THE GEOLOGICAL SURVEY OF WYOMING

HORACE D. THOMAS, State Geologist

BULLETIN 51

A FIELD GUIDE TO THE ROCKS AND MINERALS OF WYOMING

by

William H. Wilson

STATE OF WYOMING GEOLOGICAL SURVEY 1933

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WILLIAM H. WILSON

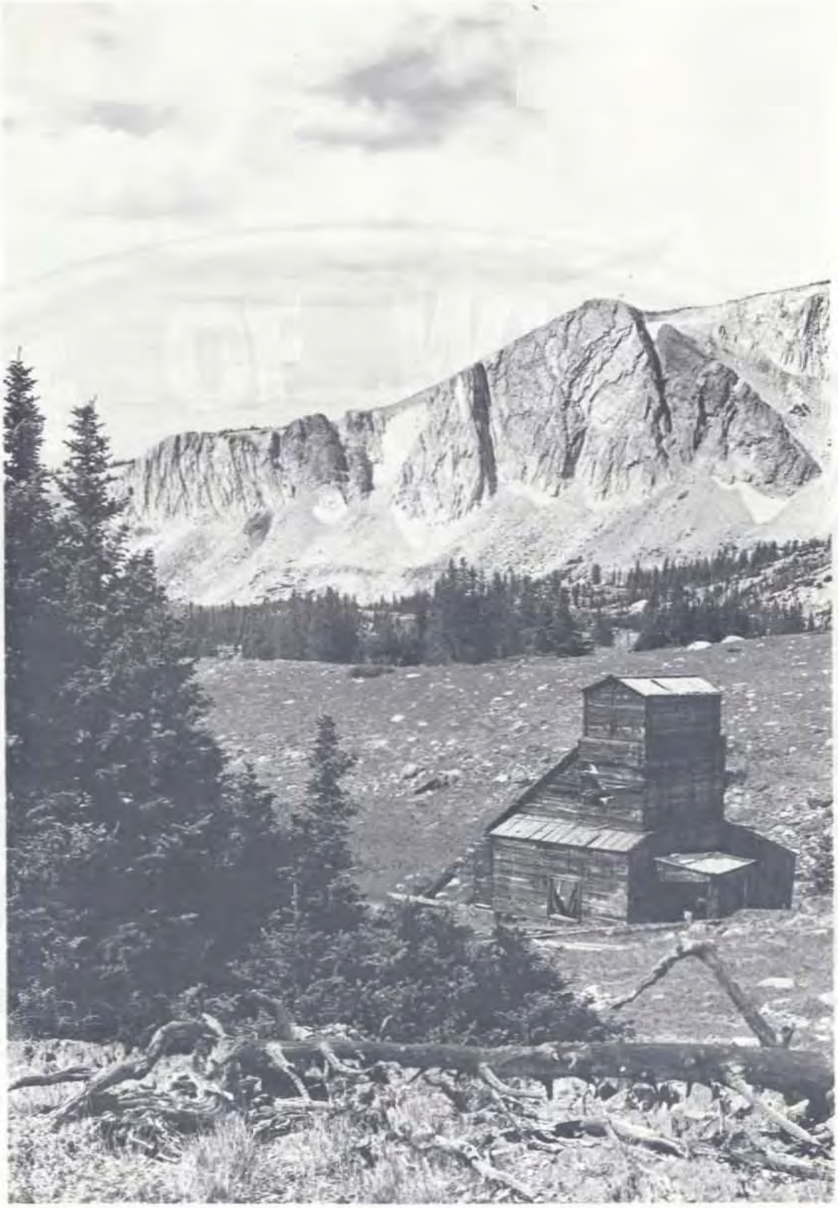
UNIVERSITY OF WYOMING

LARAMIE, WYOMING

AUGUST, 1965

This publication is dedicated to Dr. Samuel Howell Knight, former State Geologist (1933-40), and head of the Department of Geology at the University of Wyoming (1917-63). For more than fifty years his life has been devoted toward the understanding of Wyoming geology, but perhaps more important has been his influence in the training of many successful geologists, who, in turn, have contributed much to this field of study.

William H. Wilson



View looking northwest towards the Snowy Range, Albany and Carbon Counties. Red Feather mine in the foreground. Precambrian Medicine Peak quartzite intruded by dark colored diabase dikes in the background. Photo by H. D. Pownall.

ERRATA — BULLETIN NO. 51

P. iii; Granite—Granodiorite is a minor leading.

P. 3, line 1; "harness between" should read *"hardness between."*

P. 8, line 5; "Sodium sulfate," should read *sodium sulfate."*

P. 8, line 13; "Ft. Union Hanna," should read *"Ft. Union, Hanna."*

P. 15, line 27; "(such as schist," should read*"(such as schist) and."*

P. 18, line 24; "in dilute of hydrochloric," should read *"in dilute hydrochloric acid."*

P. 18, line 28; "or firm-like" should read *"or firn-like."*

P. 20, line 29; "Figure 3," should read *"Figure 4."*

P. 23, line 6;"Althought garnets," should read *"Although garnets."*

P. 24, line 33; "ILemite (see magnetite)," should read*"ILmenite (see magnetite)."*

P. 24, line 37; ": Jadeite and aluminum-sodium silicate," should read, *": jadeite an aluminum-sodium silicate,."*

P. 27, line 27; "(a magnetic looking mineral containing titanium)" should read, *"(a magnetite-looking mineral containing titanium)"*

P. 40, line 14; "(see Fig. 3)" should read*(see Fig. 4)."*

P. 42, line 10; "a petragraphic microscope." should read *"a petrographic microscope."*

P. 47, line 41; "Yellowstone National Park of Northwestern Wyoming." should read *Yellowstone Park of northwestern Wyoming."*

P. 59, line 30; "and finer-grained sandstone grade into shales." should read *"and finer-grained sandstones grade into shales."*

P. 72, line 9; "metalic and sulfide minerals." should read *"metallic and sulfide metallic and sulfide minerals."*

p. 53, line 33; "cal and physieo-chemical process." should read, "cal and physio-chemical process."

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A FIELD GUIDE TO THE ROCKS AND MINERALS OF WYOMING

by

William H. Wilson*

INTRODUCTION

This pamphlet has been prepared especially for the use of high school students and others with little or no previous training in geology and mineralogy. The list of minerals and rocks is by no means complete and is not intended to be so. Many different minerals and rocks have been found in Wyoming which are not listed here, conversely, some minerals are listed which are not presently important in Wyoming's economy but are important to the economy of other states in the Rocky Mountain area.

Since many of the localities are located by township and range, it is advisable for the collector to secure a Wyoming Base Map which may be secured from the U.S. Geological Survey, Federal Center, Denver, 25 Colorado. Good topographic maps of various parts of Wyoming are also available from the above agency. The Wyoming Highway Department also issues a very good highway map showing major and minor roads.

Many of the areas listed in the following pages are located on private property, and it is necessary to secure permission before trespassing. The collecting of specimens is prohibited in National Parks and Monuments and certain withdrawn areas of National Forests. Further, some areas of private property occur within National Forests and Parks, and it is also necessary to obtain permission to trespass on these areas.

There are amateur mineral collectors in most towns in Wyoming. In many of the larger towns, there are formal organizations. Local Chambers of Commerce can usually give the names of persons or groups interested in rocks and minerals. In addition, inquiry may be made in towns mentioned for specific directions on how to reach places cited.

For a more comprehensive listing of minerals in Wyoming, it is recommended that the collector secure Bulletin No. 50, titled, "Mineral Resources of Wyoming." This may be obtained for $1.00 per copy from the Geological Survey of Wyoming, Box 3008, University Station, Laramie, Wyoming. The more avid collector and student of geology may be interested in the Geological Map of Wyoming. This map, which shows the many geological formations in different colors, may be secured from the U.S. Geological Survey at a cost of $2.50.

* Assistant State Geologist, Geological Survey of Wyoming

PHYSICAL PROPERTIES, TESTS, AND EQUIPMENT

A mineral is a homogeneous substance of characteristic chemical composition and usually possesses a regular external shape. Minerals have physical properties, such as color, luster, fracture, cleavage, hardness, specific gravity (or heft or weight), and crystal form. These properties usually enable one to identify the particular mineral in question, or to at least place it in a group of those with similar characteristics.

Color

Color can be a useful property in identifying some minerals; however, it should be realized that such factors as impurities, changes in chemical composition, grain size, and tarnish, commonly effect the color.

Luster

Luster refers to the character of light that is reflected by the mineral. Metallic is the luster of metals. Vitreous is the luster of glass and is the most common luster of the rock-forming minerals. Resinous luster is like that of resin. Pearly luster is similar to that of a pearl. Silky is the luster of silk. Submetallic luster is duller than that of metallic luster and is found in black opaque minerals. Actually, submetallic luster could be considered as a luster between vitreous and metallic.

Fracture and Cleavage

The tendency for a mineral to break parallel to certain directions is called cleavage. Mica is an example of a mineral with one direction of cleavage. Calcite is a good example of a mineral with three directions of cleavage.

When a mineral does not break along certain planes, it is called fracture. Most fracture terms are self explanatory, however, conchoidal and hackly require definitions. Conchoidal refers to rudely concentric rings formed on the fracture surface similar to that of broken glass. Hackly is an irregular and jagged fracture that is best characterized by copper.

Hardness

Hardness of a mineral is the resistance to abrasion or the scratch of some pointed object of known hardness. The conventional standard of hardness (actually relative in value) is the Moh's scale listed below.

1. Talc	(softest)	6. Feldspar	
2. Gypsum		7. Quartz	
3. Calcite		8. Topaz	
4. Fluorite		9. Corundum	
5. Apatite		10. Diamond	(hardest)

For example, if quartz scratches an unknown mineral but feldspar does not then the mineral can be considered as having a harness between six and seven. One can make up a hardness set (or purchase one) by using the above minerals, or by using the common materials listed below.

Hardness	Material
2 - 3	Fingernail
3 - 4	Copper penny
4 - 6	Window glass
5 - 6	Knife blade
6 - 7	Steel file

Streak

Streak is the color of the powdered mineral when it is scratched on a rough porcelain-like plate. The streak may also be observed by merely scratching the mineral with a knife blade. The streak of the mineral is generally the same even though the color of the mineral may be variable. Most common rock-forming minerals have a colorless streak.

Specific Gravity (Heft)

Mineralogists use either specific gravity or density as an expression of the weight or mass of minerals. Since the average rock collector does not have the means at his disposal to calculate or express these values, we have adopted weight as a relative expression of the heft of these minerals. For example, lead is heavy while mica is light. Of course, the heft of the mineral will also depend upon the size of the specimen.

Form

Because of the atomic arrangement of the elements, a mineral may possess a definite geometric form (Fig. 1.). These forms are called crystals which are usually described as a cube, pyramid, prism (elongated side), tabular (flat), rhombohedron (six faces of parallelogram outline), octahedron (eight-sided), dodecahedron (12-sided), etc. Since conditions of growth are usually unfavorable for the formation of good crystals, they are not common. These minerals, then, are usually described as aggregates, granular, massive, finely crystalline, earthy, etc.

Equipment

The following equipment will be useful to the collector.

Necessary	Optional
Rock hammer	Mortar and pestle
Hand lens (10 power triplet preferred)	Simple chemical identification set
Knife or file	Gold pan
Magnet	Geiger counter
Streak plate (or rough porcelain plate)	Ultra-violet lamp (short wave model)
Dilute hydrochloric acid	Hardness set
Chisel (particularly useful in fossil collecting)	
Collecting bag	
Area maps	

A very few minerals are magnetic, hence, by the use of a magnet, the identification of such a mineral is easily made.

Some minerals and rocks effervesce (bubble) upon application of a drop of dilute hydrochloric acid. This, or muriatic acid, can be purchased at a drug store. Dilute hydrochloric acid can also be mixed by adding one part concentrated acid to nine parts water. *Caution:* pour the acid into the water: do not pour the water into the acid, since severe acid burns might occur.

A SUMMARY OF THE GEOLOGY OF WYOMING*

Introduction

It is not the purpose of this pamphlet to discuss in detail the geological features of Wyoming, but a brief description is included for those who may be interested in the geological history of the State in order to achieve a better understanding of the formation and occurrence of the rocks and minerals. In order that the reader may orient himself with respect to the geological distribution of the various rocks and mineral resources, it is convenient to divide the State into several geological provinces (Fig. 2, Table 1):

1. The mountain cores of Precambrian crystalline rock.
2. The volcanic area of Yellowstone National Park and the Absaroka Mountains, and other isolated areas of Tertiary igneous rocks which occur in the Black Hills, Rattlesnake Hills, and Leucite Hills.
3. The basin areas of Paleozoic, Mesozoic, and Tertiary sedimentary rocks.

As a generalization, it might be stated that the metallic(copper, gold, lead, silver, iron, etc.) mineral deposits are almost entirely restricted to the first two areas, while coal, petroleum, uranium, and the nonmetallic minerals (bentonite, gypsum, phosphate, trona, etc.) are limited to the third-mentioned province.

* Summarized and modified from Thomas, H. D., (1957), Geologic History and Structure of Wyoming: Contribution of the Geological Survey of Wyoming, Reprint No. 18, 11 pp.

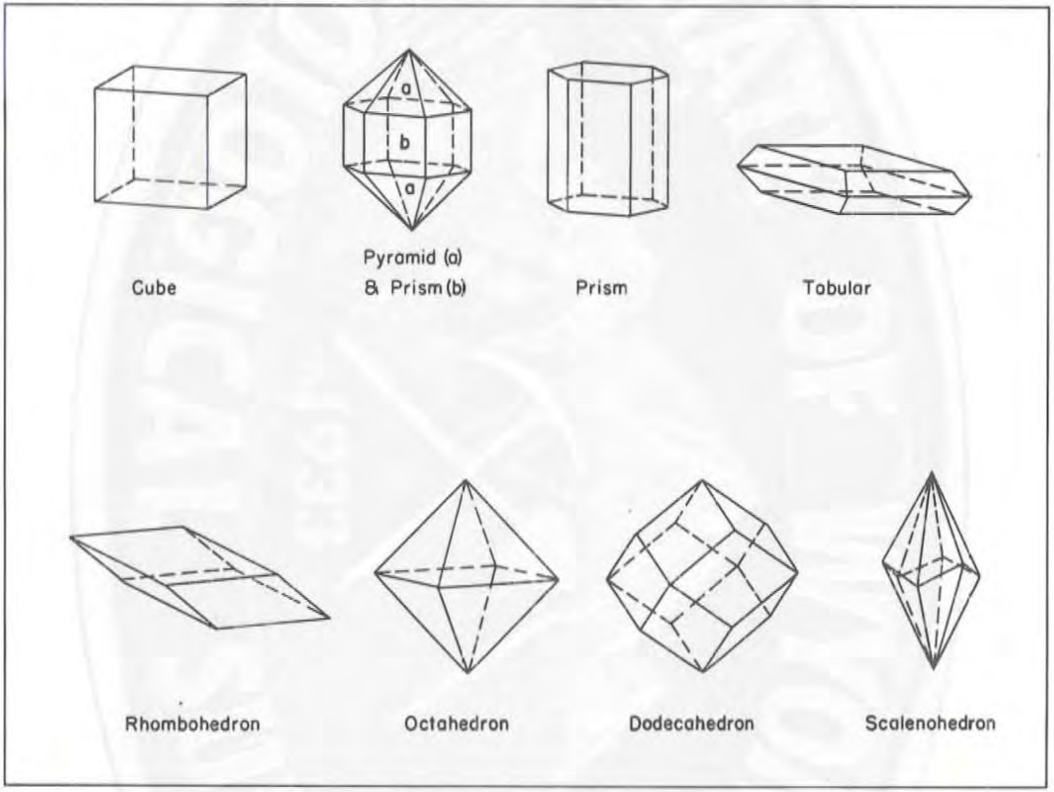


Figure 1. Crystal forms of some common minerals.

