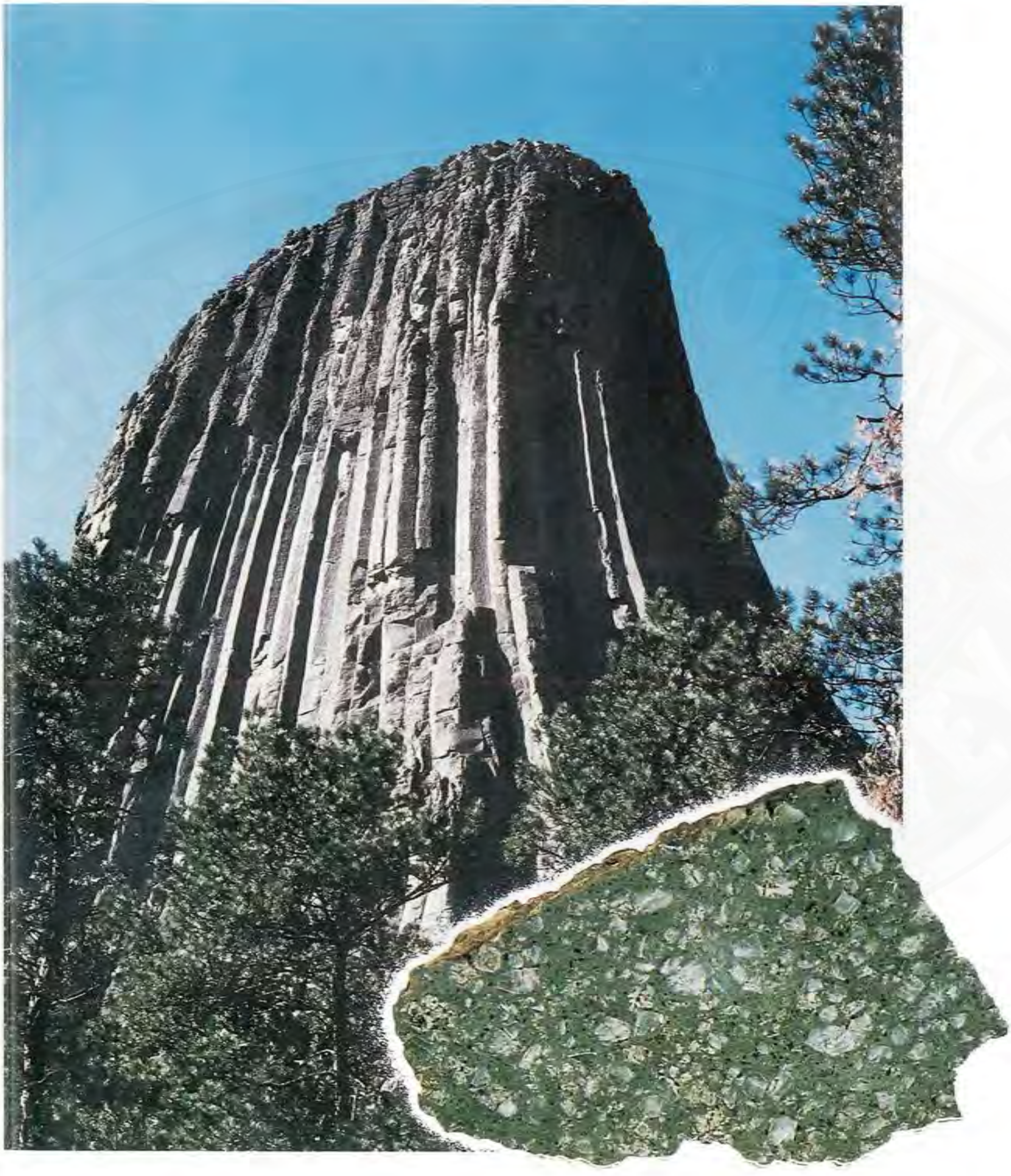
MINERALS and ROCKS of WYOMING

by

W. Dan Hausel



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Gary B. Glass, State Geologist
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Front cover: Devils Tower in the Black Hills, northeastern Wyoming, the neck of a Tertiary volcano that has been exposed by erosion. Its spectacular columnar jointing developed when the molten rock cooled and contracted. (Photograph by David Fountain.) Devils Tower is composed of phonolite, a rare high-sodium/potassium volcanic rock. (Photograph by Sheila Roberts.)

THE GEOLOGICAL SURVEY OF WYOMING
Gary B. Glass, State Geologist

BULLETIN 66

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W. Dan Hausel

1869 1890

Laramie, Wyoming
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Introduction

Rocks greater than three billion years old, rocks that are presently being formed and rocks of every age in between are found in Wyoming. Much of the State is underlain by common rocks and rock-forming minerals that can be found in almost any region of the world, but a few specimens are so rare that they are found only at one or two localities in the Cowboy State and at a few scattered localities worldwide.

Some rare specimens found in Wyoming include both diamond-bearing and diamond-barren kimberlite in the Laramie Range of southeastern Wyoming. These rocks were discovered in the early 1960s, but it was not until 1975 that some were found to contain diamonds and to have every characteristic of diamondiferous kimberlite from South Africa. Not only is the kimberlite a collector's item, but a variety of peridotite and eclogite nodules found in the kimberlite intrusives are also rare specimens. These nodules are fragments of the Earth's mantle and crust from as deep as 120 miles below the surface. Although industrial- and gem-grade diamonds are sometimes found in the kimberlite, they are rare.

Some rare volcanic flows and plugs are found just north of Superior and a short distance northeast of Rock Springs. The Boar's Tusk, north of Rock Springs, forms a spectacular volcanic plug, or neck, and is all that remains of the interior plumbing of a 1.0 to 1.5 million-year old volcano (**Plate 1A**). The Boar's Tusk is formed from wyomingite. Similar rocks to these potassium-rich lavas occur in Western Australia (Carmichael and others, 1974, p. 516-517). But one important difference between the Australian and the Wyoming rocks is that the Australian rocks contain diamond. At the Argyle pipe in northwestern Australia, the potassium-rich igneous rock known as lamproite (pronounced lamp-row-ite) contains more diamonds per ton than any other rock in the world. It is reported that the northwestern Australian rocks run as high as 6.8 carats per ton (Engineering and Mining Journal, November 1983, p. 120). Average diamond ore generally runs only about 0.25 carats per ton (McCallum and Mabarak, 1976).

Some other interesting and rare minerals are found southwest of Rock Springs near the Utah-Wyoming border. Red pyrope garnet and green chromium-rich pyroxene, discovered in anthills just north of Cedar Mountain, are similar to the garnet and pyroxene found in kimberlite (**Plate 1B**); (McCandless, 1984). The source of these minerals has not yet been identified, but they may have been eroded from some nearby ultramafic pipes.

Wyoming jade is very rare. Some pieces of apple green jade collected in Wyoming are nearly priceless. The jade found in Wyoming is an amphibole known as nephrite and is often called "Wyoming jade". Much of the jade from southeastern Asia is formed from another mineral known as jadeite, a pyroxene. These two forms of jade are essentially indistinguishable by the naked eye and require x-ray identification to examine the atomic arrangement of atoms. Jade in Wyoming has been found as far west as the Prospect Mountains, at the southern edge of the Wind River Range, and as far east as the northeastern slope of the Laramie Range (Figure 1). As recently as the 1970s, a seven-ton boulder of black jade was discovered in the Prospect Mountains. Much of the jade in Wyoming comes from the Granite Mountains north of Jeffrey City.

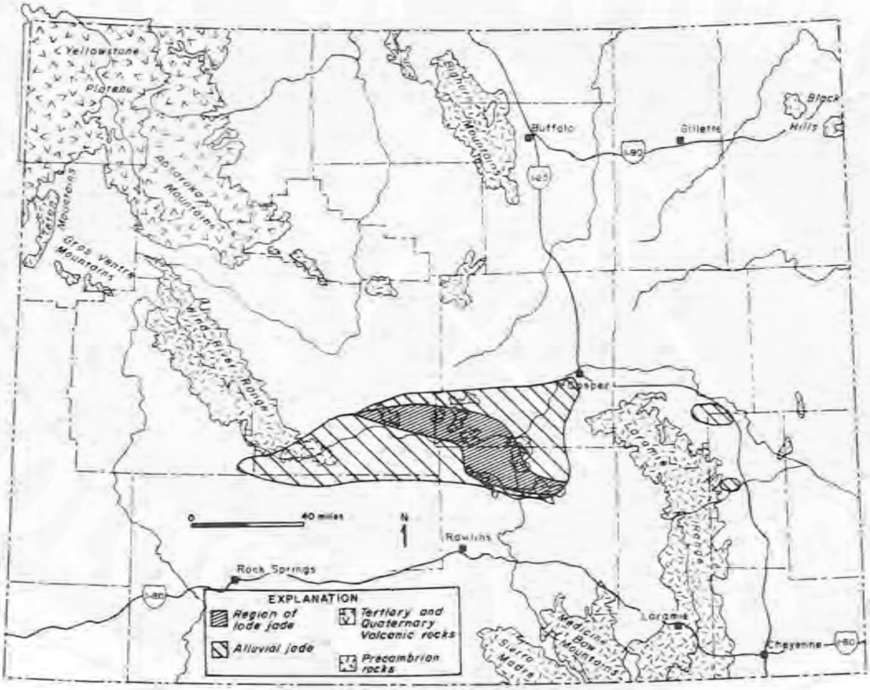


Figure 1. Principal jade occurrences in Wyoming.

Some other rare minerals in Wyoming include sapphires, rubies, aquamarine beryl and barite. High-quality sapphires and rubies have been found in the Granite Mountains north of Jeffrey City (Love, 1970), and some thumbnail-size ruby specimens found in the Green Mountain area (Avon Brock, personal communication, 1983) are enough to excite even the most inexperienced novice mineral collector.

Agate and flint occur at a number of localities. These pieces of chalcedony are quite common in Wyoming and worldwide. The uniqueness of some varieties of Wyoming chalcedony (pronounced kal-said-o-knee) is manifested in the arrangement of color bands and patterns. Beautiful specimens are prized by rock hounds and collectors all over the West.

This bulletin is designed to give a general introduction to Wyoming's rocks and minerals. It is a revision of books by Wilson (1965) and Root (1977) that were also published by the Geological Survey of Wyoming but are now out of print. A list of books found at the end of the publication is suggested for supplemental information.

Geologic history of Wyoming

A description of the Earth's history is nearly inescapable in any discussion of rocks and minerals. Therefore, a brief summary of geologic history is provided below. Publications by Blackstone (1971) and Glass and Blackstone (1986) are highly recommended for additional information on Wyoming's geologic history.

Geologic time is subdivided into the Precambrian, and the Paleozoic, Mesozoic and Cenozoic Eras — which are further subdivided on the basis of important geologic events (Table 1). The Precambrian includes by far the greatest amount of geologic time, but less is known about the events in the Precambrian because metamorphism, deformation and erosion have destroyed much of the evidence.

Precambrian (4.5 billion years to 570 million years ago)

Precambrian time includes the very beginnings of the Earth (about 4.5 billion years ago) to nearly 570 million years ago. Geoscientists divide the Precambrian into the Archean (greater than 2.5 billion years ago) and Proterozoic (less than 2.5 billion years ago). About two billion years ago, the Earth's atmosphere became sufficiently enriched in oxygen to change the surface of the Earth forever. Before oxygen was a common component in the atmosphere, many minerals remained unoxidized. Vast accumulations of magnetite iron formation were common, and stream placers often contained pyrite and uranium nuggets much the same as modern placers contain gold nuggets. But when oxygen became enriched in the atmosphere, it combined with (or oxidized) many minerals: magnetite was converted to hematite; pyrite was oxidized to hematite and limonite; and uranium was oxidized and carried away in solution in the streams. Pyrite and uranium nuggets were no longer deposited in stream placers.

Table 1. Geologic time chart of Wyoming.

TIME[1]	ERA	PERIOD	EPOCH	EVENTS IN WYOMING	MINERAL RESOURCES IN WYOMING
0	CENOZOIC	QUATERNARY	Holocene	Present climate.	Sand and gravel, placer gold.
			Pleistocene	Ice Age, glaciers.	
1.6		TERTIARY	Pliocene	Teton Mountains formed, terrestrial deposition.	Gypsum.
5.3			Miocene	Intense volcanic activity in Yellowstone area, temperate climate.	Copper-molybdenum porphyries in Absaroka Mountains; uranium in Baggs area.
24			Oligocene	Terrestrial deposition of great amounts of volcanic ash, warm temperate climate.	Copper-molybdenum porphyries in Absaroka Mountains.
37			Eocene	Green River lake and terrestrial deposition, subtropical climate.	Uranium and coal in basins; trona and oil shale in the Green River Basin; clinker.
58			Paleocene	Terrestrial deposits, tropical climate.	Uranium and coal in basins; clinker; gas.
66	MESOZOIC	Cretaceous		Transgression and regression of seas, Rocky Mountains begin to rise, abundant cephalopods.	Bentonite along flanks of mountain ranges; some coal; oil and gas; and uranium in Black Hills.
135		Jurassic		Seas withdrew, broad flood plains, many dinosaurs.	Copper-silver-zinc in the Overthrust Belt; oil and gas; gypsum.
180		Triassic		Fluctuation of shore line, wide tidal flats, mild climate.	Gypsum; oil and gas.
245	PALEOZOIC	Permian		Shallow seas in western Wyoming, invertebrates common.	Phosphate in Overthrust Belt; gypsum; oil and gas.
270		Pennsylvanian		Local uplift in south-central and southern Wyoming.	Limestones along flanks of mountain ranges; oil and gas; copper.
		Mississippian		Entire state submerged in warm tropical seas.	Thick limestone deposits; oil and gas.
350		Devonian		Seas in northwestern and western Wyoming.	Diamond-bearing kimberlites; oil and gas.
400		Silurian		Probably emergent (record incomplete in Wyoming).	—
440		Ordovician		State inundated by shallow warm waters.	Oil and gas.
500		Cambrian		Seas transgressed from west across entire state.	"Rawlin's red" hematite quartzites in the Rawlins uplift; oil.
570	Major unconformity			Long interval of erosion at close of era.	Anorthosite in the Laramie Range.
	PRECAMBRIAN	PROTEROZOIC		Land reduced to broad plains of low relief.	Gold, copper, platinum (?) veins and shears in the Medicine Bow Mountains.
					Beryl, lepidolite, feldspar, copper sulfide pegmatites at Copper Mountain.
					Numerous beryl and feldspar pegmatites in Laramie Range and at South Pass.
1000				Mountain building.	Copper in the Silver Crown district, Laramie Range.
				Widespread ancient seas.	Volcanogenic copper-zinc silver sulfide deposits in the Sierra Madre.
				Continents in existence.	Copper-bearing quartzites in the Sierra Madre.
				Atmosphere becoming more oxygen-rich.	Uranium paleoplacers in the Medicine Bow Mountains and Sierra Madre, becoming less common as earth's atmosphere gets more oxygen rich.
2500		ARCHEAN			Banded magnetite iron formation at South Pass, Copper Mountain and Seminoe Mountains.
				Reducing atmosphere (low oxygen).	Uranium and gold paleoplacers in the Medicine Bow Mountains and Sierra Madre.
				Formation of primitive continents.	Gold-bearing veins and shears at South Pass.
4500					Tungsten deposits at Copper Mountain.

[1] In millions of years before the present.

Through time, the Precambrian rocks in Wyoming were weathered to a featureless plain and buried under hundreds of feet of layered sedimentary rocks. But hundreds of millions of years after the Precambrian, during the Cretaceous Period, Wyoming and the rest of western North America experienced a major tectonic event. At many localities thin long slices of the Earth were forced upward. Within the eroded cores of these slices of mountain ranges are the only exposures of Precambrian rock found today in Wyoming. As one can imagine, we have only a fragmented Precambrian terrain to piece together; it is like having a large jigsaw puzzle with most of the pieces missing. This is one of the primary reasons why we know so little about the geologic history of the Precambrian.

The cores of these mountain ranges contain very old metamorphic rocks that represent former sedimentary, volcanic and plutonic rocks that have been altered by heat and pressure. In many areas, they are highly deformed and fractured, with numerous quartz veins (**Plate 1C**). Many of the historic gold and copper mining districts, such as South Pass and Encampment, occur in this terrain.

Large regions of the Precambrian terrain were intruded by granite. For example, the Sherman Granite intruded Precambrian metamorphic rock in the southern Laramie Range about 1.4 billion years ago. This granite is exposed along Interstate 80 between Granite, Wyoming, and the Lincoln Monument.

Paleozoic Era (570 million years to 245 million years ago)

The history of life took a dramatic turn at about 570 million years ago at the base of the Cambrian Period, which marks the beginning of the Paleozoic Era. Stokes (1966, p. 183) writes: *It is generally agreed that the Cambrian began with the appearance of certain primitive orthopods, the trilobites . . .* Shells and other preservable hard parts of animals are common constituents of rock from the Paleozoic onward.

During much of the Paleozoic, Wyoming was submerged under seas that deepened to the west. Similar to our oceans today, these ancient seas were saturated in calcium-carbonate, which allowed carbonate-producing organisms to deposit thick layers of limestone. East of Laramie, a deep canyon cut into Casper Formation limestones exposes some of this rock that was deposited in Paleozoic seas. This canyon lies west of the Lincoln Monument along I-80 and is just one of several similar canyons cut in limestone. Another spectacular canyon, Wind River Canyon between Thermopolis and Shoshoni along Highway 20, is cut through a variety of rock units including a thick section of Madison Limestone that was also deposited in a marine environment. Because the formations are labeled with highway signs, this canyon provides a great opportunity to identify examples of carbonate rock. The Madison and Bighorn formations are two of the more prominent limestone and dolomite units exposed in the canyon.

At times, the Paleozoic deposition of marine sediments was interrupted by minor upwarping of the shelf, causing the seas to retreat and erosion to occur. Also during the Paleozoic, sandstones, shales, evaporites and chert were deposited. Sometime during mid-Paleozoic time (Devonian), diamond-bearing kimberlites erupted at the surface in southeastern Wyoming.

Late in the Mississippian Period, the seas were pushed back by a rising mountain range known as the Ancestral Rockies. These were the ancient forerunners of the Rocky Mountains. Uplift and erosion continued into the Pennsylvanian Period. By Permian time, stability returned to the region, the Ancestral Rockies were gone, and the ancient seas again covered much of the state. In western Wyoming, unusual conditions resulted in the deposition of thick phosphorites in a deep marine trough.

Mesozoic Era (245 million years to 66 million years ago)

Wyoming remained relatively stable during the early part of the Mesozoic Era. Shallow seas covered much of Wyoming and deepened to the west in Idaho. The deep trough along the western edge of Wyoming continued to receive sediment. The Late Jurassic rocks record a gradual retreat of the seas. Rocks of the Jurassic Period contain numerous land-dwelling fossils. At Como Bluff, Wyoming, Morrison Formation sediments contained abundant dinosaur bones that were quarried from the late 1800s until 1903. Many excellent and complete dinosaur skeletons were recovered from this quarry (Blackstone, 1971; see also Hausel and Jones, 1984).

Beginning in the Cretaceous Period, tectonic forces greatly altered the Wyoming landscape. Rocks in the deep sediment-filled trough along the western edge of Wyoming began to rise, forming a range of mountains. Along the eastern flank of this uplift, thick layers of Cretaceous sandstones, shales and coals were laid down as another epic of mountain building began, known as the Laramide Orogeny.

During Late Cretaceous to early Tertiary time, uplifts of the Rocky Mountains towered over the adjacent basins and plains. The intense deformation associated with the Laramide Orogeny spanned at least 40 million years from the Late Cretaceous into the early Cenozoic.

Cenozoic Era (66 million years ago to present)

When the Cenozoic Era began, the Wyoming mountain ranges and adjacent basins were well defined. In the early part of the Cenozoic Era, tropical climates and distinct (flat-bottom) basins were the right combination for swamps and vast lakes. Organic debris (peat) accumulated in giant rain forests and swamps, and was later converted into thick coals of almost unimaginable proportions. More than 1.1 trillion tons of coal occur in Paleocene and Eocene sediments in the Powder River Basin of northeastern Wyoming (Glass, 1984; Ayers, 1986)! Several coal beds are more than 100 feet thick.

In southwestern Wyoming, during the Eocene Period, an intermountain lake so large that it could have swallowed the Great Salt Lake, covered much of the southwestern portion of the State. This body of water, known as Lake Gosiute, contained untold species of fish. At times it shrunk to a relatively small saline lake that precipitated unique assemblages of evaporite alkaline minerals including trona. The remains of this lake were captured in the Green River Formation fossil fish beds (Grande, 1984) **(Figure 2)**, oil shales and trona beds. The Wyoming trona beds are the largest in the world, containing an estimated resource of 134 billion tons.

In Yellowstone National Park and to the east, volcanic activity began. This resulted in the deposition of enormous thicknesses of volcanic rock. These thick flows and associated sediments now form one of the most impressive mountain ranges in Wyoming — the Absarokas (pronounced Ab-saŕe-oh-kas).

Late in Cenozoic time (Pleistocene Epoch), worldwide climates cooled considerably and many mountain glaciers formed in the Wyoming ranges. Only one million years ago, very rare potassium-rich lavas erupted near the present site of Rock Springs.

Mineral and rock identification

Rock and mineral identification is aided by a number of physical and chemical tests that are relatively easy to perform. To identify a particular rock, the minerals that form the rock must first be identified.

Minerals are essentially solid chemical substances that have distinctive chemical and physical properties. To identify minerals, these properties have to be determined. Experience is helpful in deciding which test to begin with, but generally testing is done in a specific order.

Figure 2. Fossil fish preserved in the Tertiary Green River Formation lake-bed sediments (collected and photographed by S.H. Knight in 1899, from University of Wyoming American Heritage Center).

To begin, examine the geometry and habit of the mineral — is it a cube, does it form bladed crystals or is it just a mass of material? Write this information down in a notebook. Next, note the mineral color. Does it have metallic or glassy luster? Scratch it with a knife. Does it scratch, and if it does, what is the color of the scratch or streak? How hard is the mineral? What does the fracture look like? Does it cleave? How heavy is it?

These are many of the questions about a mineral's physical properties that you may have to answer. Additional simple chemical tests may be necessary for positive identification. In a few cases, sophisticated tests such as x-ray diffraction or microscopic examination by a trained mineralogist may be necessary.

After the minerals are identified, their relative percentages are noted, and the texture of the rock is described. This information is applied to simple charts to determine the rock name. In the following pages, the physical and chemical tests are described, and simple rock identification charts are provided.

Not all minerals and rocks can be identified in this manner. Many can be identified easily, but a few will require physical tests and hours of study. Some minerals may require an experienced mineralogist to perform sophisticated tests. Many universities and state geological surveys have mineralogists on staff able to help in the identification of these enigmatic minerals.

Minerals

Physical properties of minerals

Mineral — what is it?

You may be confused about the difference between a mineral and a rock. A *mineral* is a natural or synthetic homogenous solid substance with distinct physical and chemical properties. Minerals possess well-defined internal atomic structures. Because synthetic minerals are becoming more common in our daily lives, the adjective synthetic is always used to distinguish them from natural minerals. If we envision a mineral to be a single homogeneous component, then we can imagine rocks to be made up of several of these components, or minerals. Rocks form from numerous crystals of the same mineral species, such as Wyoming jade, which is an aggregate of individual nephrite crystals, or they can form from combinations of a variety of mineral species. Granite, for example, is composed of intergrown quartz, orthoclase, plagioclase and biotite crystals.

Mineral identification

It is important to be able to identify individual minerals, not only to know what the mineral is, but also to determine the rock type. Because minerals have distinct physical and chemical properties, any mineral can be identified using combinations of physical and chemical tests. Some minerals may be more reluctant to give up their identity than others, and in these cases, more specialized tests (i.e. x-ray diffraction) are required for positive identification (**Figure 3**). While collecting in the field, the individual is limited to a few simple tools, but in most cases these are sufficient (**Table 2**).

Table 2. Tools for field identification of minerals.

Fingernail (hardness = 2½)
Pocketknife (hardness = 5)
Hand (magnifying) lens
Magnet
Plastic bottle of dilute (10%) hydrochloric acid*

**Vinegar will work in place of dilute hydrochloric acid, although chemical reactions will be mild. Muriatic acid is another term for dilute hydrochloric acid and can be purchased at many drug stores.*

Figure 3. Mineral identification by specialized tests such as x-ray diffraction is common at many geological surveys, bureaus of mines and universities. At the Geological Survey of Wyoming, x-ray analysis is carried out with a state-of-the-art computerized diffractometer (photograph by Karl Albert).

These tools are easy to carry and can provide a lot of information about the hardness of a mineral, the crystal form or habit, magnetism and chemistry. Those properties will be discussed in the following sections.

Equipment for a more elaborate, but low-cost laboratory for rock and mineral identification is listed in **Table 3**. Items shown as optional are more expensive but can be added to your home laboratory through time.

Crystal geometry

Crystals, which are well-formed minerals, have symmetry and are separated into six **crystal systems** based on that symmetry. Unless you have a well-developed crystal, it may be very difficult to determine which system your crystal fits in, but if you can determine the crystal system, you have an important piece of information to aid in identification of an unknown mineral. For an experiment, get a household salt shaker and a magnifying lens. Salt, which is sodium chloride (NaCl), is a simple mineral and has chemical and

Table 3. The home mineral and rock testing laboratory.

Equipment

- Pocketknife.
- Hand lens or magnifying glass.
- Plastic bottle of dilute (10%) hydrochloric acid.
- Hardness kit.
- Streak plate (white porcelain tile).
- Flame and bead test kit.
- Butane torch or alcohol candle.
- Gold pan.
- Porcelain crucible.

