness.

Corundum

(Aluminum oxide)

Corundum is an accessory mineral in many metamorphic rocks. It is sometimes found in abundance in reaction zones separating metamorphosed dark-colored igneous intrusive rocks from granites or light-colored gneisses and schists. Corundum occurs in gem varieties called sapphire (blue) and ruby (deep red). Ordinary corundum is used as an abrasive. Synthetic corundum today supplies most of the demand both for gem and common corundum.

Physical Properties

Color	Gray, brown, red, blue
Luster	Adamantine or vitreous
Cleavage	Poor in two directions
Hardness	9
Streak	White
Specific Gravity	4.02
Crystal Form	Tapering hexagonal prisms or pyramids

Occurrences in Wyoming

In Wyoming, the most interesting deposits of corundum are found in Precambrian metamorphic rocks of the western Granite Mountains, southeast of Lander, in Fremont County. Some such deposits may be seen just south of US Highway 287, 30 miles southeast of Lander.

Epidote

(Calcium aluminum-iron silicate)

Epidote commonly occurs in metamorphic rocks as the alteration product of feldspars, pyroxenes or amphiboles. It is also frequently formed during the metamorphism of impure limestones.

Physical Properties

Color	Bright yellowish green (pistachio green)
Luster	Vitreous
Cleavage	Perfect in one direction, imperfect in another
Hardness	6-7
Streak	White
Specific Gravity	3.35-3.45
Crystal Form	Prismatic

Occurrences in Wyoming

Epidote is found in most of the metamorphic rock regions of Wyoming.

Graphite

(Carbon)

Much of the graphite found in metamorphic rocks may have been formed by metamorphic recrystallization of organic carbon. Graphite is used in pencils, dry lubricants and heat-resistant materials. Most of the graphite used today is manufactured from coal or coke.

Physical Properties

Color	Black to dark steel-gray
Luster	Metallic to earthy
Cleavage	Perfect in one direction
Hardness	1-2
Streak	Black
Specific Gravity	2.2
Crystal Form	Tabular with hexagonal outline. Very similar in appearance to molybdenite

Occurrences in Wyoming

Graphite is found in Precambrian metamorphic rocks in the northern Laramie Range of Albany and Platte Counties and in the Haystack Range of Goshen County.

Iron Minerals

(Iron oxides)

Although magnetite and hematite (the most important ore minerals of iron) are both found in a wide range of geological settings, the most characteristic occurrence of these minerals is in taconite and other iron-rich sediments which were originally laid down in shallow seas. The rocks generally contain a large amount of quartz in the form of chert. Magnetite is also commonly found as an accessory mineral in igneous rocks, in metalliferous vein deposits and concentrated as a heavy, resistant, detrital mineral in river and beach sands and some sandstones. Hematite is also found in unmetamorphosed sedimentary rocks and in igneous and vein deposits.

Physical Properties

Magnetite

Color	Black
Luster	Metallic
Cleavage	None
Hardness	5½-6½
Streak	Black
Specific Gravity	5.18
Crystal Form	Octahedra
Other Characteristics	Attracted by a magnet, may act as a natural magnet

Hematite

Color	Reddish brown, red, black, gray
Luster	Metallic to dull, earthy
Cleavage	None
Hardness	5½-6½
Streak	Brick-red
Specific Gravity	5.26
Crystal Form	Usually tabular, may be grouped in rosettes, more rarely in nearly cubic rhombohedra

Occurrences in Wyoming

As has been previously mentioned, magnetite occurs with ilmenite in deposits of igneous origin at Iron Mountain in the Laramie Mountains northeast of Laramie. Because of metallurgical treatment problems of the intergrown titanium and iron minerals, the Iron Mountain deposit has not yet been developed for iron ore. The two major iron mining districts in the state, Hartville in Platte County and

Atlantic City in Fremont County, are in metamorphosed bedded sedimentary rocks of Precambrian age. The Hartville ore is mainly hematite (Plate VI-2) and the Atlantic City ore is magnetite taconite.

The Hartville deposits have been mined almost continuously since 1898 and supply ore to the iron and steel industry in Pueblo, Colorado. Since 1962, the mine at Atlantic City has shipped large tonnages of pelletized taconite ore to a plant near Salt Lake City, Utah.

Other large, undeveloped iron deposits have long been known to exist at Bradley Peak, eight miles west of Seminoe Dam, in Carbon County, and at Copper Mountain, ten miles east of Boysen, in Fremont County.

Kyanite

(Aluminum silicate)

Kyanite (Plate VI-3) is one of a group of minerals having identical chemical composition but different crystal structure. Such a group of minerals are called polymorphs. Other members of this group are andalusite and sillimanite, which are both rare in Wyoming.

Kyanite is found as an accessory mineral in metamorphic gneisses and schists. Kyanite and its polymorphs are used mainly in high temperature ceramic coatings for spark plugs.

Physical Properties

Color	Cornflower blue to blue-green
Luster	Vitreous
Cleavage	Perfect in one direction
Hardness	5 parallel to length of crystals, 7 at right angles to this direction
Streak	White
Specific Gravity	3.56-3.66
Crystal Form	Long, tabular, prismatic, in bladed clusters

Occurrences in Wyoming

Kyanite is found at numerous places in the Precambrian schists and gneisses of Wyoming. It occurs in relative abundance near the head of Cottonwood Creek, about five miles southeast of Encampment, in Carbon County.

Serpentine

(Hydrous magnesium silicate)

Serpentine is a mineral characteristically produced by the metamorphic alteration of dark-colored igneous rocks. In some cases, serpentine may make up practically an entire rock mass. The rock in such occurrences is called serpentinite. The fibrous variety of serpentine called chrysotile (Plate VI-4) is the world's chief source of asbestos. Chrysotile occurs in narrow veins in fine, silky, flexible fibers.

The fire-resistant and fibrous nature of chrysotile allows it to be woven into a fireproof cloth. The more common, massive variety of serpentine is sometimes used as an ornamental building stone.

Physical Properties

Color	Mottled shades of green, yellow, gray, black
Luster	Greasy, silky when fibrous
Cleavage	None visible
Hardness	2-5
Streak	White
Specific Gravity	2.20-2.65
Crystal Forms	Platy in massive variety, fibrous in chrysotile

Occurrences in Wyoming

Serpentine is found in Precambrian metamorphic rocks in most of the mountain ranges of Wyoming. It was formed as a result of metamorphic alteration of olivine, pyroxene and amphibole in the dark colored igneous rocks. Asbestos serpentine is found in some abundance on Casper Mountain, eight miles south of Casper. A mill built in 1910 for asbestos production proved unsuccessful and no asbestos has been produced since then.

Talc

(Magnesium silicate)

Talc is a soft, greasy-feeling mineral produced by the metamorphism of magnesium-bearing silicates such as olivine, pyroxene and amphibole. Talc may be found as an accessory mineral in schists, or in massive, cryptocrystalline concentrations known as soapstone.

Talc is used in talcum powder, paint, ceramics, paper and rubber. Soapstone can be cut into slabs and used in wash tubs, sinks and laboratory table tops.

Physical Properties

Color	White, gray, green
Luster	Pearly to greasy
Cleavage	Perfect in one direction like mica
Hardness	1
Streak	White
Specific Gravity	2.7-2.8
Crystal Form	Very rare crystals are tabular with hexagonal outline
Other Characteristics	Talc is most readily identified by its soft, greasy feel

Occurrences in Wyoming

Talc occurs at several sites in the Precambrian metamorphic rocks west of Wheatland in the Laramie Range.

Vermiculite

(Magnesium-aluminum-iron alumino-silicate)

Vermiculite is a micaceous-appearing mineral that expands greatly when heated. It is most frequently found at the contact between dark-colored metamorphic schists, amphibolites or serpentinites, and intruding granitic igneous rocks.

Because of its property of expansion, vermiculite is useful for making light-weight insulating material and as a light-weight aggregate in concrete. Vermiculite is also widely used as a soil conditioner in potting mixes and as a fire base in charcoal barbeque grills.

