The Geological Survey of Wyoming
Gary B. Glass, State Geologist

Industrial Minerals and Construction Materials of Wyoming

by Ray E. Harris

Reprint No. 50 • 1992

Laramie, Wyoming

Text printed on 50% recycled fiber paper.

Reprint of 400 copies by Pioneer Printing and Stationery Company, Cheyenne, Wyoming.

This and other publications available from: The Geological Survey of Wyoming
Box 3008, University Station
Laramie, Wyoming 82071-3008
(307) 766-2286 • FAX (307) 766-2605

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Originally published in the Wyoming Geological Association, Forty-Second [Annual] Field Conference Guidebook, 1991.

INDUSTRIAL MINERALS AND CONSTRUCTION MATERIALS OF WYOMING

RAY E. HARRIS[1]

ABSTRACT

Industrial minerals and construction materials are relatively low-cost products produced in relatively large amounts. Salt and stone were used by earliest man. Today, every state in the United States and every region of the world produces some industrial minerals and construction materials.

Industrial minerals and construction materials produced in Wyoming include aggregate (including railroad ballast), bentonite, common clay, decorative stone, feldspar, gypsum, leonardite, limestone, mineral pigment, shale, sodium sulfate, sulfur, and trona. Other industrial minerals and construction materials produced in Wyoming in the past include alum, asbestos, dimension stone, epsomite, fluorspar, garnet, graphite, halite, mica, phosphate, pumice and pumicite, silica raw materials, and vermiculite. Industrial minerals having development potential include anorthosite, decorative and dimension stone, diamond (industrial), diatomite, garnet, halite, mica, phosphate, potash, rare earth oxides, silica rock and silica sand, sinter, tantalum and columbium (niobium), vermiculite, and zeolites. Occurrences of alunite, cordierite, kyanite and related minerals, peat, rutile, staurolite, talc, tripoli, and wollastonite are also found in Wyoming.

INTRODUCTION

As defined by the U. S. Bureau of Mines, industrial minerals are "rocks and minerals not produced as sources of the metals but excluding mineral fuels" (Thrush, 1968). This article follows this definition, even though it includes substances that are not minerals, such as rocks (*e.g.* limestone), compounds (*e. g.* leonardite), or rock products (*e.g.* aggregate). For the purposes of this article, industrial minerals include those covered by the above definition, but exclude precious and semiprecious stones, except when diamond, garnet, and other minerals are industrial minerals (not of gem quality). Industrial minerals are generally produced in relatively large volumes and sell for relatively low prices.

This article is a summary of the occurrences, uses, and development potentials of industrial minerals that occur in Wyoming. Currently, with the exception of some small-scale gold production, all of Wyoming's nonfuel mineral production is classified as industrial minerals. About 20% of the value of Wyoming's mineral industry comes from the production of industrial minerals. **Table 1** lists industrial minerals known to occur in Wyoming.

Construction materials are industrial minerals used specifically for construction, including buildings, dams, highways, and other structures. Some of these materials are used for nonconstruction projects. For example, gypsum is a construction material when used in cement or wallboard, but is not a construction material when used in chemical processes. Construction materials have the lowest cost of all industrial minerals. **Table 2** lists construction materials found in Wyoming

[1]Geological Survey of Wyoming
P.O. Box 3008 University Station
Laramie, Wyoming 82071

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Aggregate

Aggregate is sized gravel, sand, or crushed rock used to provide mass and weight to concrete, paving material, fill, or similar materials. It is also used as landscape rock, gravel road surfacing material, roofing gravel, or similar products. Ballast is a specialty construction aggregate used in railroad bed construction. Decorative aggregates are used for the same purposes, but are also selected for their color or other visual quality.

Construction aggregate is rock used in construction to provide weight or volume. Some aggregate is used either without the addition of other material such as in fill, small dams, levees, roadbase, etc. or mixed with a binder such as asphalt or cement. Construction aggregate is usually graded according to strength and sized. The largest sized construction aggregate (rip-rap) consists of boulder-sized pieces. The smallest sized aggregate, fine sand and rock

Table 1. Industrial minerals found in Wyoming. Bold type indicates materials discussed in this article.