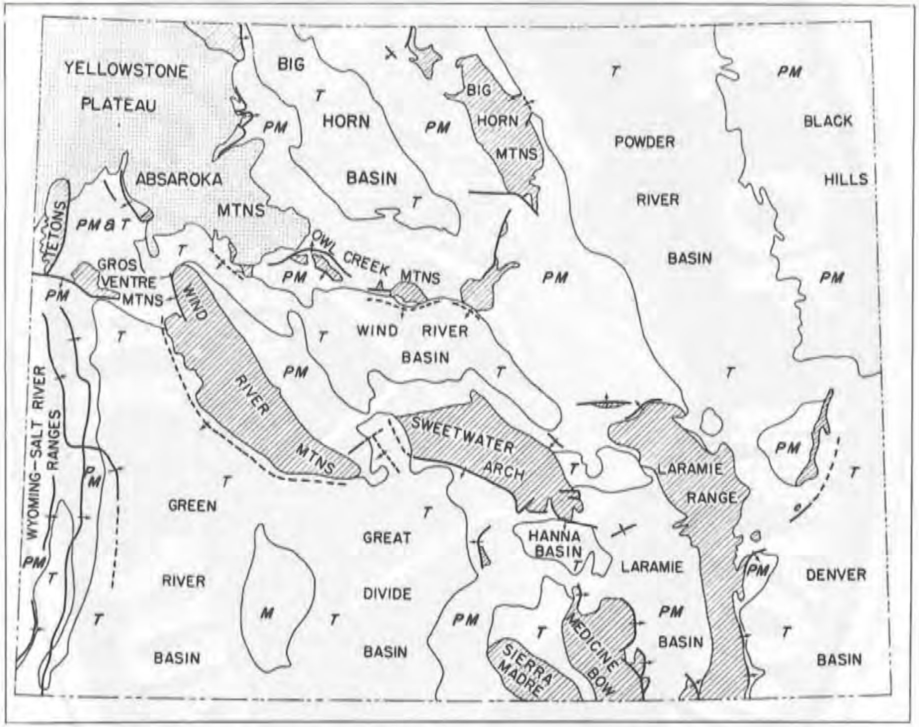


Figure 2. Generalized geological index map of Wyoming showing major mountain ranges and basins. Precambrian rock areas are cross hatched. Paleozoic and Mesozoic rock areas are indicated by the symbol PM. Mesozoic rock areas are indicated by the symbol M. Tertiary rock areas are indicated by the symbol T. Tertiary volcanics are shown by the coarse stipple. Faults are shown by heavy lines with arrows showing direction of movement of hanging wall of thrust faults.

Table 1. Generalized Wyoming Time-Rock Table.

Era	Period	Epoch	Duration (millions of years)	Representative Rock Units	Representative Rock Types	Mineral Resources
Cenozoic	Quaternary	Recent		Alluvium	variety of different types	Sodium sulfate sand and gravel
		Pleistocene	1	Glacial deposits		
	Tertiary	Pliocene	12	Ogallala fm.	shale, sandstone, volcanic ash, etc. (volcanic rocks in northwest part of State)	uranium, coal, oil & gas, oil shale, trona, (gold, lead, copper, silver, molybdenum in igneous rocks)
		Miocene	12	Arikaree fm.		
		Oligocene	11	White River group		
		Eocene	22	Wasatch, Green River fms.		
		Paleocene	5	Ft. Union Hanna fms., etc.		
Mesozoic	Cretaceous		72	Many formations	shale, sandstone, conglomerate, etc.	bentonite, clay, coal, oil & gas, uranium, cement rock
	Jurassic		46	Morrison fm. Sundance fm. Gypsum Springs fm.	shale, limestone, sandstone	oil & gas, gypsum
	Triassic		49	Nugget sandstone Popo Agie, Jelm fms.	shale, sandstone, conglomerate	oil & gas
				Dinwoody, Chugwater fms.	dolomite, limestone, sandstone, shale	oil & gas gypsum

	Permian		50	Phosphoria fm.	shale, chert, redbeds, etc.	oil & gas, phosphate rock, vanadium
	Pennsylvanian		30	Upper Casper fm.	limestone sandstone	oil & gas, limestone
				Tensleep sandstone	sandstone	oil & gas
				Amsden fm.	sandstone, shale	oil & gas
Paleozoic	Mississippian		35	Madison limestone	limestone, chert	oil & gas limestone, uranium
	Devonian		60	Darby fm.	shale, sandstone, dolomite	oil & gas
	Silurian		20		limestone	
	Ordovician		75	Bighorn dolomite	dolomite	oil & gas
	Cambrian		100	Gallatin-Deadwood fms.	limestone, sandstone	
				Flathead-Gros Ventre fms.	quartzite, shale sandstone	oil & gas
Proterozoic Archeozoic	Precambrian Time				granite, gneiss, schist, marble, etc.	iron, copper, uranium, gold, silver, lead, molybdenum, tungsten, beryl, rare-earths

Present geologic knowledge indicates that the age of the earth is approximately five billion years. The oldest known rocks in Wyoming are approximately 2.76 billion years.

Precambrian Time

Precambrian rocks are exposed in the cores of most of the Wyoming mountain ranges. These rocks are composed of a great thickness of sedimentary and igneous rocks which were folded and metamorphosed and then intruded by large bodies of gabbro, anorthosite, basalt, and granite. This period of time, which is not too well documented from a geological standpoint, covered many millions of years. After these events, the old mountains were eroded and, by the beginning of Paleozoic time, the land surface was reduced to a peneplane (nearly featureless plain).

Paleozoic Time

During the Cambrian Period (oldest period of the Paleozoic), a sea entered Wyoming from the west and in it were deposited sandstones, shales, and some limestone. The sea continued to expand until Late Cambrian time and covered all but the southeastern part of the State. By the end of the Cambrian Period, the sea had completely withdrawn from Wyoming.

Wyoming continued to remain emergent from the sea during earlier Ordovician time; however, some marine sandstone and shale were deposited in the northern part of the State during the middle of the period. These beds contain the earlist record of fish remains in the State, and these are the oldest vertebrate fossils known in geological history. Later in Ordovician time, it is believed that the entire State was submerged and the sea deposited the Bighorn dolomite.

It is likely that the State was also completely submerged during the Silurian Period. During early Devonian time, however, the southern part of the State was uplifted and subjected to erosion. The Silurian rocks were completely removed from the State except for a small limestone remnant south of Laramie and the Ordovician Bighorn dolomite was removed from all but the northern part of the State. The outlier south of Laramie besides yielding Silurian fossils has also yielded fossils typical of the Bighorn dolomite.

Late in Devonian time, the sea again entered Wyoming; however, it was of limited geographical extent, covering only northwestern and western Wyoming. In it were deposited dolomite, red shale, and some sandstone.

Early in Mississippian time, most, if not all, of the State was covered by a sea which deposited the Madison limestone. Exposures of Madison are present throughout the State with the exception of the southeastern corner. Uplift and erosion occurred during or shortly after the deposition of the Madison. Elsewhere, Late Mississippian rocks are represented by remnants in the Wind River Mountains and in the northwest part of the State.

Rocks of Pennsylvanian age are the oldest system to be represented in all parts of the State. These had a complex depositional history, since the different rock types intertongue or interfinger with one another, while others represent different ages within the Pennsylvanian Period. Coarse-grained sandstones occur in the southeastern part of Wyoming, while limestones are also present along the Laramie Range and in the Hartville uplift of eastern Wyoming. Red shales appear in many of these rocks as well as in central and northern Wyoming. Sandstones occur in the western, southern, and northern parts of the State. Some formations overlap into the Permian Period. Thus it might be said that the seas attained maximum extent during early Middle Pennsylvanian times and then retreated both eastward and westward. During the last half of Pennsylvanian times, central Wyoming was emergent. Pennsylvanian rocks of Wyoming are important oil producers.

The entire State became entirely emergent during the early part of Permian time. During Middle Permian time, the seas entered Wyoming from the north and deposited chert, cherty limestone, black shale, and phosphate rock in western Wyoming. These rocks are called the Phosphoria formation, and in addition to high-grade phosphate rock, they also contain significant amounts of vanadium, as well as over 30 other elements. In central Wyoming, the Phosphoria is replaced by interbedded red shales and limestones known as the Goose Egg formation. In Late Permian time, the Phosphoria sea completely withdrew from Wyoming.

Mesozoic Time

No folding occurred in Wyoming at the end of Paleozoic time, since Mesozoic rocks rest directly upon Paleozoic rocks with no angular discordance. Triassic, Jurassic, and Cretaceous rocks were deposited statewide. Where they are absent today, it is because of post-Cretaceous erosion. More than 30,000 feet of Mesozoic rocks were deposited in western Wyoming.

The Triassic seas invaded Wyoming from the west and initially deposited shale, siltstone, and dolomite. Later, the red shales of the Chugwater formation were laid down in a depositional environment not well understood. Many spectacular exposures of these redbeds can be seen along, or near, some of the major highways in Wyoming. Later in Triassic time, a thin limestone was deposited over much of the State. This was followed by the deposition of a sequence of varicolored clays, sandstones, and conglomerates of Late Triassic age. Finally, a thick sandstone was deposited in western Wyoming. This unit, which is known as the Nugget sandstone, thins out eastward in the State.

During Jurassic time, the sea again spread from west to east over Wyoming. A thick basal limestone was first deposited in western Wyoming, and this was followed by sandstones. These beds thin eastward with the lower limestone being replaced by redbeds and gypsum in the eastern part of the State. Overlying the sandstones are the variegated (variations of color) shales of the Morrison formation. This formation is quite famous in eastern Wyoming, since it has yielded many dinosaur bones. The bones of one of these dinosaurs, called *Brontosaurus*, were excavated near Sheep Creek in Albany County. The skeleton of this reptile, which is one of the largest dinosaurs to have lived on earth was reconstructed and is now on exhibit at the geology museum of the University of Wyoming at Laramie.

In Cretaceous time, the sea spread over Wyoming from east to west. Sandstones, shales, and limy sediments were deposited in eastern Wyoming. As the sea oscillated back and forth, more shale, and sandstone, and coal were deposited. The thickest sequence of Cretaceous rocks was deposited in a large basin-like depression in southwestern Wyoming where more than 25,000 feet of beds are known . A smaller trough (now called the Hanna Basin) existed in south-central Wyoming during Late Cretaceous time and about 20,000 feet of shale and sandstone were deposited there. Cretaceous sandstones are important oil and gas producers in Wyoming.

The Laramide Orogeny, a period of intense folding and faulting and mountain building movements, began during Late Cretaceous time.

Cenozoic Time

By early Cenozoic time, the mountains and basins of the State were well outlined. As the mountains continued to grow, they were subjected to erosion which caused the deposition of sediments in the basins (Fig. 17). These crustal movements also produced structures such as anticlines (dome-like) and synclines (trough-like) in the basins. Oil was concentrated in many of the anticlines, and this resulted in the discovery of many of the earlier oil fields in the State.

Nonmarine sedimentary rocks, representing all of the epochs of the Tertiary Period, crop out in Wyoming. Many mammal remains have been found in these rocks. During the early part of Tertiary time, several large-lakes were present. One, called Lake Gosiute, was located in the Green River Basin of southwestern Wyoming. Oil shales and trona beds were deposited there.

Early Tertiary time was the scene of extensive volcanic activity in the northwestern part of the State, and this has continued up until relatively recent times. Yellowstone National Park and the Absaroka Mountains are composed almost entirely of these volcanic rocks.

Mountain glaciation occurred in Pleistocene time (very Late Cenozoic) and sculptured the mountains of the State into the forms that are observed today.

TABLE 2

Minerals Arranged in the Order of Increasing Hardness

Hardness	Color	Distinguishing Characteristic	Mineral
1-1½	lead gray, bluish cast	greenish-gray streak, one direction of cleavage	Molybdenite
1-2	black to steel-gray	black streak, foliated masses	Graphite
1-5½	yellow to brown	usually earthy	Limonite
1½	yellow to dark brown	micaceous, expands when heated	Vermiculite
1½-2½	yellow	light weight, massive, incrusting crystal, ignites	Sulfur
2	colorless to tan	very good cleavage in 3 directions	Gypsum
2	yellow to green	radioactive	Tyuyamunite
2-2½	yellow to green	radioactive, fluoresces yellow to green	Autunite
2-3	yellow	radioactive, yellow streak	Carnotite
2-3	yellow to orange yellow	radioactive, pale yellow or orange yellow streak	Uranophane
2-4	green or blue	tendency to stick to tongue	Chrysocolla
2-6	steel-gray to black	sometimes sooty, fibrous	Pyrolusite
2½	usually black	flakes and plates, micaceous	Biotite mica
2½	usually pale lavender	micaceous	Lepidolite
2½	usually colorless	flakes and plates, micaceous	Muscovite
2½	pale yellow to brown	flakes and plates	Phlogopite
2½	lead-gray	metallic, very heavy, sometimes crystallizes as cubes, one direction of perfect cleavage	Galena
2½	greenish-yellow	radioactive, fluoresces yellow-green	Schroeckingerite
2½-3	black	metallic black or sooty black	Chalcocite
2½-3	copper-red to brown	very heavy, maleable	Native copper
2½-3	gold yellow	heavy, sectile	Gold
3	colorless to black	effervesces in dilute hydrochloric acid	Calcite
3	reddish- brown	purple tarnish	Bornite
3½	variable	effervesces in warm dilute hydrochloric acid	Dolomite
3½-4	blue	effervesces in dilute hydrochloric acid	Azurite
3½-4	brass yellow	irridescent tarnish	Chalcopyrite
3½-4	red	brittle, brownish-red streak, sometimes translucent	Cuprite
3½-4	bright green	effervesces in dilute hydrochloric acid	Malachite
3½-4	variable, usually brown	resinous luster, perfect cleavage	Sphalerite
4	variable, colorless to brown, often purple	often crystallizes as cubes, perfect cleavage	Fluorite
4-6	usually greenish	fibrous, silky, flexible fibers	Asbestos

Table 2 (Cont.) Minerals Arranged in the Order of Increasing Hardness

Hardness	Color	Distinguishing Characteristic	Mineral
4-7	white, blue, green	hardness varies from 4-5 parallel to length of crystal or 6-7 across the crystal, perfect cleavage	Kyanite
4½-5	white, yellowish, gray	fluoresces a bluish white	Scheelite
5-5½	yellowish to brown	radioactive, usually occurs as small grains and crystals	Monazite
5-6	usually dull to bright red	reddish streak, heavy; Specularite is a metallic gray	Hematite
5-6	steel-gray to black	submetallic luster, black streak, massive form	Psilomelane
5-6	brown to black	radioactive, heavy, often small cubic crystals	Uraninite
5-8	black	radioactive, heavy, dark red to black streak	Columbite-Tantalite
5½	black	heavy eight-sided crystals common	Chromite
5½-6½	brownish-black	radioactive, glassy texture	Euxenite
5½-6½	black	metallic, heavy, magnetic	Magnetite
5½-6½	variable	waxy luster, some may be fluorescent	Opal
6	usually green to black	six-sided cross-section, two direction of cleavage at an angle of 124 degrees	Amphibole
6	variable, white, pink, gray common	good cleavage, striations apparent on plagioclase variety	Feldspar
6	colorless to gray	trapozohedral crystals	Leucite
6	pale green to black	square cross-section	Pyroxene
6-6½	light green to black	dense, very fine-grained, tough	Jade
6-6½	pale brass-yellow	brittle, often striated, cubes common	Pyrite
6-7	tin white	black streak, cubes or eight-sided crystals	Sperrylite
6½	brown to black	usually radioactive	Allanite
6½	usually olive-green	rounded grains and granular masses	Olivine
6½	white to grayish	similar to feldspar but heavier	Spodumene
7	colorless to blue	similar to quartz but less common	Cordierite
7	yellowish-green to black	yellowish green color characteristic	Epidote
7	variable	conchoidal fracture, varieties are agate, jasper, chert, quartz crystal, etc.	Quartz
7-7½	dark red to reddish-brown	twelve- or twenty-four-sided crystals common	Garnet
7½	black	triangular cross-section, striated parallel to length of mineral	Tourmaline
7½	variable, usually brown	small prismatic crystals, some may be radioactive and some may fluoresce a yellowish-orange	Zircon
8	usually pale green	six-sided cross-section	Beryl

MINERALS

Agate (see Quartz)

Allanite

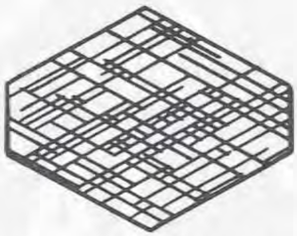
Properties: color, brown to black; luster, vitreous or pitchy; fracture, conchoidal; hardness, 6.5; weight, medium to heavy; form, massive to tabular to slender crystals, also small grains.