Physical Properties

Color	Yellow, brown, black
Luster	Vitreous to pearly
Cleavage	Perfect in one direction
Hardness	1 ½
Streak	White
Specific Gravity	2.8-3.2
Crystal Form	Hexagonal shaped plates
Other Characterstics	Expands when heated

Occurrences in Wyoming

Vermiculite has been mined from Precambrian rocks northeast and southeast of Encampment in Carbon County, west of Wheatland in the Laramie Mountains, ten to twelve miles south of Glenrock in Converse County and in the Sweetwater District, 26 to 28 miles west of Alcova. Numerous other small vermiculite occurrences have been noted in Precambrian rocks in most parts of the state.

Less Common Minerals In Pegmatites

Pegmatites are very coarsely crystalline igneous rock bodies formed by crystallization of water-rich melt remaining in the late solidification stages of large masses of molten igneous material. The pegmatite minerals are discussed separately from those of the conventional igneous rocks because certain relatively rare minerals and chemical elements are selectively concentrated in this rock type.

Basically, most pegmatites are composed of quartz, feldspar and mica (the simple pegmatite). When the rare minerals are also present, the pegmatite is classified as complex.

Beryl

(Beryllium-aluminum silicate)

Beryl contains the rare chemical element beryllium and is a mineral constituent of many complex pegmatites. Common beryl is the major source of beryllium metal, used in alloys, nuclear reactors and glass and procelain. Gem varieties of beryl, emerald (green), aquamarine (greenish blue) and morganite (pink) are among the most valuable of gemstones.

Physical Properties

Color	Usually green, light yellow, gray
Luster	Vitreous
Cleavage	Poor in one direction
Hardness	7½-8
Streak	White
Specific Gravity	2.75-2.80
Crystal Form	Hexagonal prisms
Other Characteristics	Beryl is easily mistaken for quartz in the field

Occurrences in Wyoming

Beryl is found in complex pegmatites of Precambrian age ten miles northeast of Guernsey, in the Haystack Range. Complex pegmatites just north of Wyoming State Highway 230, four miles north of the Colorado state line in Albany County, contain beryl, tantalite-columbite and other rare minerals. Beryl is also found in Precambrian pegmatites of the Bridger-Owl Creek Mountains in Fremont County.

Lithium Minerals

Several lithium-bearing minerals are found almost exclusively in complex pegmatites. Two of these are spodumene, a lithium pyroxene, and lepidolite, a lithium mica. Lithium is used in glass, lubricants, batteries and some nuclear reactors.

Physical Properties

Spodumene

Color	White, gray
Luster	Vitreous
Cleavage	Prismatic (See Fig. 10)
Hardness	6½-7
Streak	White
Specific Gravity	3.15-3.20
Crystal Form	Prismatic

Lepidolite

Color	Pink, lilac, grayish-white
Luster	Pearly
Cleavage	Perfect in one direction
Hardness	2½-4
Streak	White
Specific Gravity	2.8-3.0
Crystal Form	Platy with hexagonal outline

Occurrences in Wyoming

Spodumene is found in a complex pegmatite on the north spur of Black Mountain, seven miles southwest of Ervay, in the Rattlesnake Hills of Natrona County. Lepidolite is found in some of the complex pegmatites of the Bridger Range in Fremont County.

Tantalite-Columbite

(Iron-manganese tantalum-niobium oxides)

The two rare chemical elements tantalum and niobium are found in nature almost exclusively in the tantalite-columbite mineral series in complex pegmatites. Niobium and tantalum are used in alloy steels, electronic tubes and nuclear reactors.

Physical Properties

Color	Black to brownish-black
Luster	Submetallic
Hardness	6
Streak	Dark red to black
Specific Gravity	5.2-7.9
Crystal Form	Short prismatic to thin tabular

Occurrences in Wyoming

A tantalite-columbite bearing pegmatite is found in the Precambrian rocks of the Medicine Bow Mountains, just north of Wyoming State 230, four miles north of the Colorado state line.

Thorium and Rare Earth Minerals

Thorium and the rare earth group of chemical elements usually occur together in several minerals which are found in complex pegmatites. Thorium can be used in metal alloys for high-speed aircraft and spacecraft construction and nuclear reactors. It was often used in the past for incandescent gas mantles in lanterns.

The rare earths are a group of 15 little-known metals which are finding increasing use in alloys, glass and arc lights. Allanite is a mineral much like epidote, but with rare earths and thorium replacing some of the calcium atoms in the epidote structure. Euxenite is a thorium-rare earth oxide which also contains some niobium and tantalum. Monazite is the chief ore mineral of thorium and the rare earths. It is a phosphate of the metals. Monazite is a heavy, resistant mineral and therefore can be found concentrated in some beach and river sands.

Physical Properties

Allanite

Color	Brown to black
Luster	Vitreous to pitchy
Cleavage	None
Fracture	Conchoidal
Hardness	5½-6
Streak	White
Specific Gravity	3.5-4.2
Crystal Form	Prismatic

Euxenite

Color	Brownish black
Luster	Vitreous to greasy
Cleavage	None
Fracture	Sub-conchoidal
Hardness	5½-6½
Streak	Brown
Specific Gravity	5.0-5.9
Crystal Form	Short prismatic

Monazite

Color	Yellowish to reddish-brown
Luster	Resinous
Cleavage	None
Fracture	Sub-conchoidal
Hardness	5-5½
Streak	White
Specific Gravity	5.0-5.3
Crystal Form	Rare, usually in granular masses

Occurrences in Wyoming

Thorium-rare earth minerals occur in numerous Precambrian pegmatites in the Laramie, Sierra Madre, Big Horn and Medicine Bow Ranges. In the 1950's several thousand pounds of euxenite were produced from a pegmatite just west of the North Platte River, nine miles north of the Colorado state line, in Carbon County. Monazite-bearing black sandstones are found at the base of the Cambrian Deadwood Formation at Bald Mountain, on the west side of the Big Horn Mountains, in Big Horn and Sheridan Counties. Bald Mountain lies just south of US Highway 14A on the county line. Thorium and the rare earths occur in anomalous concentration in altered Tertiary igneous rocks of the Bear Lodge Mountains, six to eight miles northwest of Sundance, in Crook County.

Tourmaline

(Sodium-iron, magnesium-lithium-boron alumino silicate)

Tourmaline is found primarily in pegmatites. The mineral occurs in a wide range of colors. Many of the lighter colored, transparent varieties make very attractive, semi-precious gemstones.

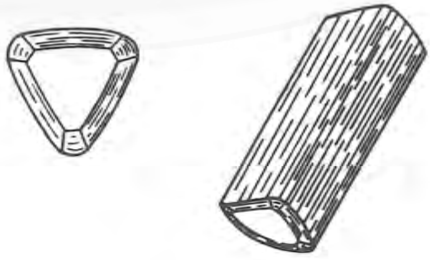
Physical Properties

Color	Black, brown, red, pink, blue, green, yellow
Luster	Vitreous
Cleavage	Poor
Fracture	Sometimes conchoidal
Hardness	7 ½
Streak	White
Specific Gravity	3.00-3.25
Crystal Form	Prismatic with curved triangular cross-section (See Fig. 16)

Occurrences in Wyoming

Tourmaline occurs in the complex pegmatites of the Haystack Range of Goshen County and at Black Mountain in the Rattlesnake Hills of Natrona County. Other complex pegmatites in the Laramie, Medicine Bow and Bridger Mountains also contain black tourmaline as an accessory mineral. To date, no tourmaline of gem quality has been reported in Wyoming.

FIGURE 16—Typical prismatic crystal form and triangular cross-section of tourmaline



Less Common Minerals In Vein Deposits

A large and important part of the world's minerals are found in mineral veins. Vein deposits are formed by mineralized waters moving through fractures or openings in rocks, precipitating part of their mineral matter as they go. The mineral-bearing waters which form vein deposits may be derived from ordinary ground water, from cooling igneous intrusions or a mixture of both.

Mineral veins almost always contain large amounts of some of the more common minerals, such as quartz or calcite, along with more valuable minerals. In mining terminology, these common minerals which are of no economic value are gangue minerals. The minerals which can profitably be mined are ore minerals.