Commodity[1]	Best available reference (If not discussed in this article)
Aggregate	
Ballast (railroad)	
Construction	
Decorative	
Alum minerals	Harris and King (1986a)
Alunite	Harris and King(1986a)
Anorthosite	
Asbestos	
Bentonite	
Clay(common)	
Cordierite	Osterwald and others (1966)
Diamonds (industrial)	
Diatomite	
Feldspar	
Fluorspar	
Garnet	
Graphite	
Gypsum	
Kyanite and related minerals	Osterwald and others (1966)
Leonardite	
Limestone	
Mica	
Mineral pigment	
Peat	Sturges (1968)
Phosphate	
Pumice and pumicite	Harris and King (1986b)
Rare Earth Oxides and Yttrium	
Rutile	Harris (1990a)
Saline minerals	
Epsomite	
Halite	
Potash	
Shale	
Silica raw materials	
Sinter (including travertine)	
Sodium sulfate	
Staurolite	Osterwald and others (1966)
Stone (decorative and dimension)	
Sulfur	
Talc	
Tantalum & columbium (niobium)	
Tripoli	
Trona	
Vermiculite	
Wollastonite	Osterwald and others (1966)
Zeolites	

flour, are used in some products, such as in plastics or rubber. All counties in Wyoming produce construction aggregate. Most of the construction aggregate quarried in Wyoming is produced for use in road construction material (road-base, sub-base, and road surfacing material).

Table 2. Construction materials found in Wyoming.

Aggregate
Construction aggregate [sand, gravel (river rock), and crushed stone]
Decorative aggregate
Lightweight aggregate (includes pumice and pumicite, expanded shale, vermiculite and others)
Roofing granules
Cement raw materials
Limestone
Gypsum
Shale, marl, and other additives
Iron oxide and other mineral additives used in relatively small amounts
Stone
Dimension stone
Decorative stone
Insulating material (includes vermiculite and other material)

Some construction aggregate consists of sized gravel from ancient or recent river gravels, terraces, or glacial deposits. In spite of the various geologic sources, this material is generally called "river rock". These gravels can be produced at very low cost. However, they have variable composition and may contain rock types with minerals that decrease the strength of the product. For example, sulfide minerals and chert react chemically with cement. Sometimes the gravel is crushed before sizing. Where uniform quality is desirable, aggregate is produced by crushing quarried rock (**Figure 1**). Limestone and granitic rocks are most often used in Wyoming. Limestone is currently the preferred rock type for highway surfacing. Wyoming exports some crushed limestone to Nebraska for highway construction aggregate. In areas far from limestone sources (particularly the center of the Powder River and Green River basins) other material is used. Clinker (baked

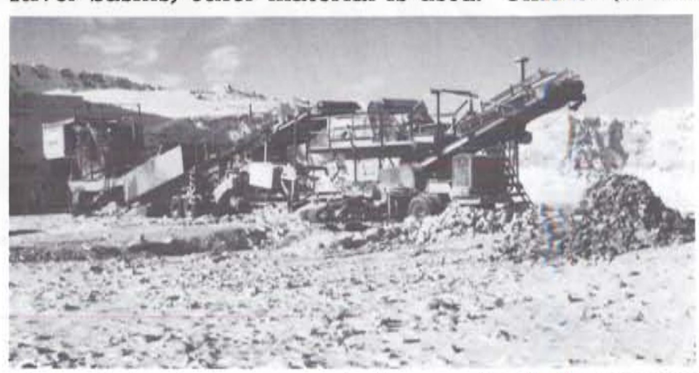

Figure 1. Rock crusher producing construction aggregate from a Wyoming quarry (Bone quarry southwest of Lusk).

and fused shale) is used in the Powder River Basin, even though it is not very durable, since it is the only aggregate available.

Railroad ballast (a type of construction aggregate with unique size, shape, magnetic, durability, and weight specifications, see Harris, 1987a) is used to weight and secure railroad ties and track. Railroad ballast sources are located near railroad lines. Two localities in Wyoming - Granite, west of Cheyenne, and Guernsey Stone, near Guernsey (**Figure 2**) - have produced large amounts of ballast in recent years. Other localities in Wyoming contain suitable rock and may be future sources (Harris, 1987a). Ballast from Wyoming is used in other states, and ballast from other states is used in Wyoming. Pricing variabilities unrelated to transportation costs have produced this phenomenon.

Figure 2. Air view (looking southeast) of the Guernsey Stone Company quarry one-half mile north of Guernsey. Aggregate from this quarry has been used for railroad ballast, other construction aggregate, and decorative aggregate.

Decorative aggregate is selected for appearance as well as physical suitability. Colored rock is used as aggregate to produce colored concrete products for buildings and other structures, and colored rock is used without additives in landscaping, on roofs, etc.

In Wyoming, Georgia Marble Company operates a marble quarry (**Figure 3**) and processing plant at Wheatland that produces sized crushed white marble used for roofing granules, landscaping, and as a coloring agent for polyvinylchloride (PVC) plastic, etc. Clinker (baked and fused rock) quarried and crushed near Gillette and Buffalo is produced for landscape rock. A river rock from the Guernsey area is sold to Wal-Mart Stores for landscape rock. Small amounts of crushed red granite, gray marble, and other rocks were shipped from Wyoming in the past. Due to the variety of granite, quartzite, marble and other rock in Wyoming, this could become a flourishing industry in the State (Harris, in press).

Figure 3. White Marble quarry west of Wheatland (operated by Georgia Marble).