Allanite usually contains some thorium and hence is usually radioactive. Allanite occurs as disseminated grains in some granitic rocks and as good crystals and large masses in some pegmatites.

Allanite, occurring in Precambrian pegmatites, is reported from the following localities in Wyoming: secs. 3 and 10, T. 14 N., R. 79 W., and sec. 2, T. 18 N., R. 72 W., in Albany County; sec. 3, T. 13 N., R. 81 W., Carbon County; sec. 6, T. 46 N., R. 83 W., Johnson County; secs. 12 and 13, T. 39 N., R. 88 W., and secs. 7 and 18, T. 39 N., R. 87 W., Natrona County; 14 miles northwest of Wheatland, Platte County; and sec. 25, T. 56 N., R. 104 W., Park County.

Amphibole

Properties: color, white to green to black; luster, vitreous to silky; cleavage, perfect; hardness, 6; weight, medium; form, prismatic to fibrous crystals, irregular, massive.



Cross-section of amphibole

Amphibole is a group of minerals that includes tremolite, actinolite, nephrite, hornblende, etc. Hornblende is the most common mineral of the group and varies in color from dark green to black. It differs from the pyroxene minerals by its cleavage angles of 56 degrees and 124 degrees and its six-sided cross-section (see sketch above).

Hornblende is a widespread rock-forming mineral occurring in Precambrian igneous and metamorphic rocks (such as schist and in Tertiary volcanic rocks that crop out in Wyoming.

Asbestos (Chrysotile)

Properties: color, usually shades of green, also yellow, brown and gray; luster, silky or fibrous waxy; hardness, 4 to 6; weight, medium; form, fibrous.

The two sources of asbestos are chrysotile, a fibrous serpentine, and the various fibrous amphiboles. Of these, chrysotile is the most important and must possess flexibility, long fine fibers, and high tensile strength. Asbestos has a wide range of industrial applications; however, the greatest use occurs in the manufacture of roofing shingles and sheets.

All of the asbestos deposits in Wyoming are in Precambrian rocks. Known deposits occur in sec.15, T. 31 N., R.77 W., Converse County; sec. 26, T. 30 N., R. 100 W., and sec 19, T. 30 N., R. 96 W., Fremont County; secs. 16 and 17, T. 39 N., R. 79 W., and secs. 19, 20, 29, and 30, T. 31 N., R. 78 W., Natrona County; sec 19 or 20, T. 47 N., R. 116 W., and at the head of Berry Creek, Teton County. No asbestos is being produced in Wyoming at the present time.

Beryl

Properties: color, usually pale green but some crystals are white or yellow; luster, vitreous; cleavage, poor; hardness, 8; weight, medium; form, six-sided prism.

Transparent gem varieties of beryl are emerald (dark green), morganite (pink) and aquamarine (pale blue or green). Massive white beryl is similar to quartz and is difficult to recognize without special equipment or tests.

All of the known beryl deposits in Wyoming occur in Precambrian pegmatites. No gem varieties have been reported, however. These deposits are located in the southern part of the Medicine Bow Range, Albany and Carbon counties; Copper Mountain in Fremont County; Haystack Range in Goshen County; and on Casper Mountain in Natrona County. Beryl is an important source of beryllium which is used in alloys and in the manufacture of glass and porcelain. Small quantities of beryl are occasionally produced in Wyoming.

Calcite-Aragonite

Properties: color, variable-white, yellow, brown, pink, gray, greenish, black, etc.; luster, vitreous; cleavage, perfect; hardness, 3; weight, medium; form, variable shapes.

Calcite is a common rock-forming mineral that effervesces (bubbles) in dilute hydrochloric acid . Limestone and marbles are rocks that are composed almost entirely of calcite. Calcite also occurs in a variety of crystalline shapes that are colorless and transparent when pure.

Calcite is common in Wyoming and is found in a wide variety of sedimentary and metamorphic as well as in some igneous rocks. Some individual occurrences of calcite are located in the following areas. Pseudomorphs of calcite after aragonite are common in the Satanka shale in Albany County. In a section of the Goose Egg formation (Permo-Triassic age) in sec. 19, T. 12 N., R. 76 W., at Red Mountain, aragonite crystals occur in red sandy shale 20 feet above a massive gypsum bed, near the base of the formation. The crystals are hexagonal prisms, usually short prismatic to tabular, and in tabular penetration twins (Fig. 3A). Abundant goedes (see sedimentary rocks) containing many calcite crystals occur in the lower Niobrara shale (Upper Cretaceous) in sec. 36, T. 19 N., R. 82 W., Carbon County. Calcite scalenohedrons and rhombohedrons (crystal forms) occur in the vugs and cavities of the volcanic rocks on the west slope of Spar Mountain, approximate section 24, T. 45 N., R. 103 W., Park County. Vertical calcite veins, containing some uranium, and up to 24 feet wide, cut the Tensleep formation (Pennsylvanian) in secs. 30 and 31, T. 25 N., R. 81 W., and sec. 36, T. 25 N., R. 82 W., in Carbon County.

Clear transparent calcite is often used for optical purposes. Calcite, or limestone, mined in Wyoming, is used in the manufacture of Portland cement, sugar refining, building stone and as railroad ballast.

Chromite

Properties: color, black; luster, metallic; fracture, brittle; hardness 5½; weight, heavy; form, eight-sided crystals.

Chromite has been found on Casper Mountain, Natrona County. It occurs as disseminated grains and as lenses in Precambrian schist. It was formed by crystallization in an ultra-mafic igneous rock that was later changed into a schist over one billion years ago.

Chromite is a mineral that is used in preparation of the alloy ferrochrome, chromite fire brick, and in the paint and chemical industries. It has been estimated that approximately 1,600 tons of chromite ore had been produced in Wyoming by 1920. No production has been recorded since then.

Columbite-Tantalite

Properties: color, brownish-black to black; luster, sub-metallic to sub-resinous; cleavage, distinct; fracture, sub-conchoidal, brittle; streak, dark red to black; hardness, 5 to 8; weight, medium heavy to heavy; form, massive, short prismatic or thin tabular crystals.

Columbite-tantalite is usually found in some complex pegmatites of Precambrian age in Wyoming. Some of these pegmatites which are known to contain these minerals, are located in sec. 3, T. 13 N., R. 81 W., Carbon County; sec. 32, T. 13 N., R. 78 W., Albany County; and on Copper Mountain in Fremont County.

Columbium and tantalum, which are extracted from the above minerals, are used in alloys, steels, electronic tubes, chemical industry, etc. A limited amount of columbite-tantalite has been produced in Wyoming.

Copper Minerals

Azurite. Properties: color, blue; luster, vitreous to transparent; fracture, conchoidal; hardness, 3¼ to 4; streak, light blue; weight, medium heavy; form, tabular, short prismatic, columnar, radial, earthy. Effervesces in dilute hydrochloric acid.

Bornite. Properties: color, reddish-brown with a purplish tarnish; luster, metallic; fracture, conchoidal, brittle; hardness, 3; streak, gray-black; weight, heavy; form, usually massive, cubic crystals.

Chalcocite. Properties: color, sooty-black to black; luster, metallic; fracture, conchoidal; hardness, 2½ to 3; streak, black; weight, heavy; form, prismatic, tabular, massive.

Chalcopyrite. Properties: color, brass yellow-may have an irredescent tarnish;luster, metallic; fracture, uneven, brittle; hardness, 3½ to 4; streak, greenish-black; weight, medium-heavy; form, massive to pyramidal crystals.

Chrysocolla. Properties: color, green or blue; luster, vitreous; fracture, conchoidal; hardness, 2 to 4; streak, white; weight, medium; form, fibrous, earthy, massive. Similar to malachite but does not effervesce in dilute hydrochloric acid. Tendency to stick slightly to tongue when tasted.

Cuprite. Properties: color, red; luster, sub-metallic; fracture, conchoidal, brittle; hardness, 3½ to 4; streak, brownish-red; weight, heavy; form, cubes, eight-sided crystals, massive, granular, earthy.

Malachite. Properties: color, bright green; luster, velvety or dull; fracture, uneven; hardness, 3½ to 4; streak, pale green; weight, medium to medium heavy; form, massive, incrusting, fibrous, acicular. Effervesces in dilute of hydrochloric acid.

Native Copper. Properties: color, copper-red to brown; luster, metallic; fracture, hackly; hardness, ductile and malleable; streak, metallic; weight, very heavy; form, usually massive dendritic or firm-like.

Copper is found in many types of deposits, such as veins, replacement bodies, disseminated deposits in igneous and sedimentary rocks, and cavity fillings and replacements in basaltic lavas. Native copper is often found in many localities, but the principal ore is chalcocite, which contains about 80 percent copper and 20 percent sulfur. Chalcopyrite and bornite are other important copper-iron-sulfide minerals that occur in Wyoming. In addition to these are the oxidized minerals, of which the most important are malachite, chrysocolla, and cuprite. These are often found near the surface of copper deposits where they have been exposed by erosion. Surface waters oxidize the copper ore minerals and also leach out part of the copper down to the groundwater table. Often secondary copper sulfides are precipitated below the groundwater table which have produced some of the greatly enriched ore deposits that have made mining history in the Rocky Mountain area.

At the present time there are no producing copper mines in Wyoming, but during the period 1899-1908 the State was one of the leading copper producers in the nation. Total production of copper in the State during the years 1867-1950 has been reported to be more than 16,000 short tons. All of this came from Precambrian rocks. Most of the copper was produced from the Encampment district in Carbon County, but some has come from the Hartville district, Platte County; the Copper Mountain district, Fremont County; and the Douglas Creek district, Albany County. Copper prospects also occur in the Tertiary volcanic rocks of the Kirwin and Sunlight Basin areas of the Absaroka Mountains of Park County.

Cordierite

Properties: color, colorless, yellow gray, brown, shades of blue; luster, vitreous; hardness, 7; weight, medium; form, massive or as irregular grains—similar in appearance to quartz.

Cordierite, a complex magnesium-iron-aluminum silicate, is found in a wide variety of metamorphic gneisses and schists, granites, volcanic rocks, and certain sediments that have been subjected to heat. It is used for various industrial items that must withstand high temperatures, such as thermocouple insulators, industrial burner tips, chemical stoneware, automotive parts, etc.

Although there has been no production in Wyoming, an estimated 500,000 short tons of cordierite is found in two large deposits in the Laramie Range, Albany County. These deposits, which are of Precambrian age, are located in secs. 13, 14, and 24, T. 17 N., R. 72 W., and secs. 17, 18, 19, and 20, T. 17 N., R. 71 W. Its use, however, is limited because of the high iron content. It is possible that it may be used some time in the future for low thermal expansion bodies where color, dielectric properties and strength are not critical factors.

Dolomite (see Limestone)

The properties of dolomite are similar to calcite, except that it is sightly harder and effervesces in warm dilute hydrochloric acid. The crystals are commonly rhombohedral and curved. Dolomite pseudomorphs after aragonite, locally called "Indian pennies" (Fig. 3B), occur in a gypsum bed at the base of the Chugwater formation (Triassic age) and on top of the uppermost limestone of the Permian-Triassic Embar (Goose Egg ?) formation about ten to fifteen miles northeast of Lovell, Big Horn County, and along the southwest flank of the Bighorn Mountains. Dolomite pseudomorphs after shortite occur in the Wilkins Peak member of the Green River formation in southwestern Wyoming.

Figure 3. Calcite pseudomorph after aragonite (A). "Indian penny" (B).

Epidote

Properties: color, yellowish-green to black; luster, vitreous; cleavage, perfect; hardness, 7; weight, medium; form, elongate crystals, massive, fibrous, granular.

Epidote is a common constituent of some Precambrian metamorphic rocks of Wyoming. Some of the copper prospects in the Laramie, Medicine Bow, and Sierra Madre Mountains are associated with epidotized rocks and veins of epidote. Epidote also occurs as an alteration product of plagioclase feldspars in the mineralized areas which are found in volcanic rocks of the Absaroka Mountains of northwest Wyoming.

Euxenite

Properties: color, brownish-black; luster, glassy to greasy; fracture, sub-conchoidal; hardness 5½ to 6½; streak, brown; weight, medium-heavy; form, commonly massive.

Euxenite is a rare earth mineral that occurs in some pegmatites and placer deposits. Because it contains some thorium and uranium, it is radioactive. Rare earth metals have various uses; one of which is, as an additive to special high alloy steel.

Euxenite-bearing pegmatites occur in Precambrian rocks in sec. 3, T. 13 N., R. 81 W., Carbon County. Approximately 10,000 pounds of euxenite was produced from a small mine in this area between 1956 to 1958.

Feldspar Minerals

Orthoclase. Properties: color, white or pink; luster, vitreous to pearly; cleavage, good to perfect; hardness, 6; weight, medium; form, usually short prismatic crystals. Microcline is similar in appearance, except that some of it is green (amazonstone).

Plagioclase. Properties: color, white to dark gray, sometimes reddish-brown; form, tabular crystals or irregular grains and cleavable masses. Other properties are similar to orthoclase; however, sometimes it may be differentiated from that mineral by the presence of twinning striations. Figure 3 illustrates the difference between striae in plagioclase and perthitic streaks and veinlets in microcline.

Although the word orthoclase has long-established usage, its existence has been seriously questioned by many mineralogists. Orthoclase is more correctly referred to as potassium feldspar with microcline and sanidine as the principal members of the potassium feldspar group.

The feldspars are the most abundant of all minerals and are found in many rocks. Commerical deposits, however, are almost entirely restricted to pegmatites. The potassium feldspars, such as microcline, are widely used in the ceramic industry for glass, enamel, and pottery, and in soaps, abrasives, and false teeth. Labradorite, a plagioclase feldspar, often shows a display of colors, and is used for ornamental stone, moonstones or sunstones.

Wyoming has produced an estimated 90,000 tons of feldspar. Casper

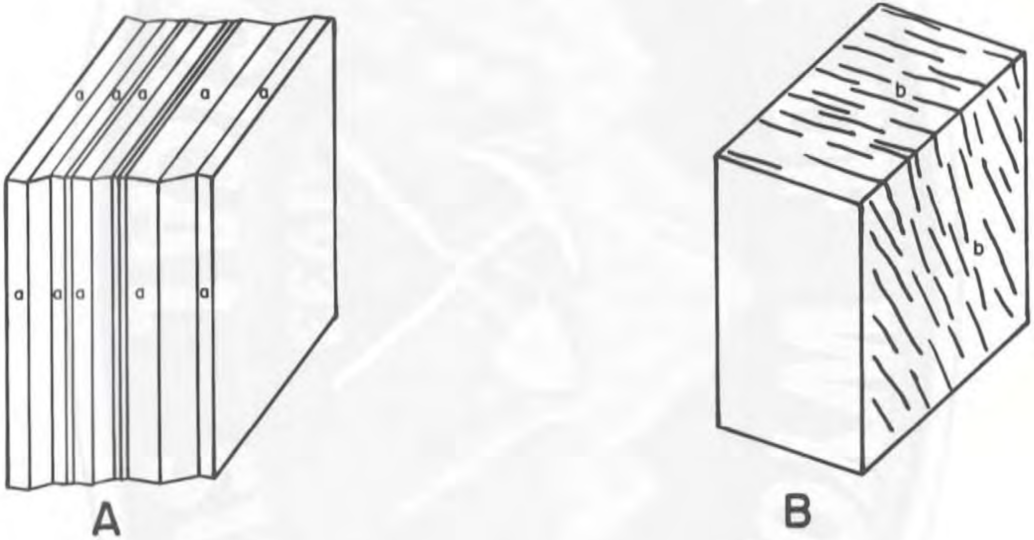


Figure 4. Plagioclase twinning (striations in A, and perthite streaks in potassium feldspar (B).
Stria appear on plagioclase (A) because all cleavage surfaces marked "a" reflect light simultaneously. Tip specimen approximately 7 degrees and the other set will reflect light.
Irregular and discontinous veinlets of perthite (b) in potassium feldspar occur at an angle of approximately 70 degrees to lower right edge of specimen.