Optional Equipment

- Stereo microscope.
- Geiger counter or scintillometer.
- Polarscope.
- Mineral light.
- Specific gravity balance.[1]

[1] *An inexpensive specific gravity beam balance or jolly balance can be constructed at a very low cost (see Sinkankas, 1964, p. 182-190).*

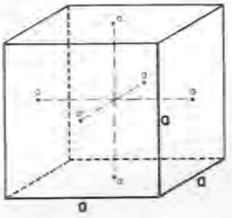
physical properties (one of them being taste) — just like any other mineral. Shake a few grains out on the table and examine the crystal shape, or geometry, of salt. It's a cube! Pyrite, gold, galena, diamond and many other crystals also form cubes, or modifications of cubes, and are included in the **isometric** (cubic) crystal system (**Figure 4**).

Crystal habit

Under favorable geologic conditions, many minerals will develop crystals with well-formed geometric shapes. Often mineral species form characteristic habits, or forms that are very common and are therefore used for mineral identification. For example, quartz often grows in very characteristic columnar hexagonal prisms capped by a hexagonal pyramid. The characteristic prism and transparent luster are a dead give away for quartz. Bronze-colored, metallic luster cubes are so typical of pyrite that often no other tests are needed for identification. The characteristic habit of diamond is equant octahedral crystals. The habit combined with its greasy luster, are often enough to identify the mineral. Some common crystal habits are described in **Figure 5**.

However, large, well-formed crystals are relatively uncommon, and mineral habits are more often expressed as finely crystalline,

(a) ISOMETRIC SYSTEM

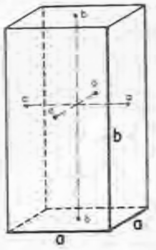


Common Crystal Habits

Cubes
Octahedrons
Dodecahedrons
Trapezohedrons
Pyritohedrons
Tetrahedrons

All axes are of equal length $a=a=a$ and all angles between axes are right angles (90°).

(b) TETRAGONAL SYSTEM

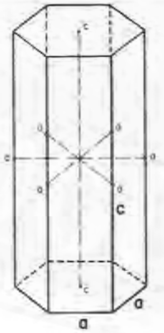


Common Crystal Habits

Square Prisms
Square Prisms with Pyramids
Dipyramids without prisms
Flattened square prisms
Pseudotetrahedral

Two axes are of equal length $a=a\neq b$, and all angles between the axes are right angles (90°).

(c) HEXAGONAL SYSTEM



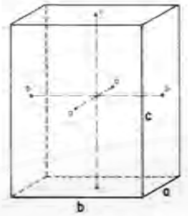
Common Hexagonal Crystal Habits

Long hexagonal prisms
Short hexagonal prisms
Tabular hexagonal prisms
Hexagonal prisms with pyramids and
   rhombohedrons
Rhombohedrons
Scalenohedrons

Only the horizontal axes are equal in length $a=a=a\neq c$. The horizontal axes are separated by 120° and all of the horizontal axes (a) form right angles with the vertical axis (c).

Figure 4. (This and facing page.) The crystal systems.

(d) ORTHORHOMBIC SYSTEM

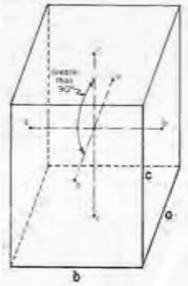


Common Crystal Habits

Long prisms
Short prisms
Tabular prisms
Stubby grains
Pseudohexagonal prisms

All axes have different lengths a≠b≠c, and each axis is located at right angles from the other two.

(e) MONOCLINIC SYSTEM

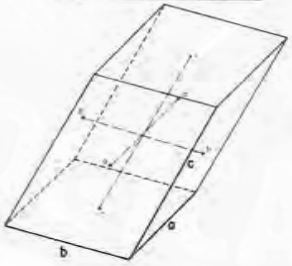


Common Crystal Habits

Long Prisms
Short Prisms
Blocky
Platey

All axes have different lengths a≠b≠c, and the a axis is inclined to the c axis. Monoclinic means one-inclined.

(f) TRICLINIC SYSTEM



Common Crystal Habits

Platey
Tabular
Blocky

All axes are of different lengths a≠b≠c, and there are no right angles.

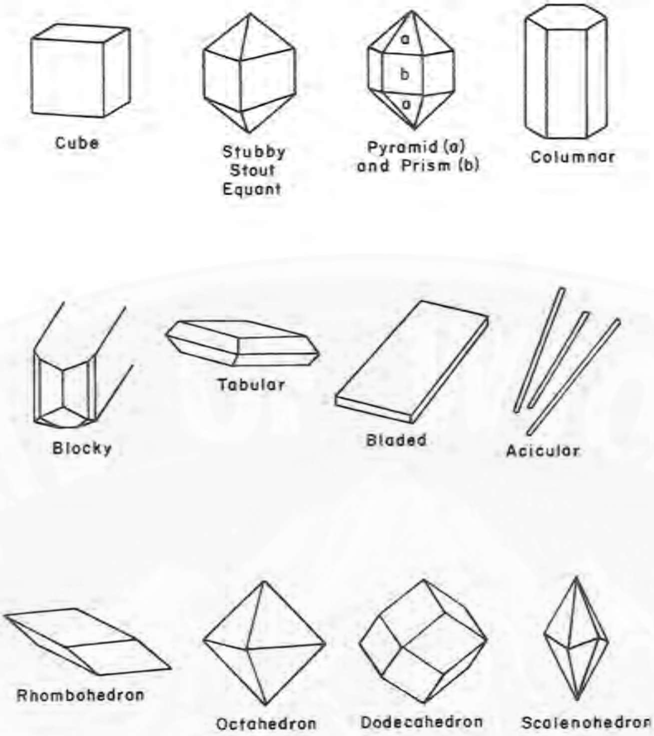


Figure 5. Diagrams of some common crystal habits (modified from Sinkankas, 1964).

earthy, granular or formless masses, or other aggregates. This information is also useful when supplemented with other tests and observations.

Color

Color can sometimes be an important clue to mineral identification; many of us can easily visualize the colors of jade, gold and turquoise. In the metallic minerals, color is usually fairly constant for a particular mineral. The bright brass color of untarnished chalcopyrite is unmistakable, as is the warm yellow color of gold. One can also learn to recognize the characteristic tarnishes.

Many of the nonmetallic minerals appear in a wide range of colors. Quartz, a silicate, can be colorless, white, gray, purple, yellow, brown, red, pink or even black. In such cases, the color of the mineral is not by itself sufficient evidence for identification. Variations in color in a single mineral species are due principally to different kinds and amounts of impurities included in the crystal structure. For example corundum, an aluminum oxide, generally occurs as an unattractive cloudy mineral specimen with as much as 10 percent impurities. The impurities not only render corundum cloudy, but also produce a wide variety of colors including gray, grayish blue, blue, brown, violet, green and red. The coloring agents in the impurities are not well established, although traces of iron oxide and chromium probably are important.

In some specimens of corundum, trace amounts of impurities may produce colored transparent crystals. These transparent forms of corundum are highly prized as gemstones, the most valuable being ruby (Table 4).

Table 4. The corundum gemstones (from Bauer, 1968).

Color	Variety
Red	Ruby
Blue	Sapphire
Colorless	Leuco - sapphire
Light bluish green	Oriental aquamarine
Green	Oriental emerald
Yellow green	Oriental chrysolite
Yellow	Oriental topaz
Aurora red	Oriental hyacinth
Violet	Oriental amethyst

Some rare varieties of corundum may also have oriented needle-like inclusions of rutile. These inclusions reflect light and produce a star effect when polished (star sapphire).

Luster

Luster describes the appearance of a mineral's surface in reflected light. Pyrite, galena and chalcopyrite have the appearance of metals, and are thus said to display metallic luster. Vitreous luster describes a mineral like quartz that has the appearance of glass. Adamantine luster occurs in minerals like diamond that strongly refract light. Other terms used to describe the luster of nonmetallic minerals include resinous (sphalerite), greasy (serpentine) and silky (asbestos). Minerals like chromite, that have a luster between metallic and vitreous, are said to have submetallic luster.

Streak

The streak of a mineral is its color in a fine, powdered form. For example, pyrite (fool's gold) forms brittle brassy colored metallic crystals, but has a greenish black streak. The streak is best observed by scratching the specimen across hard, white, unglazed porcelain tile (streak plate) (**Figure 6**), or by scratching the surface of the mineral with a knife blade. Minerals that are harder than the tile or a knife blade do not streak; their white streak produced on the tile is actually powdered tile.

Figure 6. Scratching a streak plate with a galena cube produces a characteristic lead-gray streak (photograph by Karl Albert).

Hardness

The relative hardness of a mineral can be very important to aid in the identification of mineral species. The sample should be relatively unweathered and not stained on the surface, otherwise an erroneous hardness may be determined. Splintery and granular minerals can also give erroneous hardness results. A fair amount of pressure must be applied in order to scratch the unknown mineral.

The conventional hardness scale used by mineralogists is known as Moh's scale (**Table 5**). Moh's scale consists of ten minerals of given hardness.

Table 5. Moh's hardness scale.

MOH'S SCALE

Hardness	Mineral	Some common tools useful for measuring hardness
1	Talc	Fingernail (H=2.5)
2	Gypsum	Old copper penny (H=2.5)
3	Calcite	
4	Fluorite	
5	Apatite	Knife blade (H=5)
6	Feldspar	Window glass (H=6)
7	Quartz	Steel file (H=7)
8	Topaz	
9	Corundum	Carborundum (H=9.5)
10	Diamond	

Diamond is considered to be the hardest naturally occurring substance known on the Earth and has a relative hardness of ten. This is for cubic diamond. Recently, a new polymorph of diamond was discovered in the northern central Siberian Plateau of Russia in what is called the Popigay Depression. The diamonds in this structure are reported to be hexagonal and to be three times harder than cubic diamond (Edward Erlich, personal communication, 1985).

Note that window glass has a hardness of only six (Table 5). Many hundreds of minerals including diamond are harder than window glass. Unfortunately, the old adage that "whatever will scratch glass is diamond" is obviously not true. A light blow with a hammer also will break diamonds quite easily, so they are not nearly as indestructible as many people are led to believe.

Fracture and cleavage

If a mineral breaks along definite parallel planes, these parallel planes are the *cleavage*, or parting. Cleavage planes are parallel planes of weakness in the mineral's internal structure. For example, mica has perfect cleavage in one direction. Other minerals, such as feldspar, have two cleavage directions, and some are bounded by as many as three directions of cleavage (**Figure 7A**). Calcite, for example, has three directions of perfect cleavage that are clearly seen in most specimens (**Figure 7B**).

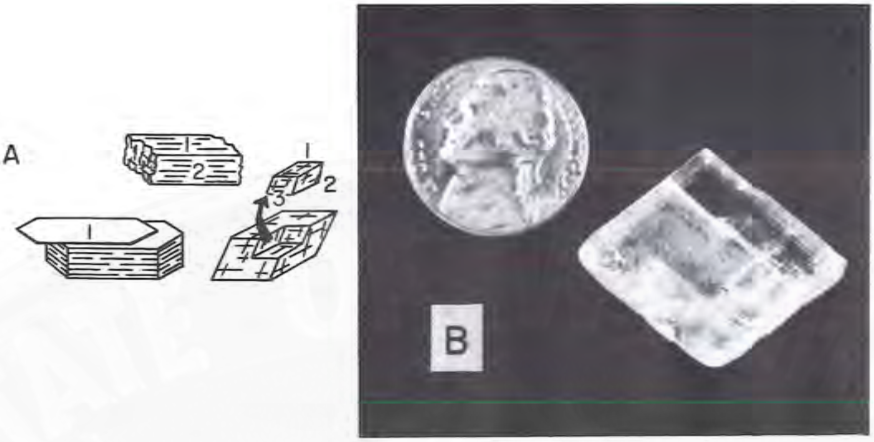


Figure 7. (A) Cleavage in minerals; mica (left) has one prominent direction of cleavage, feldspar (center) has two and calcite (right) has three. (B) Rhombohedral calcite with three directions of cleavage. Note fractures are parallel to cleavage and crystal faces.

The quality of cleavage may be expressed as indistinct, poor, good or perfect. There are also several types of cleavage that are described by terms such as cubic, basal (micaceous) or prismatic (**Figure 8**).

Parting is very similar in appearance to cleavage. Partings form parallel to planes of weakness between mineral twins. Some crystals tend to grow attached twins (**Figure 9**).

A mineral that does not break along planar sufaces will fracture. Quartz for example, exhibits a distinct type of fracture known as conchoidal, which simply means that the surface of the break is smooth and rounded like the interior surface of a seashell. Some other common and distinctive types of fractures include fibrous, splintery and hackly (jagged with sharp edges). The names of these fractures are descriptive and need no other explanation.

Tenacity

The tenacity of a mineral is its relative resistance to breaking, crushing, bending or cutting. Most minerals are brittle, and can be crushed to a fine powder. Some native metals, such as gold and platinum, are malleable, and can be shaped by applying pressure with a knife or by hammering. Soft minerals, which have hardness

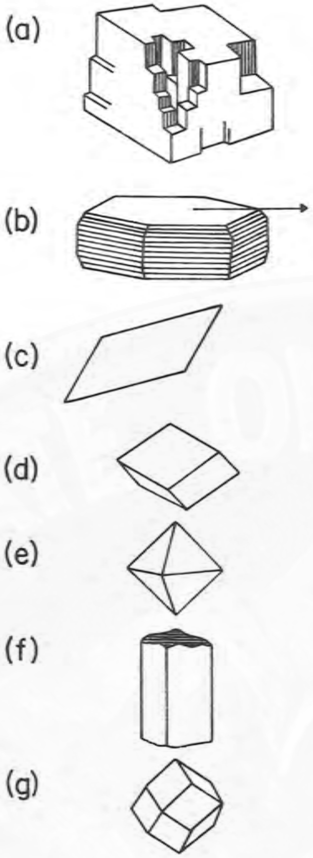


Figure 8. Types of cleavage include: (a) **cubic** *— three cleavage directions intersecting at right angles (examples: salt, galena); (b)* **basal** *— one plane parallel to base (examples: mica, topaz); (c)* **pinacoidal** *— one plane parallel to front, side or base of mineral (example: stibnite); (d)* **rhombohedral** *— three planes parallel to opposite faces of a rhombohedron (examples: calcite, dolomite); (e)* **octahedral** *— four planes parallel to each pair of faces (examples: diamond, fluorite); (f)* **prismatic** *— two parallel planes or three parallel planes along the sides of a mineral (examples: amphibole, pyroxene); and (g)* **dodecahedral** *— six parallel planes to each pair of faces of a dodecahedron (example: sphalerite). Modified from Vanders and Kerr (1967, p. 83).*

Figure 9. Twinned crystal of potassium feldspar.

less than three, are sectile, they can be cut into shavings with a knife. Flexible minerals bend easily without breaking, and elastic minerals spring back to their original shape after they are released.

Specific gravity and heft

Specific gravity is a ratio of the weight of a given volume of a substance to the weight of an equal volume of water. If a mineral has a specific gravity of 3.0 (water has been assigned the specific gravity of one), a given volume of the mineral weighs 3.0 times as much as the same volume of water.

Specific gravity (S.G.) is measured in the laboratory as follows:

$$\text{S.G.} = \frac{\text{weight of mineral in air}}{(\text{weight of mineral in air}) - (\text{weight of mineral in water})}$$

For example, an unknown mineral has the following measurements:

weight of mineral in air	1,250 grams
weight of mineral in water	800 grams

$$\text{Its specific gravity} = \frac{(1{,}250 \text{ grams})}{(1{,}250 \text{ grams}) - (800 \text{ grams})} = 2.78$$

Accurate measurements of specific gravity of minerals are not practical in the field; therefore the mineral collector should develop a good feel for the relative weight, or heft, of a rock or mineral specimen. Heft is a subjective expression of the relative density, or weight, of a specimen. For example, the heft of a hand specimen of galena (specific gravity = 7.4 to 7.6) would be high when compared to quartz (specific gravity = 2.65). Halite (specific gravity = 2.16), better known as common salt, is light, and has a low heft. Nephrite (Wyoming jade) (specific gravity of 3 to 3.5) has a medium, or moderate, heft. Of course, similar size specimens should be compared for their heft.

Magnetism

Magnetism is tested by moving a magnet over a mineral and noting whether or not there is an attractive force. Some magnets are very weak and it is best to obtain a strong magnet so that there can be no question about the magnetic properties of a sample.

Minerals that are strongly magnetic are called ferromagnetic. These include magnetite and pyrrhotite. Both of these minerals are ironbearing. Weakly magnetic minerals are termed paramagnetic, which can include some iron silicates. Except in rare cases, the magnet is used only to test for ferromagnetic minerals.

Chemical tests

Reaction to hydrochloric acid (HCl)

Carbonates, which are relatively common at the Earth's surface, react with hydrochloric acid producing carbon dioxide (CO_2) gas — the same gas that is found in many soft drinks. The reaction is an effervescence or bubbling action with hundreds of tiny CO_2 bubbles being released from the surface of the carbonate. Some carbonates, like calcite, react readily; others, like dolomite, have only weak reactions; and some, like rhodochrosite, have to be stimulated by heating.

Hydrochloric acid can also be used to identify certain metallic oxides such as tenorite. Tenorite is a black, sooty copper oxide that forms a surface stain on some mineralized samples. If a sample of tenorite is dowsed with hydrochloric acid and vigorously rubbed with a well-used rock pick, hammer or pocket knife, native copper will form a thin, shiny, copper-penny colored metal coat on the rock pick.

The hydrochloric acid that is used is diluted in water to 10 percent acid and 90 percent water. This is also called muriatic acid and can be purchased in many drug stores. If the acid you purchase is not diluted, add one part concentrated hydrochloric acid to nine parts water. **Caution:** Always pour acid into water — do not pour water into the acid; a potential violent reaction may result in severe acid burns.

Flame test

Heating powdered mineral specimens in a torch flame may produce vivid-colored flames diagnostic of certain chemical elements (Table 6). The results of a flame test can provide the collector with some additional information to aid in the identification of unknown mineral species. One drawback of this test is that a portion of the mineral must be pulverized and destroyed.

Tools necessary for this test are a torch (for example, butane), an iron wire loop, a cobalt-blue glass filter (optional) and dilute hydrochloric (muriatic) acid. The iron wire loop can be made from soft iron wire by forming a 1/8-inch diameter loop on one end, and a five- to six-inch handle on the opposite end. Sodium, which is universal in water, will contaminate the iron wire each time the wire is cleaned in water. To remove the effects of the contaminate,

Table 6. Characteristic flame tests.

Flame Color	Element
Vivid red	Strontium
Streaks of red	Lithium
Red orange	Calcium
Vivid and persistent yellow	Sodium
Yellow green	Barium
Yellow-green flashes	Boron
Faint yellow green	Molybdenum
Pale green	Antimony
Pale greenish white	Bismuth
Strong vivid green	Copper
Pale blue green	Phosphorous
Streaky blue green	Zinc
Vivid blue	Arsenic
Pale blue	Lead
Persistent violet	Potassium

a cobalt-blue filter that absorbs the bright yellow sodium light band can be used in the line of sight of the flame, or the wire must be thoroughly cleaned in hydrochloric acid. To clean the loop, dip it in hydrochloric acid and place it in the torch flame to burn off sodium contaminates.

To do the flame test, wet the iron wire loop in hydrochloric acid and dip it into the powdered mineral. Then hold the loop in the flame and note the color of the flame.

Charcoal block test

The charcoal block test aids in the identification of some metals. By heating a metalliferous oxide, carbonate, sulfide or silicate powder in contact with charcoal, specks of the native metal can be reduced onto the charcoal **(Figure 10)**. The unknown mineral powder is placed into a small pit scooped out of the block and wetted to keep the powder from blowing away. In some cases, to aid in the reduction, sodium carbonate is mixed with the mineral powder. The unknown mineral powder is then melted, and specks of metal may be reduced onto the charcoal block. This test is used to identify certain metals such as copper, lead, gold or platinum.

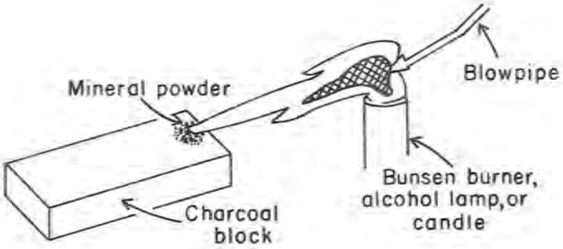


Figure 10. Charcoal block test.

Bead test

The bead test produces a small globule of stained glass that is colored by trace-metal oxides. The procedure requires the manufacture of a glass globule from borax or phosphate flux, which is then contaminated with mineral powder. Borax powder can be found in almost any grocery store, and sodium phosphate (or sodium ammonium phosphate) can be obtained from a drug store. A platinum wire, also required for the procedure, is sold by mineralogical supply houses and should be approximately 28-gauge. One end of the wire is imbedded into a glass rod to use as a handle and the other end is curled around a pencil point to form a small loop.

First, heat the platinum loop to remove any contaminates and then dip it into the flux. Melt the flux on the loop and repeat the process until a well-formed clear glass globule surrounds the loop. After the bead forms, pick up a few specks of mineral matter on the bead and reheat until the mineral powder is absorbed. Heat the bead with the aid of a blowpipe in a reducing flame (**Figure 11A**). Then repeat the test with a fresh bead and heat in an oxidizing flame (**Figure 11B**). Do this for the borax bead followed by the phosphate bead and compare the results to **Table 7**. Just a few small specks of the powder are necessary to color the bead. Too much mineral powder on the bead will make it opaque.

Specialized tests

X-ray diffraction

X-ray diffractometers are used in several phases of mineralogical research and mineral exploration. Often state institutions (geological surveys, bureaus of mines, universities) will provide mineral identification services free of charge for the general public and mineral collectors.

X-ray diffractometers are expensive and sophisticated instruments used to identify unknown minerals (**Figure 3**). They work on the premise that each mineral species has its own unique atomic

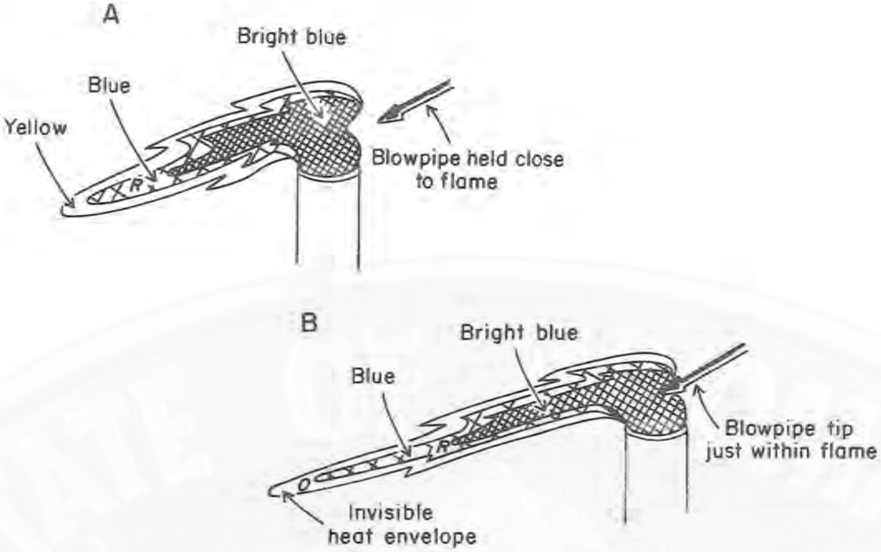


Figure 11. Oxidizing (O) and reducing (R) flames produced with the aid of a blowpipe. (A) The reducing flame is produced by holding the blowpipe near the flame and constantly blowing air through the pipe directed at the flame. The reducing (oxygen-removing) flame is the blue portion of the flame. (B) The oxidizing flame results from blowing oxygen into the flame with the blowpipe in the flame. The oxidizing (oxygen-adding) portion of the flame is the invisible heat envelope. (After Vanders and Kerr, 1967.)

structure and that the structure can be identified by the reflection of x-rays. But because there are more than 2,000 known mineral species, the effectiveness of x-ray diffraction depends partially upon having a complete list of diffraction patterns to compare with the unknown patterns. Computerization has made this task easier, but impure mineral species, interference from mineral inclusions and interference from mineral aggregates often makes identification difficult. Ideally, x-ray identification works well with single, pure minerals.

X-rays are electromagnetic vibrations that have a much shorter wavelength than light — the wavelength of x-rays are about 10,000 times smaller than visible light! Because of the extremely small wavelength, x-rays will pass through almost any substance to a greater or lesser degree, and they are not visible to the human eye. Photographic plates, or films, are much more sensitive to electromagnetic radiation than our eyes, and so we can take photographs of x-rays.

In a similar way that light is reflected by a mirror, x-rays are reflected by the atomic planes in minerals. By reflecting x-rays

Table 7. Bead tests (modified from Sinkankas, 1964, p. 269).

		Borax bead		Phosphate bead	
Element	Bead color	Oxidizing flame	Reducing flame	Oxidizing flame	Reducing flame
Copper	Opaque red	—	x	—	x
	Blue green	x	—	—	—
	Blue	—	—	x	—
Chromium	Green	x	x	x	x
Cobalt	Blue	x	x	x	x
Iron	Yellow	x	—	—	—
	Pale yellow	—	—	x	—
	Green	—	x	—	—
	Colorless	—	—	—	x
Manganese	Violet	x	—	x	—
	Colorless	—	x	—	x
Molybdenum	Green	—	—	—	x
	Brown	—	x	—	—
	Colorless	x	—	x	—
Nickel	Yellow	—	—	x	x
	Brown	x	—	—	—
	Opaque gray	—	x	—	—
Titanium	Violet	—	x	—	x
	Colorless	x	—	x	—
Tungsten	Yellow	—	x	—	—
	Blue	—	—	—	x
	Colorless	x	—	x	—
Uranium	Yellow	x	—	—	—
	Green	—	—	—	x
	Pale green	—	x	x	—
Vanadium	Yellow	—	—	x	—
	Green	—	x	—	x
	Colorless	x	—	—	—

off of these atomic mirrors or planes, scientists can obtain a "picture" of the crystal structure. Each mineral has its own individual arrangement of atomic planes, and thus can be identified by its individual x-ray pattern. The x-ray pattern obtained from an unknown mineral is compared to a file of known x-ray patterns to find a match.