In Wyoming, most vein deposits of proven or potential economic value have been found in Precambrian igneous and metamorphic rocks or in Tertiary volcanic and sedimentary rocks, mainly in the Absaroka Mountains.

Copper Minerals

In Wyoming, most copper production comes from vein deposits of Precambrian age. The sulfides bornite, chalcocite, chalcopyrite and covellite are the copper minerals most common in vein deposits. The copper carbonates malachite and azurite, the silicate chrysocolla and the oxide cuprite are frequently found in veins which have been exposed to oxidizing conditions near the surface. Veins containing oxidized minerals near the surface usually contain an unoxidized suite of sulfide minerals at depth.

The uses of copper are, of course, numerous. Copper is used by the electrical industry because of its electrical conducting properties. It is resistant to corrosion and is used in plumbing and in a wide variety of alloys such as brass and bronze.

Physical Properties

Azurite

Color	Blue
Luster	Vitreous, earthy, silky
Cleavage	None
Fracture	Conchoidal
Hardness	3½-4
Streak	Blue
Specific Gravity	5.06-5.08
Crystal Form	Rare cubic, dodecahedral and octahedral
Other Characteristics	Effervesces in dilute hydrochloric acid

Chalcocite

Color	Gray to dull black
Luster	Metallic
Cleavage	None
Fracture	May be conchoidal
Hardness	2½-4
Streak	Blue
Specific Gravity	5.5-5.8
Crystal Form	Usually fine grained and massive

Chalcopyrite

Color	Bright brass-yellow, sometimes tarnished to bronze irridescence
Luster	Metallic
Cleavage	None
Hardness	3½-4
Streak	Greenish-black
Specific Gravity	4.1-4.3
Crystal Form	Tetrahedra

Chrysocolla

Color	Greenish blue
Luster	Vitreous to earthy
Cleavage	None
Fracture	Conchoidal
Hardness	2-4
Streak	Light blue
Specific Gravity	2.0-2.4
Crystal Form	Commonly cryptocrystalline

Covellite

Color	Indigo-blue, irridescent
Luster	Metallic
Cleavage	None
Hardness	1½-2
Streak	Gray-black
Specific Gravity	4.60-4.76
Crystal Form	Rare, tabular, hexagonal, usually massive

Cuprite

Color	Red
Luster	Metallic to adamantine
Cleavage	None
Fracture	Conchoidal
Hardness	3½-4
Streak	Brownish red
Specific Gravity	3.90-4.03
Crystal Form	Prismatic, usually in radiating fibers

Malachite

Color	Bright green
Luster	Vitreous, silky
Cleavage	Perfect in one direction, but rarely seen due to fine, fibrous crystal habit
Hardness	3½-4
Streak	Green
Specific Gravity	3.9-4.0
Crystal Form	Slender prismatic usually as radiating fibers
Other Characteristics	Effervesces in dilute hydrochloric acid

Occurrences in Wyoming

There are, at present, no producing copper mines in Wyoming. Around the turn of the century, however, Wyoming was among the nation's leaders in copper production. This production came mainly from one mining district, the Encampment District of Carbon County (Plate VI-5). Copper minerals in the Encampment District are generally associated with quartz veins which cut through Precambrian metamorphic and igneous rocks.

Some copper has been produced in the Hartville district of Platte County, the Copper Mountain District of Fremont County and the Douglas Creek District of Albany County. In the Absaroka Mountains, copper is known to occur in veins and disseminations in Tertiary volcanic rocks in the Kirwin and Sunlight Basin areas.

Fluorite

(Calcium fluoride)

Fluorite is most frequently found in veins, sometimes in association with metallic ore minerals, such as those of lead and silver. Fluorite is used mainly as a flux for making steel and in the preparation of hydrofluoric acid.

Physical Properties

Color	Most commonly purple, yellow, light green or blue
Luster	Vitreous
Cleavage	Perfect in four directions forming octahedra
Hardness	4
Streak	White
Specific Gravity	3.18
Crystal Form	Cubic

Occurrences in Wyoming

Fluorite of potential economic value is found in the Bear Lodge Mountains of Crook County, about five miles northwest of Sundance. In these occurrences, veins and pods of fluorite are found within the Mississippian age Pahasapa Limestone. The mineralizing fluids apparently came from several small bodies of Tertiary intrusive rock nearby.

Galena

(Lead sulfide)

Galena is the principal ore of lead. It is most commonly found in veins associated with zinc and silver minerals. Galena is also found in replacement and cavity-filling deposits in limestone.

Lead is used in batteries, paint pigments, cable coverings, solder and other alloys, and in bullets and shot.

Physical Properties

Color	Lead-gray
Luster	Metallic
Cleavage	Perfect in three directions forming cubes
Hardness	2½
Streak	Lead-gray
Specific Gravity	7.4-7.6
Crystal Form	Cubic

Occurrences in Wyoming

There are currently no lead deposits under production. Small vein deposits of galena, usually containing slight amounts of silver and gold, have been found in the Precambrian rocks of the Medicine Bow and Sierra Madre Mountains of Albany and Carbon Counties, in Paleozoic limestones cut by Tertiary intrusives at Black Butte, ten miles southeast of Sundance, in Crook County and in Tertiary volcanic rocks of the Kirwin and Sunlight Basin Districts in Park County.

Gold

Gold is most frequently found in quartz-rich mineral veins associated with granite and other silicic igneous rocks. Most gold is found as the native metal (uncombined with other chemical elements). Since gold is chemically inert, resistant to mechanical abrasion and extremely heavy, the mineral may be concentrated as nuggets, grains and dust in stream placer deposits where erosion of gold-bearing veins has supplied detritus (Plate I-1). Placer gold can be recovered by hand-panning the sands or, on a larger scale, by washing the sands through a sluice in which the gold collects behind crossbars or riffles on the sluice floor.

Since gold is the monetary base for much of the world, the great majority of the gold produced in a given year goes to maintain national monetary reserves. Much smaller amounts are used for jewelry and industrial purposes.

Physical Properties

Color	Bright yellow
Luster	Metallic
Cleavage	None
Fracture	Hackly
Hardness	2½-3
Streak	Yellow
Specific Gravity	19.3
Crystal Form	Irregular octahedral, often in branching clusters

Occurrences in Wyoming

Most of the gold produced in Wyoming has been recovered from vein deposits in Precambrian rocks of the Atlantic City-South Pass District of Fremont County. Small amounts of placer gold may be panned in Douglas Creek in the Medicine Bow Mountains, in the Sweetwater River and its tributaries in the southern Wind River Mountains and along Snake River in the southern end of Jackson Hole.

Molybdenite

(Molybdenum sulfide)

Molybdenite is the most common ore mineral of molybdenum. It is most commonly found in vein deposits related to granitic intrusives.

Much molybdenum is recovered as a by-product of copper mining. Molybdenum is used in steels to increase their strength and hardness at high temperatures.

Physical Properties

Color	Gray
Luster	Metallic
Cleavage	Perfect in one direction
Hardness	1-1½
Streak	Grayish black
Specific Gravity	4.62-4.73
Crystal Form	Hexagonal plates
Other Characteristics	May easily be confused with graphite

Occurrences in Wyoming

No molybdenum production has been reported in Wyoming. However, molybdenite occurs with copper in veins and disseminated deposits in Tertiary volcanic rocks of the Kirwin and Needle Creek areas of the Absaroka Mountains in Park County. Molybdenite also occurs in Precambrian rocks near Temple Peak in the Wind River Mountains of Sublette County and in the Laramie Range, northeast of Laramie, in Albany County.

Pyrite

(Iron sulfide)

Pyrite or "fool's gold" is found in a wide variety of geological situations, but is most common in vein deposits associated with copper, zinc and lead minerals. Pyrite is also found in igneous rocks as an accessory mineral and in some shales, sandstones and limestones. Pyrite is of little economic value, but is sometimes mined for the manufacture of sulfuric acid.