Mountain, Natrona County; Haystack Range, Goshen County; Laramie Range, Albany and Laramie counties; and Copper Mountain, Fremont County; are a few of the localities that have produced feldspar.

Fluorite (Fluorspar)

Properties: color, pure varieties are colorless and transparent, commonly in shades of yellow, green, violet, blue, or brown; luster, vitreous; cleavage, perfect; hardness, 4; weight, medium; form, crystals are usually cubes, less commonly octahedrons (eight-sided) or dodecahedrons (ten-sided).

Fluorite, a calcium fluoride, is found in many types of rocks, such as dolomites, limestones, granites, and pegmatites. It is also found in veins associated with lead, silver, zinc and tin minerals. The mineral is used as an electrolyte and as a flux in metallurgy and the steel industry. Other uses are the manufacture of hydrofluoric acid, opal glass, enamelware, ornamental stones, and lenses and other optical equipment.

The only known locality where fluorite has any potential economic importance is in the Pahasapa limestone (Mississippian age) which crops out in the Bear Lodge Mountains of Crook County, Wyoming. Nineteen short tons of fluorite were shipped from this locality in 1944. Fluorite is also reported to occur in a pegmatite located in sec. 5, T. 15 N., R. 70 W., Laramie County.

Galena

Properties: color, lead-gray; luster, metallic; cleavage, perfect; hardness, 2½; streak, lead-gray; weight, very heavy; form, cubes and massive.

Galena, a combination of 87 percent lead and 13 percent sulfur, is the principal ore of lead. Varying amounts of silver are commonly present, and curved cleavage planes are a good field guide as to its presence. In addition to silver, galena often occurs with zinc and copper minerals. Galena occurs in many types of deposits, such as replacement bodies in sedimentary rocks, hydrothermal veins in igneous rocks, and in pegmatites.

At the present time there are no producing lead and silver mines in Wyoming. During the past, only 32 tons of lead has been reported mined in the State. Most of the 58,000 troy ounces of silver produced has been as a by-product of early copper production.

There are many small lead-silver deposits in the State. The most important ones are in the Precambrian rocks of the Medicine Bow and Sierra Madre Mountains of Albany and Carbon counties; Paleozoic limestones of the Black Butte area, Crook County; and in the Tertiary igneous rocks of the Absaroka Mountains, Park County.

Garnet

Properties: color, variable, commonly dark red or reddish-brown; luster, vitreous or resinous; hardness, 7 to 7½; streak, white or pale shade of color; weight, medium to medium heavy; form, dodecahedrons (twelve-sided) or trapozohedron (24-sided), coarse to fine-grained granular masses.

Garnet is a name for a group of minerals which vary somewhat in chemical composition. Some transparent, unflawed types can be cut into attractive gems.

Garnets occur in schists, gneisses, granites, metamorphosed limestones, etc. In addition to the manufacture of gems, garnet is used for abrasives. Althought garnets occur in various Precambrian metamorphic rocks in Wyoming, no gem quality varieties have been reported.

Gold

Properties: color, gold-yellow; luster, metallic; fracture, hackly; hardness, 2½ to 3, malleable; streak, gold-yellow; weight, very heavy; form, dendritic, leafy, rounded or flattened grains or scales.

Small grains of gold are often confused with pyrite or chalcopyrite (both called "fools-gold") or "golden" biotite mica which is wet or under water. The color and sectility of gold are the distinguishing factors.

Gold is found in both placer and vein deposits. Since it is chemically inert, most of the metal is found as native gold or alloyed with silver in veins. Gold is found in small placers and vein deposits at many places in Wyoming. Most of the gold is usually found in or near the Precambrian rocks, but some gold is found associated with the Tertiary igneous rocks in the Wood River and Sunlight Basin areas of Park County, and the Black Hills area of northeastern Wyoming.

One may pan for gold in such places as Douglas Creek in the Medicine Bow Mountains of southeastern Wyoming; the Sweetwater River and tributaries in the southern part of the Wind River Mountains; and along parts of the Snake River in the southern part of Jackson Hole, northwest Wyoming. Successful panning is a matter of practice. In essence, the pan should be filled with gravel or crushed rock and water (water level above the rock). Then the pan is shaken by a gyratory (irregularly circular) motion with frequent tipping of the pan (away from the individual) and brushing out of the lighter portions of the rock material that has risen to the top. This proceedure is carried out until nothing but the gold (if present) and other heavy minerals remain. Chromite, garnet, magnetite, zircon, etc., are few of the other minerals that are often present in the heavy mineral concentrate. The magnetite may be removed from the dry concentrate with a magnet.

Most of the gold produced in Wyoming has come from the Atlantic City-South Pass-Sweetwater district where it was discovered some time during the 1840's. The total recorded production from this district for the period 1867-1950 has been 80,031 ounces valued at $1,909,413.

Graphite

Properties: color, iron-black to dark steel-gray; luster, metallic to dull earthy; cleavage, perfect; hardness, 1 to 2; streak, black; weight, light to medium; form, foliated masses, grains, scales, etc.

Graphite may be confused with molybdenite; however, the black streak serves to differentiate the two minerals. Graphite, which consists entirely of carbon, is found in Wyoming in Precambrian metamorphic schists, gneisses, and crystalline limestones. In these rocks it is found embedded as isolated scales, as large irregular masses, or as veins. Some of the graphite deposits are found in the northern part of the Laramie Range, Albany and Platte counties; in the Haystack Range, Goshen County, and in the Pedro Mountains of Carbon County.

Graphite is used in the manufacture of pencils, dry lubricants, paints, polishes, and in the manufacture of refractory crucibles. Most graphite is produced artificially. Only one small shipment of graphite has been reported from Wyoming, and this was in 1926.

Gypsum

Properties: color, colorless and transparent to tan, etc.; luster, vitreous to transparent; cleavage, very good; hardness, 2; weight, medium; form, tabular or long prismatic crystals, granular, massive, earthy, fibrous, etc. Varieties; see sedimentary rocks.

Hematite

Properties: color, dull to bright red-specularite variety is steel-gray; luster, earthy to sub-metallic, specularite is metallic; fracture, uneven; hardness, usually 5 to 6; streak, red or reddish-brown; weight, medium heavy to heavy; form, tabular crystals, earthy, massive, etc.

Hematite is the major ore of iron. It occurs as a primary accessory mineral in igneous rocks, in hydrothermal veins, and in metamorphic and sedimentary rocks as bedded deposits.

Most of the iron ore mined in Wyoming, prior to 1962, was hematite from the Sunrise mine in Platte County. The ore body lies in Precambrian schist. This was formerly one of the largest iron mines operating west of the Mississippi River, and it has operated almost continuously since 1898. Other hematitic iron ore deposits are found in the Precambrian rocks of the Shirley and Seminoe Mountains, Carbon County; the Good Fortune mine, Platte County; Atlantic City and Copper Mountain areas, Fremont County; and in the Cambrian sandstones near Rawlins, Carbon County.

Ilemite (see magnetite)

Jade (Nephrite)

Properties: color, light green to black; luster, glistening; fracture, splintery; hardness, 6 to 6½; weight, medium; form, dense and fine-grained.

There are two mineralogic types of jade: jadeite, and aluminum-sodium silicate, which belongs to the pyroxene group of minerals; and nephrite, a calcium-magnesium silicate, which belongs to the amphibole group. The jade found in Wyoming, is the nephrite variety, and it is a tough, compact, fine-grained mineral. The light-green translucent nephrite is the most desirable for gem stone. Not all specimens will take a high polish, because of differences in quality. Further, jade often contains small dark specks which are softer and leave pits in the polished surfaces.

Jade occurs in the Sweetwater River district (southeast of the Wind River Mountains) in Fremont County, in an area comprising about 700 square miles. It occurs as individual deposits associated with Precambrian granite, granitic gneiss, diabase dikes, and as pebbles and boulders in Tertiary alluvial deposits. Most of the Precambrian vein deposits occur in a narrow east-west zone near the northern part of the Granite Mountains (within the Sweetwater Arch area of Fig. 1). Northeast-trending, dark colored diabase dikes in this general area are also known to contain black jade. The alluvial jade in the Sweetwater area occurs as "slicks", indicating a natural polishing by wind or water or both, or may be coated with a brown, tan, or light gray rind, indicating a chemical weathering.

Boulders of the light-green translucent variety of jade have been found in abundance in only two relatively limited areas. The largest boulder of this type of jade so far reported weighed about 3,200 pounds. On the basis of the general geological structure, it appears that the original Precambrian source of the light-green jade may have been buried by later sediments and thus may never be located.

The above areas have been so thoroughly picked over during the past ten years that today the light-green jade in Wyoming is largely depleted. New finds of dark-green and black jade have been reported in recent years, however, and one of these is in an area located south of Douglas in Converse County. Other black jade deposits have been reported from the Kortes Dam area, Carbon County; near Daniel, Sublette County; the Owl Creek Mountains, Fremont and Hot Springs Counties, and the Sierra Madre Mountains, Carbon County.

It should be mentioned that there are two other green rocks that commonly occur in the above areas which superficially resemble jade. The abundance of these rocks, coupled with the fact that they have often been mistaken for jade, has given rise to exaggerated stories of the abundance of jade in the area. Truckloads of green serpentine have been transported for miles only to be found worthless. A green quartzite is also found in these areas and has frequently been confused with jade. The positive identification of jade can only be confirmed by X-ray analysis in association with other physical tests.

It is possible, of course, that new areas containing gem quality jade will be found, but the entire Sweetwater area has been fairly well combed by present prospectors. None of the jade collectors has depended entirely on collecting and selling jade as a livelihood for any length of time. The average jade hunter has simply found it to be a pleasant way to spend spare time.

Kyanite

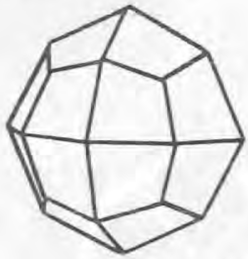
Properties: color, light blue, green, white or gray; luster, vitreous to pearly; cleavage, perfect; hardness, 4 to 5 parellel to blades or cleavage, 6 to 7 across blades or cleavage; weight, medium; form, long bladed crystals that may be somewhat bent or curved.

Kyanite deposits in Wyoming occur in schists, gneisses, and pegmatites of Precambrian age. Known deposits occur in sec. 35, T. 24 N., R. 71 W., Albany County; sec. 20, T. 14 N., R. 83 W., Carbon County; and about 23 miles southwest of Wheatland, Platte County.

Kyanite is a source of mullite (aluminum silicate) which, in turn, is used in the manufacture of spark plugs and other refractories.

Leucite

Properties: color, colorless to gray; luster, vitreous; cleavage, very imperfect; hardness, 6; weight, medium; form, usually occurs in trapozohedral crystals which may show fine striations (see sketch below).



Leucite is not a common igneous rock-forming mineral; however, it is included here because of its presence in wyomingite and other associated igneous rocks which crop out in the Leucite Hills of Sweetwater County. The mineral is rather difficult to identify in hand specimen; however, the trapozohedral form of individual crystals is the most useful guide to its identification.

Lithium Minerals

Lepidolite. Properties: color, usually pale lavender but can be pale yellow, pale gray, or colorless; luster, vitreous; cleavage, perfect; hardness, 2½; weight, medium; form, fine to medium-grained micaceous aggregates.

Petalite. Properties: color, colorless to gray, occasionally reddish or greenish-white; luster, vitreous or pearly; cleavage, perfect; fracture, rudely conchoidal; hardness, 6½; weight, medium.

Spodumene. Properties: color, white or grayish-white; luster, vitreous; cleavage, perfect; fracture, splintery; hardness, 6½; weight, medium; form, long prismatic crystals or platy masses.

The three lithium minerals noted above have been reported from Precambrian pegmatites in Fremont and Natrona Counties. Spodumene crystals, up to 18 inches long, occur at Black Mountain which is located in sec. 1, T. 32 N., R. 89 W. Lavender-colored crystal aggregates of lepidolite occur on Copper Mountain in sec. 28, T. 40 N., R. 93 W.;

and irregular masses of petalite occur in sec. 22, T. 40 N., R. 93 W.

Lithium compounds are used in ceramics, greases, fuels, air conditioning, pharmaceuticals, cosmetics, etc. A small shipment of lithium ore was reported from Wyoming in 1954.

Limonite

Properties: color, various shades of yellow or brown; luster, silky, sub-metallic or dull and earthy; hardness, up to 5½; streak, yellowish-brown; weight, medium to medium-heavy; form, earthy.

Limonite, a hydrous iron oxide, usually results from the weathering of iron minerals such as pyrite and magnetite, or iron silicates such as biotite mica, pyroxene, and hornblende. Limonite occurs in many of the mineralized areas of Wyoming as well as in various rock types ranging in age from Precambrian to Tertiary. Large bodies of limonite are potential sources of iron ore; however, no such deposits are currently known in Wyoming.

Magnetite

Properties: color, black; luster, metallic; cleavage, none; fracture, uneven; hardness, 5½ to 6½; streak, black; weight, heavy; form, octahedron (eight-sided crystals), granular masses. Magnetic.

Magnetite is commonly found as a primary mineral in igneous rocks, hydrothermal veins, magmatic segregation deposits, contact metamorphic and replacement deposits, and as a detrital mineral in sandstones and river sands and gravels. Magnetite deposits and occurrences are common in Wyoming and are found in various rock types ranging in age from Precambian to Tertiary.

Sometimes magnetite contains titanium, or is intergrown with ilmenite (a magnetic-looking mineral containing titanium). Ilmenite, however, is non-magnetic. Titaniferous magnetite occurs in irregular bodies of varying size in the Laramie Range of Albany County. The largest of these is located at Iron Mountain, and this is a potential ore of iron as well as titanium. A smaller deposit of this type, located in sec. 2, T. 21 N., R. 71 W., was formerly mined (1962) for use as heavy aggregate. Magnetite-ilmenite also occurs as concentrated disseminated grains in the Mesaverde formation of Upper Cretaceous age. These deposits, which can be recognized by the brownish-black color of the beds, are located at Sheep Mountain, Albany County; near Cowley and Lovell, Big Horn County; near Grass Creek and Cottonwood Creek, Hot Springs County; Clarkson Hill and Poison Spider, Natrona County; and in the Red Creek and Salt Wells Creek areas of Sweetwater County.

The Precambrian taconite (see Taconite) deposits located north of Atlantic City, and on Copper Mountain, Fremont County, contain fine-grained magnetite.

Manganese Minerals

Psilomelane (pronounced "silomelane"). Properties: color, dark steel-gray to black; luster, sub-metallic to dull; hardness, 5 to 6; streak, brownish-black; weight, medium to medium-heavy; form, usually occurs as botryoidal (grape-shaped), massive or stalactitic forms.

Pyrolusite. Properties: color, dark steel-gray to black, sometimes sooty or a bluish cast; cleavage, perfect; fracture, uneven, brittle; hardness, variable, 2 to 6; streak, black or bluish-black; weight, medium-heavy; form, massive, columnar, or fibrous.

Pyrolusite and psilomelane, both manganese oxides, are important manganese ore minerals. They usually occur together where they have been concentrated in irregularly bedded deposits by the weathering of other manganese minerals. In addition to the two minerals listed above, there are many other manganese oxides and hydroxides which are virtually indistinguishable from one another. Small manganese deposits of the above nature are found in the State in various rock types ranging in age from Cambrian to Oligocene. These are located in Albany, Fremont, Johnson, Natrona, Washakie, and Weston Counties. Manganese oxides, associated with altered igneous rocks occur north of Sundance, in the Warren Peaks area of Crook County. Dendritic (fern-like) growths of pyrolusite are often observed on fracture surfaces of Mississippian and other limestone that crop out in the State.