Single well-formed crystals can be x-rayed directly, depending on their size. If a mineral is not well formed, it can be crushed to a powder and x-rayed. During crushing, the unknown mineral is broken into millions of tiny specimens and many of these, by statistical chance, will have the proper orientation to reflect x-rays from their atomic planes.

Polarizing microscope

Polarizing microscopes are used to examine the optical characteristics of slices of rock known as thin sections. Thin sections are cut, mounted on microscope slides and ground to about 0.001 inch thick so that light can be transmitted through the specimen. When these thin sections of rocks are examined under a microscope many crystallographic features of individual minerals appear to be more distinctive than they would be in hand specimen (Plate 1D).

Fluorescence

Certain minerals fluoresce under ultraviolet light, and in some cases fluorescence aids in identification. However, fluorescence is diagnostic only in a few cases because it often results from minor impurities in some minerals. For example, calcite from Franklin, New Jersey, contains traces of manganese that cause the mineral to fluoresce bright pink. At other localities, different trace elements cause calcite to fluoresce orange, yellow or green. Also some calcite will not fluoresce.

The term fluorescence is derived from the mineral fluorite, which is well known for its brightly fluorescent mineral specimens. Some of the best fluorite in Wyoming occurs in the Bear Lodge Mountains north of Sundance. This fluorite is purple to lavender in color, but is rarely, or only weakly, fluorescent.

Scheelite, a calcium-tungstate found on Copper Mountain north of Shoshoni, Wyoming, is white and blends in with quartz and feldspar of the country rock gneiss. The scheelite is indistinguishable in visible light, but under short-wavelength ultraviolet light it fluoreses light blue, and under long-wavelength ultraviolet light it does not fluoresce; in this case, fluorescence is diagnostic.

Only a few other minerals from Wyoming fluoresce. Many specimens of calcite fluoresce white in short- and long-wave ultraviolet light. Some Wyoming diamonds fluoresce blue; many varieties of chalcedony fluoresce blue; youngite fluoresces light yellowish green, and many of the brightly colored secondary uranium minerals fluoresce a brilliant yellowish green, yellow or green (see Uranium).

Radioactivity

Some minerals spontaneously emit subatomic particles from their atoms. This spontaneous emission is known as radioactive decay. One product of radioactive decay is the release of gamma rays. Geiger counters and scintillation counters are designed to detect and measure gamma radiation in the field or laboratory. Uranium, thorium and some potassium minerals are radioactive, and thus, radiation detectors can be used to help identify some minerals that contain these radioactive elements and their daughter elements (new elements produced by radioactive decay). For more information on radioactivity, refer to Phillips and Greeley (1978).

Wyoming minerals

Unless otherwise noted, the following descriptions of minerals are specifically for Wyoming minerals. The mode of occurrence of some of these minerals at localities outside the State may be different. Only those chemical and physical properties useful for identifying the Wyoming minerals are listed.

Before you begin collecting or prospecting, become familiar with the trespass, claim staking and collecting laws that apply in Wyoming. It should be obvious, but people forget that they must have the landowner's consent on private property before entering to collect or prospect. Although you have a right to walk on National Forest Lands and many other Federal and State lands, you should obtain permission from surface lessees (ranchers) in areas outside the Forest Service lands. These lessees have the right to collect surface damages even on Government lands, and much of these lands are checker-boarded with private lands. Generally, all that is needed is an introduction and a respect for staying on existing roads, closing fences and general courtesies. A general reference to land ownership is the *Land Status Map of the State of Wyoming*, published by the U.S. Bureau of Land Management. For information on leases and claim staking, refer to Hausel (1986a).

Some rock-forming minerals

Andalusite (aluminum silicate)

Color — black, gray, pinkish brown, white; luster — vitreous, but dull when altered; cleavage — good prismatic; hardness — 6.5 to 7.5; streak — white; specific gravity and heft — 3.1 to 3.2, low to medium; habit — rough prismatic crystals often partially altered to muscovite (sericite). Many crystals form nearly square cross sections; crystal system — orthorhombic.

Andalusite forms distinct porphyroblasts (large crystals enclosed by fine-grained minerals) in muscovite schists in many of the State's metamorphosed sedimentary terrains. These andalusite-muscovite schists are reported in Precambrian rocks in a number of Wyoming's mountain ranges.

Probably the best locality for collecting andalusite is the South Pass region in the southern Wind River Mountains south of Lander. There, fine-grained mica schists and metagreywackes (mica quartzites) throughout the Anderson Ridge area contain abundant andalusite crystals and andalusite pseudomorphs that have been entirely replaced by sericite mica and quartz.

Excellent specimens of oval-shaped andalusite and andalusite pseudomorphs, locally known as "peanuts", occur in "peanut" schist near the Rose gold mine in the South Pass - Atlantic City district. (See Hausel, 1984, for location of the mine.) Several miles southeast of the Rose mine, near the Sweetwater River, are some other good collecting localities. Good, tabular, square, black andalusite crystals averaging 1/8 to 1/4 inch in diameter occur in a narrow band of schist in the extreme southeastern corner of sec. 24, T.29N., R.98W. (Lewiston Lakes Quadrangle). In the NE¼ sec. 3, T.28N., R.98W., on the north bank of Strawberry Creek, muscovite schist is filled with excellent two- to four-inch long prismatic andalusite crystals (Figure 12).

Amphibole Group (complex silicates)

Color — white, green to black; luster — vitreous to silky; cleavage — perfect amphibole cleavage (Figure 13A); hardness — 5 to 6; streak — white; heft — low to medium; habit — prismatic to fibrous crystals, irregular, massive; crystal system — monoclinic.

Amphibole is a general term for a group of minerals that includes actinolite-tremolite, nephrite, hornblende and others. Hornblende is the most common amphibole in Wyoming: it is found in Precambrian metamorphic rocks and in Tertiary igneous rocks.

The amphiboles are common constituents in many igneous and metamorphic rocks, where they often display good prismatic habits. Most amphiboles are black.

Calcite (calcium carbonate)

Color — white, yellow, brown, pink, gray, green, black; luster — vitreous; cleavage — perfect rhombohedral (Figure 7B); hardness — 3; streak — white to grayish; specific gravity and heft — 2.71, low; habit — extremely varied, most common are rhombohedron and scalenohedron crystals or finely crystalline masses; crystal system — hexagonal; chemical identification — will effervesce vigorously in cold, dilute hydrochloric acid.

Calcite sometimes fluoresces white, red, yellow, pink or blue under ultraviolet light.

Limestones and marbles are rocks that are formed almost entirely of calcite. Good rhombohedral crystals are often found in vugs in limestone, or in quartz veins that contain appreciable calcite and

Figure 12. Two- to four-inch long prismatic crystals of andalusite in muscovite schist from Strawberry Creek near Lewiston, a typical crystal habit of andalusite found in the southern Wind River Mountains.

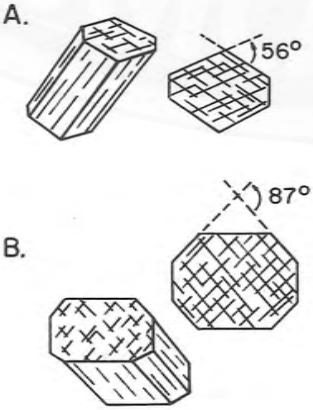


Figure 13. (A) Typical amphibole (56°) cleavage and (B) typical pyroxene (near right-angle) cleavage. Sometimes amphiboles and pyroxenes are very similar in general appearance, but their distinct cleavages make them distinguishable.

siderite (an iron carbonate). The siderite, colored brown to yellow brown, often accompanies calcite in some veins.

Dolomite (calcium-magnesium carbonate)
Color — white, gray, brown; luster — vitreous to dull; cleavage — perfect rhombohedral; hardness — 3.5 to 4; streak — white; specific gravity and heft — 2.85, low; habit — massive or rhombohedral crystals, often with curved faces; crystal system — hexagonal; chemical identification — the powdered mineral will react weakly in cold, dilute hydrochloric acid.

Epidote (complex calcium-aluminum-iron silicate)
Color — commonly distinctive pistachio green, also yellow green or brownish green; luster — vitreous; cleavage — perfect basal cleavage; hardness — 6 to 7; specific gravity and heft — 3.2 to 3.5, moderate; habit — in Wyoming, epidote is found as pistachio green masses, or fibrous masses replacing mafic minerals (biotite and amphibole) and feldspars in many granites and metamorphic rocks; crystal system — monoclinic.

Feldspar (aluminosilicate of sodium, potassium and calcium)
Color — commonly colorless, yellow, pink or white; luster — vitreous; cleavage — blocky; hardness — 6; specific gravity and heft — 2.56 to 2.59 for the potassium (potash) feldspars and 2.62 to 2.76 for the sodium to calcium feldspars), moderate; habit — plagioclase (calcium-sodium-rich feldspar) forms tabular crystals, and potassium-rich varieties produce prismatic crystals. Some plagioclase feldspars show fine striations on the cleavage faces. Amazonite, a variety of potassium feldspar, is recognized by its distinct green color.

Plagioclase feldspar is best seen in the Laramie anorthosite complex in the central Laramie Range. Anorthosite is an igneous rock composed almost entirely of plagioclase feldspar. The anorthosite complex is exposed over nearly 350 square miles and samples can be collected over a wide region. The anorthosite crops out along the Rogers Canyon Ninth Street Road, 11 miles northeast of Laramie, and specimens can be gathered along Highway 34 in Sybille Canyon north of Laramie.

The potash or potassium-rich feldspars include microcline and orthoclase. Large crystals of potash feldspar are abundant in Precambrian pegmatites at many sites in Wyoming. A variety of potassium feldspar known as microcline, which forms at low temperatures, was mined for several years on Casper Mountain in secs. 17, 18, 20, T.32N., R.79W.; at Copper Mountain to the north of Shoshoni (Figure 14); and from several pegmatites in the Laramie Range along

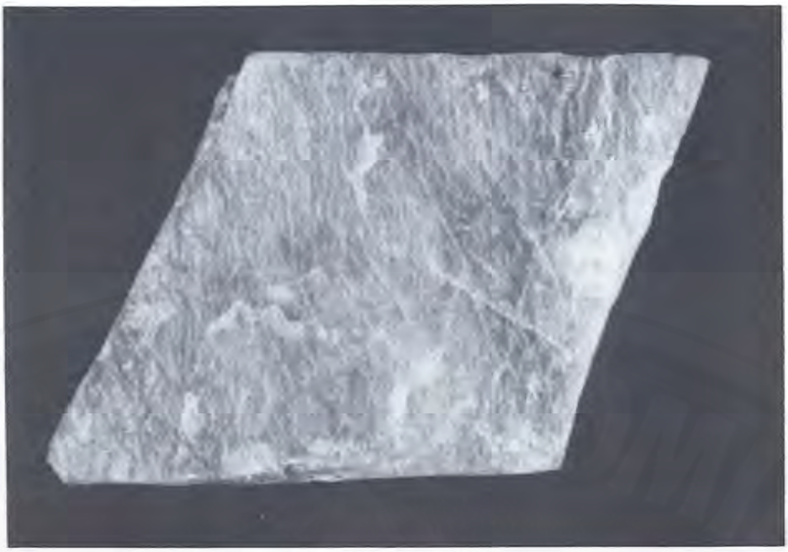


Figure 14. Microcline feldspar from Copper Mountain.

Highway 287 south of Laramie. The feldspars are common rock-forming minerals that in some cases have industrial uses. The mineable feldspar is used as an abrasive filler for household products and ceramics. In the past it was also used to manufacture false teeth.

Garnet Group

Luster — vitreous to resinous; cleavage — none; hardness — 6.5 to 7.5; streak — white; crystal system — isometric (cubic).

There are several varieties of garnet but only those that are commonly found in Wyoming are discussed here. Pyrope, almandine and spessartite occur in the State, generally as well-formed, rounded, dodecahedral or trapezohedral crystals.

Pyrope

Color — red to purple red, and yellow orange; specific gravity — 3.50 to 3.80; habit — these garnets are always rounded and exhibit no crystal faces.

Pyrope has relatively high magnesium and chromium contents and is associated with ultrabasic and ultramafic igneous and metamorphic rocks. Many pyropes in Wyoming occur as xenocrysts in kimberlite intrusives in the State Line district about 20 miles south of Laramie. They have also been found as porphyroblasts in garnet peridotite xenoliths (nodules) hosted by the kimberlite (**Plate 2A**) and as detrital minerals in anthills near Cedar Mountain in the southern Green River Basin (**Plate 1B**).

Almandine

Color — red to reddish brown; specific gravity — 3.85 to 4.32; habit — almandine garnets with good dodecahedral crystal habit have been collected in the central Sierra Madre in T.14N., R.85W.

This is a common garnet found in metamorphic rocks, especially mica schists (Plate 2B), throughout the State. Excellent outcrops of almandine garnet-mica schist occur in the vicinity of a mine in Section 8, T.14N., R.85W.

Spessartite (Spessartine)

Color — orange red, orange, to yellow orange; specific gravity — 4.19.

Garnets of this type occur in granite pegmatite in the Eagle Rock - Happy Jack area of the southern Laramie Range and in pegmatites at Copper Mountain in the Owl Creek Mountains.

Kyanite (aluminum silicate)

Color — white, gray, green to blue; luster — vitreous; cleavage — perfect pinacoidal; hardness — 5 parallel to length, and 7 across the length of crystals (an excellent test is to scratch the suspected mineral with a pocket knife — parallel to the length of the crystal it will scratch with difficulty, but across the length it will not scratch); specific gravity — 3.53 to 3.65; habit — generally bladed crystals (porphyroblasts) in Precambrian schists associated with staurolite, garnet, rutile and mica. The long bladed crystals display good basal parting. Often the crystals are fibrous; crystal system — triclinic.

Kyanite is trimorphous with andalusite and sillimanite. Kyanite occurs in several of Wyoming's metamorphic terrains. It is reported in the Copper Mountain area, and in the Elmers Rock region of the Laramie Range. The Grizzly Creek prospect in the Laramie Range (sec. 35, T.24N., R.71W.) contains abundant kyanite and sillimanite in gneiss and schist. Several prospects near the headwaters of Cottonwood Creek in the Encampment District of the Sierra Madre are rich in kyanite (sec. 20, T.14N., R.83W.). Some of the kyanite crystals in this area are as large as six inches long and range from white to light blue. At one location in sec. 20, disseminated emerald green kyanite has been reported (Osterwald and others, 1966).

Rare kyanite-eclogite xenoliths (nodules) have been found in some kimberlite pipes in the State Line district (see diamond). These contain garnet, pyroxene and small tabular grains of blue kyanite. The crystal habit of kyanite in these kyanite eclogites is quite different from the bladed grains found in metamorphic terrains.

Mica group (hydrated silicate)

Biotite, muscovite, phlogopite, fuchsite, lepidolite and chlorite are all micas that occur at various localities statewide. The micas are characterized by perfect basal cleavage and form layers, or sheets of mica, that are called mica books (**Figures 7A and 8**). The micas are monoclinic, but they commonly develop six-sided crystals and are thus termed pseudohexagonal.

Biotite is a black mica found in schists and granites; **muscovite** is a white to colorless mica that occurs statewide in granite, pegmatite, schist and gneiss. Because of its bronze-white color and its tendency to form small thin flakes, many people mistake fine-grained muscovite (sericite) mica for gold flakes. In Mark Twain's classic book *Roughing It*, this was an error he made during his first prospecting venture in Nevada. However, muscovite is brittle, whereas gold is malleable. Very fine-grained muscovite is termed **sericite. Phlogopite** is a bronze to black mica that occurs in kimberlite, wyomingite and other related igneous rocks. **Fuchsite** is a green chromium-rich muscovite mica that contains up to five percent chromium. Some good specimens of fuchsitic quartzite have been collected near Gold Hill in the Medicine Bow Mountains. **Lepidolite** is a pink to lilac, lithium-rich mica associated with lithium-rich pegmatites. Lepidolite pegmatites crop out along the southern edge of Copper Mountain in the vicinity of Hoodoo Creek (secs. 22, 27, T.40N., R.93W).

Olivine (magnesium-iron silicate)

Color — olive green; luster — vitreous; fracture — conchoidal; hardness — 6.5 to 7; specific gravity — 3.27 to 3.37; habit — generally as small rounded grains; crystal system — orthorhombic.

Some olivine occurs as fine to aphanitic (microscopic) grains in a few Tertiary basalt flows in the Absaroka Mountains. Partially to entirely serpentinized olivine grains occur in some dunites and serpentinites in the South Pass Precambrian terrain along the southern tip of the Wind River Range. Partially to entirely serpentinized olivine occurs in Devonian kimberlite in the southern Laramie Range south of Tie Siding.

Pyroxene Group (silicates of calcium, iron, magnesium and aluminum)

Color — predominately black, less commonly green or white; luster — vitreous to dull; cleavage — perfect prismatic; cleavage traces intersect at right angle (**Figure 13B**); hardness — 5 to 6; specific gravity and heft — 3.2 to 3.5, moderate; habit — commonly long prismatic crystals; crystal system — orthorhombic and monoclinic.

Pyroxene is a common rock-forming mineral found in many volcanic rocks. It occurs as fine grains barely visible to the unaided eye in basalts and gabbros, however, many andesites have larger prismatic crystals. A pyroxene cut parallel to the basal section will produce a square cross section because of its right-angle cleavage (Figure 13B), whereas amphiboles, which are very similar and often mistaken for pyroxene, have diamond-shaped cross sections with faces intersecting at 56° to 124° (Figure 13A).

Pyroxene is common in volcanic rocks in the Absaroka Mountains of northwestern Wyoming. Wyoming pyroxenes have no economic value except for a lithium-rich pyroxene (spodumene) located on the north edge of Black Mountain in the Rattlesnake Hills (sec. 1, T.32N., R.89W.). Here a pegmatite hosts several large bluish gray, greenish or lavender spodumene crystals that are as much as 1.5 feet long and 8 inches wide. Tourmaline occurs as an accessory mineral in the pegmatite (Osterwald and others, 1966).

Quartz (silicon dioxide)

Luster — vitreous or waxy; fracture — conchoidal; hardness — 7; specific gravity and heft — 2.65; low to moderate; habit — coarse-crystalline varieties of quartz often occur as excellent hexagonal prisms capped by a pyramid (Plate 2C); whereas compact micro-crystalline quartz (chalcedony) occurs in irregular masses (see Chalcedony); crystal system — hexagonal.

Quartz is the most common rock-forming mineral on the surface of the Earth. Many metamorphic, sedimentary and igneous rocks contain significant amounts of quartz. Some sedimentary and metamorphic rocks (sandstone and quartzite) are formed almost entirely of quartz. Its ubiquitous nature commonly results in the development of quartz veins in metamorphic and igneous rocks (for example, Plate 1C).

The two varieties of quartz, coarsely crystalline and cryptocrystalline, are quite varied and occur in many colors. Coarsely crystalline varieties of quartz may include beautiful six-sided pyramids. These well-formed crystals develop in geodes (hollow, crystal-lined nodules) or in vugs in the host rock. Colored varieties of quartz include milk white (milky quartz), purple (amethyst), pink (rose quartz), black (smoky quartz), colorless and transparent (rock quartz) and yellow to reddish brown (citrine). Quartz with brown to red inclusions is termed ferruginous quartz.

Well-formed, iron-stained quartz crystals occur in Precambrian pegmatite along Highway 287 south of Tie Siding. Many of these have well-developed prisms and pyramids, but are somewhat unattractive to many collectors because of the iron staining.

Amethyst is not very common in the Cowboy State, although one large, 310-pound, amethyst-lined geode was found in southern Wyoming several decades ago.

Wyoming crystalline quartz is collected for mineral specimens, and chalcedony (cryptocrystalline quartz) is often used in jewelry. In the past, some quartzite was mined and used as an abrasive and ballast; and silica sands (nearly pure quartz sandstone) are being considered for the manufacture of glass containers.

Serpentine Group (hydrated magnesium silicate)

Color — shades of green, yellow, red, white and black (most commonly green); luster — waxy, greasy to silky; hardness — 2.5 to 5; specific gravity — 2.2 to 2.6; habit — compact masses or as fibrous asbestos. The serpentine group includes a variety of massive forms known as antigorite, chrysotile, clinochrysotile, lizardite and pecoraite.

Serpentine is a hydrothermal and deuteric alteration product of ultrabasic, ultramafic and mafic igneous rocks, and is produced by the alteration of olivine and pyroxene. Serpentine may occur in amphibolites, tremolite schist, talc schist or in rocks completely formed of serpentine that are known as serpentinites and occur in metamorphic terrains in Wyoming. Wyoming kimberlites consist almost entirely of serpentine.

Sillimanite (aluminum silicate)

Trimorphous with andalusite and kyanite. Color — white, colorless, gray, light brown or bluish; luster — vitreous to silky; cleavage — perfect pinacoidal; fracture — uneven; hardness — 6.5 to 7.5; specific gravity — 3.23 to 3.27; habit — aggregates of slender prismatic crystals with striations, or fibrous masses; crystal system — orthorhombic.

Sillimanite is found in micaceous schists with garnet, andalusite, cordierite and muscovite. Excellent hand specimens of sillimanite schist with 0.5-inch long sillimanite crystals (porphyroblasts) and minor kyanite occur along Mill Creek (sec. 19, T.29N., R.101W.) north of Anderson Ridge in the South Pass region of the Wind River Mountains. The Grizzly Creek prospects in the Laramie Range also carry some sillimanite with the kyanite-rich schists (see KYANITE). Sillimanite with kyanite and andalusite occurs in metapelites of the Elmers Rock greenstone belt west of Wheatland (Graff and others, 1982).

Tourmaline (a complex aluminum silicate)

Color — predominately black and less commonly green, rarely exhibits color zoning; luster — vitreous to translucent; fracture —

many tourmaline crystals have basal fractures perpendicular to the striations; hardness — 7 to 7.5; specific gravity and heft — 3.03 to 3.25, moderate; habit — tourmaline crystals have triangular cross sections with striations parallel to the long axis; crystal system — hexagonal.

Tourmaline occurs in granite pegmatites with muscovite, quartz, beryl and feldspar. Nearly all of the tourmaline recovered in Wyoming is black and opaque (schorl) (**Figure 15**).

Pegmatites in the Anderson Ridge area near South Pass contain abundant black tourmaline, with less common beryl. In particular, pegmatites in secs. 30, 31, T.29N., R.101W. are enriched in tourmaline, with some specimens up to one foot long. Tourmaline also occurs with beryl in pegmatites of the Hartville uplift.

Industrial minerals

Asbestos (Chrysotile) (See also Serpentine.)

Color — shades of green, yellow, brown and gray; luster — silky, fibrous or waxy; hardness — 2.5 to 5; heft — low to medium; habit — fibrous.

Asbestos is a fibrous form of serpentine often found with talc. Asbestos is a secondary mineral formed by alteration of mafic and ultramafic metamorphic rocks.

Some asbestos occurs with serpentinites and talc-tremolite schists near the entrance of the Atlantic City iron mine at South Pass in the Wind River Mountains (see Hausel, 1984), but the best specimens in Wyoming come from Casper Mountain in secs. 16 and 17, T.32N., R.79W. about eight miles south of Casper (**Plate 2D**). Cross-fiber chrysotile veinlets about 1/8 to 1/4 inch wide separate layers of massive serpentine. The Smith Creek deposit in SE¼ sec. 19, SW¼ sec. 20, NW¼ sec. 29, NE¼ sec. 30, T.31N., R.78W., and the Green Hill deposit in sec. 23, T.31N., R.78W., also contain good asbestos specimens (Osterwald and others, 1966, p. 8-9).

Asbestos in lenticular serpentinite masses in granitic country rock occurs south of Beaver Hill (sec. 19, T.30N., R.96W.) near Highway 287 west of Jeffrey City, and some asbestos occurs in the Halleck Canyon area north of Sybille Canyon of the central Laramie Range (sec. 18, T.22N., R.71W) (Graff and others, 1982).

Some uses of asbestos include the manufacture of textiles, shingles, gaskets, brake linings, putties and plastics. Asbestos is not mined in Wyoming.

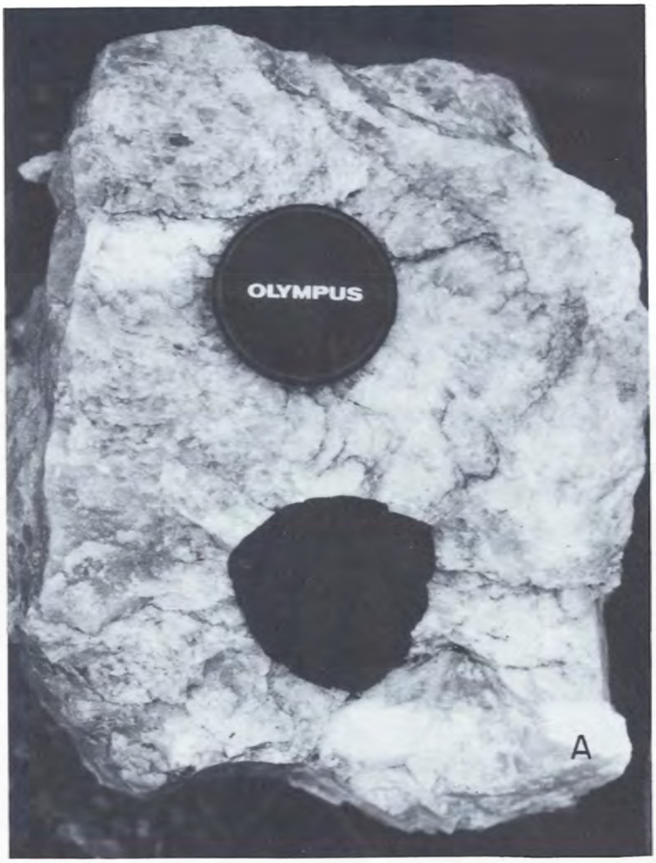


Figure 15. (A) Tourmaline with triangular cross section in quartz from Anderson Ridge, and (B) tourmaline pegmatite from the Sierra Madre west of Encampment (photograph 15B by Karl Albert).