Anorthosite

Anorthosite is a plutonic igneous rock composed almost entirely of plagioclase feldspar, usually the variety labradorite (Thrush, 1968). The Laramie Anorthosite underlies about 216 square miles in the central Laramie Mountains and is one of the largest anorthosite bodies in North America

Anorthosite is both an industrial rock and a potential source of aluminum. The primary interest in the Laramie Anorthosite is for its alumina content (see Rocky Mountain Energy 1985; Grubbs and Moose, 1981; Harrer, 1954; and Brown and others, 1947). As an industrial material, anorthosite is a source of feldspar (Potter, 1989). Mafic-free and sulfide-poor phases of anorthosite are potential decorative stones, including a phase that contains labradorite with a bright blue iridescence (Harris, in press). Small quantities of the Laramie Anorthosite were quarried for construction aggregate (Harris, 1990b).

Asbestos

Asbestos is a group of minerals characterized by a fibrous habit. The most common asbestos mineral is chrysotile, a variety of serpentine, but fibrous amphiboles are also used. This fibrous property is now suspected as the cause of various forms of silicosis and as a carcinogen. As a result, though asbestos products are still made, the demand for asbestos is very small. Asbestos is currently used in roofing materials, friction products (such as brake linings), asbestos-cement pipe, packing and gaskets, paper, and certain other products (Virta, 1989). Before 1940, small amounts of asbestos were produced from a few deposits in Wyoming (Beckwith, 1939). Most of these are in the northern Laramie Mountains, though there are also asbestos deposits in the Wind River and Teton mountains (Osterwald and others, 1966). It is not likely that there will be a demand for Wyoming asbestos in the near future.

Bentonite

Bentonite is a clay formed by the diagenetic alteration of volcanic ash. It has many uses because it expands many times its original volume when wet, has a high viscosity when mixed with large amounts of water, and has some useful chemical properties including high cation-exchange capacity. Wyoming produces more bentonite than any other state, and, after trona, bentonite is the second most valueable industrial mineral produced in Wyoming.

Bentonite is produced in the Black Hills, the Bighorn Basin, and near Kaycee. All of the commercially produced bentonite in Wyoming comes from upper Cretaceous strata, particularly the Mowry and Frontier formations and their equivalents. The properties of bentonite vary from place to place and from top to bottom within a bed. Some of this variation is caused by surface alteration (Rath, 1986). Bentonite is usually mined from many separate pits, analyzed for quality, then dried and blended in a mill (**Figure 4**). Since each use requires slightly different physical and chemical properties, the blend varies for each intended use.

The primary use of bentonite is in well drilling fluids, particularly for oil well drilling, so that bentonite production varies directly with the amount of oil well drilling. Bentonite is also used as a thickener, lubricant, sealant, (especially in industrial pond liners and waste isolation barriers), and as an additive (in cosmetics, aerosol sprays, and agricultural feed).

Figure 4. Baroid Drilling Fluids, Incorporated, bentonite mill at Colony, in northeastern Crook County. Bentonite from different pits is stockpiled outside of the mill and blended within the mill to produce bentonite products.

Clay (common)

Common clay is an industrial classification (by use) of clay. Clay minerals are hydrous aluminosilicate minerals with a sheet-like structure. Common clay is clay or clay-like material that is sufficiently plastic to permit molding (Ampian, 1985); it is composed of the minerals illite, smectite, and kaolinite (Patterson and Murray, 1983). Common clay was produced in almost every county in Wyoming during the early years of statehood for bricks, which were used locally (Harris and King, 1987). At present, common clay is mined in Uinta County and shipped to Utah for making bricks. Occasionally clay pits are opened for an immediate local need. For example, clay was mined from a pit near Laramie in 1986 for use in the construction of an impermeable barrier around a contaminated former industrial site.

Diamond (industrial)

Industrial grade diamonds are found in Wyoming in the State Line district south of Laramie (see Hausel and others, 1985; McCallum, this volume). The major uses for industrial diamonds are in machinery, diamond tipped drill bits, stone and ceramic processing saws and polishing abrasives, and abrasive sand. At the present time, industrial diamond is not produced in the United States (Austin, 1989).

Diatomite

Diatomite, also known as diatomaceous earth or kieselguhr, is a siliceous sedimentary rock composed of the skeletal remains of single-celled aquatic plants called diatoms (Kadey, 1983; Thrush, 1968). Diatomite is found in geologically young rocks that have not been subjected to metamorphism or destructive diagenesis. Diatomite is produced in Nevada, Arizona, Idaho, Oregon, Utah, and Washington (Williamson, 1966). It is used primarily in filter aids and mineral fillers (Meisinger, 1989a). Pure diatomite can be used in untreated form.