Physical Properties

Color	Pale, brass-yellow
Luster	Metallic
Cleavage	None
Hardness	6-6½
Streak	Greenish or brownish black
Specific Gravity	5.02
Crystal Forms	Cubes with striated faces, octahedra, pyritohedra (Fig. 17)

Occurrences in Wyoming

Pyrite is found in mineral veins in Precambrian rocks of Albany and Carbon Counties, and in Tertiary volcanic rocks of the Absaroka Mountains. Pyrite usually accompanies uranium minerals in the uranium deposits in Mesozoic and Cenozoic sandstones.

Scheelite

(Calcium tungstate)

Scheelite is an important ore mineral of tungsten. The mineral is found most frequently in quartz veins, but can also be found in

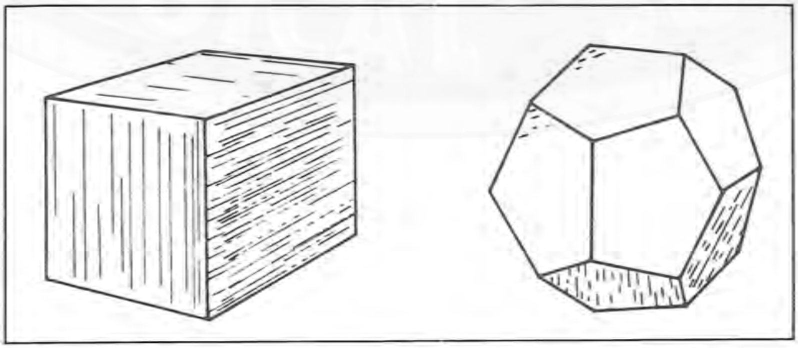


FIGURE 17—The striated cube (left) and the pyritohedron (right) are the common crystal forms of pyrite

pegmatites and metamorphic rocks. Tungsten is used much like molybdenum, as a hardener in steels.

Physical Properties

Color	White, yellow, brown
Luster	Vitreous to adamantine
Cleavage	Good, yielding pyramidal forms
Hardness	4½-5
Streak	White
Specific Gravity	5.9-6.1
Crystal Forms	Dipyramids
Other Characteristics	Glows under ultraviolet light

Occurrences in Wyoming

No scheelite deposits have been commercially exploited in Wyoming. The most extensive deposits found to date are at Copper Mountain in Fremont County.

Sphalerite

(Zinc-iron sulfide)

Sphalerite is the most important zinc ore mineral. Sphalerite is most commonly found in vein deposits in association with lead minerals.

Zinc is the metal used in galvanizing iron and steel. It is also combined with copper to make brass, used as a pigment in paints and used in plates for electric batteries.

Physical Properties

Color	Yellow, brown, black
Luster	Resinous
Cleavage	Perfect yielding dodecahedral forms
Hardness	3½-4
Streak	White, yellow, brown
Specific Gravity	3.9-4.1
Crystal Forms	Tetrahedron, dodecahedron, cube

Occurrences in Wyoming

Sphalerite is found in minute amounts accompanying galena in some of the lead deposits of Wyoming. There has been no zinc production in the state.

Rocks of Wyoming

Rocks are aggregates or mixtures of minerals and organic matter formed by geologic processes. All rocks may be placed into one of three groups (igneous, metamorphic or sedimentary) on the basis of the processes which formed them.

IGNEOUS ROCKS

The rocks which are called igneous (derived from the Latin word ignis, meaning fire) were formed by the solidification of molten rock from deep within the earth. Igneous rocks which solidified without reaching the surface are called intrusive. Igneous rocks which did not completely solidify until after the parent molten rock material had reached the surface are called extrusive (Fig. 18).

Igneous rocks are most easily classified on the basis of their mineral content and texture. Texture refers both to the size and shape of the individual mineral grains within a rock and the relationship of the grains to one another. The texture of a rock is related, in general, to the speed at which its parent molten material cooled and crystallized. Extrusive rocks which chill rapidly upon reaching the surface, are usually extremely fine-grained or even glassy (obsidian). Deep-seated intrusive rocks, which are allowed to cool more slowly, almost always have large mineral crystals.

Some rocks exhibit an uneven texture in which large, well-formed mineral grains are surrounded by a much finer-grained matrix. These rocks are called porphyries and the texture, porphyritic. In most cases, porphyritic texture was caused by a change in the cooling rate of the molten rock as it approached or erupted onto the surface. The large crystals were formed early, under a relatively slow rate of cooling, but the remaining liquid melt crystallized rapidly to form a fine-grained matrix as cooler temperatures near the surface were encountered.

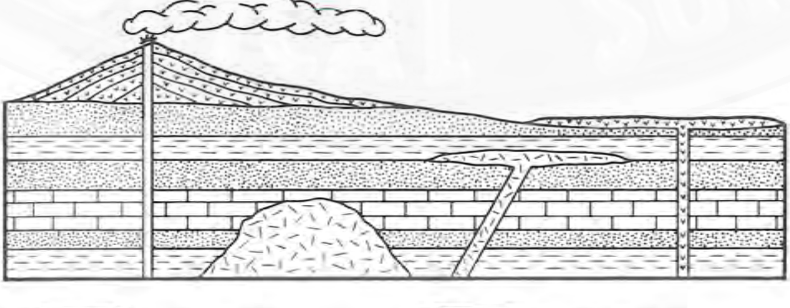


FIGURE 18—Cross-section illustrating the relationship between intrusive and extrusive igneous rocks and bedded sedimentary rocks

Texture or grain size	Light Colored. Principal minerals: orthoclase feldspar, some biotite or amphibole.		Intermediate. Principal minerals: plagioclase and orthoclase feldspar, amphibole, biotite, pyroxene.		Dark Colored. Plagioclase feldspar pyroxene, amphibole, olivine.
	With quartz	No quartz	With quartz	No quartz	
Very coarse-grained	Pegmatite				
Coarse-to medium-grained	Granite	Syenite	Granodiorite Quartz diorite	Diorite	Gabbro Pyroxenite (pryroxene only) Peridotite
Fine-grained (1)	Rhyolite	Trachyte	Dacite	Andesite	Basalt
Porous	Pumice		Pumice		Scoria
Glassy	Obsidian				
Fragmental or broken	Fine-grained; ash or tuff Coarse-grained; breccia or agglomerate				

Note: (1) If mixed grain or crystal sizes occur, then the rock is called a porphyry—example, andesite porphyry.

TABLE 2—Simplified classification of igneous rocks

As can be seen from the Igneous Rock Classification Chart (Table 2), the most important criterion for igneous classification is the kind and relative amount of feldspars present. The distinction between potassium feldspar and plagioclase feldspar is most easily made in the field by noting the presence or absence of twinning striations on the crystal faces. Plagioclase feldspar almost always exhibits striations which can be seen with the aid of a low power hand lens.

Field identification of fine-grained igneous rocks without mineral grains large enough for hand specimen identification is difficult and must be based, primarily, on the overall color and texture of the rock.

Some Fine-Grained Igneous Rocks

Andesite

Andesite is a fine-grained, usually gray igneous rock whose major minerals are plagioclase feldspar, potassium feldspar, amphibole, pyroxene and biotite mica. If quartz is present in visible amounts, the rock is instead classified as a dacite. Andesites and dacites are common in the Tertiary intrusive and extrusive rocks of the Absaroka Mountains.

Basalt

Basalt is a fine-grained, black to green igneous rock composed of plagioclase feldspar, pyroxene and, sometimes, olivine. Basalts can be either intrusive or extrusive, but are best seen in Wyoming in the Yellowstone Park-Absaroka Mountains lava flows of Tertiary Age.

Obsidian

Obsidian is natural volcanic glass produced by extremely rapid chilling of molten rock material extruded onto the earth's surface. It is most frequently jet black, but may also be gray, brown or red. Like all other glasses, obsidian exhibits conchoidal fracture. In the cooling of an igneous melt to form obsidian, individual minerals have not had time to form and segregate from the rest of the melt. The only mineral crystals which can be seen in obsidian are found in small spherical globules called spherulites or in mineral-filled gas bubbles called lithophysae.