Barite (Barium sulfate)

Color — colorless, white, gray, blue; luster — transparent, vitreous, resinous: cleavage — good basal and prismatic cleavage at right angles; hardness — 3 - 3.5; specific gravity and heft — 4.5, relatively high; habit — commonly tabular orthorhombic crystals, or massive granular concretions; crystal system — orthorhombic.

Barite is found at scattered localities across the State (Osterwald and others, 1966). Some excellent specimens of blue transparent barite (Plate 3A) are reported from the Sheep Creek area 39 miles northeast of Medicine Bow (sec. 10, T.26N., R.75W.). Scattered barite concretions are sometimes found in the Shirley Basin that weakly fluoresce under long-wavelength ultraviolet light.

Massive barite, mined elsewhere, is crushed and used in drilling mud and in the paint, glass and rubber industries. Barite is not mined in Wyoming.

Beryl (Beryllium oxide)

Color — green, white, blue green and greenish yellow; luster — vitreous; fracture — conchoidal to uneven; cleavage — imperfect basal; streak — white; specify gravity and heft — 2.66 to 2.9, low to moderate; habit — commonly six-sided hexagonal prisms with flat terminations; crystal system — hexagonal.

Beryl crystals are reported from pegmatites statewide. The crystals range from less than one inch to more than one foot long. The majority of the minerals are yellowish green to green although at least one specimen of aquamarine beryl was collected from a pegmatite in the Anderson Ridge area of the Wind River Range. Gem quality aquamarine beryl has also been found in pegmatites near Hoodoo Creek along the southern flank of Copper Mountain in the Owl Creek Mountains (McLaughlin, 1940).

Pegmatites throughout the Hartville uplift contain beryl (Millgate, 1964), and excellent crystals several inches long have been mined from a pegmatite on Casper Mountain (Knittel, 1978, p. 60) (Figure 16). Beryllium is a strategic metal that is used most extensively as an alloying agent in heat-resistant metals. Beryllium alloys are used to construct space vehicles. Gem varieties of beryl include transparent blue aquamarine and deep green emeralds.

Fluorite (calcium fluoride)

Color — violet to dark purple; luster — vitreous; cleavage — perfect octahedral; fracture — subconchoidal to splintery; hardness — 4; specific gravity and heft — 3.18, moderate; habit — generally well-formed cubic crystals or granular masses; crystal system — isometric.

Figure 16. Hexagonal beryl crystal from Casper Mountain.

Fluorite from the Bear Lodge Mountains forms massive granular replacement of Pahasapa Limestone (**Plate 3B**). Some cubic crystals occur in vugs. The Bear Lodge fluorite occurs near Tertiary intrusives where it lies in contact with the limestone. Some good specimens have been collected in secs. 15, 23, 27 and 28, T.52N., R.63W.

Purple fluorite grains have also been found in a pegmatite near Pole Mountain in the Laramie Range (SW¼ NW¼ sec. 5, T.15N., R.70W.; Osterwald and others, 1966, p. 75).

The principal use for fluorite is in the manufacture of hydrofluoric acid. In metallurgy, it is used as a flux and an electrolyte.

Gypsum (hydrated-calcium sulfate)

Color — white to transparent; luster — vitreous to earthy; cleavage — good in three directions and perfect in one direction; hardness — 2, can be easily scratched with a fingernail; specific gravity and heft — 2.32, very low; tenacity — tends to bend and break with a splintery fracture; habit — massive, prismatic, or tabular crystals with one well-formed flat surface, parallel fibrous crystals (satin spar, Plate 3C), sometimes in "fish tail" twin crystals; crystal system — monoclinic.

Gypsum is exposed in Permian, Triassic and Jurassic redbeds along the flanks of several of the State's mountains. The Goose Egg, Chugwater and Gypsum Spring Formations commonly host gypsum beds.

Near Cody, Wyoming, the Gypsum Spring Formation has been a source of gypsum for sheet rock for many years.

Leucite (potassium-aluminum silicate)

Color—white to gray; luster—vitreous to dull; hardness — 5.5 to 6; specific gravity — 2.42; habit — trapezohedral grains in potassium-rich igneous rocks; crystal system — tetragonal (pseudocubic).

Leucite occurs in abundance in potassium-rich lava flows and plugs in the Leucite Hills north of Rock Springs and Superior, Wyoming. Large crystals in these rocks are rare and leucite is predominately an aphanitic mineral in the volcanic rocks (see also wyomingite in Wyoming Rocks section). In the past these leucite-bearing lavas have been considered as a potential potash resource.

In the Black Hills of northeastern Wyoming, phonolite and related rocks (see Wyoming Rocks section) contain large alkali feldspar and sometimes pseudoleucite crystals enclosed by a fine-grained (microscopic) groundmass or matrix. Pseudoleucite is a mineral that is a pseudomorph of leucite. These rocks are well exposed throughout Devils Tower National Monument and in the Bear Lodge Mountains. **(Rock and mineral specimens cannot be collected within National Monuments or National Parks.)**

Sheridanite (a chlorite mineral); (see Mica)

Color — greenish white; luster — pearly; cleavage — perfact basal; hardness — 2 to 3; specific gravity — 2.68 to 2.80; habit — sheridanite is a well-foliated to massive, talc-like chlorite that feels greasy.

The mineral was named after its type locality in Sheridan County, Wyoming, where it was first identified. Sheridanite was discovered on the Little Falls claim (sec. 10, T.53N., R.84W.) about 150 yards downstream from the lower falls of North Piney Creek in Sheridan County.

Sulfur

Color — yellow; luster — resinous; hardness — 1.5 to 2.5; streak — pale yellow; specific gravity and heft — 2.05 to 2.09, low.

Sulfur occurs in many hot spring deposits including some along the Yellowstone highway, a few miles west of Cody; and some in altered limestone along Wyoming Highway 120, three and one-half miles northwest of Thermopolis (Root, 1977).

Most of the sulfur produced in Wyoming is recovered from natural gas saturated with hydrogen sulfide. This particular gas in known as sour gas.

Sulfur is used in the manufacture of sulfuric acid, paper, gunpowder and rubber.

Talc (hydrated magnesium silicate)

Color — white to green; luster — pearly to greasy; cleavage — micaceous; hardness — 1, talc is very soft and can be easily scratched with a fingernail; specific gravity and heft — 2.58 to 2.83, low to moderate; habit — occurs as compact to foliated masses with a greasy or talcum-powder feel.

Talc is a metamorphic mineral formed by alteration of magnesium silicates and commonly is found with serpentine and actinolite-tremolite.

Talc schists lie just west of the Atlantic City iron mine at South Pass (sec. 34, T.30N., R.100W.) and north and west of Lewiston Lakes (sec. 19, T.29N., R.97W.) near historic Radium Springs. Similar talc schists occur in the Halleck Canyon area (sec. 13, T.22N., R.72W.) of the Elmers Rock greenstone belt, and in the Garrett region (secs. 29, 32, T.25N., R.73W.) north of the Elmers Rock greenstone belt.

Talc has several industrial uses including ceramics and paints. One well known product of talc is crayons.

Trona (sodium bicarbonate)

Color — tan to white; luster — vitreous to earthy; cleavage — perfect in one direction; hardness — 2 to 3; specific gravity and heft — 2.14, low; habit — flattened prismatic crystals that are fibrous (Figure 17) to massive; crystal system — monoclinic; miscellaneous — has an alkaline taste.

Trona is an alkaline mineral of unusual abundance in the Green River Basin of southwestern Wyoming. The world's largest resource of trona occurs in 42 beds of the Green River Formation west of Rock Springs. Estimated trona resources are 134.4 billion tons (Burnside and Culbertson, 1979).

The trona was precipitated from a relatively shallow saline lake during periods of intense evaporation, similar to the way salt beds are formed in the Great Salt Lake. This prehistoric lake, known as Lake Gosiute, covered much of southwestern Wyoming during the Eocene, 50 to 60 million years ago.

Today, five underground mines produce trona from depths as great as 1,700 feet. These mines lie north and south of Little America along Interstate 80. The mined trona is processed and used in the glass, paper, soap, petroleum refining and textile industries. Bicarbonate of soda (baking soda) is one of the better known household products of Wyoming trona.

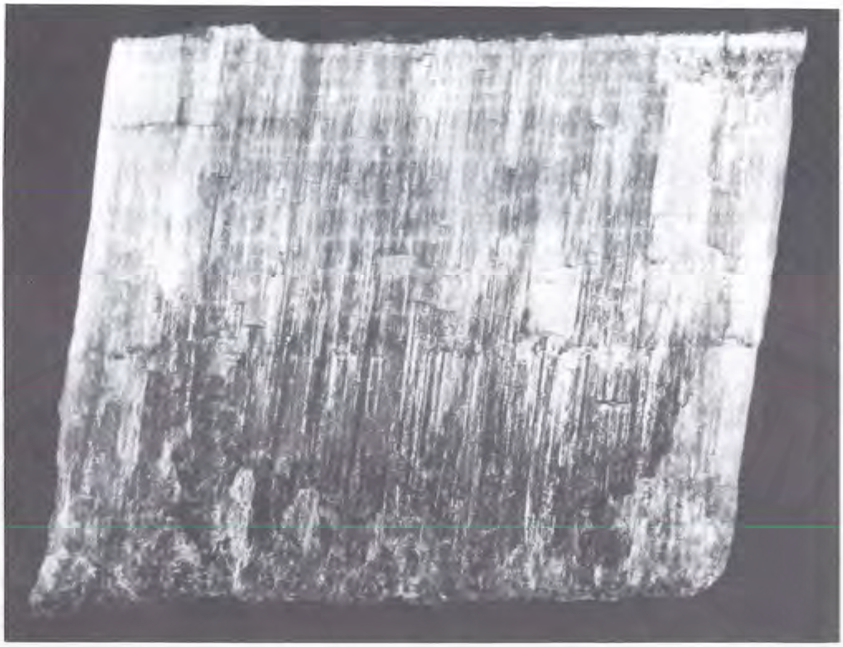


Figure 17. Sample of flattened massive fibrous trona from the FMC trona mine, Green River Basin.

Vermiculite (hydrated magnesium-aluminum-iron silicate)

Color — yellow to brown; luster — pearly; cleavage — perfect micaceous; hardness — 1.5; habit — micaceous grains; crystal system — monoclinic.

Vermiculite is a soft, pliable, micaceous clay mineral that varies greatly in color and appearance. When heated, it will expand as much as 30 times its original volume. This characteristic makes vermiculite well suited for insulation and fireproofing. In the past, some vermiculite was mined from the Laramie Range and Sierra Madre.

Zeolite Group (hydrated sodium-potassium-calcium-aluminum silicates)

Zeolites are scattered throughout the Wagon Bed Formation near Jeffrey City and occur in volcanics of the Absaroka Mountains. They are also found in cavity fillings in the Green River Formation. In the Washakie Basin of southwestern Wyoming, tuffaceous units of the Washakie and Green River Formations contain enormous resources of the zeolite clinoptilolite.

Clinoptilolite

Color — white to light green; luster — earthy; specific gravity and heft — 2.1 to 2.2, low; hardness — 3.5 to 4; habit — minute, fine granular masses.

Clinoptilolite has good water-absorbing and ion-exchange properties. A wet tongue tends to stick to this mineral because of its excellent water-absorbing capacity. Zeolites have been used in water softeners, and in the manufacture of catalysts for oil refining. A few individuals in the Rock Springs region have found the clinoptilolite to be an excellent kitty litter because it absorbs odors effectively.

Radioactive minerals

Allanite (Hydrated calcium-iron-aluminum silicate)

Color — brown to black; luster — translucent to opaque, resinous or pitchy, submetallic; cleavage — none; hardness — 5.5 to 6; streak — white; specific gravity and heft — 3.9 to 4.0, moderate to high; habit — tabular, prismatic to acicular, commonly compact masses; crystal system — monoclinic.

Some allanite contains thorium, and is radioactive. Crystals of allanite may be tabular, but allanite is most often found as compact masses in pegmatites. Allanite may also occur as disseminated grains in some granites.

Allanite has been identified in several pegmatites in Wyoming. Four-inch long allanite crystals are reported in a pegmatite in the Laramie Range of Albany County (sec. 2, T.18N., R.72W.), and up to 3-inch crystals have been recovered from pegmatites in secs. 12 and 13 T.39N., R.88W., and in secs. 7 and 18, T.39N., R.87W. in the southern Bighorn Mountains (Osterwald and others, 1966, p. 220-222).

Monazite (a rare-earth phosphate)

Color — yellow, reddish brown; luster — vitreous, waxy or resinous; fracture — conchoidal to uneven; cleavage — good basal parting with good cleavage in one direction; hardness — 5 to 5.5; specific gravity — 4.6 to 5.4; habit — thin to thick tabular crystals, sometimes as equant grains, crystal faces are often rough or striated, occurs in granites, pegmatites, gneisses and associated placer deposits; crystal system — monoclinic.

The basal conglomerate of the Flathead Formation at Bald Mountain (T.56N., R.91W.) is one of the better known monazite localities in Wyoming. Some gold occurs with the monazite.

(Uranium minerals are common in Wyoming's basins. Only a few of the better known minerals are noted).

Uraninite (uranium oxide)

Color — brown to black; luster — submetallic; greasy to dull; hardness — 5 to 6; streak — brown, black or gray; specific gravity and heft — 9 to 9.7; very high; habit — cubes, octahedrons, but most commonly massive; crystal system — isometric.

Coffinite (hydrous uranium silicate)
Color — black; luster — dull to adamantine; hardness — 5 to 6; streak — brown to black; specific gravity and heft — 5.1, relatively high; habit — most often in fine aggregates, rarely as tetrahedrons; crystal system — tetragonal.

Carnotite (potassium-uranium vanadate)
Color — lemon yellow or greenish yellow; luster — dull earthy; hardness — 2 to 3; streak — yellow; specific gravity and heft — 5.03, relatively high; habit — commonly as powdery aggregates coating quartz grains in sandstone; fluorescence — carnotite generally is nonfluorescent.

Autunite (calcium-uranium phosphate)
Color — lemon yellow (**Plate 3D**) to pale green; luster — vitreous; cleavage — perfect; hardness — 2 to 2.5; streak — yellow; specific gravity — 3.1 to 3.2; habit — commonly thin tabular crystals and coatings on sand grains; crystal system — tetragonal; fluorescence — bright yellowish green or apple green.

Schroeckingerite (hydrated fluorocarbonate sulfate of sodium, calcium and uranium)
Color — greenish yellow; luster — viterous; cleavage — perfect in one direction; hardness — 2.5; specific gravity — 3.1 to 3.2; habit — commonly, thin tabular crystals, or coatings on sand grains; crystal system — triclinic; fluorescence — bright yellowish green and occasionally light bluish green.

Tyuyamunite (calcium-uranium vanadate)
Color — yellow to green; luster — waxy; cleavage — perfect micaceous; hardness — 2; specific gravity — 3.67 to 4.35; habit — prismatic to tabular, scaly, nonfluorescent; crystal system — orthorhombic.

Although uranium is found in metamorphic and igneous rocks in Wyoming, the great majority of the State's resources are hosted by sandstones in the basins. During the uranium boom of the late 1970s, when Wyoming was the second largest producer in the United States, uranium was mined from several districts (**Figure 18**).

Uranium minerals are numerous and chemically complex, but can be differentiated into two groups on the basis of color and degree of oxidation. Most Wyoming ores are black to brown minerals of the reduced (unoxidized) type. Uraninite and coffinite fit in this category. Oxidized uranium minerals are brightly colored and are found

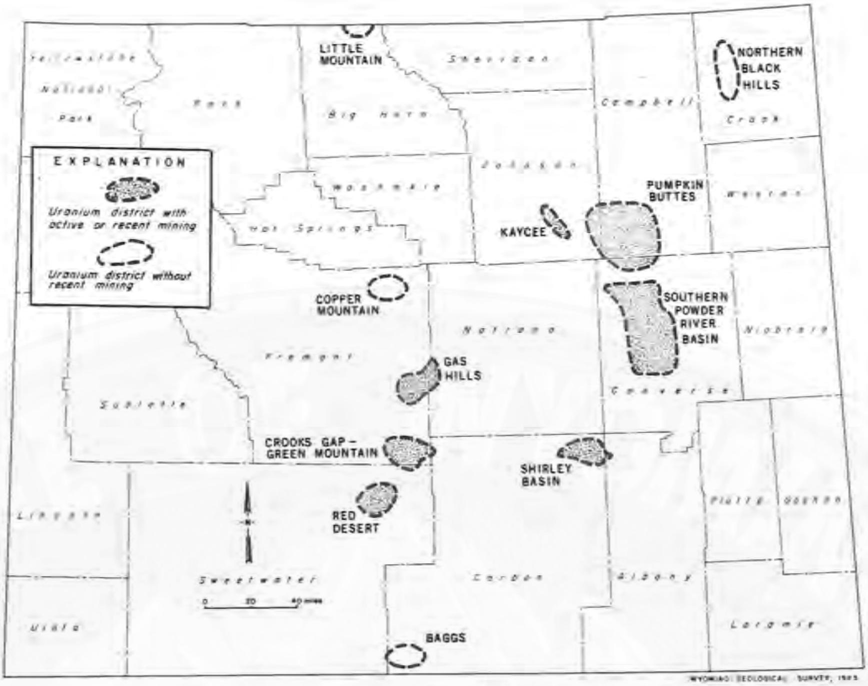


Figure 18. Map of uranium districts in Wyoming.

at or near the Earth's surface where oxygen from the atmosphere combines with the uranium. Carnotite, autunite, schroeckingerite and tyuyamunite are typical oxidized uranium minerals.

All uranium minerals naturally emit beta and gamma rays detectable by scintillometers and geiger counters. These instruments are used to prospect for uranium.

Much of the uranium produced during the boom of the 1970s occurred in roll fronts in sandstone. The roll fronts are concentrations of uranium located at a chemical interface. On the upslope side of a roll front, the ground water and associated minerals are oxidized; downslope, everything is reduced (unoxidized). The roll fronts occur in stream-deposited sandstones. It is believed that oxygen-rich ground water traveled downslope picking up uranium until much of the oxygen in the water was lost. At this point, uranium precipitated.

This type of sandstone uranium deposit is found in the Powder River Basin, the Shirley Basin, the Great Divide-Washakie Basin and the Wind River Basin. Detailed information on the location of many of these deposits is available in Osterwald and others (1966).

Chalcedony

Color — multicolored; luster — vitreous or waxy; fracture — conchoidal; hardness — 7; specific gravity and heft — 2.57 to 2.64, low to moderate; habit — irregular microcrystalline masses.

Cryptocrystalline varieties of quartz (chalcedony) are quite varied in color and are often used in jewelry and as rock specimens (**Plate 4A, 4B**). Several varieties of chalcedony produce attractive ornamental stones. Agate has concentric banding thought to develop in cavities such as in geodes, or in veins. Most often, only small fragments of these cavity fillings are found.

Moss agate is an unbanded agate that has irregular dendritic markings. Other varieties of chalcedony include onyx (alternating layers of dark and light chalcedony), sard (yellowish and reddish brown translucent chalcedony), chrysoprase (apple-green translucent chalcedony), jasper (dark red to yellowish brown opaque chalcedony), prase (dull green chalcedony), bloodstone (green chalcedony with red jasper spots), chert (dull black, white or gray opaque chalcedony) and flint (dull gray to black opaque chalcedony).

Many varieties of quartz are also given local-usage names by rock hounds, so that one particular variety could have more than one name.

Opal is submicroscopic silicon dioxide with water that is found in cavity fillings and often exhibits brilliant internal color dispersion.

Banded and moss agates and petrified wood are popular collectors' items in Wyoming (**Figure 19**). Rainbow or iris agate will diffract ordinary light into the colors of the rainbow when thinly sliced. Iris agate is found along the Wind River near Riverton, and wood-cast agate is collected in the Wiggins Formation of the Absaroka Mountains. Wood-cast agate is chalcedony that has filled and taken on the external form of cavities created by the rotting and removal of buried limbs, roots and trunks of trees. In contrast, petrified wood is formed by mineral replacement of the organic material as it lies in the ground, with retention of some of the internal features characteristic of wood. The Wiggins Formation of the Absaroka Mountains is a good source for agate-filled casts of tree trunks and limbs. Much of this material is gray to white and has either concentric or horizontal banding (Root, 1977).

Dryhead agate is an attractive red and white banded agate found in the Phosphoria Formation south of the Pryor Mountains. The agate also occurs in Dryhead Creek and along the Bighorn River northeast of Lovell (Wilson, 1965). Seams of agate in Guernsey Formation limestones near Hartville (Platte County) were mined

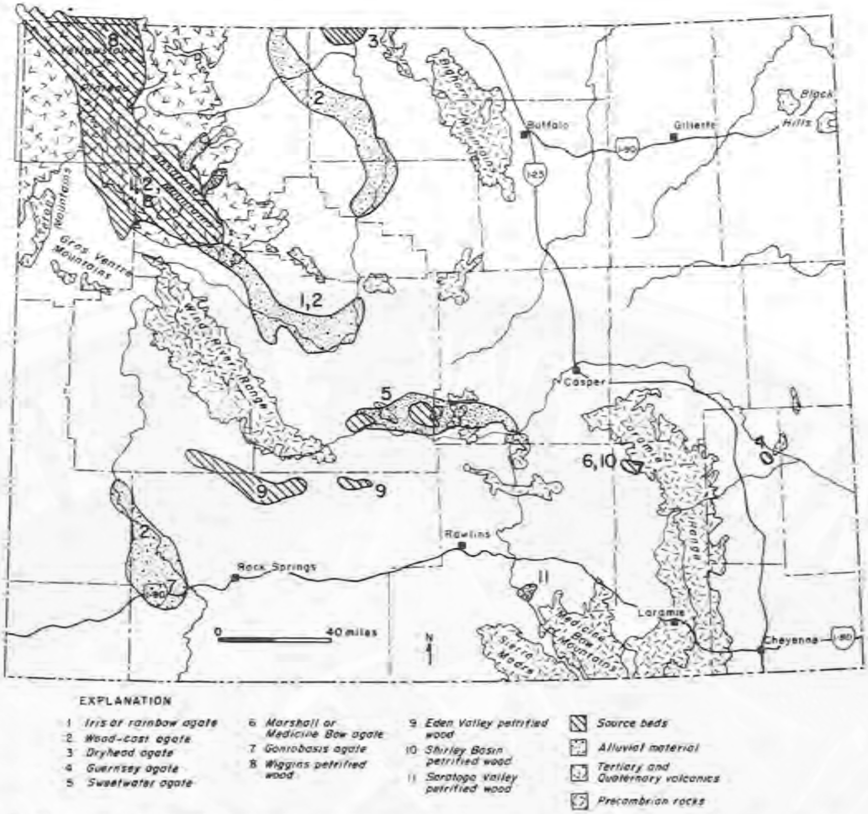


Figure 19. Principal agate and petrified wood localities in Wyoming (after Root, 1977).

commercially in the early part of the century. These are white moss agates and cream-colored banded agate (Root, 1977). Youngite, a mixture of drusy quartz and banded agate encrusting pink breccia (Plate 4B) occurs in natural caves developed in Mississippian limestone near the Guernsey and Glendo Reservoirs a few miles northwest of Guernsey. This popular agate will fluoresce light green in both long- and short-wave ultraviolet light.

One common variety of agate indigenous to Wyoming is the Sweetwater moss agate. The agate is a dark, gray-blue agate with clusters of black manganese dendrites. Some of the best localities lie along Sage Hen Creek northeast of Jeffrey City. Small pebbles of the agate are also collected along the Sweetwater River where it parallels U.S. Highway 287 near Jeffrey City (Love, 1970). Some agates from this region will fluoresce yellow green in shortwave ultraviolet light (Vanders and Kerr, 1967).

White moss agate is found in the Casper Formation near Marshall in Albany County, and occurs with pieces of jasper in gravels southwest of Marshall.

At Steamboat Mountain in the Leucite Hills (secs. 9, 10, 15 and 16, T.23N., R.102W.), the orendite and wyomingite lava flows contain amygdules that are sometimes lined with crusts of chalcedony (Wilson, 1965).

Goniobasis agate is a dark brown siliceous rock filled with shells of the fossil snail, *Goniobasis.* This rock takes a high polish and produces very attractive specimens of brown agate filled with agatized snail shells (**Figure 20**). The rock caps buttes along Interstate 80 between Green River and Granger. Some of these specimens weakly fluoresce white, yellow or light blue in long-wave ultraviolet light.