In Wyoming, large deposits of diatomite are found in Yellowstone National Park in lacustrine rocks in active and inactive thermal areas. Other deposits of diatomite of unknown size are found in Pliocene and Miocene rocks in Teton County, and on Casebier Hill in Goshen County. No diatomite has been produced in Wyoming (Harris and King, 1986c).

Feldspar

Feldspar is the name of a group of framework aluminosilicate minerals that are the most abundant minerals in igneous rocks. Feldspar of commercial grade occurs in large bodies of uniform grade with no iron oxides or other mineral impurities (Rogers and Neal, 1983). Deposits of commercial-grade feldspar are usually pegmatites. Ninety-nine percent of all feldspar mined is used in ceramics and as an ingredient in glass making, where it functions as a flux (Potter, 1989). The remaining one percent is used in abrasives and other products.

Small amounts of feldspar are mined from a pegmatite on Casper Mountain. Many pegmatites in the southern Laramie Mountains were mined for feldspar in the early 1950s, and some pegmatites north of Bonneville produced feldspar until 1982.

Fluorspar

Fluorspar, rarely called florspar (Thrush, 1968), is the mineral fluorite, CaF_2. It is an important source of fluorine and is also used as a flux in metal refining. Fluorite is variable in color and is fluorescent. Since it usually contains small amounts of uranium and thorium as well as rare earth elements and yttrium, fluorite is commonly slightly radioactive (Deer and others, 1966).

Fluorspar is found in the Bear Lodge Mountains in Crook County, in the southern Laramie Mountains in Albany County, and in other scattered localities in Wyoming. Fluorspar was produced until recently by the Ozark-Mahoning Company at Kings Canyon, Colorado, 2 miles south of the Wyoming State Line southwest of Laramie. However, there has never been any large-scale production from Wyoming (Harris and King, 1988).

Garnet

The mineral group garnet is used as an industrial mineral and as a semiprecious gemstone. Its primary use is in abrasives. Fifty percent of all garnet production is used for sandblasting sand for cleaning and finishing the hulls of ships. The remaining uses of garnet are in filtration (30%), in sandpaper for wood finishing (10%), in electronic components (7%), and in ceramics and glass(3%) (after Austin, 1989a).

In the United States, garnet is produced from large deposits in the Adirondack Mountains of New York and from smaller deposits in Idaho and Maine (Austin, 1989a). Small amounts of garnet were mined in Wyoming in the early 1900s from localities near Garnet Hill in the Haystack Hills in Goshen County. Wyoming has large garnet resources, and garnet may be a future industrial mineral product for the state.

Graphite

Graphite is a soft, platy mineral composed of carbon. It was formerly called plumbago (black lead). Graphite is either mined or produced synthetically from coke or other carbon residues. It is used by several hundred manufacturing firms in the United states in refractory linings (26%), dressings and molds in foundries (15%), lubricants (14%), brake linings (13%), pencils (7%), and as a carbon additive in steel making (5%), and other applications (20%) (Taylor, 1989). The demand for graphite should increase as a result of its substitution for asbestos in brake linings and other friction products.

Graphite is found in Wyoming in Precambrian metamorphic rocks. Most graphite occurrences are in the Laramie Mountains and the Hartville uplift (Harris, 1989a). Currently, there are no producing graphite mines in Wyoming, although there was some production of graphite from Platte County around 1900. Moderate to large resources of graphite may occur at some of these localities (Harris, 1989a).

Gypsum

Gypsum ($CaSO_4 \cdot 2H_2O$) is an evaporite mineral. In Wyoming, gypsum is found in the Pennsylvanian Amsden Formation, the Permian-Triassic Goose Egg and Spearfish formations and their equivalents, the Jurassic Gypsum Spring Formation, and locally in the Jurassic Sundance Formation. Quaternary deposits of gypsite are found near outcrops of these units, especially near Laramie, where they were mined for gypsum in the past.

Gypsum is used as a cement retarder, in agriculture as a soil conditioner, in industrial building products (especially wallboard), or in plaster (Davis, 1989). Gypsum is produced in many states. Although Wyoming is not a major gypsum producer, it contains gypsum deposits that are close to the pacific northwest and the State could become a principal supplier to that area.

There are three gypsum producers in Wyoming. Two of these are located in the Bighorn Basin and manufacture wallboard from gypsum. The third, near Laramie, produces gypsum for use as a retarder in portland cement. Gypsum production in Wyoming has remained relatively constant over the past five years. Wyoming is expected to continue to be a producer of gypsum. Available resources are enough to support expanded production.

Leonardite

Leonardite is a naturally occurring organic material formed in place by the (diagenetic) oxidation of lignite or coal (Thrush, 1968). Leonardite is mined near Glenrock and processed in a plant in Casper for use as a well-drilling fluid additive. It can also be used as a wood stain.