Most obsidians were formed from rock melts with essentially the same chemical composition as granite or rhyolite. The Tertiary lava flows of Yellowstone National Park contain abundant obsidian. One of the most famous sites is at Obsidian Cliff in the northwest part of the park. Due to its homogeneity, obsidian was very useful to the American Indian for working into tools and arrowheads.

Phonolite

Phonolite is a rare, fine-grained, igneous rock which occurs in parts of Wyoming. Phonolite is chemically unusual because it is low in silica (no quartz is present) and relatively high in sodium and potassium. Almost all phonolites are porphyritic, with large crystals of feldspar and leucite surrounded by a gray fine-grained matrix.

The most famous phonolite site in Wyoming is at Devil's Tower in Crook County (Plate VII-1). The tower is an isolated pinnacle of phonolite which is most likely the eroded remnant of a once more extensive lens-shaped, igneous intrusive (laccolith). Leucite-bearing phonolites are found in the Leucite Hills, northeast of Rock Springs, in Sweetwater County.

Pumice

Pumice is a very lightweight, frothy appearing rock largely composed of glass. The chemical composition of pumice is much like obsidian's. The frothy texture of the rock was produced by the expansion of gas and steam bubbles liberated when the melt reached the surface.

Pumice is most frequently found forming the upper surface of lava flows or as fragments blown out of volcanoes. It is generally white or light gray. Black or dark gray rocks of similar texture are called scoria. Pumice occurs in Tertiary rocks of the Leucite Hills in Sweetwater County and the Yellowstone Park-Absaroka Mountains area.

Rhyolite

Rhyolite is a light colored, fine grained igneous rock which is chemically equivalent to granite. Rhyolites are frequently finely porphyritic in texture, showing small crystals of quartz, feldspar or mica within a pink, white, gray or yellow matrix. Rhyolites of Tertiary age occur as extrusive flows and intrusive plugs and dikes in the Yellowstone Park-Absaroka Mountains area.

Tuff

Tuffs are light-colored, fine-grained, extrusive igneous rocks composed of volcanic ash, small fragments of pumice and broken crystals. Tuffs represent debris blown into the air during explosive volcanic activity. Such debris settles as a blanket over the landscape according to the prevailing wind patterns.

In certain types of volcanic explosions, the small particules may still be hot when they settle to the ground. The heat may build up within tuff to the degree that individual particles are partially melted, flattened out and welded together. Such rocks are called welded tuffs and are extremely difficult to distinguish from ordinary rhyolite flow rock.

Tuffs containing large, angular rock fragments are called volcanic breccias. The large fragments may represent part of the volcanic vent wall-rock which was broken away during explosive eruption. Tuffs, welded tuffs and volcanic breccias are extremely common in the Yellowstone Park-Absaroka Mountains Tertiary volcanics.

Some Coarse-Grained Igneous Rocks

Anorthosite

Anorthosite is a gray, coarse-grained intrusive igneous rock composed almost entirely of plagioclase feldspar. Minor amounts (less than ten percent) of dark minerals such as pyroxene, olivine and ilmenite-magnetite may accompany the feldspar.

The large Precambrian anorthosite mass of the Laramie Range, northeast of Laramie, has been investigated as a potential aluminum source.

Gabbro

Gabbro is a gray, green or black, coarse-grained, intrusive igneous rock composed of plagioclase feldspar, pyroxene, olivine and sometimes hornblende. Peridotite (composed of pyroxene and olivine) and pyroxenite (composed almost wholly of pyroxene) are similar in color and texture to gabbro but lack feldspar.

Gabbro, peridotite and pyroxenite intrusives are common in the Medicine Bow Mountains south and west of Albany in Albany County and in the Sierra Madre Mountains in Carbon County.

Granite

Granite is a white, light gray or pink, coarse-grained igneous rock composed of potassium feldspar, quartz and, usually, biotite (Plate VII-3). Subordinate amounts of plagioclase feldspar and hornblende may also be present. In most granites, the texture is even and equigranular (grains of the different minerals are approximately the same size). Some granites, however, are porphyritic, containing well-formed potassium feldspar crystals larger than the average grain size in the rock.

Granite is the most common coarse-grained igneous rock and plays a prominent part in the make-up of the continental masses. Granite forms a large part of the Precambrian basement underlying younger sedimentary rocks in the basins and forms the exposed cores of most mountain ranges in Wyoming.

Granite is of great economic importance because of its relationship in many mining districts to metalliferous vein deposits. It is apparent in these districts that the vein-forming solutions have been derived from the large masses of crystallizing granitic melt. Granite is an important building stone in some parts of the country.

In Wyoming, Precambrian granites are exposed in the cores of most mountain ranges. At Vedauwoo, in the Laramie Range along US Interstate 80 between Laramie and Cheyenne, one can see a large granite mass which has been shaped into spectacular rounded forms by weathering processes (Plate VII-2). Wyoming granite is used in crushed form as road-building material for highways and railroads.

SEDIMENTARY ROCKS

Sedimentary rocks are formed at or near the earth's surface by a wide variety of mechanical, chemical and organic processes. In general, sedimentary rocks are composed of detrital mineral and rock fragments weathered or eroded from preexisting rocks, mineral material chemically precipitated from solutions and material produced as a function of organic activity either as actual plant and animal remains or mineral material secreted or precipitated by the organisms.

Sedimentary rocks are characterized by their layering or bedding. The classification of sedimentary rocks is based on mineral content, grain size and origin (Table 3).

Some Sedimentary Rocks

Coal

Coal is made up almost entirely of compressed, partially decomposed plant material. Coals form in wet environments in which access to oxygen is restricted. Such environments exist in swamps, marshes and bogs where the remains of generations of plant life are rapidly covered and protected from oxidation by the remains of succeeding generations.

Coal is composed largely of carbon, hydrogen and oxygen combined in highly complex chemical compounds. It is energy from the sun, stored in these complex organic molecules by photosynthesis, which is released and utilized by man when coal is burned.

Coals are classified or ranked according to differences in the proportions of the three major chemical elements. The high rank coals in general have been subjected to higher pressures and temperatures during the period of burial and compaction than have lower ranked coals. The application of heat and pressure to organic debris tends to drive off water, oxygen and hydrogen, leaving a higher and higher proportion of carbon as time passes. The ranks through which organic material may pass if geologic conditions allow its development to continue include (from lowest rank to highest) peat, lignite, sub-bituminous coal, bituminous coal and anthracite coal.

Enormous reserves of bituminous and sub-bituminous coal of Cretaceous and Tertiary ages are found in the state. Only anthracite, the highest rank coal, is not common in Wyoming. Most coal development to date has centered around Sheridan, Gillette, Hanna, Rock Springs and Kemmerer. One of the thickest coal beds in the state is well exposed in the Wyodak strip mine between Moorcroft and Gillette in Campbell County.

Present environmental considerations create a high demand for Wyoming's coals because they are low in sulfur. This factor, along with future construction of plants which will chemically convert coal

Grain Size	Chief Mineral	Cement	Rock Name
Clastic Rocks			
1/16 inch or greater	Any rock or mineral fragment	Silica, calcite iron oxide, clay, sand, silt	Breccia (angular) Conglomerate (rounded)
Less than 1/16 inch but still visible	Quartz, feldspar	Silica, calcite, iron oxide, clay, gypsum or anhydrite	Sandstone (coarser) Siltstone (finer)
Dense (not visible)	Clay minerals		Shale (bedded, fissile) Claystone (more massive)
Chemical and Organic Rocks			
Variable	Calcite	Calcite	Limestone
	Dolomite	Dolomite	Dolomite
	Gypsum, anhydrite	Not applicable	Gypsum, anhydrite
	Halite	Not applicable	Rock Salt
Dense	Silica	Not applicable	Chert
Not applicable	Carbon	Not applicable	Coal

TABLE 3—Simplified classification of sedimentary rocks

into burnable gas (coal gasification), will undoubtedly cause continued rapid expansion of Wyoming coal production.

Amber, which is ancient, fossilized tree resin, has been found associated with coal in the Hanna Coal Basin (Plate VIII-1).