The chief uses of manganese are to purify steels or to make wearing surfaces of steels more resistant to abrasion. Manganese is also used for dry batteries, chemical compounds, insecticides, bricks, plastics, and welding rods. The only recorded production in Wyoming has been approximately 212 tons.

Mica Minerals

Biotite. Properties: color, dark green, brown or black; luster, vitreous to sub-metallic; cleavage perfect; hardness, 2½; weight, medium-light; form, flakes and plates, sometimes hexagonal crystals of varying size.

Lepidolite. (see lithium minerals)

Muscovite. Properties: color, colorless to pale shades of gray, green or brown. Other, similar to biotite.

Phlogopite. Properties: similar to biotite except that the color is pale yellow to brown.

Biotite, muscovite, and phlogopite, occur in various types of igneous rocks. In addition, they occur as detrital minerals in sediments and alluvial deposits. In the latter type of deposit, particularly when wet or under water, some mica flakes may be mistaken for gold. Biotite and muscovite are also common in certain gneisses and schists. Varying-sized plates of biotite and muscovite occur as "books" in certain Precambrian pegmatites. These are located in the Laramie Range, Albany and Platte counties; the southern part of the Medicine Bow Range, Albany and Carbon counties; the Copper Mountain area, Fremont County; and in the Haystack Range, Goshen County. Phlogopite characteristically occurs in wyomingite and other associated igneous rocks of the Leucite Hills area in Sweetwater County.

Depending upon quality, muscovite mica is used in the electrical industry, and as fillers and dusting mediums. Small amounts of scrap and sheet mica are occasionally produced in Wyoming.

Monazite

Properties: color, yellowish to brown; luster, resinous to translucent; cleavage, distinct; hardness, 5 to 5½; weight medium-heavy; form, small grains or crystals.

Monazite is difficult to recognize; since, the grains and crystals are quite small. Monazite, however, is radioactive because of the thorium content.

Monazite occurs as an accessory mineral in granite, varying-sized crystals in some pegmatites, and as a detrital mineral in some conglomerates, sandstones, and alluvial deposits in Wyoming. These occurrences have been noted in the basal conglomerate of the Cambrian Deadwood Formation at Bald Mountain, in the northern part of the Bighorn Mountains, Big Horn and Sheridan counties; a pegmatite in sec. 3, T. 13 N., R. 81 W., Carbon County; and in stream gravels of Warm Springs Creek, west of the town of Dubois. It also occurs in the black sandstones of the Mesaverde formation (see magnetite or zircon).

Monazite is a source of thorium, which is used in nuclear reactors, special alloys, and in the manufacture of incandescent gas mantels.

Molybdenite

Properties: color, lead-gray with a bluish cast; luster, metallic; cleavage, perfect, flexible laminae; hardness, 1 to 1½; streak, greenish-gray; weight, medium-heavy; form, thin to thick tabular crystals, scales.

Molybdenite, the most common molybdenum mineral, usually occurs as scales or foliated crystals associated with quartz veins or disseminated in granitic-type rocks. In Wyoming, molybdenite is known to occur in Precambrian granitic rocks near Temple Peak in the Wind River Mountains of Sublette County, and in quartz veins at the Strong Mine (sec. 4, T. 16 N., R. 71 W.) in the Laramie Range of Albany County. Molybdenite also occurs associated with Tertiary volcanic and intrusive rocks in the Kirwin and Needle Creek areas of the Absaroka Mountains of Park County.

Molybdenum is used in steels where hardness and toughness are necessary. No molybdenum production has thus far been reported in Wyoming.

Olivine

Properties: color, usually olive-green; luster, vitreous; hardness, 6½; weight medium to medium heavy.

Olivine usually occurs as rounded grains and granular masses in mafic igneous rocks such as basalts and in some meteorites. When it forms major rock masses, it is called dunite. Peridot is the name applied to transparent olivine of good color which can be cut into attractive gem stones.

Olivine occurs in some of the mafic (dark-colored) igneous rocks of Precambrian age in Wyoming, as well as in the Tertiary Early Basalt flows of the Absaroka Mountains. The gem variety, however, has not been reported.

Opal

Properties: color, variable from colorless to shades of gray, brown, red, etc.; luster, vitreous, waxy or resinous; hardness 5½ to 6½; weight, medium-light; form, massive. Some may fluoresce under the short wave ultra-violet lamp.

Opal occurs in fissures and cavities of many rock types. In Yellowstone National Park, it is found in deposits associated with hot springs. Petrified wood found in the Absaroka Mountain area of northwest Wyoming, is often replaced by opal. Opal concretions occur in Tertiary rocks near Smith Creek in Carbon County, and fluorescent opal has been reported from conglomerates near Lusk, Niobrara County.

Pyrite

Properties: color, pale brass-yellow, may be tarnished; luster, metallic; fracture, brittle-conchoidal; hardness, 6 to 6½; streak, greenish or brownish-black; weight, medium-heavy; form, cubes, octahedrons, etc., often striated (parallel lines).

Pyrite, sometimes called "fools gold", is the most common sulfide mineral. Hardness and brittleness, distinguish it from gold. Pyrite occurs in many kinds of geological environments. In Wyoming, pyrite occurs in many of the mineral veins in Precambrian crystalline rocks of Albany and Carbon counties, and in the Tertiary volcanic rocks of Park County.

Marcasite, which is essentially similar to pyrite, is found in some shales and limestones in the State.

Pyrite is sometimes mined as a source of sulfur for use in the manufacture of sulfuric acid. None is mined in Wyoming.

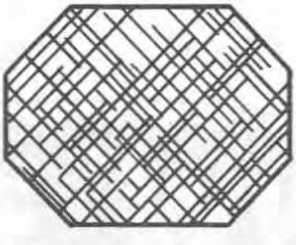
Platinum (Sperrylite)

Properties: color, tin white; luster, metallic; streak, black; hardness, 6 to 7; weight, heavy; form, cubes or eight-sided crystals.

Sperrylite usually occurs in mafic igneous rocks and associated with some chalcopyrite deposits. It is also found as a detrital mineral in certain alluvial (river gravels) deposits. In Wyoming, sperrylite has been reported from the Rambler mine, Independence mine, and Centennial Ridge, all in the Medicine Bow Mountains of Albany County. Small amounts of platinum were reported produced from the above area during the years 1902, and 1915 to 1920. Platinum is usually used in the manufacture of jewelry, medical instruments, and electrical apparatus.

Pyroxene

Properties: color, white or pale green to black; luster, vitreous; cleavage, good; hardness, 6; weight, medium; form, prismatic crystals, square cross section, irregular grains, massive, etc.



Cross-section of pyroxene

The pyroxene group of minerals, while similar to the amphiboles in hand specimen, can be distinguished by the cleavage angles of 87 and 93 degrees (nearly square) or eight-sided cross-sections (see sketch above). The pyroxene group, which includes the varieties hypersthene, augite, etc., are important minerals of intermediate to mafic igneous rocks such as andesites, basalts, and gabbros. In Wyoming, these rock types are principally confined to Precambrian rocks and to the Tertiary volcanic rocks of the Absaroka Mountains and Yellowstone National Park of northwest Wyoming.

Quartz Minerals

General Properties: color, variable, colorless to any shade; luster, vitreous to waxy or dull; cleavage, none; fracture, conchoidal; hardness 7; weight, medium; form, variable.

Quartz minerals occur as two general types: the macrocrystalline and the chalcedony (cryptocrystalline) varieties. The macrocrystalline type includes rock crystal (tranparent), milky (milk-white), amethyst (purple), rose, yellow, and smoky. The chalcedony varieties include carnelian and sard (red to reddish-brown), agate (banded forms), moss agate (white to cream-colored matrix enclosing manganese oxide moss-like forms), jasper (yellow, brown, red), chert and flint (massive chalcedony usually gray or black), and silicified wood (see rocks).

Agate.

In Carbon County, from Saratoga north along Wyoming Highway No. 130 to Walcott Junction, the "flats" are literally strewn with small sections of agatized and opalized wood that fluoresce green. Agates are also common a few miles west of Saratoga.

Rainbow agates have been found along the Wind River near Riverton, in Fremont County. Agates and moss agates are plentiful in a large area in southeast Fremont County, southeast of the Wind River, and north of Sweetwater River, and along Sage Hen Creek, 18 miles northwest of Split Rock. These types are called Sweetwater agates. Sweetwater type agates also occur near Marshall, in northwestern Albany County.

Petrified or agatized wood in various colors has been found in Sweetwater County, west of Wamsutter along the old road to Baggs. Clear chalcedony and vein moss agate occur along outcrops of the Bridger formation in areas north of Wamsutter, Sweetwater County, and in an area north and east of Farson, Sweetwater and Sublette counties.

A brown agate crowded with silicified shells of the fossil snail, *Goniobasis*, commonly but incorrectly called *Turritella*, is widespread in the Green River Basin. This rock takes a high polish, and because of the random orientation of the spiral shells, polished surfaces show an intricate pattern. A ledge of flint caps buttes along U.S. Highway 30 between Blacks Fork, west of Green River, and the town of Granger.

Volcanic type agates or chalcedony occur in stream gravels in the western half of the Bighorn Basin, of Big Horn, Hot Springs, Park, and Washakie Counties. These also occur in a relatively large area between Labarge and Granger; Lincoln, Sweetwater and Uinta Counties.

Fortification (banded) type agates occur along outcrops of the Phosphoria formation, south of the Pryor Mountains, in the Dryhead Creek area of Big Horn County. Veins of banded agate and drusy quartz (locally called "Youngite") occur in Mississippian limestone beds a few miles northwest of Guernsey, Platte County.

Chalcedony

Steamboat Mountain in the Leucite Hills (T. 23 N., R. 102 W.) of Sweetwater County, contains some amygdaloidal lavas that are occasionally lined with beautiful crusts of chalcedony. The amygdules are from three to six inches long.

The Early Basalt flows of the Absaroka Mountains in northwest Wyoming also contain chalcedony amygdules in many places.

Quartz Crystals

Quartz crystals are abundant in the feldspar pits south of Laramie, along U.S. Highway 287, near the Colorado-Wyoming border.

Quartz has many uses, such as in the construction industry, as fluxes, in the manufacture of glass, abrasives, etc. The colored varieties are often used as semi-precious stones.

Scheelite

Properties: color, white, yellowish, brownish, greenish, gray; luster, vitreous; cleavage, good; fracture, uneven; hardness, 4½ to 5; weight, medium; form, commonly massive or granular. Fluoresces a bluish-white under the short wave ultraviolet lamp.

Scheelite, a combination of calcium, tungsten, and oxygen, is the most important tungsten mineral in Wyoming. This mineral is usually found in quartz veins in metamorphic rocks or pegmatites of Precambrian age in Wyoming. The most important scheelite deposits in the State are found at Copper Mountain, Fremont County. In addition, small deposits have been found in the Laramie Range of Albany and Converse Counties; the Lewiston area of Fremont County; and the Bighorn Mountain area of Washakie County.

Most tungsten is used as a hardener in the manufacture of high speed steels. Some scheelite has been shipped from Wyoming in the past, but there are no active producing mines at the present time.

Silver (see Galena)

Sphalerite

Properties: color, variable, but usually brown; luster, resinous; cleavage, perfect; fracture, conchoidal; hardesss, 3½ to 4; streak, light yellow to brown; weight, medium-heavy; form, commonly massive-cleavable, or tetrahedrons.

Sphalerite is the most important zinc mineral and is usually associated with galena. Small amounts of sphalerite are often associated with lead veins in Wyoming; however, there has been no recorded production of zinc in the State.

Sulfur

Properties: color, yellow; luster, resinous to greasy; fracture, brittle-uneven; hardness, 1½ to 2½; weight, light; form, crystals, massive, incrusting shapes.

Sulfur deposits in Wyoming occur in the following areas as: hot springs deposits west of Cody, along the Yellowstone highway, and in the Sunlight Basin area of Park County; in the Permian Embar limestone, about three and one-half miles northwest of Thermopolis in Hot Springs County; and as hot springs deposits near Auburn, Lincoln County.

In recent years, Wyoming has become an important producer of sulfur because of the extraction of this element from "sour-gas" (hydrogen sulfide-bearing) wells in the Bighorn Basin. Some of this sulfur is shipped to Riverton for the manufacture of sulfuric acid which is used in the uranium mills. No figures on the production of sulfur in Wyoming are available, but it has been produced in Big Horn, Park, and Washakie Counties.

Tourmaline

Properties: color, black; luster, vitreous; cleavage, poor; fracture, brittle, conchoidal to uneven; hardness, 7½; weight, medium; form, prismatic crystals usually striated, triangular cross section.

Tourmaline is a common mineral in many of the Precambrian pegmatites of Wyoming. Some of the lithium-bearing tourmalines are of gem quality; however, none of these has been reported in the State.

Uranium Minerals

There are many uranium minerals, but autunite, carnotite, schroeckingerite, tyuyamunite, uranophane, and uraninite are among the most important varieties that occur in Wyoming. Their most significant property is that they can be detected with a geiger or scintillation counter. These mineral emit alpha, beta, and gamma particles, which, in turn, produce pulses of current in the tube of the counter. These are recorded as "clicks" in the earphones or as readings on a meter or both.

Autunite. Properties: color, lemon yellow to pale green; luster, vitreous; cleavage, perfect; hardness, 2 to 2½; streak, yellowish; weight, medium; form, scaly or micaceous aggregates. Fluoresces a brilliant yellow or apple green.

Carnotite. Properties: color, lemon yellow to greenish-yellow; luster, usually dull or earthy; cleavage, perfect; hardness, 2 to 3; streak, yellow; weight, medium heavy; form, disseminated in sandstones as powder-like masses.

Schroeckingerite. Properties: color, greenish-yellow; luster, vitreous; hardness, 2½; streak, greenish-yellow; weight, medium; form, clusters of scaly aggregates. Fluoresces a vivid yellow-green.

Tyuyamunite. Properties: color, yellow to green; luster, waxy; cleavage, perfect; hardness, 2; streak, none; weight, medium; form, massive scales, radial aggregates.

Uraninite. Properties: color, brown to black; luster, sub-metallic to greasy to dull; fracture, uneven to conchoidal; hardness, 5 to 6; streak, brownish, black or grayish; weight, heavy; form, cubes, eight-sided crystals, massive.

Uranophane. Properties: color, yellow to orange-yellow; luster, pearly to greasy; hardness, 2 to 3; streak, pale yellow or orange-yellow; weight, medium; form, massive to finely fibrous.

Uranium deposits in Wyoming are known to occur in rocks of Precambrian age and in at least 33 different rock formations ranging in age from Cambrian to Pliocene. Most of the current production comes from the sandstones of the Eocene Wind River formation of the Gas Hills area, Fremont and Natrona Counties, and the Shirley Basin area of Carbon County. Additional production comes from the Fall River and Lakota sandstones (Lower Cretaceous age) in the Black Hills area of Crook County, the Wasatch formation (Eocene age) in Campbell, Converse, and Johnson Counties, and the Browns Park formation (Miocene ? age) in Carbon County.

Additional uranium prospects are located in the Little Mountain area (formerly a producing area), Big Horn County; Red Desert and Lost Creek areas of Sweetwater County; Pedro Mountains, Shirley Mountains-Freezout Hills areas, Carbon County; Esterbrook area, Albany County; Lance Creek and Lusk areas, Niobrara County; and the Sunlight Basin area, Park County. Radioactive dinosaur bones are not uncommon and have been found in Albany, Big Horn, Carbon, and Teton Counties. There are many other uranium prospects in the State, and with increased exploration, it is not unlikely that additional deposits will be found.

At the present time (1965), the production of uranium is one of the largest mining industries in the State. Wyoming is considered to have the second largest uranium reserves in the United States; New Mexico ranks first. There are five uranium mills operating in the State; three are located in Fremont County, one in Natrona County, and one in Carbon County. Most of the uranium mined today is used in the production of atomic energy materials for military purposes.

Other uses include such things as nuclear power plants for the generation of electricity, atomic powered ships, submarines, and possibly railroad locomotives, medicinal uses, etc.