Limestone

Limestone is a rock composed primarily of the mineral calcite ($CaCO_3$). Several rock units in Wyoming contain high-grade limestone. These include the Cambrian Gallatin and Pilgrim limestones (in northwest Wyoming), the Devonian-Mississippian Guernsey Formation, the Mississippian Madison and Pahasapa limestones, the Permian-Pennsylvanian Casper, Hartville and Minnelusa formations, the Permian Minnekahta Limestone, the Triassic Alcova and Thaynes limestones, and the Cretaceous Niobrara and Greenhorn formations.

Limestone is used as an industrial mineral for purposes other than construction aggregate (see Aggregate). Limestone consisting of over 95% calcite ($CaCO_3$) is used to produce lime (CaO). Lime is used in refining beet sugar; in cement; as a flux in steel refining; in water treatment (including neutralizing bodies of water affected by acid rain); in stack gas scrubbers (for the removal of sulfur compounds from the gas); in the manufacture of glass, refractories, mineral fillers, abrasives, and soil conditioners; in chemicals; and many other products (after Carr and Rooney, 1983).

Limestone is quarried in Wyoming for the manufacture of cement near Laramie. It is also quarried north of Hartville (**Figure 5**) for use in emissions control in the coal-fired electricity generating plant north of Wheatland. In recent years, limestone was quarried for use in sugar beet refining north of Fort Laramie, near Lovell, and on the west slope of the Teton Range south of Alta. Limestone is also used as decorative and dimension stone.

Figure 5. Bass Quarry, north of Hartville, from which limestone is quarried, crushed, and used as a stack-gas scrubbing agent at the Laramie River Power Station near Wheatland. In early 1991, Dakota Coal, a subsidiary of Missouri Basin Electric and the operator of the power plant, announced plans to construct a calcining plant on this site and ship lime from the plant to Wheatland and a power plant at Beulah, North Dakota.

Mica

Mica is a group of platy minerals including muscovite, biotite, and phlogopite. Muscovite, and rarely phlogopite, are the only micas that have industrial potential. Sericite is fine-grained muscovite characterized by a distorted platy structure (Chapman, 1983).

Mica is split into very thin sheets that are durable and transparent, and which have dielectric and insulating capabilities. Categories of mica include *sheet mica* (large sheets that can be cut, punched, or stamped into various shapes and sizes), punch mica (an archaic term for sheet mica cut by a punch), and *scrap and flake mica* (small flakes that used to include the waste from sheet mica production) (Chapman, 1983). In the past, sheet mica was used for glazing stove windows, doors, lamp chimneys, and lampshades (Gwinn, 1951). The production of mica declined in the late 1940s and early 1950s as other material substituted for mica for these uses. Now, there is an increase in the use of scrap and flake mica for pearlescent additives to paint, pigment, and decorative facing material. In the past, the best mica was the clearest and most colorless. Now, colored varieties are in demand.

In Wyoming, mica is most often found in mineable amounts in pegmatites. Sericite is found in some Precambrian schists. The principal areas of muscovite-bearing pegmatites are the Medicine Bow Mountains, Sierra Madre, northern Laramie Mountains, and the Hartville uplift (Harris, 1989b). Some of these occurrences may contain enough mica to be mineable.

Mineral pigments

Mineral pigments are naturally occurring insoluble minerals used to provide color to selected products (after Thrush, 1968; and Hancock, 1983). The most common mineral pigments are iron oxides. In Wyoming, mineral pigments were one of the first mineral products to be used and even exported. Archaeological evidence indicates that red hematite pigment from the Sunrise area of Platte County was used by prehistoric Indians for body decoration and carried to other areas for trade (George Frison, Wyoming State Archaeologist, personal communication, 1986).

In modern times, red iron-oxide pigment occurring as pockets of replacement ore in the Madison Limestone one mile north of Rawlins in Carbon County was mined for paint pigment. This product, known as "Rawlins Red", was a major source of pigment used on railroad cars. Currently, small amounts of iron-oxide fines, waste from past iron mining at Sunrise in Platte County, are being shipped to the eastern United States for use as pigment in cosmetics (the color is known as Desert Dust) and to South America for use as pigment in railroad car paint.

Phosphate

Phosphate rock is the source for calcined phosphate compounds, 90% of which are used as a major component of fertilizer. The remaining 10% of phosphate production is used to produce industrial chemicals such as elemental phosphorous or phosphoric acid (Stowasser, 1989).

The Permian Phosphoria Formation in western Wyoming is an important resource of phosphate rock. Phosphate production in Wyoming began in 1906 from a mine near Cokeville (Lloyd, 1970). Phosphate has not been mined in Wyoming since 1977, but before then it was one of the major industrial materials produced in the state. The largest Wyoming phosphate operation was the mine and calcining plant at Leefe, west of Kemmerer in Lincoln County. The mine at this location closed in 1977; the plant closed about 1985 and has since been dismantled. Currently, there are no plans to resume phosphate mining in Wyoming.