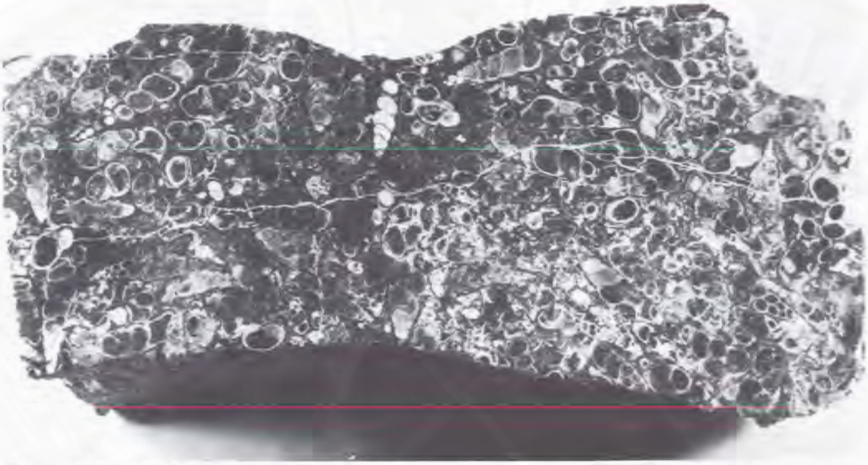


Figure 20. Polished slab of Goniobasis *agate from the Green River Basin (photograph by Karl Albert).*

Petrified wood is organic woody material that has been replaced by microcrystalline quartz or opal. Most Wyoming petrified wood formed 30 to 40 million years ago, when trees were buried under volcanic ash. A few large petrified trees may be seen in Yellowstone National Park at Specimen Ridge and Amethyst Mountain, and in the Absaroka Mountains to the east. The Wiggins Formation in the Absaroka Mountains contains abundant petrified wood locally, and some petrified pine cones and seed clusters have also been preserved (Root, 1977).

Some of the most attractive petrified wood in the State is found northeast of Farson, just south of the Wind River Range. This is the famous Eden Valley wood, which is black to dark gray. Petrified wood has also been identified along the old Casper Road about 35 miles north of Medicine Bow and on the flats along Wyoming State Highway 130 and 14 miles south of Walcott Junction. Some moss agate and clear chalcedony occur in outcrops of the Bridger

Formation north of Wamsutter. Agates also occur in the Mineral Hill district of the Black Hills and have been recovered from placer gold diggings.

Corundum (aluminum oxide) (See also section on Color, this volume.) Color — gray, grayish blue, brown, red or purple. **Ruby** is a deep red variety of corundum, and **sapphire** is blue to bluish white corundum; luster — adamantine to vitreous, less often transparent to translucent; parting — crystals have good rhombohedral and basal parting; hardness — 9, second only to diamond of the naturally occurring minerals; specific gravity and heft — 4.0 to 4.1, moderately high; habit — commonly found as hexagonal, six-sided prismatic crystals that are frequently barrel shaped with rough, rounded surfaces (**Plate 4C**). Striations, when present, are due to repeated twinning; crystal system — hexagonal.

Most rubies and sapphires collected in Wyoming have been poor quality although a few gem-quality specimens are reported. One excellent specimen of ruby schist was collected from Green Mountain east of Jeffrey City. The schist has several deep red rubies ranging up to thumbnail size. Unfortunately the rock was a piece of float and the source area has not been found (Avon Brock, personal communication, 1983).

Love (1970) discussed several occurrences in the Granite Mountains near Jeffrey City. According to Love, rubies were found with jade in Precambrian mica schist near the western edge of the Granite Mountains (NE¼ sec. 13, T.30N., R.93W.). The rubies are highly altered and pale red, but a few are gem quality. Another locality (sec. 20, T.32N., R.91W.) contains mica schist boulders with some veins and pods of dark green and black jade with dark red rubies. A few of the rubies are as large as one inch in diameter but they are badly fractured. In T.31N., R.96W., on the Marion claim, pale to bright red rubies occur in mica schist. Some specimens from here have been cut into gems (Osterwald and others, 1966, p. 66).

Pale blue sapphires and colorless corundum occur in rounded micaceous nodules up to one inch in diameter (**Plate 4C**). These are in mica schist surrounded by gray-brown granite in sec. 26, T.30N., R.96W., east of the Bureau of Land Management road between Highway 287 and Atlantic City. Love (1970) reports that the sapphires and colorless corundum are abundant, but badly fractured. Some gray jade also occurs in aplite dikes in the area.

At the Roff deposit in Albany County (sec. 18, T.24N., R.70W.) mica schist contains accessory corundum and kyanite. In Carbon County, corundum specks have been identified with kyanite and sillimanite in a vermiculite deposit (sec. 15, T.15N., R.83W.) along the northwestern edge of the Medicine Bow Mountains (Osterwald and others, 1966).

Diamond (isometric carbon)

Color — colorless, pearly white, brown, yellowish brown and black; luster — transparent to translucent with brillant adamantine to greasy luster; cleavage — perfect octahedral; fracture — conchoidal, specimens are brittle and break easily; hardness — 10, hardest of all naturally occurring minerals; specific gravity — 3.5 to 3.53; habit — diamonds from Wyoming are clear (less often black to brown) dodecahedrons, octahedrons, macles, twins or irregular crystals. Many faces of the crystals contain etched triangles; crystal system — isometric; fluorescence — some specimens are weakly fluorescent; miscellaneous — diamonds are naturally grease attractive and nonwettable, thus the uncoated diamonds will tend to adhere to grease and float on water (Hausel and others, 1985).

Both gem-quality and industrial diamonds occur in Wyoming, with some of the diamonds weighing nearly one carat (Plate 4D). The largest diamond recovered from Wyoming state property was a clear, gem-quality stone weighing 0.86 carat. The gem-quality diamonds have an unusually high percentage of beautiful brilliant white colors. Of all of the diamonds recovered in Wyoming, nearly 50 percent are gem quality.

The industrial diamonds are frosted, contain numerous mineral inclusions, or are badly flawed in some other way to make them unsuitable for gems. These diamonds are used for grinding tools, stone saws and drill bits. Bort diamonds are granular to microcrystalline diamonds that are often colored brown, gray or black. These are poor-quality stones that are crushed and used as an abrasive. Carbonado is a black opaque bort composed of amorphous carbon and diamond. Grit is broken diamond fragments with sharp edges. Of the industrial diamonds recovered in Wyoming, the greatest number are of the better grade used for drill bits and other cutting tools. Only a small percentage of these are classified as bort.

Diamonds have been recovered from kimberlite pipes located 20 miles south of Laramie. Several small intrusives of the diamond-bearing rock intrude granite a short distance west of Highway 287 near the Colorado-Wyoming State Line. These rare volcanic rocks occur in secs. 5, 8, 9, 16 and 21, T.12N., R.72W. In 1980 and 1981, 126 diamonds totaling 15.38 carats were recovered from State of Wyoming lands. Several more were found on Union Pacific lands in Wyoming.

At another location, in the northern Medicine Bow Mountains, two octahedral diamonds were found in a gold placer in N½ NW¼ sec. 2, T.16N., R.81W. The larger of these two stones weighed approximately 0.1 carat. These diamonds were good-quality clear stones with a few minor mineral inclusions. The placer is located in Cortex Creek along the northwestern edge of the Gold Hill district near the base of the Snowy Range.

Jade (nephrite)

Color — Wyoming jade is black, olive green, emerald green, light apple green and rarely gray to white (**Plate 5A, 5B**). Snowflake jade has a mottled coloration due to the intermixing of other minerals and nephrite. The lighter colors of nephrite are highly valued; luster — vitreous to waxy; cleavage — the prismatic varieties of actinolite-tremolite have amphibole cleavage; hardness — 5 to 6; streak — white; specific gravity and heft — 2.8 to 3.5, moderate; habit — prismatic, massive or fibrous. Tremolite is the name given to the white variety of amphibole that is rich in magnesium and poor in iron, and actinolite is the blackish or greenish iron-rich member (**Figure 21**). The nephrite (jade) form is submicroscopic, intricately interwoven, actinolite-tremolite mineral fibers that produce a massive and extremely tough gemstone. The common habits of actinolite-tremolite are prismatic, asbestos-form masses; coarse crystalline grains with excellent amphibole cleavage (**Figure 13A**), or tough, compact masses known as nephrite or **Wyoming jade**. All three varieties occur in Wyoming. They result from the alteration of pyroxene in metamorphic terrains. Actinolite-tremolite will alter to talc, serpentine, chlorite and epidote.

Coarse crystalline grains are relatively brittle because of their excellent amphibole cleavage and hardness of only about 5.5. But the nephrite form of actinolite-tremolite is one of the toughest gemstone materials known.

Nephrite can be easily confused with a number of other minerals and special care must be taken for accurate field identification. The following rules are useful for field identification of jade according to Root (1977):

(1) Nephrite is heavier than the average rock of the same size.

(2) Nephrite cannot be scratched with an ordinary knife blade.

(3) Nephrite has a smooth, almost waxy appearance (**Plate 5A**).

(4) If the end is ground off of a suspected Wyoming jade specimen, the fresh surface should not sparkle or glitter in the sun. If it sparkles, it is not jade.

Positive identification of nephrite almost always requires testing by x-ray diffraction. Rocks that are often mistaken for nephrite

Figure 21. Tremolite schist (komatiite) from Bradley Peak, Seminoe Mountains. The long, black, prismatic tremolite crystals are quite distinct.

include fine-grained quartzite, serpentinite, epidotite and even metadiabase. These often occur in the same geologic environment as nephrite. Quartzite can be distinguished by its granular texture that tends to sparkle on a freshly broken surface. Serpentinite and epidotite are softer and can be scratched with a knife. Close inspection of a metadiabase often reveals the presence of numerous individual crystal grains.

Nephrite occurs at scattered localities from the Wind River Mountains to the northern Laramie Range in a narrow east-west band that encloses the Granite Mountains north of Jeffrey City (**Figure 1**). Veins of jade are rarely found in the mountainous terrain, and pebbles and boulders of jade in alluvial fans are also uncommon. The jade areas have been picked over for years, but new discoveries are possible, as shown in the early 1970s when one prospector discovered a seven-ton boulder of black jade in the Prospect Mountains at the south tip of the Wind River Range.

Fibrous actinolite-tremolite has been reported at a number of localities. One of the best localities is in the South Pass-Atlantic City gold mining district. Here the actinolite-tremolite forms a massive metamorphic rock that is exposed around a number of the historic mines and found on many mine dumps.

Metalliferous minerals

Arsenopyrite (arsenic sulfide)

Color — silver white to steel gray (Plate 5C); luster — metallic; hardness — 5.5 to 6; streak — black; specific gravity and heft — 6.07, relatively high; habit — often in granular masses or short prismatic crystals with striations; crystal system — orthorhombic; alteration — alters to yellow-green scorodite.

Arsenopyrite has been reported in some of Wyoming's gold mining districts and is often considered to be the source of much of the gold found in the historic mines. Bayley and others (1973) and Prinz (1974) reported a close association of gold with arsenopyrite in the South Pass — Atlantic City district. Hausel (1986b) indicated that gold was also commonly associated with pyrite at South Pass.

Characteristics used to identify arsenopyrite include its common association with quartz veins in gold mining districts, its steel-gray color, association with yellowish green scorodite (oxidized arsenopyrite) stains, and a distinct garlic odor emitted when powdered.

Many of the historic mines in the South Pass - Atlantic City district contain small fragments of arsenopyrite in quartz on the mine dumps. Massive specimens of arsenopyrite have been collected from two exposed veins in a cliff on the north bank of the Sweetwater River in the SE¼ sec. 9, T.28N., R.98W. of the Radium Springs Quadrangle, and pieces of arsenopyrite are also scattered on the Dream mine dump about one hundred yards upstream from the veins.

Good specimens of massive arsenopyrite with interspersed short prismatic needles (Plate 5C) occur at Garrett in the central Laramie Range (secs. 22 and 28, T.25N., R.73W.). This area also contains rare specimens of berthierite (an antimony-iron sulfide); it is the only locality in Wyoming where an antimony-bearing mineral has been identified. The berthierite is similar in appearance to the massive arsenopyrite, but has a high silver metallic sheen with some associated blood-red hematite alteration. One sample of berthierite collected near the Garrett School House assayed 0.25 ounce of gold per ton.

Cassiterite (tin oxide)

Color — shades of brown to brownish black, occasionally gray, white or yellow; luster — adamantine to dull; hardness — 6 to 7; specific gravity and heft — 7.0, high; habit — usually short prismatic tetragonal crystals, bipyramids, or fine granular or botryoidal masses. Often occurs as contact or penetration-twinned crystals; crystal system — tetragonal.

The only locality in Wyoming where cassiterite has been identified is in the Mineral Hill district in the Black Hills of Crook County. Tin placers and pegmatites occur in the Mineral Hill district in association with gold. Cassiterite is found in granite pegmatite on a ridge between Bear Gulch and Sand Creek. The mineral grains range from 1/8 to 1/2 inch in diameter and are generally anhedral (formless), although some well-developed euhedral crystals have been reported. The cassiterite occurs as inclusions in feldspar, and less often in quartz and mica. Cassiterite in the host pegmatite rarely exceeds two percent (Welsh, 1974).

In placers along Bear Gulch, Sand Creek and Sand Creek Crossing, cassiterite occurs as subangular fragments up to one inch in size. The grains are intermixed with garnet, magnetite, columbite-tantalite, wolframite, gold and rare minute topaz grains (Irving and Emmons, 1904, p. 95-97). Cassiterite is the principle ore mineral of tin.

Chromite (chromium oxide)

Color — black; luster — submetallic; hardness — 5.5; streak — brown; specific gravity and heft — 4.3 to 4.6, relatively high; habit — usually granular masses associated with serpentine, rarely octahedrons; crystal system — isometric; magnetism — weak to nonexistent.

Chromite is an ore of chromium. It has been reported at a few localities in Wyoming. In an area east of Mill Creek, in the Halleck Canyon area of the central Laramie Range (sec. 13, T.22N., R.72W.), chromite veinlets and disseminated chromite occur in serpentinite (Fields, 1963; Graff and others, 1982).

In Deer Creek canyon (sec. 11, T.31N., R.77W.) about 15 miles southwest of Glenrock, a serpentinite belt contains fine-grained compact masses of chromite in layers ranging from two to five feet wide (Spencer, 1916; Beckwith, 1939). A rare chromium chlorite mineral was also identified in the deposit. This mineral is called kammererite (Diller, 1920).

On Casper Mountain, south of the town of Casper in the SW¼ sec. 16, SE¼ sec. 17, and NE¼ sec. 20, T.32N., R.79W., chromite lenses, pods and disseminations are scattered throughout talc schist (Beckwith, 1939).

Copper Minerals

Copper-bearing minerals are common throughout Wyoming and include several mineral species. Some of the better collecting localities include Jelm Mountain, the Sierra Madre, Seminoe Mountains, Copper Mountain, Lake Alice area and the Absaroka Mountains (Figure 22). In many areas, copper has been mined with silver, zinc, lead and other metals. For information on specific collecting localities refer to Osterwald and others (1966).

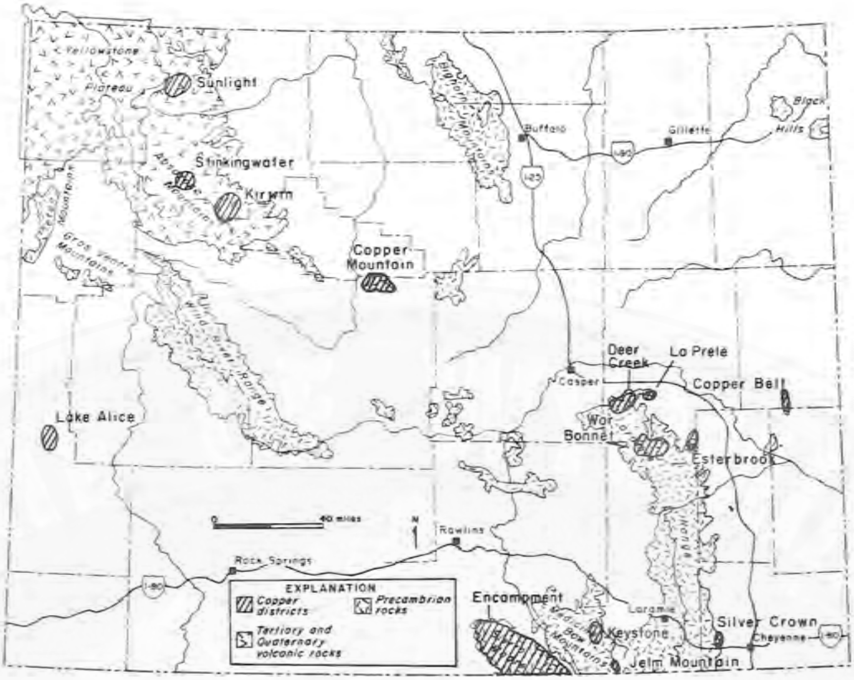


Figure 22. Wyoming's copper mining districts.

Azurite (copper carbonate)

Color — blue (Plate 5D), luster — dull to vitreous; hardness — 3.5 to 4; streak — blue; specific gravity — 3.77; habit — often occurs as crusts and coatings associated with green malachite. Less often as vitreous botryoidal masses; chemical identification — effervesces in cold dilute hydrochloric acid.

Azurite has been found in association with other copper minerals at several prospects and mines in the Sierra Madre.

Chalcocite (copper sulfide)

Color — black to lead gray; luster — metallic; hardness — 2.5 to 3; streak — shining dark lead gray; fracture — conchoidal; specific gravity and heft — 5.5 to 5.8, high; habit — commonly occurs as soft, subsectile masses associated with malachite.

Chalcopyrite (copper-iron sulfide)

Color — bronze gold; luster — metallic; hardness — 3.5 to 4; streak — greenish black; specific gravity — 4.1 to 4.3; habit — massive; chemical identification — powdered chalcopyrite will fuse to a metallic globule on charcoal.

Chalcopyrite (Plate 6A) has been found in all of Wyoming's copper districts. Some excellent specimens have been recovered from the Hercules and Portland mines (SW¼ sec. 29, T.14N., R.85W.) near Battle in the Sierra Madre (see Osterwald and others, 1966).

Chrysocolla (copper silicate)

Color — blue to green; luster — vitreous; hardness — 2 to 4; specific gravity — 2 - 2.3; habit — compact masses and crusts; chemical identification — sometimes mistaken for azurite but chrysocolla will not react to hydrochloric acid.

Chrysocolla has been mistaken for turquoise, but it has an inferior hardness, and turquoise has not been identified in Wyoming. Good chrysocolla specimens have been collected from the Sunday Morning prospect (SE¼ sec. 29, T.26N., R.85W.) in the Seminoe Mountains.

Cuprite (copper oxide)

Color — earthy red; luster — earthy; hardness — 3.5 to 4; streak — shades of shining brownish red; specific gravity — 5.8 to 6.2; habit — masses and stains; associations — with tenorite, and malachite; chemical identification — pour muriatic acid on a specimen and rub with well-used rock pick. Native copper will coat the hammer (see Reaction to hydrochloric acid section).

Malachite (copper carbonate)

Color — green (Plate 5D); luster — earthy to vitreous; hardness — 3.5 to 4; streak — pale green; specific gravity — 4; habit — botryoidal masses and coatings and crusts; chemical identification — effervesces in muriatic acid.

Malachite is the most common copper mineral found in Wyoming. Mines in the Sierra Madre, Lake Alice district and on Jelm Mountain commonly have abundant malachite.

Tenorite (copper oxide)

Color — black; luster — vitreous, submetallic, to earthy; hardness — 3 to 4; streak — gray; specific gravity — 6.5; habit — as stains associated with malachite and cuprite; chemical identification — see Cuprite.

Tenorite has been identified at some historic mines on Jelm Mountain and in the southern Sierra Madre. It is probably more widespread and often not identified because of its nondistinctive black color.

Galena (lead sulfide)

Color — lead gray; luster — metallic; cleavage — perfect cubic; subconchoidal fracture; hardness — 2.5; streak — lead gray (Figure 6), specific gravity and heft — 7.58, very high; habit — commonly

Color Plates 1 through 8,
pages 58 through 73

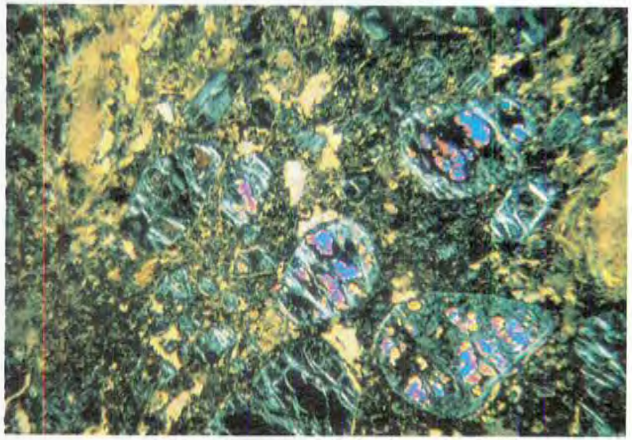


Plate 1

A	B
C	D

Plate 1A. The Boar's Tusk, located 28 miles north of Rock Springs, is a spectacular volcanic neck formed from a rare volcanic rock known as wyomingite.

Plate 1B. Red pyrope garnet and green chrome diopside pebbles on an anthill along the north edge of Cedar Mountain, Green River Basin.

Plate 1C. Faulted quartz vein exposed in the Mary Ellen gold mine at South Pass.

Plate 1D. Thin-section of kimberlite rock sample as viewed enlarged 25 times through a polarizing microscope. This rock sample has been slabbed to a thickness of about 1/1000th of an inch. The rounded crystals are olivine. The yellow, purple and blue in the center of the crystals are what remains of the original olivine and the gray cobweb-like substance and black material around the olivine is serpentine that has replaced olivine. Olivine is a magnesium silicate, whereas serpentine is a hydrated magnesium silicate. During eruption of the kimberlite, large quantities of water reacted with the kimberlite,and olivine was partially or entirely hydrated, producing serpentine.

Plate 2

A	B
C	D

Plate 2A. Garnet peridotite nodule from a State Line kimberlite. Deep red porphyroblasts are pyrope, smaller green crystals are chrome diopside (pyroxene) and the remaining rock mass is serpentine.

Plate 2B. Almandine mica schist from the Section 8 mine, Sierra Madre.

Plate 2C. Beautiful hexagonal quartz crystals capped by pryamids.

Plate 2D. Fibrous asbestos (a variety of serpentine) from Casper Mountain.

Plate 3

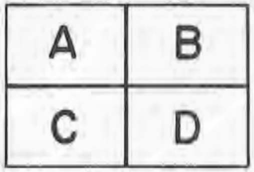


Plate 3A. Blue barite crystals from Sheep Creek area, Albany County.

Plate 3B. Fluorite specimen from the Bear Lodge Mountains, Crook County. (Specimen donated by J.T. Roberts.)

Plate 3C. Gypsum (variety satin spar) from Cedar Mountain area, Green River Basin. (Specimen donated by Ruel Triplett.)

Plate 3D. Bright yellow autunite staining a conglomeratic sandstone.


cm
1
2
3
SPEC.
DATE

Plate 4

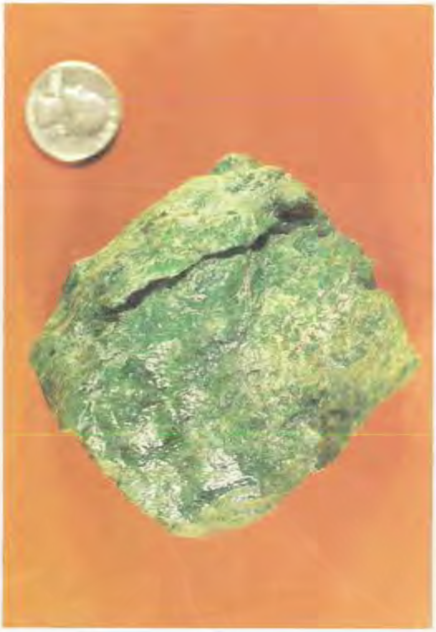
A	B
C	D

Plate 4A. Banded chrysoprase from western Wyoming.

Plate 4B. Specimens of youngite collected near the Glendo Reservoir northwest of Guernsey (photograph by Karl Albert).

Plate 4C. Specimens of corundum. Hexagonal columnar corundum (upper center and lower left) and a light blue-white sapphire enclosed in a micaceous nodule (right). Sapphire specimen donated by J.D. Love (photograph by Karl Albert).

Plate 4D. Diamonds from the Wyoming State Line district south of Tie Siding (centimeter scale) (photograph by Karl Albert).



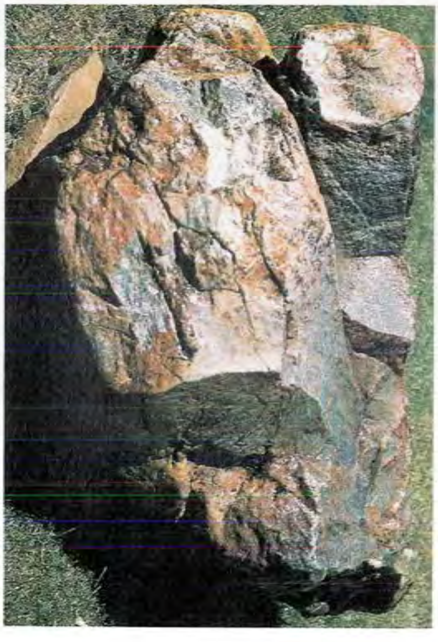


Plate 5

A	B
C	D

Plate 5A. Uncut sample of green nephrite (Wyoming jade). Note the greasy luster. (Sample donated by Jay Sundberg.)

Plate 5B. Partly wind-polished boulder of apple-green jade found by Bert A. Rhoads in Fremont County, Wyoming, in 1962. It weighed 3,200 pounds (photograph by J.D. Love.)

Plate 5C. Acicular, prismatic needles of arsenopyrite on massive arsenopyrite from Garrett.