Conglomerate

A conglomerate is a coarse-grained, detrital sedimentary rock composed of rounded pebbles, cobbles or boulders in a finer grained cement or matrix (Plate VIII-2). Depending on the area whose erosion supplied the detrital material, conglomeratic pebbles may be of any rock type. The finer-grained material between the pebbles of most conglomerates is high in clay or mud content.

Beds of conglomerate are found in many of the sedimentary formations in the state, but are especially well developed in the Cretaceous Lakota Formation of the Rattlesnake Hills area and the Eocene Wasatch Formation of western Wyoming. Coarse-grained sedimentary rocks, in which the fragments are angular, are called breccias.

Chert

Chert is a fine-grained, dense, hard rock composed of cryptocrystalline quartz. Chert occurs in a wide range of colors, from white to black. The dark gray to black varieties are also called flint.

Most chert was formed by chemical precipitation of silica, either from ground or sea water. Some chert, when studied under the microscope, contains the hard, skeletal parts of siliceous organisms such as radiolaria, diatoms and sponges. Chert is common in the Permian Phosphoria Formation of western Wyoming.

Limestone

Limestone is a sedimentary rock composed primarily of calcite. Most limestones are white, gray or buff, but some are brown or even black. Limestones range in grain size from microcrystalline (crystal grains visible only under very high magnification) to coarsely crystalline. Many limestones are primarily of granular texture, composed of shells and broken shell fragments.

Although water may deposit limestone by simple precipitation under slightly evaporative conditions, most limestones are directly or indirectly the products of organic activity. Many organisms take calcium carbonate from the water in which they live and use it to build a shell which, when the animal dies, falls to the bottom where it is incorporated with other small fragments and lime mud into a limestone. Other organisms influence the deposition of limestone by less direct means. In the process of living, any organism will cause small, local changes in the chemical environment. These local changes in the chemistry of sea or lake water can cause the precipitation of calcium carbonate as a fine mud. Most limestones are deposited in marine waters, but some are formed in freshwater lakes.

In Wyoming, limestones are most abundant in Paleozoic rocks such as the Madison Limestone and the Casper Formation. The rock is most readily identified in the field by its strong reaction to cold, dilute hydrochloric acid. Limestone is used in cement and lime, beet sugar refining and as a building stone.

Phosphate Rock

Phosphate rock is a rare sedimentary rock which occurs in relative abundance in the Permian age Phosphoria Formation of western Wyoming. Phosphate rock is generally dark (brown, gray or black) but on the outcrop may have a coating or "bloom" of a bluish color. Most phosphate rock is dense and fine-grained, but some is nodular and fossiliferous.

The mineralogy of phosphate rock is complex and poorly understood, but most of the phosphatic material appears to be hydrous tricalcium phosphate with varying amounts of calcium carbonate and fluoride. Phosphate rock of the Phosphoria Formation also contains abnormally high percentages of vanadium and other rare metals.

The Permian phosphate deposits of Wyoming formed as chemically precipitated beds in the region between a deep oceanic trough in Idaho and a broad, shallow marine shelf covering most of Wyoming.

PLATE V-1 Fishtail twin gypsum crystal from near Sheridan (From the collection of Mr. and Mrs. Paul Westedt, Cheyenne)

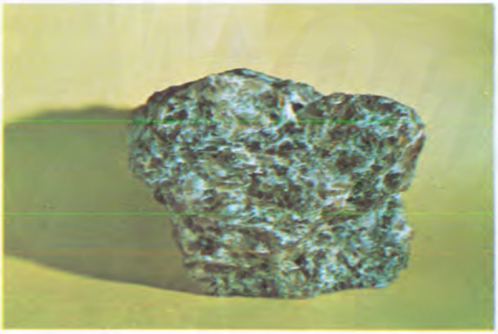


PLATE V-2 Trona from the Green River area, Sweetwater County

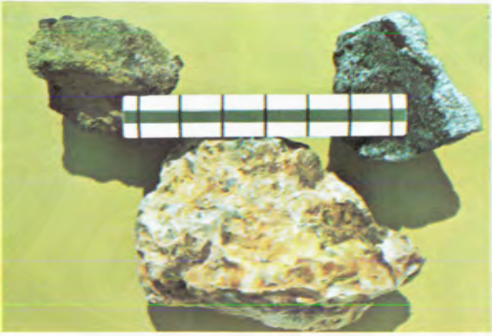


PLATE V-3 Oxidized (yellow) and unoxidized (black) uranium minerals from Wyoming (Specimens courtesy of James M. Hunter, Casper)

PLATE V-4 Site of the initial discovery of commercially significant uranium mineralization in Wyoming, Pumpkin Buttes area, Campbell County. The roll-shaped concentration of black and yellow uranium minerals lies in sandstones of Tertiary (Photo courtesy of J. D. Love, Laramie)

PLATE VI-1 Cordierite from the Laramie Range, Albany County

PLATE VI-2 Hematite iron ore from the Hartville-Sunrise area, Platte County

PLATE VI-3 Kyanite from the Laramie Range west of Wheatland

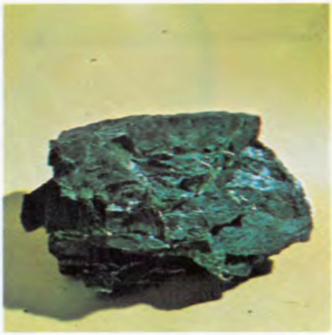


PLATE VI-4 Serpentinite with chrysotile veins from Casper Mountain, Natrona County

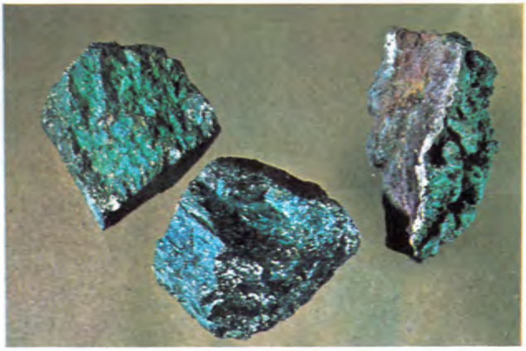


PLATE VI-5 Copper minerals from the Encampment District, Carbon County. Left, malachite and chalcopyrite; center, covellite and bornite; right, cuprite and malachite.

Slightly different chemical conditions in the deeper waters on the margin of the shelf prevented the accumulation of carbonate rock and favored the precipitation of phosphate. The rock is interlayered with dark organic shales and cherts.

Phosphate rock is presently being mined at Leefe, 25 miles west of Kemmerer, in Lincoln County. The phosphate rock is used mainly for manufacturing fertilizer.

Sandstone

Sandstone is a sedimentary rock composed of detrital grains (usually quartz) averaging less than two mm. but more than one-sixteenth mm. in diameter (Plate VIII-3). The sand grains of sandstone are cemented together by silica, calcite or iron oxide or are set in a matrix of clay and other fine-grained material. Almost any mineral or rock may be found among the detrital grains of sandstones, but the more resistant types are most common.

Sandstone is a very abundant rock in Wyoming (Plate VIII-4). Sandstones are formed in a wide variety of terrestrial and marine environments (Fig. 16). River channels, bars, deltas and beaches are all represented by sandstones in the geologic record.

Porous sandstones form the reservoirs of most of Wyoming's oil and natural gas reserves. As has already been mentioned, sandstones of Cretaceous and Tertiary age form the host rock for most of the state's important uranium ore deposits. A sandstone from the Casper Formation has been used in most of the buildings erected on the University of Wyoming campus at Laramie. Extremely pure quartz sandstones may be used as a source of silica for glass making.