In 1986, Chevron Chemical Company began producing a phosphate-based fertilizer from a plant near Rock Springs. This plant uses Wyoming sulfur, but receives its phosphate by slurry pipeline from a mine north of Vernal, Utah.

Rare earth oxides and yttrium oxide

Rare earth oxides and yttrium oxide are industrial compounds used in the manufacture of petroleum refining catalysts, ceramic and glass coloring agents, electrical products, color phosphors, laser producing equipment, and other items. Rare earth metals are used in pyrophoric alloys and permanent magnets (Hedrick, 1989). The rare earth elements are those of the lanthanide series (elements with atomic numbers 57 - 71). The element yttrium (atomic number 39) is considered together with the rare earths since it is usually found with them and since its properties are similar. Rare earth oxides have been used as a group rather than as oxides of individual elements due to the difficulty in separating the individual oxides. As new methods of separating the elements are developed, uses of individual oxides are developed. Rare earth and yttrium oxides are now used in superconductors.

Minerals containing rare earth elements are concentrated in alkaline igneous rocks, carbonatites, pegmatites, veins, and breccias, and in both fossil and Quaternary placers. There are many occurrences of rare earth and yttrium oxides in Wyoming. (For a summary of rare earths and yttrium in Wyoming, see King and Hausel, this volume.)

Saline minerals (excluding trona and sodium sulfate)

Saline minerals are found in several areas of Wyoming as bedded deposits in sedimentary rocks or as evaporite deposits in modern playas. Halite (salt, NaCl) occurs in several areas in bedded rocks; potash occurs at depth in east-central Wyoming in evaporite units; and epsomite ($MgSO_4 \cdot 7H_2O$) and other evaporite minerals are found in Quaternary playas.

Halite was important in the history of the world as a preservative. Some salt-water springs in Wyoming were known by Native Americans and early pioneers. Notable among these are the salt spring north of Newcastle in Weston County (Harris, 1988a) and the salt spring on the Salt River north of Cokeville in Lincoln County (Harris, 1987b). Presently, halite is produced in large volumes from commercial operations in 15 states. Salt is presently used for chemical production (48%), highway deicing (25%), soil treatment, food treatment, and water treatment (Kostick, 1989c).

Halite salt is not currently produced in Wyoming. Salt is found at the surface in a few localities in the state associated with brine springs. Halite occurs mixed with trona in the Green River Basin trona resource area (Culbertson, 1986). A sizable resource of halite is present at depth in the Jurassic Preuss Formation north of Border Junction in west-central Wyoming (Peterson, 1972). This deposit may be mineable by solution mining techniques.

Potash (K_2O) is a mineral product used almost exclusively in fertilizer. It has not been produced in Wyoming in the past. New Mexico currently produces most of the potash consumed in the United States (Searls, 1989).

Beds of potash are present in the subsurface in Goose Egg Formation equivalent rocks (Permian) in eastern Wyoming (Rascoe and Baars, 1972). Oil wells have penetrated this section, and a few cores of potash-rich rock have been recovered (J. D. Love, personal communication, 1984). These beds may be an economically viable resource of potash (Harris and King, 1986d).

Epsomite ($MgSO_4 \cdot 7H_2O$) is also known as epsom salt. It has been used in relatively small quantities in the past for industrial chemicals and medical products. Epsom salt is being produced from seawater, from well brines in Michigan, and from the Great Salt Lake in Utah (Kramer, 1989). In the early years of this century, at Rock Creek Lakes in Albany County (**Figure 6**) and at Poison Lake in Converse County, small plants were constructed to produce epsomite. Small resources of epsomite are present in Wyoming at these and other sites (Harris, 1987c).

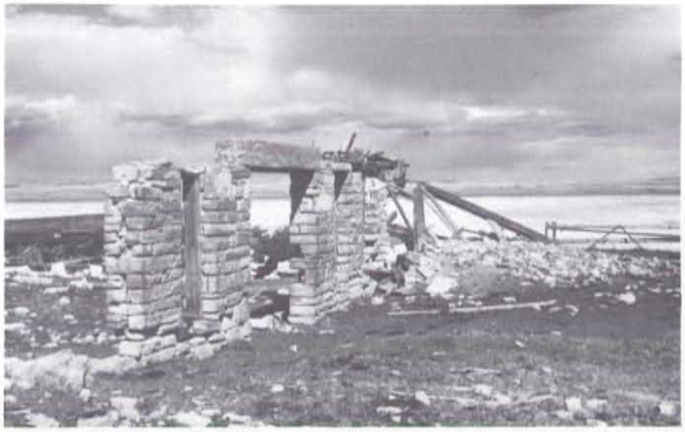

Figure 6. Abandoned epsomite processing plant at Rock Creek Lakes.