Plate 5D. Copper carbonate specimen with green malachite and blue azurite.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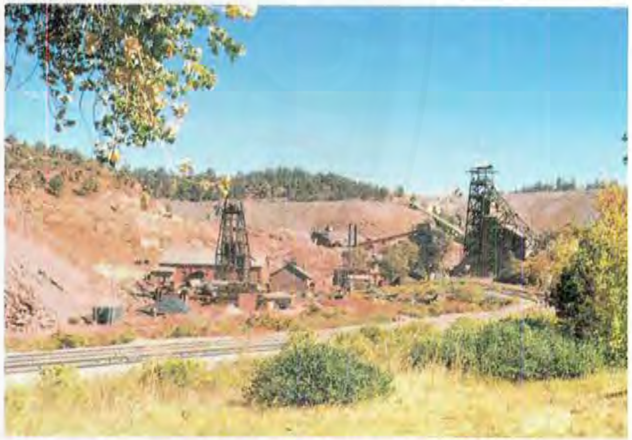


Plate 6

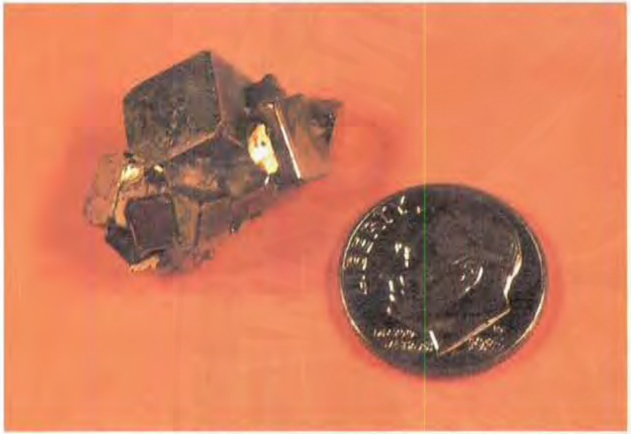
A	B
C	D

Plate 6A. Chalcopyrite, a bronze-colored metallic copper sulfide.

Plate 6B. Gold flakes and nuggets panned in the Dickie Springs — Oregon Buttes area, Wyoming (photograph by J.D. Love).

Plate 6C. Botryoidal and massive hematite (variety specularite). The orange material is limonite.

Plate 6D. The Sunrise iron mine in 1980, before it closed permanently in 1981.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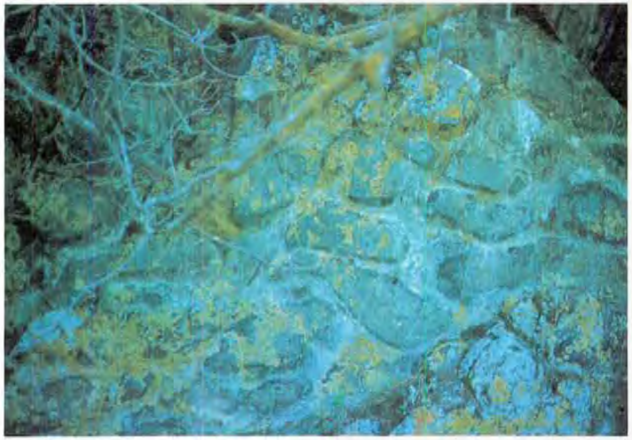


Green 1
Diamondiferous
kimberlite
Colorado

Plate 7

A	B
C	D

Plate 7A. Pyrite crystals exhibiting characteristic cubic habit and metallic luster.

Plate 7B. Marblized limestone, (light colored rock) at White Mountain in the Sunlight Basin.

Plate 7C. Pillow basalts in the Hartville uplift. These are very old (Archean?) metabasalts that still retain excellent pillow textures typical of submarine volcanic eruptions.

Plate 7D. Kimberlite from the southern Laramie Range near the Wyoming-Colorado border.

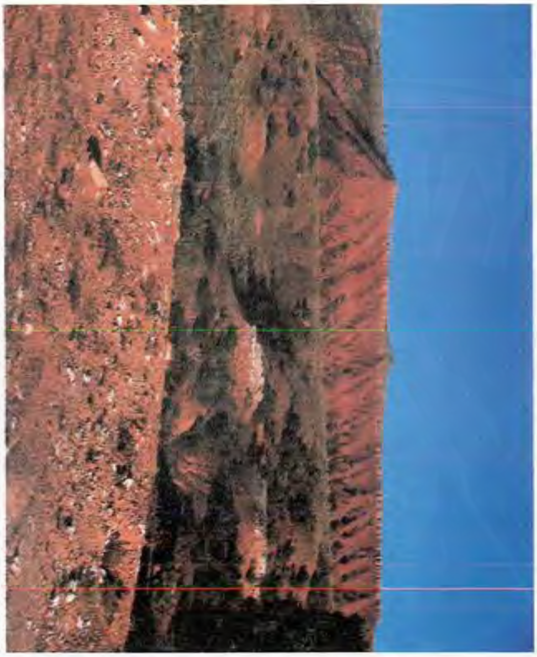

Plate 8

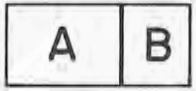

Plate 8A. Red shale constitutes much of the Chugwater Formation (mountain in background) and Goose Egg Formation (foreground) in Wyoming (photograph by Sheila Roberts).

Plate 8B. Clinker in Tertiary rocks northwest of Gillette in the Powder River Basin, Wyoming (photograph by Sheila Roberts).

soft, massive metallic material that is cleavable. Occurs less often in cubes; crystal system — isometric.

Only a small amount of galena occurs in Wyoming. The Esterbrook mine (SE¼ sec. 9, T.28N., R.71W.), in the northern Laramie Range, has produced some of the best specimens in the State. Ore shoots of solid galena up to six feet wide were intersected by the historic mine workings. The galena from the mine also carried some silver (Spencer, 1916). In 1980, the author was able to find only scattered specimens containing galena on the mine dumps.

Gold

Color — golden yellow, silvery yellow, reddish yellow; luster — metallic; fracture — hackly; hardness — 2.5 to 3, malleable; specific gravity and heft — 19.3 (pure), extremely high; habit — usually irregular masses in veins, or flakes or nuggets in stream placers; crystal system — isometric.

Gold occurs at a number of localities in Wyoming (**Figure 23**). Usually, the metal is found in limonite-stained boxworks (honeycomb structures) (see Limonite), in quartz veins, or as free gold in stream deposits (**Plate 6B**). There is very little historical data on gold discoveries in Wyoming. However, there are reports that some ore produced from the Burr mine, in the Lewiston district along the southern Wind River Mountains, may have assayed as high as 250 ounces of gold per ton. Some rare rich pockets of gold ore from the Acme mine in the Gold Hill district of the Medicine Bow Mountains were reported to assay as high as 2,100 ounces of gold per ton. Statistics on the size of recovered nuggets are essentially nonexistent although one-half inch-long nuggets were reported from stream gravels in the Black Hills region (Welch, 1974), and at least one nugget greater than 3 ounces was recovered from Rock Creek in the South Pass - Atlantic City district (Ross and Garnder, 1935).

Two prominent gold districts are the South Pass - Atlantic City and Lewiston districts. The South Pass - Atlantic City district is located 30 miles south of Lander along Highway 28. Many historic gold mines occur along a northeasterly trend between South Pass City and Miners Delight in this district. Gold production is estimated to have been 327,000 ounces. The majority of the gold was mined at the Carissa and Miners Delight mines and nearby placers (Hausel, 1980, 1984).

About 12 miles southeast of Atlantic City, the Lewiston district also has several mines, but actual gold production is unknown. Records indicate that rich gold pockets were intersected at the Burr and Hidden Hand mines, and at the Wilson Bar placer. For example

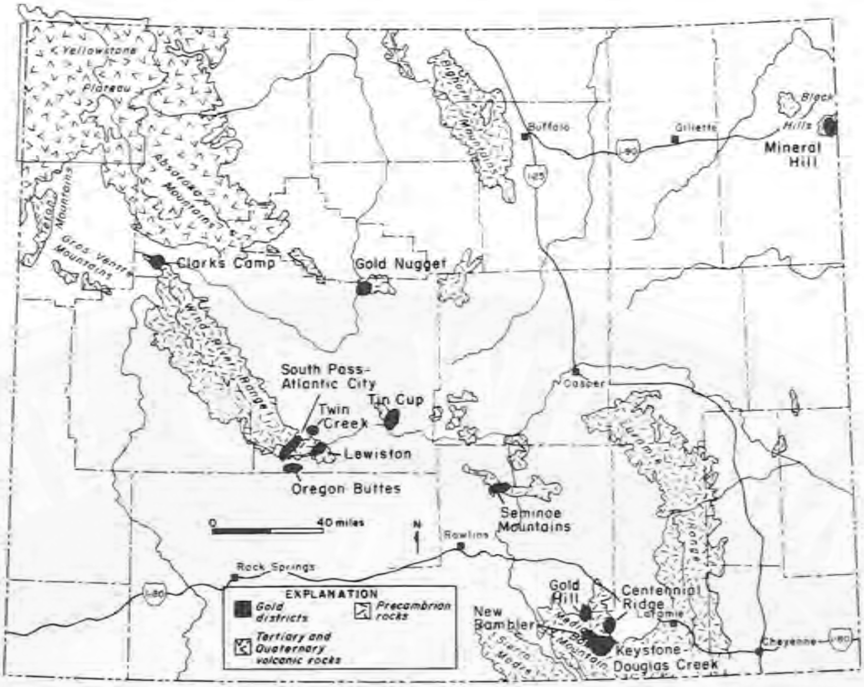

Figure 23. Gold districts in Wyoming. Much of the historic gold production was mined at the South Pass-Atlantic City district. Optimistic estimates suggest as much as 327,000 ounces of gold could have been mined there (Hausel, 1980, 1986).

when the Wilson Bar placer was discovered, several pannings produced up to one ounce of gold per pan (*The Lewiston Miner*, 1890).

Gold is quite distinctive and can be identified by its color, malleability and sectility. Gold is insoluble in ordinary acids, but soluble in aqua regia.

Hematite (iron oxide)

Color — red, steel gray; luster — dull, submetallic to metallic; hardness — 5.5 to 6.5; streak — dark red; specific gravity and heft — 4.9 to 5.3, relatively high; habit — earthy masses, botryoidal metallic masses (Plate 6C), and micaceous to platy metallic coatings or flakes; crystal system — hexagonal.

Hematite was mined north of Rawlins at one time, and used as a paint pigment. The paint was named Rawlins red and was used by the Union Pacific Railroad to paint their cabooses and boxcars. The Rawlins hematite cements quartzite of the Flathead Formation in secs. 4, 5, 8 and 9, T.22N., R.87W. immediately north of Rawlins and west of Highway 287. From the highway several mine workings are visible in the foothills.

Specularite, or metallic hematite, and earthy hematite occur in the Sunrise area of the Haystack Range iron district in the Hartville uplift of eastern Wyoming. Hematite in the Sunrise area was mined as an iron ore for nearly one hundred years producing millions of tons of hematite ore and small quantites of copper **(Plate 6D)**. Hematite was produced from several mines in this area including the Sunrise, Chicago, Good Fortune and Central ore bodies **(Figure 24)**. Both earthy and specular hematite can be found scattered throughout the district. Ore extracted from this area was shipped to blast furnaces at Pueblo, Colorado, until 1981.

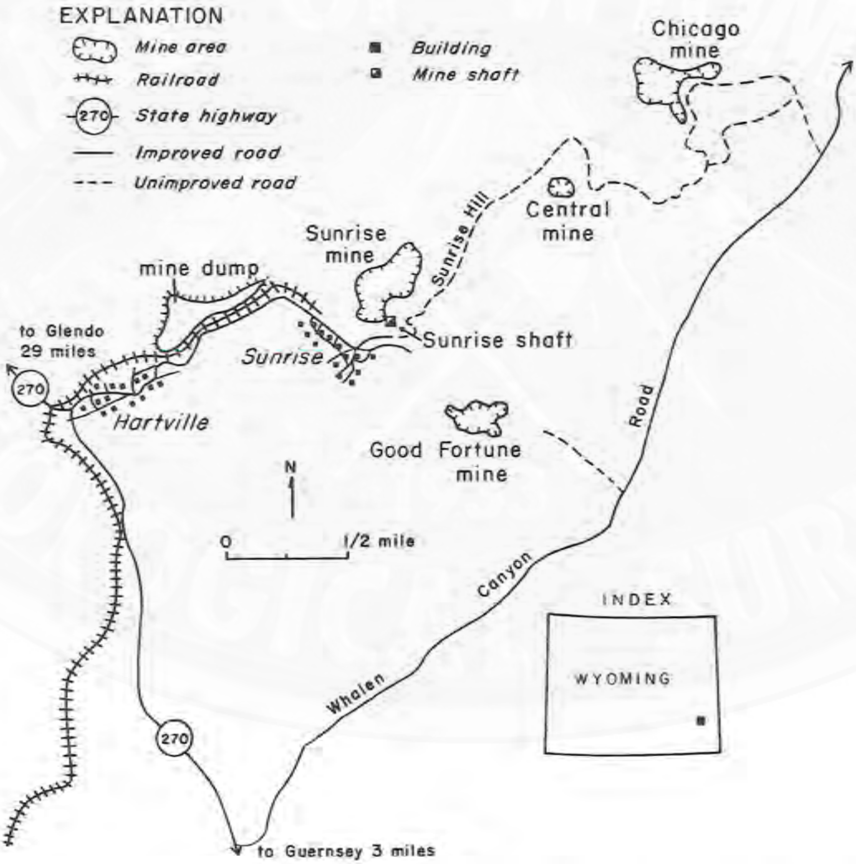

Figure 24. The Sunrise, Central, Chicago and Good Fortune mines were developed by spectacular open pits outside of the towns of Hartville and Sunrise. This historic mining district is located about 15 miles east of Interstate 25. Many of the iron mines were initially opened as copper prospects.

Ilmenite-magnetite (mixture of iron-titanium oxide and iron oxide)
Color — black; luster — metallic to submetallic; hardness — 5 to 6.5; streak — black to brown; specific gravity and heft — 4.0 to 5.2, high; habit — rounded masses in anorthosite; sulfides (up to several percent pyrite and pyrrhotite) may be associated; crystal system — ilmenite is hexagonal and magnetite is isometric; weakly to strongly magnetic.

Ilmenite-magnetite (also known as titaniferous magnetite) was mined for several years in the 1960s and 1970s at Iron Mountain in the central Laramie Range. The ore was used as a heavy-mineral aggregate in concrete for underwater pipes and for the shielding of fissionable materials. Since the ore contains appreciable titanium, there has been considerable interest in separating the titanium for use in paint pigments and for the manufacture of titanium steel. Presently, the energy requirements necessary to separate titanium from iron are too great to make this a commercially viable process.

Titaniferous magnetite deposits are scattered all over the Iron Mountain region. One of the largest, the Iron Mountain deposit (secs. 22, 23, 26 and 27, T.19N., R.71W.) includes a 5,000-foot long outcrop of massive ilmenite-magnetite exposed by the now-defunct open-pit mine operations. Further descriptions of the deposits are in Osterwald and others (1966).

Magnetism, high heft, black metallic luster and association with anorthosite are diagnostic characteristics.

Limonite (hydrated iron oxide)
Color — yellowish brown to red; luster — dull to vitreous; hardness — 1 to 5.5; heft — generally very low; habit — earthy, porous masses.

Limonite (Plate 6C) is a residue formed primarily by the oxidation and leaching of copper and iron sulfides. Massive limonite forms caps, called gossans, over many iron-copper sulfide deposits. Some very distinct porous specimens, named boxworks, may be found in these caps.

Limonite is found almost anywhere copper sulfides and iron sulfides occur. In some deposits, limonite may contain visible or microscopic gold (see Gold).

Magnetite (iron oxide)
Color — iron black; luster — metallic to dull; parting — good octahedral; hardness — 5.5 to 6.5; specific gravity and heft — 5.2, high; habit — generally well-formed octahedral or disseminated anhedral grains; crystal system — isometric; magnetism — strongly magnetic.

From 1962 to 1983, U.S. Steel Corporation produced iron ore from the Atlantic City mine at South Pass. The ore was taconite, a metamorphic rock with alternating bands of magnetite and chert (**Figure 25**). Much of Wyoming's magnetite deposits occur as banded iron formation. For example, similar deposits occur at Copper Mountain and in the Seminoe Mountains (Harrer, 1966).

Figure 25. Typical banding in taconite. These rocks are generally intensely deformed and display spectacular folds.

Prospectors worldwide often speak of black sands (sand-sized magnetite grains) in their placer gold-mining operations. Magnetite is a relatively heavy mineral and occurs as fine disseminations in many rock types. These magnetite-bearing rocks break down through weathering. In streams carrying this weathered material, magnetite will tend to separate from lighter minerals because of its relatively high specific gravity. Abundant black sand in a placer implies the presence of a good placer trap and possibly other heavy minerals, such as gold, may also occur with the black sand.

Molybdenite (molybdenum oxide)

Color — silver gray to lead gray; luster — metallic; cleavage — perfect basal; streak — shining gray; hardness — 1 to 1.5, very soft, feels greasy; specific gravity — 4.62 to 5.06; habit — disseminated grains, foliated masses or scales, and less often rough hexagonal tabular crystals; crystal system — hexagonal.

Molybdenite is reported from a few scattered localities in Wyoming. Molybdenum-bearing veins and stockworks occur along Temple Peak (sec. 24, T.32N., R.103W.) in the Wind River Mountains, and significant molybdenum resources are associated with porphyry copper deposits in the Absaroka Mountains east of Yellowstone National Park.

Molybdenum is used as a steel alloy to increase the strength and hardness of steel at high temperatures.

Platinum

Color — steel gray to silver gray; luster — metallic; hardness — 4 to 4.5, sectile; specific gravity and heft — in native state generally ranges from 14 to 19 depending on impurities, extremely high; habit — usually grains, scales and less often nuggets; magnetism — may be weakly magnetic depending on iron content.

The New Rambler mine and the Douglas Creek placer district of the Medicine Bow Mountains were historically mined for platinoids and gold. McCallum and Orback (1968) reported that platinum group metals occur in sheared and altered mafic and ultramafic rocks in the New Rambler district. Some rare crystals of a platinum sulfide known as sperrylite were also identified in the ore. Platinum and palladium are also reported in the Centennial Ridge district immediately west of the town of Centennial (McCallum, 1968).

Platinum, palladium, iridium and osmium are platinoid group metals used in jewelry, thermocouples and in chemical and electrical equipment. Like gold, the platinoids are considered to be precious metals.

Pyrite (iron sulfide) — Fool's gold

Color — brass yellow; luster — metallic; hardness — 6 to 6.5; streak — greenish black, grains are brittle and crush to a greenish black powder; specific gravity — 5.0; habit — generally massive or cubes with striated faces, less often pyritahedrons; crystal system — isometric.

Pyrite (Plate 7A) is commonly found with chalcopyrite, sphalerite, galena, gold and arsenopyrite in many of Wyoming's base- and precious-metal mining districts. Marcasite, a polymorph of pyrite, has been reported in some uranium deposits as disseminated grains.

In the South Pass–Atlantic City district, excellent specimens of cubic pyrite with calcite and quartz have been collected from the Snowbird mine northeast of Atlantic City. Massive pyrite samples with chalcopyrite occur in magnetite iron formation at the Itmay mine (sec. 14, T.13N., R.86W.). Elsewhere in the Sierra Madre, Osterwald and others (1966) report several pyrite localities. Pyrite is of no value, except as mineral specimens or where the sulfide contains appreciable quantities of gold (see Gold).

Pyrrhotite (iron sulfide)

Color — brass yellow; luster — metallic; hardness — 3.5 to 4.5; streak — black; specific gravity and heft — 4.6 to 4.7, high; habit — occurs in granular masses; crystal system — hexagonal; magnetism — generally weakly to moderately magnetic.

Pyrrhotite is similar in appearance to pyrite, but it will produce a grayish black streak, and may also be weakly magnetic. Massive specimens of pyrrhotite have been collected in the Esterbrook district north of Laramie Peak.

The Maggie Murphy mine (sec. 22, T.28N., R.71W.) and the Three Cripples mine (NW¼ sec. 16, T.28N., R.71W.) in the Esterbrook district contain massive pyrrhotite in veins (Osterwald and others, 1966). The Maggie Murphy is reported to include veins that are 10 to 40 feet wide and have some disseminated chalcopyrite and malachite in addition to pyrrhotite (see Copper).

Scheelite (calcium tungstate)

Color — white; luster — dull to vitreous; hardness — 4.5 to 5; specific gravity — 6.1; habit — commonly disseminated to massive granular; rarely in distinct octahedral or tabular crystals; crystal system — tetragonal; fluorescence — scheelite fluoresces white to light blue under short-wave ultraviolet light but does not fluoresce under long-wave ultraviolet light.

Without short- and long-wave ultraviolet light it is difficult, if not impossible, to identify Wyoming scheelite. Essentially all of the scheelite reviewed by the author occurs as disseminated grains in milky quartz or in quartzofeldspathic gneiss.

The better known scheelite deposits include (1) the Strong mine (sec. 4, T.16N., R.71W., sec. 32, T.17N., R.71W.) along the Ninth Street Road northeast of Laramie; (2) Copper Mountain; and (3) the Burr mine (sec. 8, T.28N., R.98W.) in the Lewiston district near South Pass.

Of these, Copper Mountain appears to be the most extensively mineralized. Several prospects in T.40N., R.93W. at Copper Mountain exhibit stratiform scheelite in quartzofeldspathic gneiss. During World War II, these deposits were examined as a potential source for tungsten. Tungsten is used as an alloy to harden steel and has important and strategic uses including the manufacture of armor-steel plating.

Rocks

Introduction

Rocks are aggregates of minerals formed by various geologic processes. Three basic rock groups are recognized — metamorphic, igneous and sedimentary.

Metamorphic rocks form from pre-existing sedimentary and igneous rock that were subjected to high temperatures and (or) pressures. Three types of metamorphism are regional, contact and dislocation. Regional metamorphic rocks occur in many of Wyoming's mountain ranges and formed from preexisting sedimentary and igneous rocks that were buried under a thick sedimentary pile for eons of time. Under the tremendous weight of the sediments new minerals and rock textures, stable at the elevated temperatures and pressures replaced the former minerals and textures.

The margins of many of these regional metamorphic terrains were invaded by hot granitic magmas. A new set of minerals formed in contact zones around the magma. These contact metamorphic rocks developed in thin belts adjacent to the granites on the edge of some regional metamorphic belts.

Tectonic forces before, during and after uplift of the metamorphic belts resulted in fracturing of the terrains. Localized dislocation metamorphic zones (shattered, broken and granulated rock) are recognized by the presence of cataclastic and mylonitic textures. These rocks are especially well developed in shear zones and faults.

Igneous rocks formed under high temperatures. Molten rock formed at depth and rose towards the Earth's surface. In some cases the magma erupted from volcanic vents. Most of these rocks are finely crystalline. Where the molten material cooled and solidified beneath the Earth's surface however, coarsely crystalline plutons, batholiths and dikes formed.

Sedimentary rocks formed at the Earth's surface by the erosion and deposition of particles of preexisting rocks, and by chemical or biochemical precipitation from ancient lakes or oceans.

Wyoming rocks

A relief map of Wyoming (**Figure 26**) is useful for demonstrating where these three rock groups are most likely to occur. Many of Wyoming's mountain ranges formed during the tectonic events that uplifted thick sections of rock along faults. Where uplift was greatest, erosion has stripped away most, or all of the sedimentary cover. These ranges are cored by exposures of some of the oldest

Figure 26. Relief map of Wyoming. Textured areas designate mountain ranges and untextured areas designate basins.

rocks in North America. Some rocks in the mountains are greater than three billion years old and consist of Precambrian metamorphics.

Large regions in the mountains were intruded by plutons and batholiths. These intrusive rocks are igneous and are dominately granites that cooled and crystallized at depth. In northwestern Wyoming, a large field of volcanic rocks erupted more than 30 million years ago from several volcanoes along the eastern Yellowstone National Park border. These volcanic rocks now form the Absaroka Mountains.

Wyoming basins and flanks of mountain ranges are predominately underlain by sedimentary rocks. During the Paleozoic and part of the Mesozoic, ancient seas covered Wyoming and rocks such as limestone and other marine strata were deposited. Later, sediments eroded from uplifted mountains were carried downslope into nearby basins. Through time, these sediments were compacted and cemented to produce sandstones, siltstones, shale and other related detrital sedimentary rocks.

With these geographic relationships in mind, each of the three rock groups can be discussed more thoroughly. The *Geologic Map of Wyoming* (Love and Christiansen, 1985) shows this general distribution of rock types.

Metamorphic rocks

According to Mason (1978, p. 3) *Metamorphic rocks are those whose characters have been changed since their original formation by processes operating within the Earth.* These changes in character that Mason speaks of are changes in texture, mineralogy or both. They result from temperature and pressure increases and alteration by solutions.

Many metamorphic rocks have distinct textures; classification of these rocks is based primarily on texture and to a lesser extent on mineralogy. Textures observed in metamorphic rocks are of two main types — foliated and nonfoliated.

Foliated rocks contain abundant mica flakes, amphibole prisms or other prismatic minerals that are arranged parallel with one another. When foliation is highly developed throughout a rock, the texture is called schistose. In some metamorphic rocks, narrow schistose layers alternate with coarsely crystalline bands that have different colors and different minerals. Such a banded texture is termed gneissic. Schists and gneisses are the most common metamorphic rocks in Wyoming (**Figure 27 and Plate 2B**).

Figure 27. Gneiss from Copper Mountain (pencil for scale).

Nonfoliated metamorphic rocks are described by a variety of textural classifications. Many of these rocks are formed from minerals with interlocking grains and may look like some igneous rocks. Because metamorphism tends to form crystals of the same grain size, many of these rocks are massive with equant grain sizes (**Table 8**).

Table 8. Simplified classification of metamorphic rocks.

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	Gneiss	Granite, rhyolite, shale, etc.
Thinly foliated	Feldspar, mica, amphibole, quartz	Schist	Andesite, basalt, rhyolite, shale, etc.
Very thinly foliated	Mica, quartz, clay, (these minerals normally cannot be seen with the naked eye).	Slate	Shale

Gneiss

Gneiss (pronounced "nice") is a metamorphic rock with coarse-grained, light colored, mineral layers that alternate with dark schistose layers (**Figure 27**). The light minerals may be quartz and feldspar while the dark minerals may be mica, amphibole or pyroxene.