Vanadium

The vanadium-bearing phosphate rocks are the potential sources of vanadium in Wyoming. The principal reserves are in the Phosphoria formation which crops out in Lincoln County; however, no discrete vanadium minerals have been reported identified. The U.S. Bureau of Mines has estimated that over 20,000,000 tons of rock averaging 0.9 to 1.0 percent vanadium pentoxide are present in this locality.

Most of the vanadium produced is used in vanadium steel alloys. Some production of vanadium has been reported from Wyoming; however, this has been recorded as a by-product of uranium production from the Powder River Basin area.

Vermiculite

Properties: color, yellow to brown; luster, pearly to sub-metallic; cleavage, perfect; hardness 1½; weight, medium- light.

Vermiculite, a magnesium-aluminum-iron silicate, is a soft, pliable, and micaceous mineral that varies greatly in color, composition and general appearance. When heated, the volume of the mineral will expand as much as thirty times. Since the mineral is fireproof and lightweight, it is well-suited for insulating purposes. It is also used for concrete and plaster aggregate, in horticultural work, refractory bricks, and as lubricants and fillers.

Some vermiculite has been intermittently produced in Wyoming from 1935 to the present time. The Wyoming vermiculite deposits are found in Precambrian rocks in parts of Albany, Carbon, Converse, Fremont, Natrona, Platte, and Sheridan Counties.

Zircon

Properties: color, variable, but usually brown or reddish-brown; luster, vitreous; hardness 7½, weight, medium-heavy; form, pointed prismatic crystals.

Zircon is a common accessory mineral in igneous rocks, such as granite and pegmatites. It also occurs as a detrital mineral in river and beach sands as well as sandstones.

Zircon crystals that are slightly radioactive and fluoresce a yellowish-orange (under the short wave ultra-violet lamp) occur in some of the titanium-bearing black sandstone beds of the Mesaverde formation (see magnetite).

Zircon is the principal source of zirconium and hafnium, used mainly in the electronics industry.

ROCKS

Introduction

A rock may be defined as an aggregate of minerals or organic materials that composes a portion of the earth's crust. Rocks may be placed in two general catagories, such as bedrock (consolidated material) and alluvial or surficial material (loose or unconsolidated material). Bedrock includes igneous, sedimentary, and metamorphic rocks. Alluvial material, which includes soils, streams, wind, lake, and glacial deposits, can consist of many minerals and rock types which were derived by the weathering and erosion of bedrock.

IGNEOUS ROCKS

Igneous rocks are those that have been formed by the solidification of molten earth material known as magma. There are two types; intrusive (Fig. 5), a type that has penetrated other rocks; and extrusive (Fig. 6), rocks that have, in a molten stage, flowed over other rocks and then solidified. Pyroclastic rocks are a variety of extrusive types that have been explosively ejected from a volcano or volcanic vent (Fig. 7).

Igneous rocks, which make about 90 percent of the total volume of the earth's crust, are believed to represent the original rock type in the formation of the earth. These rocks are classified on the basis of texture and mineral composition (Table 3).

Texture refers to the size and arrangement of the individual minerals contained in the rock. To a large extent, the texture reflects the cooling history of the molten rock. Ideally, if the rock cools slowly, large mineral crystals will develop, and the rock will have a coarse-grained texture. On the other hand, if the rock cooled quickly, small, speck-like crystals develop and the rock will have a fine-grained texture. Very rapid cooling often produces a glass such as obsidian. Very often, however, the rock cools slowly and develops some large crystals, and then flows near, or out on, the surface and quickly cools the remainder of the molten mass into fine-grained material. In this case, and if the rock is composed of about 50 percent or more large crystals (called phenocrysts) embedded in a fine-grained groundmass, then it is classified as a porphyry, i. e., andesite porphyry (Fig. 8).

Mineral composition is equally important in the classification of igneous rocks, since the minerals represent the composition, or part of

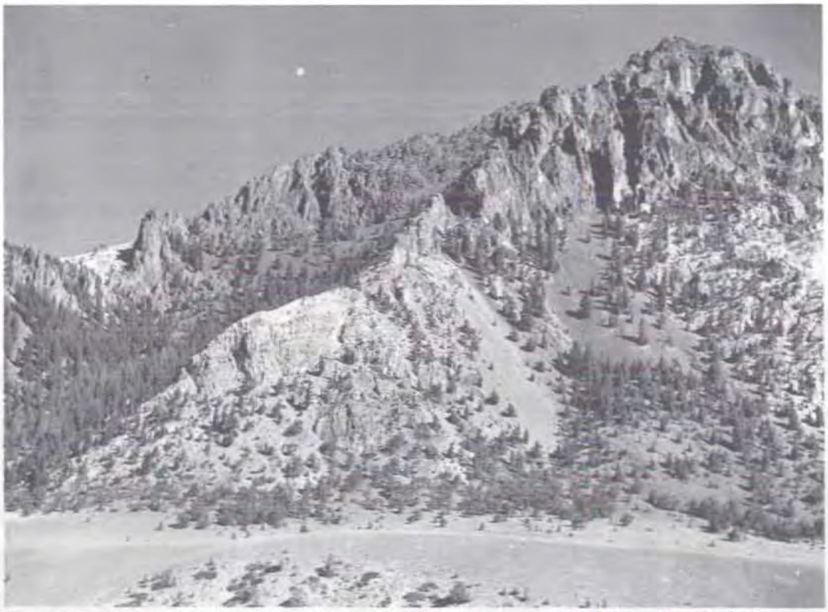


Figure 5. Volcanic plug (neck) at White Mountain, Sunlight Basin, Park County. Diorite and gabbro intrude metamorphosed upper Paleozoic limestones (light gray).

Figure 6. Tertiary vertically jointed basalt flows resting on valcanic sediments in the Greybull River area, Park County.

Figure 7. Pilot (left) and Index Peaks near Clarks Fork River, northwestern Park County. These peaks are eroded from the pyroclastic rocks of the Early Basic Breccia formation.

Figure 8. Andesite porphyry.

the composition of the parent magma. An "average" igneous rock would contain the following approximate mineral assemblage.

Mineral	Percentage
Feldspars	60
Quartz	13
Amphibole &/ or pyroxene	18
Biotite mica	4
Accessory minerals (usually less than 2% each)	5
Total	100 percent

As can be seen from the above list, the most important single step in the classification of the igneous rocks is the distinction between orthoclase and plagioclase feldspar. The criterion here is the presence or absence of repeated twinning stria (see Fig. 3). A good quality hand lens is very useful in making this distinction.

IGNEOUS ROCKS

Andesite-Dacite

Andesites (Fig. 8) are usually gray-to green-colored igneous rocks which are mottled by light and dark colored minerals. Major mineral components include plagioclase and orthoclase feldspar, amphibole (such as hornblende), pyroxene (such as augite) and biotite mica. Quartz may occur in varying amounts, but if it is present in more than five percent, the rock is called a dacite.

Andesites and dacites occur as both intrusive and extrusive bodies as a result of molten igneous rock intruding a fracture in the earth and/or flowing out on the ground and then cooling and solidifying.

Andesite and dacite flows, dikes, and small intrusive bodies of varying shapes are common in the Absaroka Mountains of northwest Wyoming.

Anorthosite

Anorthosite (Fig. 9) is a gray, usually coarse-grained plutonic igneous rock composed almost entirely of the plagioclase feldspar labradorite (a calcium-sodium-aluminum silicate). Varying amounts, or varying-sized bodies, of titaniferous-magnetite often occur associated with anorthosite.

The anorthosite mass, in Wyoming, covers most of Township 16 to 21 N., Ranges 71 and 72 W., in the Laramie Range, Albany County. The rock crops out in an area about 36 miles long and 10 to 18 miles wide. A good gravel road leads northeast from Laramie, via Rogers Canyon, to the Monolith Portland Midwest quarry in sec. 2, T. 16 N., R. 72 W., where good specimens may be obtained.

Anorthosite is a possible source of alumina, the ore of aluminum.

Table 3.—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, pyroxene.		*Dark Colored.* Plagioclase feldspar pyroxene, amphibole, olivine.
	With quartz	No quartz	With quartz	No quartz	
Very coarse-grained	Pegmatite				
Coarse-to medium-grained	Granite	Syenite Phonolite (1)	Granodiorite Quartz diorite	Diorite	Gabbro Pyroxenite (pyroxene only) Peridotite
Fine-grained (2)	Rhyolite	Trachyte	Dacite	Andesite	Basalt
Porous	Pumice		Pumice		Scoria
Glassy	Obsidian				
Fragmental or broken	Fine-grained; ash or tuff Coarse-grained; breccia or agglomerate				

Note:

(1) contains a soda-rich orthoclase and pyroxene.

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

Basalt-Diabase

Basalt is a very dark colored, heavy, fine-grained extrusive (occasionally intrusive) igneous rock that is composed primarily of plagioclase feldspar, pyroxene, and with or without olivine. Absarokite is a special variety of basalt that received its name from the Absaroka Mountains in Wyoming. It differs from the normal basalt in that it contains a special variety of orthoclase feldspar (unidentifiable in hand specimen).

Diabase is a fine-grained rock of basaltic composition; however, it has certain textural features which can usually, or only be observed with a petragraphic microscope. Many of the dark-colored dikes intruding the Precambrian crystalline rocks of the State are diabase. A unique diabase dike (Fig. 10), locally called "leopard rock," crops out in the Tongue River area, west of Dayton, in the Bighorn Mountains. Leopard rock is composed of a dark fine-grained groundmass "spotted" with large white crystals and aggregates of plagioclase feldspar up to eight inches in length.

Basalt flows are found in Yellowstone National Park, and in central and northern part of the Absaroka Mountains of northwest Wyoming. They crop out as well-joined vertical cliffs, several hundreds of feet high (Fig 6).

Gabbro

Gabbro is usually a medium gray coarse-grained plutonic igneous rock that is composed primarily of plagioclase feldspar (usually labradorite) and pyroxene. Pyroxenite and peridotite have similar textures, but are darker colored and of somewhat different mineral composition.

Small intrusive bodies of gabbro occur near and with the copper deposits of the Sierra Madre Mountains in Carbon County. Other gabbroic rocks occur in the northern part of the Bighorn Mountains, northern part of the Absaroka Mountains (Fig. 5), the Medicine Bow Mountains, and the Wind River Mountains.

Granite-Granodiorite

Granites, quartz monzonites, and granodiorites are the most abundant types of plutonic igneous rocks.

Granite (Fig. 11) is usually a light gray (some are reddish) medium- to coarse-grained rock composed principally of orthoclase feldspar and quartz. Dark minerals present may include, biotite and/or amphibole and occasionally pyroxene. Small amounts of plagioclase feldspar and muscovite may be present too.

Granodiorites are similar in appearance to granites; except that there is twice as much plagioclase feldspar as orthoclase and usually more dark minerals, such as biotite, amphibole and/or pyroxene. Quartz monzonite is a rock that is classified between granite and granodiorite. Quartz dio-

Figure 9. Anorthosite.

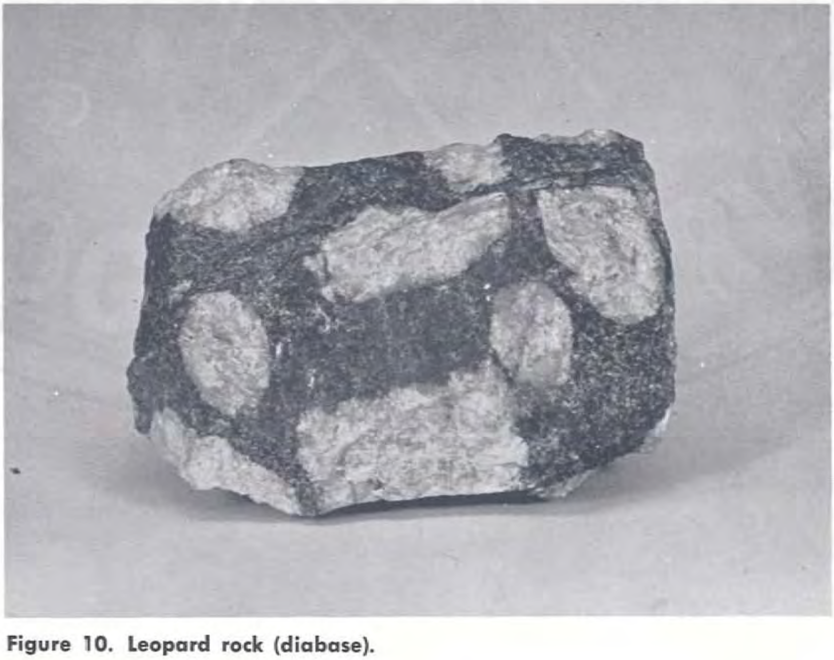


Figure 10. Leopard rock (diabase).

rite, on the other hand, is similar to granodiorite, except that less orthoclase is present. This distinction is not readily apparent to the naked eye.

Granites and granodiorites commonly occur as large intrusive bodies in all of the Precambrian mountain cores in Wyoming. The Sherman granite, which is reddish in color, is a conspicuous body of rock cropping out in the Laramie Range of Albany and Laramie Counties. In the Vedauwoo area, north of U. S. Interstate Highway 80, the Sherman granite weathers into "hoodoo"-like forms. Other smaller bodies of granites, granodiorites, etc., occur intruding the Tertiary volcanic rocks of the Absaroka Mountains of northwest Wyoming.

Granite is used as a building and ornamental stone, and in concrete aggregate. It is quarried at the town of Granite, near U.S. Interstate 80 in southeastern Wyoming, for use as railroad ballast.

Obsidian

Obsidian is usually a black-colored compact volcanic glass that shows a curved (conchoidal) fracture (Fig. 12). Some specimens are red, green, brown, or various shades of gray. Bubble-like cavities, called lithophysae, are often present, and these often contain small crystals of quartz, feldspar, topaz, zircon, tourmaline, etc. Radiating rosettes, called spherulites, composed of minute crystals of feldspar and quartz also occur in obsidians.

Obsidian is abundant in Yellowstone National Park. The most famous locality here is Obsidian Cliff which is located in the northwest part of the Park. Obsidian Cliff, which is about 200 feet high, represents part of a rhyolitic obsidian flow that has an area of about four and one-half square miles. Other fragments of obsidian occur sporadically in the Wiggins and Late Basic Breccia formations in the Absaroka Mountains of northwest Wyoming.

Pegmatite

Pegmatites (Fig. 13), are light colored very coarse-grained granitic rocks. The most common type is a "simple" pegmatite that is composed of quartz, feldspar, and muscovite or biotite mica. Complex pegmatites, which are relatively rare, contain such minerals as tourmaline, beryl, lepidolite, spodumene, columbite-tantalite, monazite, rare earth and uranium minerals in addition to the minerals found in the simple types.

Simple pegmatite dikes are common in all of the Precambrian mountain areas of the State. Complex pegmatites are known to occur in Precambrian rocks cropping out in the Haystack Range of Goshen County, the Medicine Bow Range of Albany and Carbon Counties, the Bighorn Range of Natrona and Johnson counties, and the Copper Mountain area of Fremont County.

Figure 11. Granite-granodiorite.

Figure 12. Obsidian.

Phonolite

Phonolites are fine-to coarse-grained igneous rocks that are similar in appearance to syenites. Actually, these are relatively rare rocks that are difficult to recognize in the field, since, they have certain characteristics that can be observed only under the petrographic microscope.

Devils Tower (cover photograph), in Crook County, of northeast Wyoming is composed of phonolite porphyry, and is believed to represent either the core of an eroded laccolith or small intrusive plug-like body. Devils Tower is a columnar jointed mass of light gray to brownish gray rock that is about 600 feet high and about 800 feet in diameter at the base. Fresh specimens from Devils Tower have a light-to dark-gray to greenish-gray very fine-grained groundmass which enclose phenocrysts (individual crystals) of white feldspar up to one-half inch in length and smaller dark green crystals of pyroxene.

Other phonolites are known to occur in the Missouri and Black Buttes, Nigger Hill, and Bearlodge Mountains, of northeast Wyoming; in the Rattlesnake Mountains of western Natrona County; and in the Leucite Hills of north-central Sweetwater County.