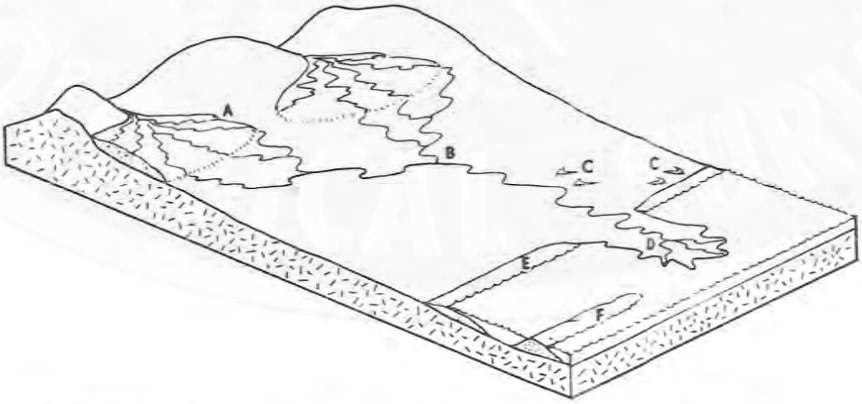


FIGURE 16—Environments of sand deposition. Sandstones which now form part of the geologic rock record were laid down in a wide variety of geologic environments. Sands may be deposited in: (A) alluvial fan deposits at the bases of steep mountain fronts (B) bars, channels and floodplains in stream valleys (C) sand dunes (D) deltas (E) beaches and (F) offshore bars.

Shale

Shale, the most abundant sedimentary rock type, is a mixture of extremely fine-grained quartz and any of a number of clay minerals. Shales are usually finely laminated or bedded. Common shale colors are gray, brown, black, green and red. Red shales of the Triassic Chugwater Formation and the Permian Goose Egg Formation form some of the most colorful outcrops in the state.

Montmorillonite shales of the Cretaceous Frontier and Mowry Formations are mined as Wyoming bentonite. Other shales are used as sources of clay for brick, tile and clay pipe.

In northeastern Wyoming, many hills and buttes are capped by clinker or natural slag beds. These clinker beds are shales which have been baked by the spontaneous burning of underlying coal beds. Clinker beds are generally brightly colored, usually red, yellow, brown or purple. Some of the natural slag is used for road and railroad bed material.

Oil shale is a very fine-grained rock which is a mixture of quartz, clay, calcium carbonate and organic matter. It yields petroleum upon heating. Most oil shale is brown to gray and finely laminated. Oil shale deposits are extensive in the Tertiary Green River Formation of southwestern Wyoming. These deposits are a unique accumulation of lake sediments which represent a tremendous potential petroleum reserve. Selected samples of oil shale from the Green River Formation have yielded almost 60 gallons of oil per ton of rock. Methods for extracting oil from these rocks economically have not yet been perfected (Plate VIII-5).

PLATE VII-1 Devils Tower, Crook County. The tower is the isolated, eroded remnant of a formerly more extensive igneous intrusion. (Photo courtesy of Wyoming Travel Commission)

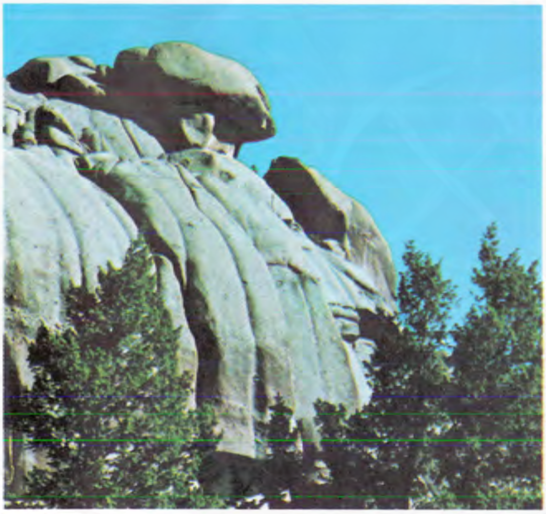


PLATE VII-2 Rounded erosional forms developed on granite at Vedauwoo, Albany County (Photo courtesy of Wyoming Travel Commission)

PLATE VII-3 Precambrian granite from the Laramie Mountains, Albany County

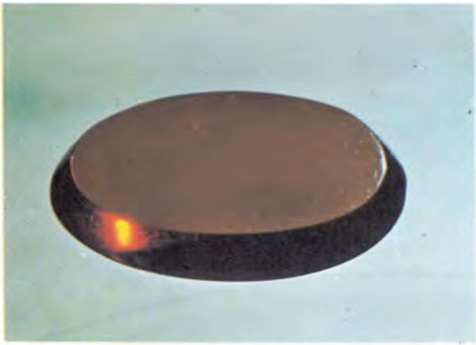


PLATE VIII-1 Cut and polished amber (fossilized tree resin) found associated with coal in Tertiary age rocks of the Hanna Basin, Carbon County (From the collection of J. D. Love, Laramie)

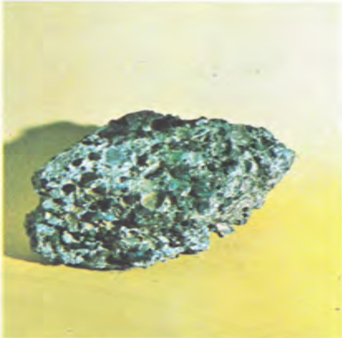


PLATE VIII-2 Conglomerate from the Wasatch Formation, Sweetwater County

PLATE VIII-3 Sand grains magnified ten time

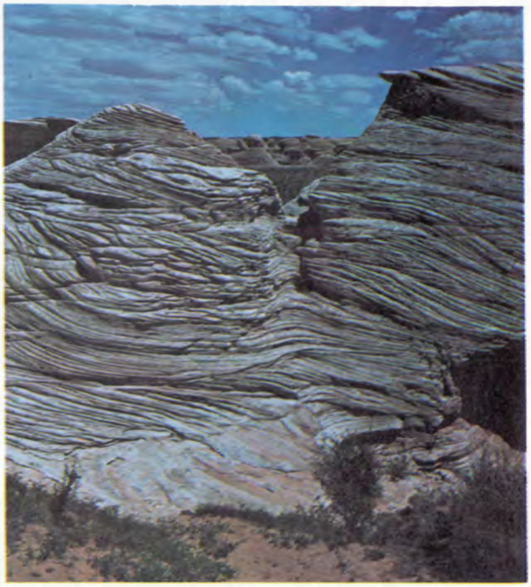


PLATE VIII-4 Sandstone outcrop at Camel Rock, Albany County (Photo courtesy of Wyoming Travel Commission)

PLATE VIII-5 Block of oil shale being placed into United States Bureau of Mines experimental retort at Laramie

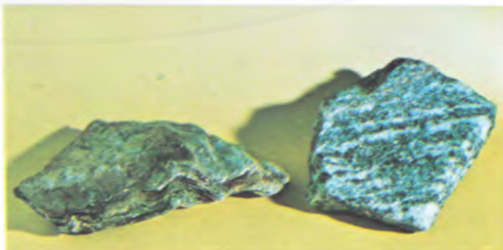


PLATE VIII-6 Schist (left) and gneiss (right) from the Medicine Bow Mountains, Albany County

METAMORPHIC ROCKS

Metamorphic rocks are rocks whose orginal mineralogy and or texture was significantly altered by conditions encountered well after emplacement or deposition. The high temperatures and load pressures which accompany deep burial, the shearing pressures associated with deformation of the Earth's crust and the high temperatures found in proximity to igneous intrusions all produce metamorphism in rocks.

Many metamorphic rocks are characterized by a parallel planar structure called foliation. In most foliated metamorphic rocks, mica flakes, amphibole prisms and other platy or prismatic minerals exhibit a parallel arrangement with one another. Such a parallel arrangement, which when highly developed is called schistosity, may cause the rock to be easily broken along the planes of foliation. Coarsely banded foliation, in which layers or lenses of differing color and mineral composition alternate within the rock, is called gneissic texture.

Schists and gneisses are two of the major metamorphic rock types (Plate VIII-6). Other metamorphic rock types are defined not so much by textural considerations as by their mineralogy and the original rock type from which they came (See Table 4).

Some Metamorphic Rocks

Amphibolite

Amphibolites are green to black rocks consisting wholly or largely of amphibole and usually having schistose texture. Amphibolites generally contain some plagioclase feldspar, but may also contain quartz, garnet, pyroxene and biotite. Amphibolites may be produced by metamorphism of intrusive or extrusive basalts or very impure dolomitic limestones or limey shales.