Shale

Shale is an industrial mineral used as an aggregate, an additive in cement, and other applications. Although clinker (baked and fused rock) and marl are not types of shale, some of these rocks mined in Wyoming were classified as shale for tax purposes. Aluminous shale is being mined near Laramie for use in cement. Other shales near Laramie were mined and expanded (by heating) into lightweight aggregate in the past.

Silica

Silica (SiO_2) is the primary ingredient for the manufacture of glass, ceramics, and related products. Quartz is the most common silica mineral. The primary sources of silica are ancient and recent quartzose sand or sandstone deposits and quartz bodies that occur in pegmatites. Silica sand is classified as a type of industrial sand. Industrial sand, a classification of sand based on both physical and chemical properties, is used for foundry sand, abrasives, traction sand, hydraulic fracturing sand (frac sand), and related products.

Silicon (Si) is a metal used in electronics and in solar cells and other applications. Silicon is refined from silica by an electrolytic process.

Wyoming contains numerous sand or sandstone deposits of 90% SiO_2 or greater see Harris (1988b and c). Silica sources are found in certain locations in the Cambrian Flathead Sandstone, the Pennsylvanian Amsden Formation, the Permian-Pennsylvanian Casper and Tensleep formations, the Jurassic Morrison Formation, the Cretaceous Cloverly Formation, and Quaternary aeolian sand dune deposits. Before 1920, many Wyoming communities had small glass plants that served local needs. The source of silica was usually any sand, and glass produced in these places was naturally colored and used primarily for containers.

Soda ash, lime, and feldspar are other major ingredients used to make glass. All of these ingredients are found in Wyoming. As economics change, producing glass close to raw material sources and in areas of less expensive energy sources may become less expensive than producing glass in densely populated areas. A glass industry in Wyoming is a future possibility.

Sinter (including travertine)

Sinter is a chemically precipitated sedimentary rock deposited from mineralized waters. Calcareous sinter is composed of calcium carbonate ($CaCO_3$) and is commonly known as travertine. Siliceous sinter is composed of silica (SiO_2). Sinter is used primarily for decorative stone. It is cut and polished for building interiors and façades, monument stone, counter and table tops, and other decorative products. Calcareous sinter is also used in agriculture as an easily soluble form of calcium carbonate.

Small amounts of travertine were mined for agricultural applications such as soil conditioners near Cody, Thermopolis, and Dubois. Most sinter deposits in Wyoming are located in the northwestern quarter and along the western edge of the state (Harris and King 1986e).

Sodium sulfate

Sodium sulfate (Na_2SO_4) is an industrial chemical used in soap and detergents (45%), in pulp and paper treatment (36%), and in glass and other products (19%) (Kostick, 1989a). Pure sodium sulfate is found in nature as the mineral thenardite (anhydrous). Hydrous sodium sulfate (mirabilite) is produced in Wyoming at the Pratt sodium sulfate deposit near Natrona in Natrona County (**Figure 7**). Other sodium sulfate-rich soda lakes are found in Wyoming (Harris and others, 1985). None of these are being mined at the present time.

Figure 7. Soda lake and workings at the Pratt sodium sulfate mine, Natrona County.

Stone (decorative and dimension)

Decorative stone is any rock product exclusive of aggregate that is used for its color or appearance. Dimension stone is cut stone used as a building material. Color and appearance are important criteria in selecting decorative and dimension stone. The stone must also meet strength, durability, and other specifications. These specifications include the absence of sulfides or minerals that could oxidize and stain or discolor the rock.

Several areas in Wyoming have produced decorative and dimension stone. Dimension stone was quarried from an Upper Cretaceous sandstone south of Rawlins. This stone was used in a number of buildings in the region including the Wyoming State Capitol and the Union Pacific Railroad depot in Ogden, Utah. A few small quarries on the northern edge of Rawlins produced dimensional stone from a medium-bedded zone in the Cambrian Flathead Sandstone. This stone was used primarily as trim on buildings in Rawlins. A sandy limestone from a quarry in the Permian-Pennsylvanian Casper Formation 6 miles north of Laramie and from another location east of Laramie was used on some of the buildings on the University of Wyoming Campus in Laramie. It is probable that some or all of the stone used on the university buildings constructed between 1920 and 1960 came from the Weber Sandstone near Ogden, Utah. There are no records of production from any quarry near Laramie in those years, and the volume of stone on all of the buildings on the university campus greatly exceeds the volume of stone removed from the Laramie quarries.

Granite, onyx, sandstone, and marble were quarried from several locations in the Hartville uplift and processed by the Jay Em Stone Company in Jay Em, Wyoming. A monument stone quarry was reportedly located in Sinks Canyon south of Lander, and gray granite was quarried for monument stone in Teton Canyon, on the west side of the Teton Range. Some green serpentine was quarried for decorative stone, and a green quartzite quarry was operated near Browns Mountain in the Medicine Bow Mountains west of Centennial. There have probably been other small quarries worked in the past for decorative stone, but many of these were unreported and produced small amounts of stone for local uses.