Gneiss forms from both igneous and sedimentary rocks. A large percentage of gneiss in Wyoming is chemically equivalent to the igneous rock granodiorite. The great majority of metamorphic rocks in the State are gneisses.

Schist

Schist is a metamorphic rock characterized by finely laminated foliation. The surfaces of schists (in particular mica schists) tend to reflect sunlight (like a mirror) due to the abundant platy or prismatic crystals that line up in parallel bands (**Plate 2B**).

Schists are usually described and named by listing their principal mineral constituents. For example, a schist composed of biotite with some garnet would be named garnet-biotite schist, or a schist with abundant andalusite would be an andalusite schist. Schists are relatively common in Wyoming's mountains.

Quartzite

Metamorphic quartzite is a hard compact rock composed almost entirely of cemented, rounded, relatively equant quartz grains. It is the metamorphic equivalent of sandstone. During metamorphism, fine-grained sand tends to dissolve, fills pore spaces between sand grains and coats larger sand grains. The tendency is to create a rock of equal grain size, and to fill the pore space between grains with quartz. Sedimentary quartzite is unmetamorphosed quartz sandstone that has been tightly cemented by secondary silica cement. When struck, quartzite will break across individual grains unlike sandstone, which breaks around grains.

Many quartzites in Wyoming are pure white, but some are brown (stained by iron-oxide) and some are light green (filled with fuchsite, a green chromium mica). Metamorphic quartzites are fairly common in the Medicine Bow Mountains and Sierra Madre.

Marble

Marble consists of calcite or dolomite and is the metamorphosed product of carbonate sedimentary rocks (limestones and dolomites). Marbles are generally white to light gray and are distinguished from their sedimentary counterparts by a greater degree of crystallinity and coarse grain size.

Marbles are not very common in Wyoming, although several outcrops are reported in the Medicine Bow Mountains, Haystack Range and Laramie Range. At White Mountain in the Sunlight Basin of the Absaroka Mountains, limestone in contact with volcanic rock was baked and metamorphosed to marble. **Plate 7B** shows that the volcanic neck at White Mountain bisects the white marble.

Amphibolite

Amphibolites are black to greenish black metamorphic rocks formed of amphibole with lesser quantities of other minerals. Amphibolites that are the metamorphosed products of sedimentary rocks are termed para-amphibolite, and amphibolites that formed from preexisting igneous rocks are called orthoamphibolites. These rocks are common in many of the State's historic base- and precious-metal mining districts.

Igneous rocks

Igneous rocks form by the solidification of molten magma from deep within the Earth. Magma that erupts at the surface of the Earth from a volcano or similar vent is termed extrusive or volcanic (**Figure 28**). Much of the heat from the extrusive magma is dissipated upon

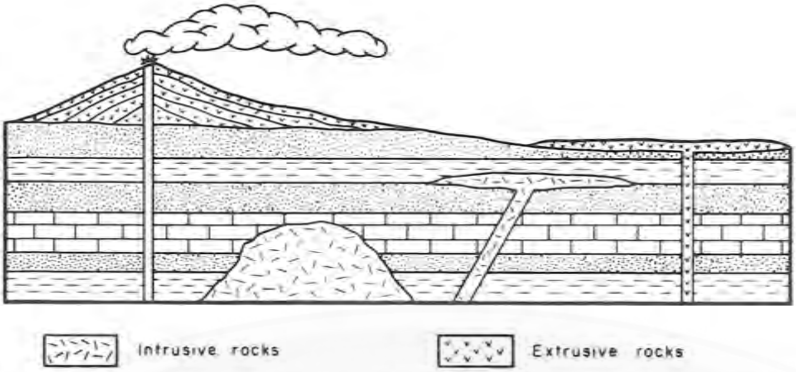

Figure 28. Cross section illustrating the relationships between intrusive and extrusive igneous rocks and bedded sedimentary rocks.

contact with the Earth's atmosphere, and the rock cools rapidly producing fine-grained textures.

Magma that does not reach the surface, but slowly cools at depth, is termed intrusive igneous rock (**Figure 28**). These rocks cool slowly and allow mineral crystals enough time to grow relatively large. Thus most intrusives, such as granite, have a coarser grained texture than most extrusive igneous rocks. The mineral grains are randomly arranged in most igneous rocks.

Rocks termed porphyritic exhibit an uneven grain size with large randomly oriented crystals (phenocrysts) enclosed by a fine-grained groundmass. The porphyritic texture is a result of changes in cooling rates as the molten rock approached the surface and erupted. The large crystals formed slowly in the melt before extrusion, but the fine-grained material crystallized quickly upon extrusion.

Igneous rock classification is based on chemistry. The minerals of the rocks are essentially solid chemicals, so in a sense, the rocks are also classified by their mineralogy. As seen on **Table 9**, the relative amount of feldspars present, and the presence or absence of quartz are important criteria for naming the rocks. The distinction between plagioclase and potassium feldspar is most easily made in the field by noting the presence or absence of fine twinning striations on the crystal faces by using a 10-power magnifying lens. Plagioclase often has twinning striations. Quartz almost always has irregular mineral shapes, but is translucent and may have a greasy appearance or luster.

Fine-grained igneous rock is difficult to classify in the field because individual minerals cannot be identified. In the field, the classification of these rocks must be based on texture and color. Generally the lighter colored rocks contain more potassium feldspar and quartz, and the darker colored rocks contain mafic minerals (amphibole and pyroxene) with little to no quartz.

Table 9. Simplified classification of igneous rocks.

	Texture or grain size	Light colored. Principal minerals: orthoclase feldspar, some biotite or amphibole.		Intermediate. Principal minerals: plagioclase and orthoclase feldspar, amphibole, biotite, proxene.		Dark colored. Principal minerals: plagioclase feldspar, pyroxene, amphibole, olivine.
Intrusive		With quartz	No quartz	With quartz	No quartz	
	Very coarse grained	Pegmatite				
	Coarse to medium grained	Granite	Syenite	Granodiorite Quartz diorite	Diorite	Gabbro Pyroxenite (pyroxene only) Peridotite
Extrusive	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.				

[1] If mixed grain or crystal sizes occur, then the rock is called a porphyry — example, andesite porphyry.

Basalt-Gabbro

Basalt is a fine-grained black, greenish black and less often reddish brown volcanic rock. Individual minerals are seldom large enough to be distinguished with the naked eye, and a microscope is usually required for mineral identification. Some varieties of basalt were saturated with volcanic gas and developed numerous gas cavities, called vesicles. These are vesicular volcanic rocks (**Figure 29**). Highly vesicular dark colored volcanic rock is termed scoria. **Pumice** is similar to scoria, however, it is often lighter colored and sufficiently buoyant to float on water (see Pumice).

Gabbro is the coarse-grained equivalent of basalt. It formed at depth and cooled slowly. The major minerals that form both basalt and gabbro are plagioclase feldspar, pyroxene and sometimes olivine.

Two varieties of basalt and gabbro are named tholeiitic and alkalic. These rocks have important chemical differences. Alkalic volcanics have higher alkali (sodium, potassium)/silica ratios than tholeiites. Basalts and gabbros containing olivine are usually alkalic.

The Absaroka Mountains of northwestern Wyoming have large regions dominated by Tertiary basalt and andesite. Many of the State's historic gold mining districts also have basalts but these are very old and metamorphosed. Some of these old basalts are not highly metamorphosed; they retain relict volcanic textures and are called metabasalt and metagabbro (**Plate 7C**). Others are sufficiently metamorphosed that they are renamed amphibolites or actinolite-

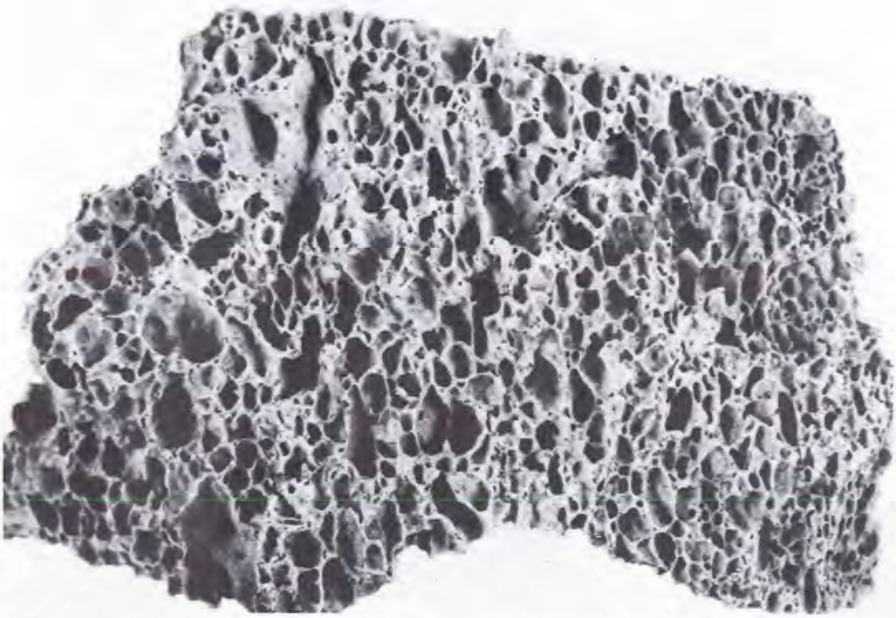

Figure 29. Vesicular volcanic rock (wyomingite) (photograph by Karl Albert).

tremolite schists, but are considered former basalts and gabbros based on their chemistry and geologic setting.

Andesite (dacite) — Diorite (granodiorite)

Andesites are fine-grained to porphyritic gray to green volcanic rocks whose major minerals are plagioclase feldspar, amphibole and pyroxene (**Figure 30**). Some potassium feldspar and mica may be present in small amounts. If quartz is present in visible amounts, the rock is called **dacite** rather than andesite. Diorite, quartz diorite and granodiorite are coarse-grained intrusive rocks that are chemically equivalent to andesite and dacite.

Andesites and dacites are common in the Absaroka Mountains and Yellowstone National Park of northwestern Wyoming. In some of the State's gold mining districts such as South Pass, slightly metamorphosed 2.8-billion-year-old andesites are called meta-andesites. Elsewhere, such as at Copper Mountain, metamorphism was sufficiently intense to change both the mineralogy and texture of some andesites. These highly metamorphosed rocks are still chemically similar to andesites and dacites, but they are now texturally quartzofeldspathic gneisses.

Granodiorite and **quartz diorite** intrusive rocks also occur near and within many of the State's gold districts and also within the Absaroka Mountains.

Figure 30. Andesite with large crystals (phenocrysts) of black amphibole enclosed by a light colored aphanitic groundmass, a typical texture of this igneous rock (photograph by Karl Albert).

In the Ferris Mountains north of Rawlins is a very unusual granodiorite coveted by rock hounds and geology students. This is the Ferris Mountains orbicular granodiorite (**Figure 31**).

Rhyolite — Granite

Rhyolites are light colored, gray, white to red volcanic rocks consisting of quartz, potassium feldspar and mica, with minor plagioclase feldspar. Texturally, they are fine-grained porphyritic to aphanitic (mineral components not distinguishable with the unaided eye), and some exhibit flow banding. Tertiary rhyolites occur as extrusive flows, flow breccias, intrusive plugs and dikes in the Absaroka Mountains. Only a minor portion of the Absaroka-Yellowstone volcanics are rhyolites.

Granites are coarse-grained intrusive equivalents of rhyolite. Precambrian granite plutons occur in most Wyoming Mountain Ranges. For example, I-80 between Cheyenne and Laramie cuts through several miles of exposures of Sherman Granite. The Vedauwoo picnic area near Buford is located within this granite. The Granite Mountains in central Wyoming are named for their major component, Precambrian granite (**Figure 32**).

Figure 31. Orbicular granodiorite from the Ferris Mountains (photograph by Karl Albert).

Figure 32. Granite in the southern Granite Mountains. Rounded weathering surface and prominent joint pattern are characteristic of this rock type (photograph by Sheila Roberts).

Pumice

Pumice is a lightweight (commonly lighter than water) frothy appearing rock largely composed of volcanic glass. The chemical composition of pumice is much like obsidian, and the frothy texture is due to numerous vesicles produced by escaping gas.

Pumice is often developed on the upper surface of lava flows, or occurs as fragments of volcanic rock blown out of volcanoes. It is generally white or gray and has mineral compositions similar to rhyolite, andesite or dacite. Pumice fragments are found in the Yellowstone-Absaroka volcanics, and in the Leucite Hills of Sweetwater County.

Obsidian

Obsidian is a dense volcanic glass produced by extremely rapid chilling or cooling of magma at the Earth's surface. Obsidian commonly is black and has a conchoidal fracture. Chemically, most obsidians are equivalent to rhyolite. The color of obsidian is due to impurities in the volcanic glass. Black obsidian is colored by disseminated magnetite, and red obsidian is colored by hematite.

The Tertiary lava flows in Yellowstone National Park contain some obsidian. Obsidian Cliff in northwestern Yellowstone is a popular tourist site.

Tuff

Tuff is a light colored, fine-grained, volcanic rock composed of volcanic ash, small fragments of pumice and broken crystals. During explosive volcanic activity such as the eruption of Mount St. Helens, volcanic ash and debris are thrown into the air and blanket the surrounding landscape. When solidified, they are termed tuffs or ash-fall tuffs.

Tuffs containing large angular fragments of rock are called tuff breccias. Some breccias contain angular fragments of volcanic rock and may be cemented by other volcanic material or tuffs; these may be called fragmental volcanics, or volcanic breccias. Such rocks generally are formed at the volcano vent.

In some volcanic eruptions, small hot particles settle on the ground and build up so that the buried particles tend to flatten or are welded together. These rocks are termed welded tuffs. Welded tuffs are difficult to distinguish from many rhyolite flows. Tuffs and volcanic breccias are common in the Yellowstone-Absaroka volcanic field.

Some unusual volcanic rocks

Phonolite is a rare porphyritic to fine-grained volcanic rock that occurs in the Black Hills of northeastern Wyoming. These rocks are low in silica and enriched in sodium and potassium; they have no quartz but contain sodium-rich feldspar and in places, potassium-rich pseudoleucite crystals (see Leucite). Both feldspar and pseudoleucite occur as large phenocrysts in an aphanitic groundmass.

Devils Tower in the Black Hills is phonolite (**cover photos**). Similar rocks occur in the Leucite Hills near Rock Springs (see wyomingite).

Rare high-potassium lamproite flows and plugs occur in the Leucite Hills north of Rock Springs and Superior. These rocks are chemically similar to phonolite at Devils Tower, Wyoming. Known as **wyomingite**, the rocks consist of large mica crystals (phenocrysts) in a fine-grained matrix (groundmass) of leucite, pyroxene, apatite and volcanic glass. Wyomingite may also contain olivine. Two similar and related volcanic rocks in the Leucite Hills are called orendite and madupite.

Kimberlite (**Plates 1D, 7D**) is a very rare igneous rock that sometimes contains accessory diamond. Hand specimens of Wyoming kimberlite are essentially indistinguishable from diamond-bearing kimberlite mined in South Africa. They are green, brown and gray serpentinized and carbonate-rich porphyritic rocks that sometimes contain large crystals of pyrope garnet, green chrome pyroxene and phlogopite mica. Rounded rocks (xenoliths) are also commonly found in kimberlite. (See also Diamond and Olivine.)

Sedimentary Rocks

Sedimentary rocks form at or near the Earth's surface by a variety of mechanical, chemical or organic processes. These rocks are composed of detrital mineral and rock fragments weathered and eroded from preexisting rocks; mineral matter organically or inorganically precipitated from solutions; and other organic materials.

Sedimentary rocks are characterized by layering or bedding (**Figure 33**). Their classification is based primarily on mineral content and grain size (**Table 10**). The following discussion of sedimentary rocks is modified from Root (1977).

Chert

Chert is a fine-grained, dense, hard cryptocrystalline quartz. It occurs in a wide variety of colors including black, white, yellow, gray, green, brown and red. Dark gray to black varieties are commonly called flint (see Chalcedony).

Figure 33. Layered sedimentary rocks at the Cravat coal mine in the Overthrust Belt, western Wyoming. Black layers are coal, light ledge-forming rocks are sandstone and light recessive layers are shale and siltstone.

Table 10. Simplified classification of sedimentary rocks.

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)
Too small to see with naked eye	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
Too small to see with naked eye	Silica	Not applicable	Chert
Not applicable	Carbon	Not applicable	Coal

Chert forms by the organic and (or) inorganic precipitation and recrystallization of silica dissolved in ground water or sea water. Many Phanerozoic cherts contain the siliceous skeletal parts of small organisms. Siliceous sponge spicule-bearing chert is common in the Permian Phosphoria Formation of western Wyoming and chert beds or nodules are found in some limestones. Cherts of Precambrian age are reported in many metamorphic terrains in the State. Many of these cherts are considered to be exhalites related to submarine volcanic activity. Iron formation at South Pass is a banded chert with alternating layers of magnetite and chert. The South Pass iron formation is also considered by many geologists to be an exhalite. Banded iron formations appear to be relatively common in Wyoming's metamorphic terrains (Harrer, 1966).

Coal

Coal is formed almost entirely of compressed, partially decomposed plant material. This organic material is originally deposited as peat in swamps, marshes and bogs where it accumulates beneath water and is rapidly covered and compacted. After burial, heat changes the peat into coal.

Coals and other organic debris are classified or ranked according to the proportions of moisture, volatile matter, fixed carbon and heat value. Ranking from lowest to highest is peat, lignite, subbituminous coal, bituminous coal and anthracite coal. The high-rank coals have been subjected to high temperatures during burial, which tend to drive off water (oxygen and hydrogen), thus enriching the coal in carbon relative to the other two major chemical elements.

Enormous resources of bituminous and subbituminous coal of Cretaceous and Tertiary age occur in Wyoming (Figures 34 and 35). Some estimates suggest that more than 1.6 trillion tons of coal resources, the second largest in the United States only after Alaska, underlie the Wyoming basins (Ayers, 1986; Glass, 1984). The Wyodak coal bed is greater than 100 feet thick in the Powder River Basin near Gillette, Wyoming. Another coal, the Lake DeSmet bed, near Buffalo, Wyoming, is over 200 feet thick.

Environmentally, the Wyoming coals are attractive. Because they are relatively low in sulfur compared to coal mined in the East, burning Wyoming coal is not considered to contribute significantly to the introduction of sulfur dioxide into the atmosphere.

Conglomerate

Conglomerate is a coarse-grained, detrital sedimentary rock formed of rounded to subangular pebbles, cobbles or boulders in a fine-grained matrix (Figure 36). The clasts are of one or several rock types.

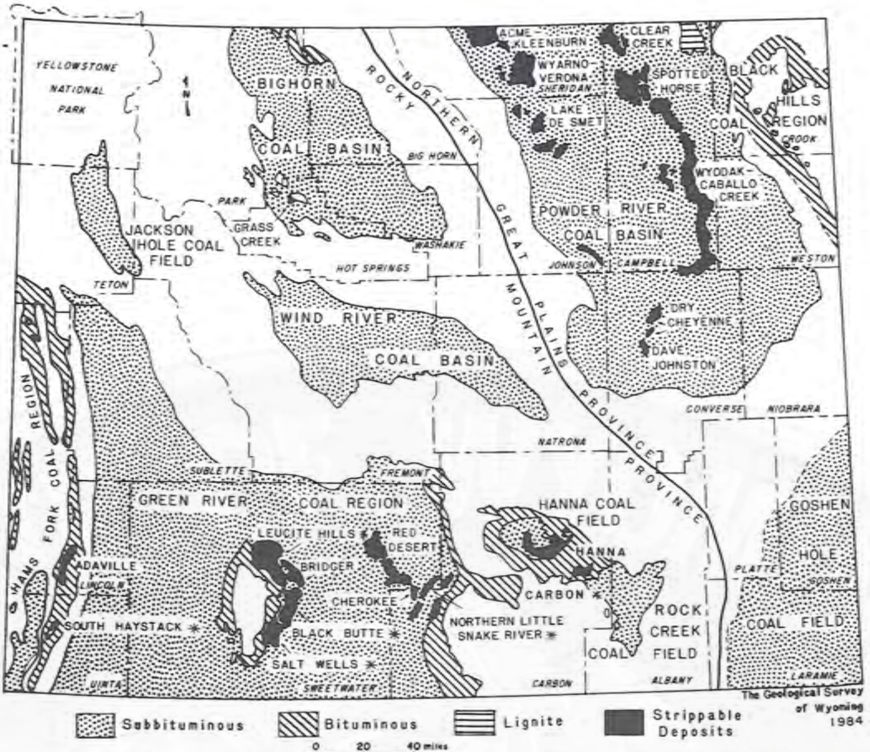

Figure 34. Map of coal-bearing regions of Wyoming.

Figure 35. Mining the Wyodak-Anderson coal bed in Amax's Belle Ayr mine, Wyoming. The coal is 70 feet thick here (photograph by Gary B. Glass).

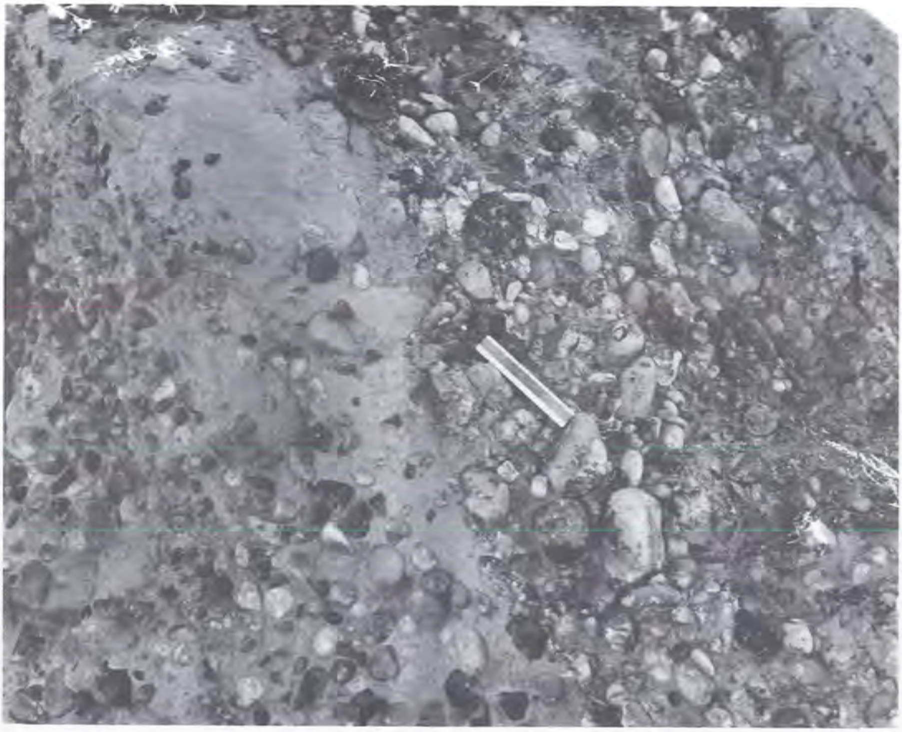

Figure 36. Tertiary conglomerate that flanks the east side of the Medicine Bow Mountains. The source of this coarse material was the uplifted mountain range (photograph by Robert S. Houston).

In Wyoming, some conglomerate beds are well developed in the Cambrian Flathead Formation on the flanks of several mountain ranges, adjacent to Precambrian rock. Good exposures of the Flathead conglomerate occur on the north edge of Copper Mountain and along the northeast flank of South Pass. Conglomerates are also common in upper Paleozoic rocks that flanked the ancestral Rocky Mountains and in Cretaceous and Tertiary rocks that formed from debris shed off mountain ranges that rose during the Sevier and Laramide orogenies.

Metaconglomerates in the Medicine Bow Mountains and Sierra Madre of southeastern Wyoming are slightly metamorphosed conglomerates. These rocks represent former stream beds deposited about 2.5 billion years ago, and like some streams today, they contain occasional placer (paleoplacer) gold deposits. Because of the lack of oxygen in the Earth's atmosphere prior to two billion years ago, these paleoplacers also contain uranium and thorium (Houston and Karlstrom, 1979).

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 high magnification) to coarsely crystalline. Many limestones are primarily composed of animal shells and shell fragments (Figure 37).

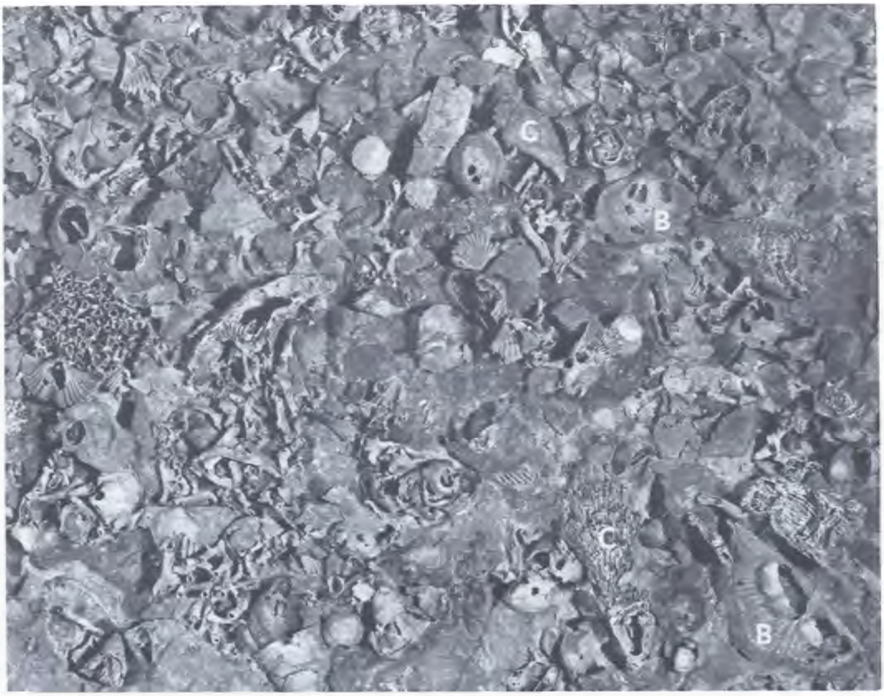

Figure 37. Acid-etched surface of limestone rock that is composed almost entirely of the shells of invertebrate animals. Brachiopods (eg. B) and corals (eg. C) dominate in this rock.