Pumice-Pumicite

Pumice is a whitish or light gray very cellular or frothy pyroclastic igneous rock composed mainly of volcanic glass. Since it is very light, it will usually float on water. The term pumice is applied to rock fragments greater than four millimeters in diameter to avoid confusion with the term pumicite. Pumicite is actually volcanic ash, and, this term is applied to uncemented or loosely cemented volcanic glass debris composed of fragments of less than four millimeters in diameter.

Pumice occurs in the Leucite Hills of northcentral Sweetwater County. Pumicite deposits occur in Miocene rocks of the Split Rock area of Fremont and Natrona Counties; Pliocene rocks of the Jackson Hole area, Teton County; and in beds of unknown age near Creston Junction, eastern Sweetwater County. Pumice fragments enclosed within a pumicite matrix occur in two deposits northeast of Kane, Big Horn County.

Rhyolite-Welded Tuff

Rhyolites are usually light-colored fine-grained igneous rocks. Often these contain visible crystals (phenocrysts) of quartz, feldspar, and some dark minerals such as biotite mica and/or amphibole. On the other hand, they may be so fine-grained that it is difficult to distinguish them from welded tuffs or even dacites. If this is the case, then the term felsite is more conveniently used. In any event, the presence of quartz and orthoclase feldspar is a good sign of rhyolitic composition.

Welded tuffs are very fine-grained volcanic rocks composed chiefly of rhyolitic glass fragments that have been welded together by internal heat and gas.

Rhyolites of Tertiary age occur as plugs, dikes, domes, and flows in Yellowstone National Park and the southern part of the Absaroka Mountains of northwest Wyoming. Late Tertiary welded tuffs are known to crop out in Yellowstone National Park and the Jackson Hole area of northwest Wyoming.

Syenite-Trachyte

Syenite is usually a light colored medium-to coarse-grained intrusive igneous rock similar to granite, except that no visible quartz is present. Trachyte is a fine-grained or porphyritic extrusive igneous rock equivalent of syenite. Essential minerals in both types include orthoclase feldspar and biotite mica and/or amphibole. Some plagioclase feldspar is also present.

Syenites occur as small to medium-sized Tertiary intrusive bodies in the northern Absaroka Mountains of northwest Wyoming, and in the Black Hills area of northeast Wyoming. An interesting black-colored coarse-grained syenite of Precambrian age crops out in the Laramie Range of Albany County, along State Highway 34. This rock contains a variety of orthoclase feldspar, called microcline, and some hypersthene (pyroxene mineral).

Volcanic Ash-Tuff

Volcanic ash is composed of uncemented pyroclastic igneous fragments less than four millimeters in diameter. The term tuff is applied to those ash fragments which are indurated or cemented together. Some tuffs or ashes may have been deposited in water, or may have been transported and redeposited by water. In the latter case, these deposits would then be considered sedimentary rocks even though they were initially products of volcanic action.

Most ashes and tuffs that occur in Wyoming are white or very light gray in color. These occur in Tertiary rocks in various parts of the State. Certain types of tuffs are useful as pozzolans in the manufacture of concrete, as building stones, and as light-weight aggregate.

Volcanic Breccia

Volcanic breccias (Fig. 14), which occur as either intrusive or extrusive igneous rocks, are composed of angular rock fragments (usually igneous) of at least one and one-fourth inches in diameter enclosed within a matrix of tuff (or fine-grained igneous rock). The term agglomerate is often used for similar rock types; however, the fragments should be more rounded than angular, and the deposit itself should be situated close to a known volcanic vent.

Volcanic breccias and agglomerates are common in the Absaroka Mountains and Yellowstone National Park of Northwestern Wyoming.

Figure 13. Pegmatite with beryl crystal (a).

Figure 14. Volcanic breccia. The one inch (1") line denotes the relative size of the fragments.

Wyomingite

The term wyomingite is applied to a yellowish-tan to dark gray fine-grained vesicular and cavity-filled extrusive igneous rock that crops out in the Leucite Hills of Sweetwater County. Since the rock is composed of the minerals leucite, phlogopite mica, and pyroxene, it can be considered a variety of phonolite.

Wyomingite and other associated rocks of the Leucite Hills area are potential sources of potash.

SEDIMENTARY ROCKS

Sedimentary rocks are the most abundant rock types that crop out on the surface of the earth. Their chief characteristic is the layered, or bedded, appearance (Fig. 15). There are three groups of sedimentary rocks.

1. *Detrital:* rocks which are composed of fragments that have weathered from other rocks and transported by wind or water and deposited in layers. These detrital sediments form consolidated rock by the process of compaction and cementation. Compaction is accomplished by the weight of additional sedimentary material being deposited on top of the earlier sediments. Water, containing silica, calcium carbonate, or iron oxide, circulates through the pore spaces between the detrital grains and eventually crystallizes to cement these materials into hard consolidated sedimentary rocks. Examples of detrital rocks are: sandstone, shale, conglomerate, and some limestones.

2. *Chemical precipitates:* rocks composed of material that has been precipitated and deposited from solutions and then hardens. An example of this, is limestone. Rock salt and gypsum are examples of rocks that have been formed as a result of evaporation from certain solutions.

3. *Organic rocks:* material that has been secreted or deposited by animals or plants or composed of animals or plant remains that has hardened into rock. Examples of these include coal and some limestones.

Sedimentary rocks often contain fossils, which are the petrified remains of animals and plants that have lived and died during the time that these rocks were deposited. Many of the sedimentary rocks in Wyoming are highly fossiliferous, and the evolution of these forms have provided many of the data that have enabled geologists to unravel the geological history of the State. In addition to fossils, such features as ripple marks, cross-bedding, and rain drop prints, are often observed in sedimentary rocks. A very spectacular type of cross-bedding, called "festoon" cross-lamination occurs in three dimensional form in the Casper formation of Pennsylvanian age in the Red Buttes and Sand Creek areas of Albany County (Fig. 16). These outcrops occur about eight miles south, and about 18 miles southwest of Laramie, respectively.

Loosely consolidated sedimentary rocks of varying resistance to weathering often erode into unusual and spectacular forms. An example of this may be seen at Hell's Half-Acre (Fig. 17), located just south of U.S. Highway 20, about 45 miles west of the town of Casper, Natrona County.

The classification of sedimentary rocks (Table 4) is based on grain size and chief mineral content. It should be remembered that this classification is relative, since many of these rocks grade into one another.

Figure 15. Steeply dipping and folded sedimentary rocks of the Lower Cretaceous Bear River formation exposed south of Evanston, Uinta County.

Figure 16. Festoon cross-bedding in the Pennsylvanian Casper formation at Sand Creek, southwest of Laramie, Albany County.

Table 4.—Simplified Classification of Sedimentary Rocks

Texture or Grain Size	Chief Mineral	Cement (matrix)	Rock Name
1/16 inch or greater in a groundmass of 1/16 inch or less.	Fragments can be any mineral or rock type.	Silica, calcite, clay, iron oxide, etc.	Breccia (angular fragments) Conglomerate (rounded fragments)
1/16 inch or less	Quartz	Silica, calcite, iron oxide, etc.	Sandstone
	Calcite	Calcite	Limestone
	Dolomite	Dolomite	Dolomite
Dense (can not be seen with naked eye).	Gypsum	Gypsum	Gypsum
	Clay	Clay	Shale
	Quartz or silica	Quartz or silica	Chert

SEDIMENTARY ROCKS

Bentonite

Bentonite is a name applied to a light gray sedimentary rock that contains at least 75 percent of the clay minerals beidellite or montmorillonite. The uses of bentonite depend upon its swelling capacity. One with high colloid content may absorb large quantities of water and swell to many times its original volume. The high-swelling types are used as drilling muds in oil wells, as binders for foundry sands, as fillers for coffer dams, and reservoir linings. The non-swelling types may be used for insecticide fillers and industrial filters. Much of Wyoming bentonite is lately being used in the agglomerating concentration of taconite iron deposits.

The beds of bentonite in Wyoming are the result of alteration of volcanic ash which was deposited in a sea that covered the State about 135 million years ago. Most of these beds occur within the Cretaceous Mowry and Frontier formations.

Wyoming is the leading bentonite-producing state and produces about half of the nation's output. Most of the bentonite is produced in Big Horn, Crook, Johnson, Natrona, Washakie, and Weston counties.

Chert

Chert is a very dense, hard, siliceous rock that commonly occurs with limestone as nodular or concretionary masses or as distinct beds. Chert appears in many colors, but the various shades of gray are the most common. Conchoidal fracture is characteristic of chert.

Chert is common in many of the Paleozoic rocks of Wyoming; particularly in the Mississippian Madison limestone and the Permian Phosphoria formation.

Coal

Coal is a rock that has been deposited under water by the decay and accumulation of vegetable matter. Later the rock consolidated into peat. The process of coalification, or the changing of peat to lignite, lignite to bituminous coal, or bituminous to anthracite coal, is a complex biochemical and physieo-chemical process.

Coal is composed of many chemical substances, but the most important from the standpoint of heating value are hydrogen, volatile hydrocarbons, and fixed carbon.

The known coal reserves in Wyoming are estimated to be 121,553,850,000 short tons, of which 13,234,950,000 is bituminous coal and 108,318,900,000 tons is sub-bituminous coal. Of the 40,055 square miles of known or probable coal-bearing land in Wyoming, 21,413 square miles or 53.46 percent, had to be ommitted in the estimate of reserves.

When this area is prospected and mapped, it is certain that additional coal will be discovered and the coal reserves of the State will be increased accordingly.

The total reported production of coal in Wyoming, up until 1960, has been 403,630,000 tons. Almost 90 percent of Wyoming's coal has been produced from the areas centering around Gillette, Hanna, Kemmerer, Rock Springs, and Sheridan.

Figure 17. Erosional forms exposed in the Eocene Wind River formation at Hell's Half-Acre, Natrona County.

Figure 18. Geode.

The coal-bearing rocks in Wyoming range in age from Lower Cretaceous to Eocene. These rocks were deposited about 50 to 135 million years ago. Most of the coal is found in the Mesaverde and equivalent formations of Upper Cretaceous age, the Fort Union formation of Paleocene age, and the Wasatch formation of Eocene age.

Wyoming coal is almost entirely sub-bituminous in rank, but ranges from lignite to high volatile A bituminous.

Concretion-Geode

Concretions are usually rounded or nodular concentrations of mineral matter enclosed in a sedimentary rock such as sandstone or limestone. These range in size from a fraction of an inch to many feet in diameter. The mineral matter contained within is usually some minor constituent of the rock, such as, chert, calcite, iron oxide, or a fossil.

A geode (Fig. 18) is outwardly similar to a concretion except that the interior is hollow and often lined with inwardly pointing crystals (usually quartz or calcite). Concretion and geodes are common in many of the sedimentary rocks in the State.

Conglomerate

Conglomerate (Fig. 19) is a cemented sedimentary rock containing rounded fragments of pebble size or larger. The matrix may be silica or clayey material, while the fragments can be of any rock type. The term volcanic conglomerate is applied to those rocks which contain volcanic rock fragments enclosed within a matrix of similar material.

Beds of conglomerate can be found in many of the sedimentary formations that crop out in the State. Volcanic conglomerates (Fig. 20) are common in the Tertiary rocks of the southern part of the Absaroka Mountains of northwest Wyoming.

Gypsum

Gypsum is a light-colored soft rock that is composed of calcium sulphate and water. It occurs in several forms: white massive rock gypsum; earthy gypsite; alabaster (fine-grained massive marble-like form); selenite (crystalline gypsum); and satinspar (a fibrous variety with silky luster). Anhydrite a calcium sulphate, is similar to gypsum, but contains no water.

The commerical gypsum beds in Wyoming lie mainly in the Permian, Triassic, and Jurassic redbeds which were deposited in ancient seas and saline lakes approximately 100-200 millon years ago. The gypsum in Wyoming is very pure and contains little salt.

Gypsum is used as a fertilizer or soil conditioner, as filler for paper textiles, and as a retarder in the manufacture of Portland cement. Calcined gypsum is used for molding, casting, pottery, dental plasters, plaster board, plaster tiles, blocks, etc. Small quarries operating intermittently in Wyoming since 1890 have produced enough gypsum to supply local demand. Gypsum board plants are located at Cody, and near Lovell.

Limestone-Dolomite

Limestone is a sedimentary rock composed mainly of calcium carbonate. It effervesces (bubbles) freely upon application of dilute hydrochloric or other common acid. Since impurities are often present, the color of limestones varies from yellowish to black. Various shades of gray, however, are the most common colors. Textures vary from fine-grained to coarsely crystalline.

Dolomite is similar to limestone, except, that it contains a varying percentage of magnesium. A useful field test for dolomite is to scratch the rock with a prospector's pick or knife and then apply dilute hydrochloric acid. If only the scratch on the rock effervesces, then it probably is dolomite.

There is every gradation between limestone and dolomite. Further, limestones may grade into sandstones and shale by an increase in the amount of sand or shale, respectively. Limestone is a very durable rock in an arid climate such as exists in Wyoming. Because of this, limestones crop out as hogback ridges and spectacular erosional scarps or cliffs. Solution cavities are not uncommon, and, when these are interconnected, a complex network of caves may be developed. Spirit Mountain Cavern, located west of Cody, along the Yellowstone Highway, is an example of solution cavities which occur in the Mississippian Madison limestone formation.

High purity limestone is used in the manufacture of cement and also in sugar refining. Other uses for limestone and/or dolomite include building stone, crushed rock, aggregate, flux, soil fertilizers, paint fillers, and in the manufacture of glass. Limestone and to a lesser extent, dolomite are abundant in Wyoming. These rocks range in age from Cambrian to Tertiary.

Oil Shale

Oil shale is intimately mingled organic and inorganic matter that yields petroleum by destructive distillation (heating). The color varies from black to brown to various shades of gray. Many oil shale beds are thinly laminated. A useful field test is the application of lighted match or torch to see if the material will burn.

Beds of oil shale occur extensively in the Green River formation of Eocene age. This formation, which crops out in southwestern Wyoming, represents a tremendous potential petroleum reserve. Selected analyses of oil shale in the Green River formation are reported to yield a maximum of almost 60 gallons of oil per ton of rock.

Figure 19. Conglomerate.

Figure 20. Layered volcanic conglomerates and light gray tuffs of the Oligocene Wiggins formation cropping out in the Absaroka Mountains, Park County.

Other oil shale beds are reported to occur in the Wasatch formation of southwestern Wyoming, and other Eocene age beds on Lysite Mountain, northern Wind River Basin; in the Bighorn Basin; and in the Jackson Hole area.

Phosphate Rock

Phosphate rock occurs in a variety of physical forms ranging from hard to soft rock. The colors vary from black to brown to shades of gray. The principal mineral in phosphate rock is collophane, a chemical combination of calcium, phosphorus, fluorine, and carbon dioxide. Phosphate rock in Wyoming occurs in the shale and chert beds of the Permian Phosphoria formation. Small amounts of vanadium and other elements also occur in these phosphatic shales. These rocks were deposited in an ancient sea that covered central and western Wyoming approximately 250 million years ago.

The most important use of phosphate rock is in the manufacture of fertilizer for phosphorus-poor soils. A small amount is used in the manufacture of elemental phosphorus, which, in turn, is used in ceramics, beverages, photography, incendiary bombs, smoke screens, etc.

At present there is only one producing phosphate mine in Wyoming. This is located 25 miles west of Kemmerer, at Leefe. There are, however, large deposits of phosphate rock in Fremont, Lincoln, Sublette, and Teton counties, and it is possible that new mines will open up in some of these localities in the future.

Pumicite (see Pumice)

Sandstone

Sandstone (Fig. 21) is a consolidated rock composed predominantly of quartz grains cemented (bound) together by silica, calcium carbonate, or iron oxide. Feldspar and other minerals also occur in sandstone. Textural variations are common, since, coarser sandstones grade into conglomerates and finer-grained sandstone grade into shales. The term volcanic sandstone is applied to those rocks containing an abundance of water-worn grains of volcanic rock.