Texture or Grain Size	Principal Mineral (s)	Rock Name	Original Rock Type
Equigranular (equal grain size)	Quartz	Quartzite	Sandstone
Equigranular to foliated	Calcite and/or dolomite	Marble	Limestone and/or dolomite
Broadly foliated (parallel layers or bands)	Feldspar, mica, amphibole, quartz, garnet, etc.	Gneiss	Granite, rhyolite, shale, etc.
Thinly foliated	Feldspar, mica, amphibole, quartz, etc.	Schist	Andesite, basalt, rhyolite, shale, etc.
Very thinly foliated	Mica, quartz, clay, (these minerals normally can not be seen with the naked eye)	Slate (1)	Shale

(1) Slate is not common as a metamorphic rock in Wyoming; however, some slate crops out in the Medicine Bow Mountains of Albany and Carbon counties.

TABLE 4—Simplified Classification of metamorphic rocks

Amphibolites occur in abundance in the Precambrian rocks of Wyoming. Many of these amphibolite bodies cut across the layering or bedding of adjacent metamorphosed sedimentary rocks and are clearly of intrusive igneous origin. The jade or nephrite rocks of Wyoming are a special form of amphibolite produced by the metamorphism of igneous gabbros, peridotites or pyroxenites in close contact with granites.

Gneiss

Gneiss (pronounced "nice") is a metamorphic rock with a coarse foliation of alternating dark and light mineral layers (Plate VIII-6). The light layers are usually composed of quartz and feldspar, while the dark layers may contain amphibole, mica and pyroxene.

Gneisses are formed from both igneous and sedimentary rocks. Gneisses of granitic composition with only faint banding or lensing of biotite rich zones are called granite gneiss. Gneisses are the most common metamorphic rock type in Wyoming.

Marble

Marble is a metamorphic rock composed of calcite or dolomite, formed by the metamorphism of carbonate sedimentary rocks (limestones or dolomites). Most marbles are light gray to white and distinguished from their sedimentary counterparts by greater crystallinity. Pure marbles do not generally show foliation. When other minerals are present, however, these may be segregated into layers.

Marble is used for interior and exterior building stone. White marble of Precambrian age occurs 15 miles west of Wheatland in Platte County. Less pure marbles occur in the Medicine Bow Mountains, the Haystack Range, the northern Laramie Range and the Big Horn Mountains.

Quartzite

Quartzite is a hard, compact metamorphic rock composed almost entirely of quartz. Metamorphism of pure quartz sandstones does not cause any important changes in mineralogy. It does promote the rearrangement and recrystallization of the original quartz grains into a tightly-bound mosaic which, when struck, will break across the individual grains rather than around the grain boundaries. Most quartzites are light colored, but some quartzites of the Medicine Bow Range are bright green because of a rare, chromium-bearing mica called fuchsite.

Schist

Schist is a metamorphic rock characterized by finely laminated foliation (Plate VIII-6). Most schists will break easily into slabs or plates parallel to the foliation. The surfaces of such slabs generally exhibit a sparkling crystallinity due to the parallel arrangement of platy and prismatic mineral grains within the planes.

Schists are usually designated by their principal mineral constituent, such as biotite schist or kyanite schist. Biotite and hornblende schists occur in abundance in Precambrian rocks throughout Wyoming.

Serpentinite

Serpentinite is a rock composed primarily of serpentine. It is produced by the metamorphism of dark igneous rocks such as gabbro, peridotite or pyroxenite. Serpentinite is usually black or dark green, but may also be yellow or reddish brown. Dark streaks of granular magnetite and chromite are commonly visible in serpentinites. Serpentinites are most characterized by their dark, dull to greasy appearance. Asbestos serpentine sometimes occurs as small streaks or veins within massive serpentinite (Plate VI-4).

Serpentinite is common in most Precambrian areas of Wyoming. The rock occurs with associated chromite and asbestos deposits on Casper Mountain in Natrona County.

Slate

Slate is a fine-grained metamorphic rock which exhibits a striking degree of cleavage, splitting readily into thin sheets. Slates are derived from and appear similar to shales. The metamorphism which produces slate from shale must be of low intensity.

Slate is not common in Wyoming but some is known in the Precambrian rocks of the Medicine Bow Mountains of Albany and Carbon Counties. Slate is used for roofing, floors and chalkboards.

Mineral and Rock Collecting Procedure and Equipment

Many people venture into the field to collect minerals and rocks without previous planning. Serious collectors, on the other hand, study the available maps, consult local rockhound organizations and, in general, know what they are looking for and how to recognize specimens when they see them.

Here are some suggestions that may be of help:

(a) Obtain copies of all available geological, topographic and county road maps and study the area carefully before venturing into the field.

(b) Consult with local rockhound organization members as to the best transportation routes and collecting areas.

(c) Prepare for an extended outing with plenty of water, food, gasoline and emergency equipment for both yourself and your transportation.

(d) Learn the ownership of the lands on which you intend to collect specimens and obtain permission from the landlord. National Parks and Monuments are closed to collecting, as are certain withdrawn areas of the National Forests. Information on restricted areas may be obtained at local National Forest offices or at Ranger Stations.

(e) Useful equipment:
Rock hammer, hand lens (10 power), pocket knife and streak plate, small magnet, safety goggles (or glasses), collecting bags with labels, small chisel, notebook, maps, dilute hydrochloric acid (10%).

The above-mentioned "dilute (10%) hydrochloric acid" may be purchased in small quantities from most drug stores. It should be kept sealed in a plastic bottle with plastic cap.

During field investigations it is not advisable to chip or split off corners of a specimen with a hammer to determine its internal color or character. Such specimens should be transported to a work shop and treated with care until they can be ground on an abrasive wheel or cut with a diamond saw.

Excellent articles describing the handling and preparation of specimens can be found in rockhound magazines on most news stands. There are also listed in these magazines numerous lapidary supply houses that distribute catalogues of available equipment and materials that can be of help.

For a more complete listing and discussion of individual mineral occurrences in Wyoming, Wyoming Geological Survey Bulletin No. 50, "Mineral Resources of Wyoming," is recommended, along with "Mines and Minerals Map of Wyoming." The Bulletin may be purchased for $1.00 per copy from the Geological Survey of Wyoming, Box 3008, University Station, Laramie, Wyoming 82071. The map comes in either rolled or folded form at a purchase price of $2.00 ($2.50 by mail).

Topographic maps of individual areas of the state may also be obtained over-the-counter in Laramie or from the Denver Distribution Section, U. S. Geological Survey, Denver Federal Center, Building 41, Denver, Colorado 80225.

Suggested Additional Reading

American Association of Petroleum Geologists, 1972, Geological highway map of the Northern Rocky Mountain Region.

Blackstone, D. L., Jr., 1971, Traveler's guide to the geology of Wyoming: Wyoming Geological Survey Bulletin 55, 90 p.

Desautels, Paul E., 1968, The mineral kingdom: Grosset and Dunlap, 251 p.

Hager, Michael W., 1971, Fossils of Wyoming: Wyoming Geological Survey Bulletin 54, 51 p.

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Keenan, J. E., 1964, Common gemstones of Wyoming in Highway geology of Wyoming: Wyoming Geological Association, p. 9-12.

Love, J. D. and Reed, John C., Jr., 1968, Creation of the Teton landscape: Grand Teton Natural History Association, 120 p.

MacFall, Russell P., 1963, Gem Hunter's guide: Growell, 278 p.

Sindankas, John, 1959, Gemstones of North America: D. Van Nostrand Company, Inc., 675 p.

Wyoming Geological Survey, 1970, Mines and minerals map of Wyoming.

Wyoming Geological Survey, 1972, Energy resources map of Wyoming.

Acknowledgements

Many of the mineral descriptions used in this book have been taken from Wyoming Geological Survey Bulletin No. 51, "A Field Guide to the Rocks and Minerals of Wyoming," by William H. Wilson, which is now out of print.

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Geologic Provinces of Wyoming