Although some limestone is precipitated chemically under 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 shells or internal hard parts. When the animal or plant dies, it is incorporated in the accumulating calcareous sediment. 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 water, but some are formed in lakes.

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

Travertine

Travertine is a chemical sedimentary rock composed almost entirely of calcite and aragonite. Often limonite stains travertine yellowish brown. These rocks are generally porous and are light gray to yellowish brown depending on the amount of limonite staining.

Travertine is deposited from spring water that is supersaturated in calcium carbonate; many travertine deposits form by precipitation of carbonate from thermal springs.

Well-known travertine deposits in Wyoming include the terrraces in Hot Springs State Park at Thermopolis (Figure 38) and the massive travertine cliffs associated with Mammoth Hot Springs in Yellowstone National Park.

Figure 38. Travertine terraces at Hot Springs State Park, Thermopolis, Wyoming (photograph by Gary B. Glass).

Phosphate rock

Phosphate rock is a rare sedimentary rock that occurs in relative abundance in the Permian Phosphoria Formation of western Wyoming. Phosphate rock is generally dark (brown, gray or black), but on the outcrop it may have a coating or bloom of a bluish color. Phosphate rock may be dense and fine grained, pelletal, nodular or 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 including gold and silver (Love, 1984).

The Permian phosphate deposits of Wyoming were precipitated from marine water in the region between a deep oceanic trough in Idaho, and a broad, shallow marine shelf that covered most of Wyoming.

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. Organic processes probably played a major role in the formation of phosphate deposits. This same suite of rocks is believed to be the source of major oil accumulations in Wyoming (Peterson, 1984, p. 59-62). The phosphate rock is used mainly for manufacturing fertilizer.

Sandstone

Sandstone is a sedimentary rock composed of detrital sand grains. The grains 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 like quartz, chert and feldspars are most common.

Sandstone is a very abundant rock in Wyoming. Sandstones are formed in a wide variety of terrestrial and marine environments. Desert sand dunes, river-channel sand bars, alluvial fans, deltas, beaches and deeper-water sand bodies are all represented by sandstones in the geologic record (Figure 39).

Porous sandstones, whose grains are not completely surrounded by cement or matrix material, form the reservoirs of most of Wyoming's oil and natural gas reserves. 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. Some extremely pure quartz sandstones (silica sands) in the Casper Formation are a potential silica resource for glass making.

Figure 39. Cross-bedded sandstone of the late Paleozoic Casper Formation near Laramie. These large cross beds probably record windblown sand dunes (photograph by Sheila Roberts).

Shale

Shale, the most abundant sedimentary rock type, is a mixture of extremely fine-grained quartz and other detrital grains and clay minerals. Shales are usually finely laminated or thinly bedded. Common shale colors are gray, brown, black, green and red. Red shales of the Triassic Chugwater Formation and Permian Goose Egg Formation form some of the most colorful outcrops in the State (**Plate 8A**).

Montmorillinite shales of the Cretaceous Frontier and Mowry Formations are mined as Wyoming bentonite. These clays, the product of volcanic ash decomposition, are abundant in Wyoming. Other shales are used as sources of clay for brick, tile and clay pipe.

Clinker

In northeastern Wyoming, many hills and buttes are capped by clinker or natural slag beds (**Plate 8B**). These clinker beds are rocks that 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 this natural slag is used for road and railroad bed material.

Oil shale

Wyoming oil shale is a very fine-grained rock that is a mixture of quartz and other small detrital grains, 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 that also represent a potential petroleum reserve. Methods for extracting oil from these rocks are not yet economic.

The use of maps for rock and mineral collecting

If you plan to spend some time looking for rock and mineral specimens in the State, it may be worth your time to get to know your local U.S. Bureau of Land Management (BLM) representative. The BLM keeps records on mining claims and land ownership, and can help determine what areas are accessible for collecting. Land status maps are also available from the BLM. (Contact U.S. Bureau of Land Management, P.O. Box 1828, Cheyenne, Wyoming, 82003, for information.)

Generalized maps of the State are great aids during the initial stages of planning a collecting trip or vacation. One such map — *The Metallic and Industrial Minerals Map of Wyoming* (Harris and others, 1985) shows the location of mountain ranges, principal roads, towns, mining districts and significant mineral occurrences. Another map *The Geologic Map of Wyoming* (Love and Christiansen, 1985) shows all major rock units, and is very helpful for identifying rock types. After locating areas of interest on these maps, the locations of the nearest towns, roads, mining districts and rock units in relation to your area of interest are quickly visualized. Once the area is outlined, more detailed maps can be obtained. These more detailed topographic and geologic maps are listed on various map indexes by name and location (see additional information in the reference section).

Topographic and geologic maps are available from the Geological Survey of Wyoming, from the U.S. Geological Survey and locally throughout the State from private distributors. Topographic maps show streams, lakes, cabins, houses, improved and unimproved roads and other cultural features in relation to hills, valleys and other topographic features. These maps essentially show three dimensions — length, breadth and relief. Relief is expressed by contour lines that show lines of equal altitude above sea level. Most topographic maps have been surveyed, so locations on the maps are easily found by legal description. Township and range are found printed in the map's margin. Each township and range block is usually subdivided into 36 sections (section numbers are printed in the centers of sections). Sections are further subdivided into four quarters — the northeast, northwest, southeast and southwest. The quarters are frequently found in legal descriptions, but they are not generally printed on maps. Further subdivisions are based on continuing the 4-quarters system. To find a spot described as SW¼ sec. 11, T.30N., R.99W. first find the boxed-in area on the map where Township 30 North and Range 99 West intersect. The spot you are looking for is in the southwest quarter of Section 11 in that box (**Figure 40A**).

Geologic maps are a geologist's interpretation of the distribution and attitudes of rock bodies and unconsolidated sediments. The base for these maps may be two dimensional without relief, but most geologic maps published recently are printed on a topographic base map (**Figure 40B**).

The geologic map can be a valuable aid when searching for a particular mineralized rock, ornamental stone, etc. For example, suppose it was reported that rock outcrops of the Phosphoria Formation in the SW¼ sec. 11, T.30N., R.99W. contained some thin beds of agate. Using a topographic map you can narrow the area down to only a square quarter mile, but the geologic map shows you where rocks of the Phosphoria Formation occur and thus considerably narrow down the area required to search for the agates.

Concluding remarks

Mineral and rock identification is not always easy and requires patience, practice and experience. There are hundreds and possibly thousands of mineral and rock species, and many have several variations. Becoming a good mineralogist and petrologist requires knowledge of a large portion of these specimens. The *Encyclopedia of Minerals* (Roberts and others, 1974) lists more than 2,200 mineral species alone, but many of these are rare, and usually you will only encounter a small number of common rocks and common rock-forming minerals.

One of the greatest aids to a mineralogist (which comes with experience) is the knowledge of rock and mineral associations. For example, a rock sample containing chalcopyrite (copper-iron sulfide) will almost always have some other sulfides such as pyrite (iron sulfide), also known as fool's gold. The pyrite will oxidize with time and produce limonite (hydrated iron oxide), and chalcopyrite may oxidize to tenorite (copper oxide) or to cuprite,

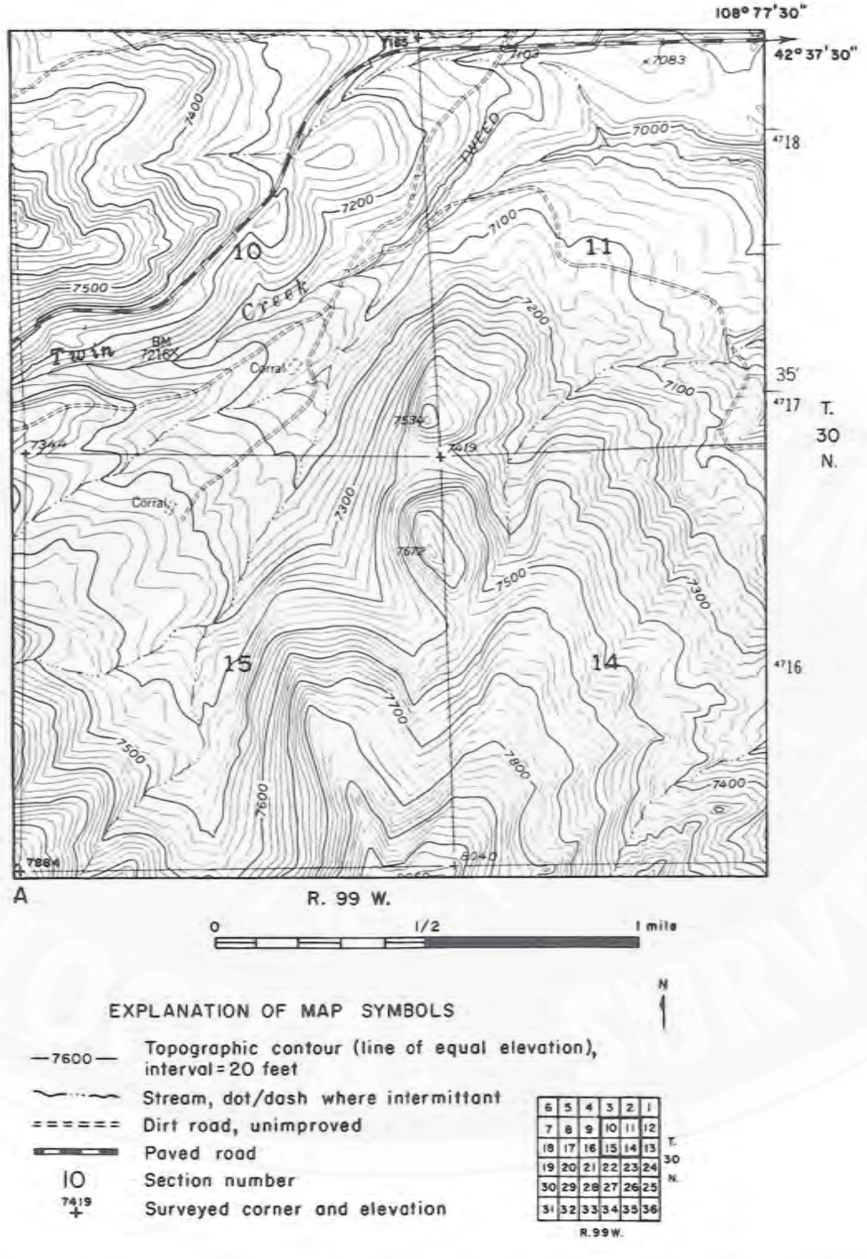

Figure 40A. A portion of U.S. Geological Survey Miners Delight topographic map. Township 30 North (T.30N.,) is labeled in the right margin and Range 99 West (R.99W.) in the lower margin. Sections are numbered and a portion of section 11 occurs at the upper right. The southwest quarter is the lower left hand portion of section 11.

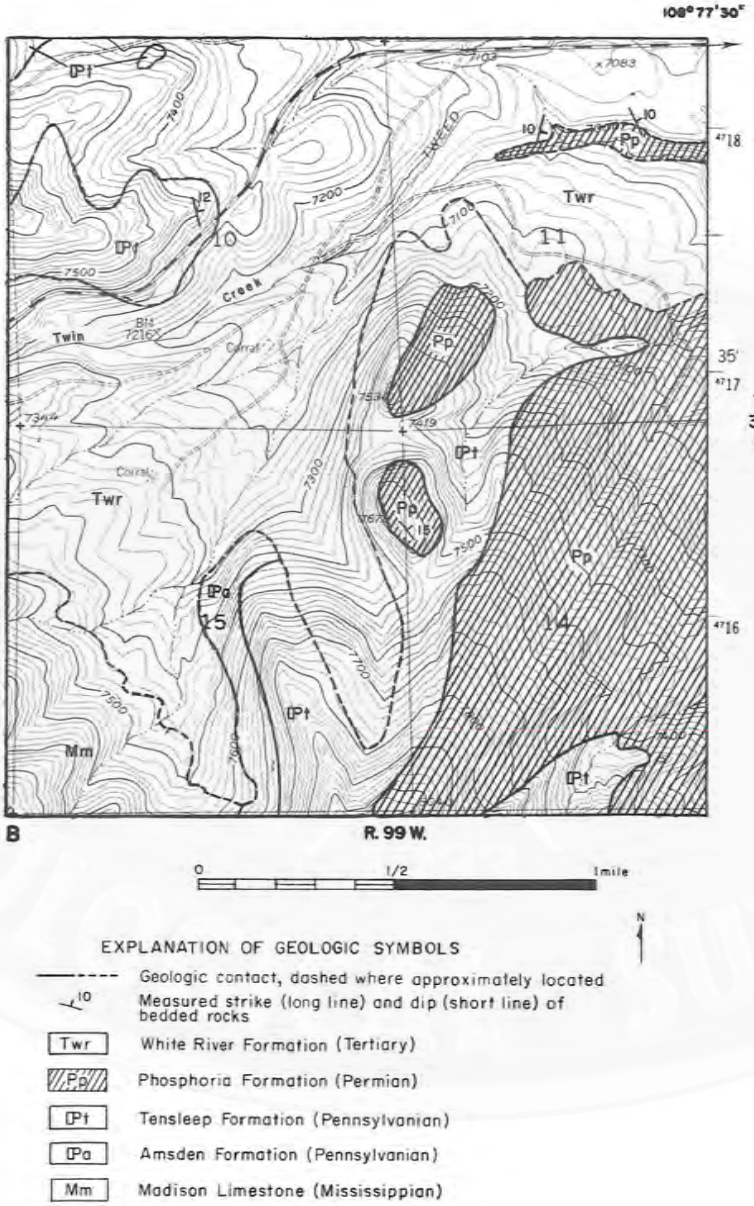

Figure 40B. A portion of the geologic map of Miners Delight Quadrangle showing same areas as in (A) but with geology added. In the SW¼ sec. 11 is an oval-shaped exposure of the Phosphoria Formation (Pp). (Redrafted from U.S. Geological Survey map GQ-460.)

(another copper oxide). If the host rock sample contains some carbonate, the copper will react to form copper carbonates (for example azurite or malachite). Or if the chalcopyrite is in a quartz vein, the copper may react with the quartz (silicon dioxide) to produce a copper silicate such as chrysocolla. Because chalcopyrite is a sulfide that forms in hot solutions, a trained mineralogist will also look for similar high-temperature sulfides in the rock specimen such as galena (lead sulfide) or sphalerite (zinc-sulfide). Such knowledge comes only with experience, being familiar with mineral and rock associations; and being familiar with the geology of the collecting area. Many of the most common associations are listed in this book along with the mineral and rock descriptions.

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Topographic map index

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MS-9A — U.S. Geological Survey coal resource occurrence and coal development potential Open File Reports in Wyoming: [compiled by G.B. Glass] 1984 (corrected edition).

MS-9B — U.S. Geological Survey Geologic Quadrangle Maps (GQ) in Wyoming: 1984 (corrected edition).

MS-9C — U.S. Geological Survey Miscellaneous Field Studies Maps (MF) in Wyoming: 1984 (corrected edition).

MS-9D — U.S. Geological Survey Miscellaneous Investigations Maps (I) in Wyoming: 1985 (revised).

MS-9E — U.S. Geological Survey Hydrologic Investigations Atlases (HA) in Wyoming: 1984 (corrected edition).

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MS-9H — Selected U.S. Geological Survey Professional Papers that contain geologic maps for Wyoming: 1984.

MS-9I — Index to U.S. Geological Survey Oil and Gas Investigations Maps (OM) for Wyoming: 1985.

MS-9J — Index to U.S. Geological Survey Open File Reports that contain geologic maps for Wyoming: 1985.

MS-9K — Index to U.S. Geological Survey Circulars, Folios and Annual Reports that contain geologic maps for Wyoming: 1985.

MS-9L — Index of Geological Survey of Wyoming publications that contain geologic maps, excluding Open File Reports: 1985.

MS-9M — Index of Geological Survey of Wyoming Open File Reports that contain geologic maps: 1985.

Glossary of selected geological terms

Alluvial — Refers to alluvium, or recent stream-deposited gravels, sands and clays that have not been cemented together.

Altered rock — One that has undergone chemical and mineralogical changes since its original formation.

Amygdule — A gas cavity or vesicle in an igneous rock.

Anticline — A rock structure in which layered rocks dip in opposite directions like the roof of a house.

Aphanitic — A texture of igneous rocks in which individual minerals are too small to be identified with an unaided eye.

Brittle — Easily broken.

Contact metamorphic — Refers to changes that take place in rocks near their contact with an igneous rock body.

Crossbedding — Lamination oblique to the main stratification of sedimentary rock layers.

Crystalline — The texture of a rock consisting of interlocking crystals or crystal fragments; usually refers to igneous or metamorphic rocks.

Detrital — Pertaining to or formed from loose rock and mineral material.

Dike — A tabular-shaped body of igneous rock that cuts across (intrudes) the structure of adjacent rocks.

Dunite — A peridotite formed principally of olivine.

Earthy — Earth-like appearance.

Eclogite — A metamorphic rock formed by extremely high pressure and temperature. Composed of pyroxene and garnet, sometimes contains diamond.

Euhedral — A well-formed mineral grain.

Exhalite — Chemical sediments of predominantly volcanic — exhalative origin. Deposits precipitated from hydrothermal fluids from submarine volcanic emanations. Common forms are chert and iron formation.

Fault — A displacement of rocks in the Earth's crust along a fracture(s).

Fibrous — Thead-like appearance.

Fissure — An extensive crack (fracture) in the rocks.

Float — A displaced fragment of rock.

Fold — A bend in layered rock.

Formation — A group of sedimentary rocks that is used as a geological map unit and named after a geographic locality, i.e., Tensleep Sandstone, Thermopolis Shale, etc.

Geode — A hollow nodule often lined with chalcedony and rarely with numerous well-formed hexagonal quartz crystals.

Greenstone belt — In Wyoming these are Archean synformal terrains of metamorphosed sedimentary and igneous rocks. Greenstone belts are often underlain by ultramafic and mafic schists, that are overlain by meta-andesites and metasediments including metagreywacke, quartzite, mica schist and iron formation. The rocks are low to medium grade regionally metamorphosed. Two examples of greenstone terrains often cited in the Wyoming literature are Elmers Rock and South Pass. Many of the historic gold districts in Wyoming lie within these terrains.

Groundmass — The fine-grained to glossy matrix of a rock.

Hydrothermal — Refers to ore deposits that have been formed by heated fluids or emanations derived from magmatic (igneous) rocks.

Iridescent — A surface film, similar to oil on water, that forms on some minerals and produces an array of prismatic colors that masks the true color of that mineral.

Laccolith — An igneous body that has intruded generally horizontally or concordant with layering and domed up layered rocks.

Lamproite — A group of dark colored intrusive or extrusive alkaline igneous rocks such as wyomingite and madupite.

Mafic rock — Refers to an igneous rock composed dominantly of dark-colored ferro-magnesian minerals.

Magmatic segregation — A process by which different rock or ore deposits are derived from a single parent magma.

Malleable — Refers to a mineral that is capable of being extended or shaped by pounding with a hammer without breaking.

Micaceous — A mineral that will separate into very small sheets.

Orogeny — Period of mountain building.

Pegmatite — An exceptionally coarse-grained granitic rock.

Phenocryst — A large conspicuous crystal in an igneous rock.

Placer — Refers to a mineral deposit that has been weathered from a vein, or other type of deposit, and concentrated by gravity and water in the gravels and sands of stream and river channels.

Plug — An intrusive mass of solidified igneous rock.

Plutonic — A general term applied to granite-like rocks that have crystallized at great depth beneath the surface of the Earth.

Porphyroblast — Large, distinct, scattered crystals in a metamorphic rock.

Prismatic — Pencil-like or lath-like shape.

Prospect — Undeveloped mineral deposit.

Pseudomorph — In this report, a mineral crystal that has the outward form of another mineral.

Pyramidal — Pyramid shape or form.

Replacement — The process by which a new mineral(s) of partly or wholly different chemical composition may grow in the body of an old mineral or mineral aggregate.

Sectile — Refers to a mineral that is capable of being carved or cut by a knife.

Sediment — A term applied to material deposited by streams, lakes, seas, wind and ice.

Serpentinite — A rock composed of serpentine.

Strata — Sedimentary beds or layers of sedimentary rock.

Striations — Parallel lines or grooves.

Sulfide — In this report, the term is applied to a mineral that is composed of sulfur and a metal (such as copper).

Syncline — Opposite of anticline. Folded rocks in which the rocks on both sides dip towards the center of the fold.

Translucent — Partly transparent.

Ultrabasic — A similar rock to ultramafic rock, but generally lighter in color. Has very low amounts of silica (less than 45 percent). Many ultrabasic rocks are also ultramafic, however a few, like kimberlite, consist almost entirely of serpentine and are ultrabasic but not ultramafic.

Ultramafic rock — An igneous rock composed essentially of dark colored mafic minerals (pyroxenes). Usually dark colored and heavy. These rocks completely lack felsic minerals (quartz and feldspar) unlike mafic rocks which often have some feldspar.

Vein — A fracture (or crack) in the Earth's crust filled with mineral matter.

Volcanic vent — An opening in the Earth's crust, out of which volcanic material was erupted to the surface.

Weathering and erosion — Weathering is the mechanical breakdown of rocks, while erosion is the progressive removal of such particles by wind, water or both.

Xenocryst — A large crystal in an igneous rock that is not genetically related (foreign crystal).

Xenolith — A fragment or block of rock in an igneous rock that is not genetically related (foreign rock).

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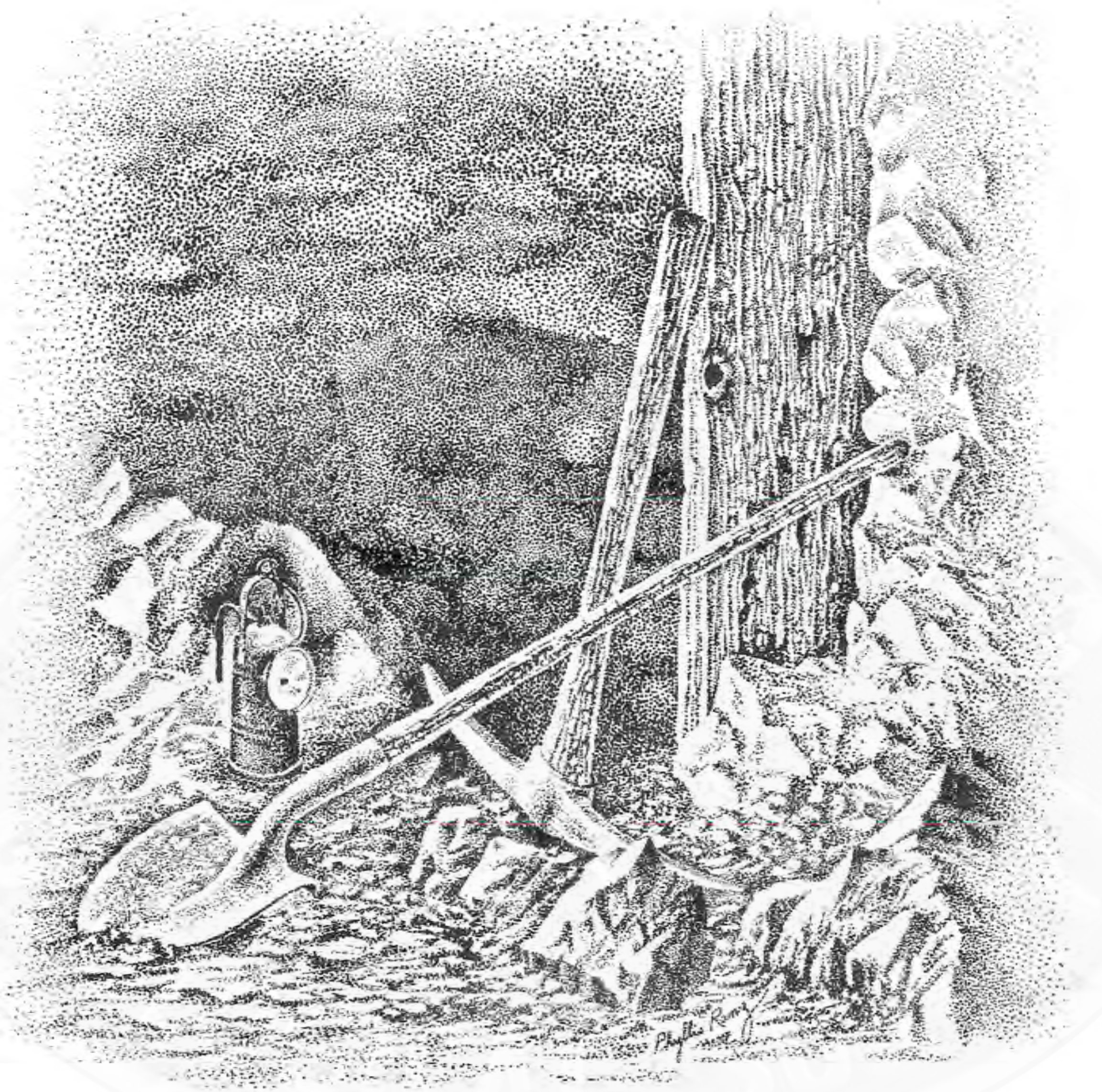

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