Sandstone is abundant in Wyoming and occurs in rocks ranging in age from Cambrian to Quaternary. Volcanic sandstones are common in the Tertiary rocks of the Absaroka Mountains of northwest Wyoming. A limy sandstone (sandstone containing a calcite cement) quarried in the Casper formation of Pennsylvanian-Permian age near Laramie, has been used in all of the major buildings constructed on the campus of the University of Wyoming since 1925. Some sandstones of early Tertiary age (such as those in the Wind River formation), are host rocks for the more important economic uranium ore deposits in Wyoming. Pure quartz sandstones are used extensively as sources of silica for the manufacture of glass and industrial chemicals.

Shale

Shale is considered to be the most abundant of the three common varieties (shale, sandstone, limestone) of sedimentary rocks. Shale is an extremely fine-grained laminated rock composed predominantly of silica. Alumina and, to a lesser extent, iron are also important constituents. Colors vary, with shades of red, brown, gray, and green, being the most common.

The most spectacular shales in Wyoming are the "redbeds" of the Triassic Chugwater and Spearfish formations. Elsewhere, shales of other colors commonly crop out as rocks ranging in age from Cambrian to Tertiary. Shales in Wyoming, are used as sources of clay for the manufacture of cement, lightweight aggregate, brick, tile, and pipe.

Taconite

In a general sense, taconite is considered to be an iron-bearing siliceous rock. Varying amounts of magnetite, hematite, and quartz are usually present. These rocks are usually heavier than the average rock type and will usually attract a hand magnet because of the amount of magnetite contained in them. They are usually finely laminated, and the color varies in shades of gray. Fracture surfaces or laminations may be stained or coated with a brownish or reddish iron oxide.

Although taconites were deposited as, and are considered here as, sedimentary iron deposits, they are actually low-grade metamorphic rocks of Precambrian age. This distinction is too involved to explain in a publication of this nature, hence the sedimentary classification is used here.

Taconite is an important source of iron ore in the United States. The Columbia-Geneva Steel Division of the U.S. Steel Corporation, mines a large taconite deposit which is located in the southern part of the Wind River Mountains, north of Atlantic City in Fremont County. This operation, 8,800 feet above sea level, is the highest large-scale open pit iron mine in the United States. Other undeveloped taconite or taconite-like deposits occur in the Precambrian rocks of the Copper Mountain area of northeastern Fremont County and the Seminoe Mountain area of northwest Carbon County.

Trona

Trona is a relatively soft yellowish-brown to gray rock (or mineral) of alkaline taste. In a general way, it is a mixture of washing soda and baking soda; however, technically, it is known as sodium sesquicarbonate.

Trona occurs predominantly as a compact and massive rock with shale inclusions in beds up to 40 feet in thickness. Specimens of striated crystalline trona (Fig. 22) however, are not uncommon in Wyoming. The trona beds, which are among the largest if not the largest deposits in the world, occur in the Eocene Green River formation of southwestern Wyoming. None of the trona beds is known to outcrop. They are currently being mined at depths ranging between 700 to 1,500 feet by the Stauffer and Intermountain Chemical Companies at mines located west of the town of Green River. It is not unlikely that other trona mines will be developed in this area in the future.

Trona is calcined to produce soda ash. Large amounts of soda ash are used in the glass, chemical, soap, paper, petroleum, and textile industries.

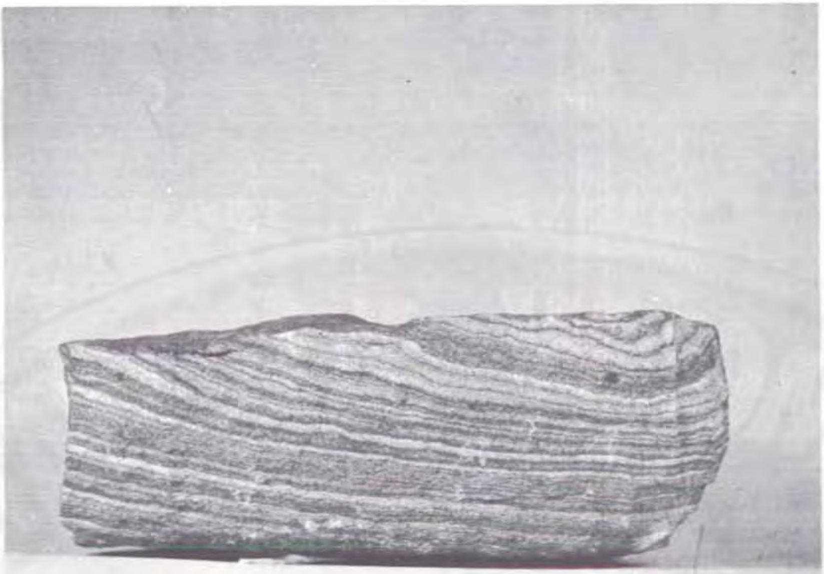


Figure 21. Sandstone.

Figure 22. Crystalline trona from Westvaco, Sweetwater County.

PETRIFIED WOOD

Petrified wood is organic material that has been converted to stone. In this case, the wood is replaced by silica (occasionally calcium carbonate) in such a manner that the original structure and form of the wood is retained or preserved. The silica is usually chalcedony or opal.

Petrified forests in Wyoming occur in the following areas: in the Wind River formation of Eocene age, about 35 miles north of Medicine Bow, near the old Casper road; in the Wiggins formation of Oligocene age (Fig. 23), near the head of Frontier Creek in the Absaroka Mountains; and in the Early Basic Breccia of Eocene age, in the Specimen Ridge and Amethyst Mt. area of Yellowstone National Park. Very fine petrified wood is found northeast of Eden, Sweetwater County. This wood weathers out of the Bridger and Green River formations of Eocene age. Many of the areas listed under agate also contain petrified wood fragments.

METAMORPHIC ROCKS

Metamorphic rocks are formed from other rocks, such as igneous or sedimentary, and later changed by solutions, heat, and pressure (or all three) into a rock that may have a different appearance or composition from the original rock. The processes of metamorphism are usually very complex, and because of this there are many types and varieties of metamorphic rocks. Further, since these metamorphic changes are not uniform, the rock may grade into the original rock, or into one that is entirely different.

The classification of metamorphic rocks (Table 5) is based primairly on texture; to a lesser extent on mineral composition. The textures are of two main types, foliated and non-foliated. Foliation refers to the banding, layering, or lamination of metamorphic rocks. Mineral grains often lie within these rocks so that their long direction is parallel to the foliation. Foliation, at times, also implies the facility with which the rock will split along, or parallel to, the layers or bands. The non-foliated rocks have a variety of textural classifications; some of which are similar to igneous rocks because of their granular appearance owing to the network of interlocking mineral grains. Finally some rocks have textures which suggest a faint banding. Since many of the Precambrian granitic bodies in the mountains of Wyoming illustrate this feature, these can be classified as gneissic granite.

Table 5.—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, etc.	Gneiss	Granite, rhyolite, shale, etc.
Thinly foliated	Feldspar, mica, amphibole, quartz, etc.	Schist	Andesite, basalt, rhyolite, shale, etc.
Very thinly foliated	Mica, quartz, clay, (these minerals normally can not be seen with the naked eye)	Slate (1)	Shale

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

METAMORPHIC ROCKS

Gneiss

Gneiss (pronounced "nice") is a metamorphic rock that is usually coarsely layered with layers of light and dark minerals (Fig. 24). The layers may be parallel and continuous or highly contorted and discontinuous. Individual layers may range from a fraction of an inch to several inches in thickness. The lighter colored layers are usually composed of granular minerals, such as quartz and feldspar, while the darker layers are schist-like in appearance and contain such minerals as biotite mica and hornblende.

Gneisses have been formed by the metamorphism of igneous or sedimentary rocks. Many grade into schists. Together, the two rock types form the largest group of metamorphic rocks.

There are many types of gneiss. Granite gneiss or gneissic granite is very common in all of the Precambrian mountain cores of Wyoming.

Marble

Marble is a granular crystalline rock composed of calcite and/or dolomite grains enclosed within a matrix of calcite. Ordinary varieties of marble, which are composed of calcite, will effervesce in dilute hydrochloric acid. Most marbles are white to gray; however, some are mottled and layered in various colors because of the impurities that are present.

Marble is formed by the metamorphism of limestone. Most of the deposits in Wyoming are Precambrian in age; however, some are Paleozoic in age. Individual marble deposits are known in the following areas: west of Jay Em in the Muskrat Canyon area of Goshen County; about 15 miles west of Wheatland, in the Marble Canyon area of Platte County; and in the Medicine Bow Mountains of Albany and Carbon counties. Other marble deposits are reported from the Bighorn Mountains; near Douglas, in Converse County; and from the west flank of the Black Hills in Crook County.

Marble is used principally for building stone and, ornamental purposes.

Quartzite

Quartzite is a granular metamorphic rock that is composed essentially of quartz. Usually, it is light in color, hard, and resistant to erosion. Since quartzite is a metamorphosed sandstone, it may be difficult to tell them apart. A useful field test is to break the rock with a hammer. If the fracture surface thus developed passes through the individual grains. the rock is called quartzite. On the other hand, if the fracture surface extends around the quartz grains, then it is called a sandstone. Some green quartzites are believed to owe their color to the presence of fuchsite (a chromium-bearing mica).

Figure 23. Petrified tree trunk within volcanic conglomerate of the Oligocene Wiggins formation. Exposure is located at the "petrified forest" on Frontier Creek, Fremont County.
Photo by J. D. Love.

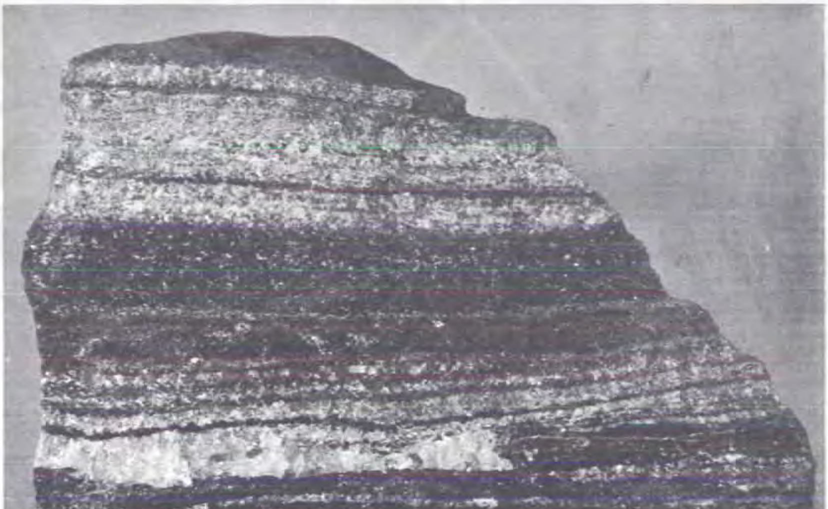


Figure 24. Gneiss.

Precambrian quartzites are known to occur in the Medicine Bow and Sierra Madre Mountains of Albany and Carbon counties. Precambrian quartzite, quarried near Guernsey, Platte County, has been used as crushed rock for railroad ballast. Cambrian quartzite, used as dimension stone, has been quarried from an area north of Rawlins, in Carbon County.

Schist

Schist is a crystalline rock with a finely laminated appearance. It has a tendency to split or break into flakes or slabs along, or parallel to, these laminae. Fine-grained schists grade into slates, and coarser grained schists grade into gneisses. The principal mineral constituents are usually identifiable in hand specimen. Because of this, one may classify the rock as a biotite schist, hornblende schist, etc.

Biotite and hornblende schists are dark colored rock types that occur in all of the Precambrian mountain cores of Wyoming. Less common types present are chlorite, talc, and graphite schists.

Slate

Slate is a fine-grained rock in which no mineral grains can be observed. Most slates are very dark in color; however, shades of red, green, or gray are sometimes observed. Shale and slate posses a type of cleavage in that the rock tends to split into smooth parallel layers or slabs. Surfaces of slate are somewhat shiny or glossy compared with that of shales which are dull in appearance.

Slate is known to occur in the Precambrian rocks of the Medicine Bow Mountains of Albany and Carbon Counties.

METEORITES

Meteorites are believed to represent the remains of another planet similar to that of the earth which either exploded, or was broken up in a celestial collision of great magnitude. Because of their similarity to rocks believed to exist below the crust of the earth, meteorites could be classified as igneous. In one sense, however, they could be classified as sedimentary; since, they were transported here. In any event, there are three main types; iron, stony-iron, and stony meteorites. Iron meteorites, also called siderites, are irregularly rounded, dark brown to black, heavy, and irregularly pitted objects with unusual cavities. They are composed of an iron-nickel alloy and will attract a magnet. If these are sawed and then etched with dilute nitric acid, a crystalline structure (called Widmanstatten figures), usually consisting of bands or lines crossing at angles of 60 degrees, often appears.

The stony-irons, or siderolites, are composed of approximately equal amounts of nickel-iron and silicate (usually olivine). The stony meteorites, or aerolites, can be further subdivided into two groups, chrondites and achrondites, as based on textural differences. The aerolites are usually irregularly rounded with a thin glossy black skin and are composed of olivine and other silicate minerals.

In the absence of observed falls, the actual identification of a meteorite is difficult. In addition to the etch test, described previously, a chemical test for nickel is useful; since, this element is always alloyed with meteoric iron.

Meteorite finds in Wyoming have been reported from the following localities: a highway cut north of Laramie, Albany County; north of Medicine Bow, Carbon County; Willow Creek, northern Natrona County; near Clareton, Weston County; near Hawk Springs, Goshen County; near Albin, Laramie County; Silver Crown area, Laramie County; and near the Bear Lodge Mountains of Crook County.

ACKNOWLEDGEMENTS

Some of the mineral descriptions were taken from the textbooks by Ford, and by Berry and Mason. Professors R. S. Houston and R. B. Parker (Dept. of Geology, Univ. of Wyoming) were kind enough to read the manuscript and offer valuable suggestions.

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GLOSSARY OF GEOLOGICAL TERMS

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

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

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

Brittle.—Easily broken.

Calcination.—The action of heat that makes a substance powdery.

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

Cross-bedding.—An oblique lamination to the main stratification of sedimentary rock layers.

Crystalline.—The term refers to the texture of igneous rocks with respect to the mineral crystals and their arrangement therein; however, in this report, it also refers to Precambrian igneous and metamorphic rocks.

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

Earthy.—Earth-like appearance.

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

Fibrous.—Thread-like appearance.

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

Fold.—A bend in layered rocks.

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

Groundwater table.—A surface or level, below which the rock and subsoil are full of water.

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 masks the true color of that mineral.

Laccolith.—An igneous body that has intruded and domed up layered rocks similar to an inverted saucer between two sheets of paper or plastic. The laccolith, however, usually has a more-or-less horizontal floor.

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

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

Malleable.—Refers to a mineral which is capable of being pounded without breaking.

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

Orogeny.—Period of mountain building movements.

Petrographic.—Refers to the study of rocks and minerals under a special type of microscope. A very thin slice is sawed off the rock and is prepared into what is called a thin section. The thin section is placed under the microscope to observe the texture of the rocks, and to aid in identifying the minerals by their optical characteristics.

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 crystalized beneath the surface of the earth.

Precambrian.—An era of geologic time prior to the Cambrian period in which rocks were so intensely disturbed, metamorphosed, and eroded on such a wide scale that the geologic history of this period is not too well documented.

Prismatic.—Pencil-like or lath-like shape.

Prospect.—Undeveloped mineral deposit.

Pseudomorph.—In this report, it refers to a mineral crystal which has the form of another mineral.

Pyramidal.—Pyramid shape or form.

Redbeds.—A colloquial geological term which refers to the red sedimentary rocks that are seen in the various sections of the world. In Wyoming, it applies to the red sediments of the Permian, Triassic, and Jurassic periods.

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.—The property of a mineral by which it is capable of being cut by a knife.

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

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 to anticline. A fold in rocks in which the rocks on both sides dip towards the middle.

Translucent.—Partly transparent.

Ultra-mafic rock.—An igneous rock composed essentially of iron, magnesium, metalic, and sulfide minerals. Usually dark colored and heavy.

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 at 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.

STATE OF WYOMING

1933

GEOLOGICAL SURVEY