There are many rocks in Wyoming that have potential as decorative stones (Harris, in press). A stone quarrying and finishing industry in Wyoming may be economically competitive with other areas and would save some transportation costs to North American consumers.

Sulfur

Sulfur is an important industrial mineral used in fertilizer (74%), organic and inorganic chemicals (10%), petroleum refining (8%), metal refining (2%), and other products and applications (6%) (after Morse, 1989). Sulfur is produced by two methods. It is mined by a method known as the Frasch process. Sulfur produced by this process is called nonrecovered sulfur. Sulfur is also produced as a by-product of the refining of natural gas containing hydrogen sulfide (H_2S). This sulfur is called recovered sulfur.

All of the sulfur produced in Wyoming is recovered sulfur. Wyoming is third in U.S. sulfur production, after Texas and Louisiana. Some Wyoming sulfur is used by the Chevron Chemical Company's fertilizer plant near Rock Springs.

Wyoming also has significant natural elemental sulfur deposits. Sulfur was mined from bedded Quaternary hot spring deposits that replace portions of the Phosphoria Formation west of Thermopolis, and large reserves are present in this area. Hot Spring deposits of sulfur are found in other areas of Wyoming (Harris and King, 1985), especially in the Sunlight Basin and at Auburn Hot Springs in northern Lincoln County.

Tripoli

Tripoli, also called tripolite, is an industrial term for a rock composed of soft and friable microcrystalline quartz. Tripoli probably forms by leaching calcium carbonate from limestone containing abundant dispersed chert. The particle sizes of tripoli range from 0.1 to 10 microns (Bradbury and Ehrlinger, 1983).

Tripoli is used in many industrial products including abrasives (buffing, scouring and polishing compounds, toothpaste, and industrial cleaners and soaps); mineral fillers in paint, plastic, and rubber; and electrical plastics (since tripoli adds dielectric properties) (Rheams and Richter, 1988; Bradbury and Ehrlinger, 1983). Other uses include refractory glasses and ceramics, carriers in insecticides, and fillers in adhesives, wallboard, and plastic wood (Metcalf, 1946).

Tripoli is produced in the eastern and southern United States. The better deposits are those with smaller particle size and whiter color. Tripoli is reported to occur in Wyoming in four places, exclusive of the tripoli that occurs as a weathering rind on chert pebbles in many surficial gravel deposits (Harris, 1989c). A large deposit was reported to occur in northern Platte County (Bartlett 1928), where the geological environment is similar to environments of tripoli deposits elsewhere. However, recent exploration has failed to locate this reported deposit.

Trona

Trona (natural sodium carbonate-bicarbonate) is the most important industrial mineral produced in Wyoming in terms of value and employment. Trona is mined from five mines west of Green River, refined to soda ash and other sodium products, and used in a variety of applications (**Figure 8**). Soda ash is used in glass (55%), sodium chemicals (including sodium cyanide, used in recovering gold from its ore) (20%), baking soda and related products (6%), flue gas desulfurization (3%), miscellaneous applications (3%), soap and detergents (1%), and water treatment (1%) (after Kostick, 1989b).

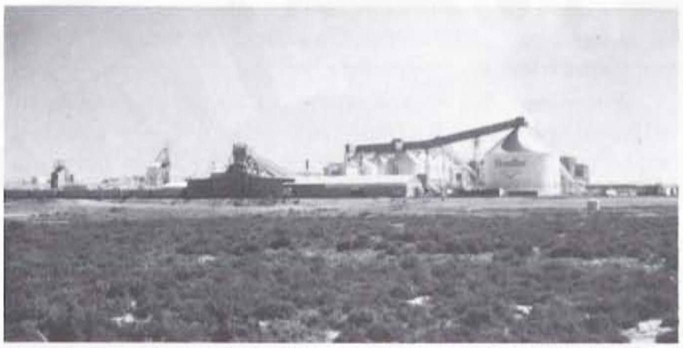

Figure 8. Rhone-Poulenc soda ash plant northwest of Green River. This plant refines trona to produce soda ash.

A resource of 134,400,000,000 tons of mineable trona and mixed trona and halite is present in the Green River Basin of Wyoming. This resource occurs in the Wilkins Peak Member of the Eocene Green River Formation, in which 42 trona beds are known, of which 25 are considered mineable (Culbertson, 1986; Leigh, this volume). Trona is an evaporite mineral deposited in a closed basin during periods in which Eocene Lake Gosiute evaporated to dryness or near-dryness (see Bradley and Eugster; 1969, Surdam and Wolfbauer, 1974; and Leigh, this paper for discussions of the geochemical conditions necessary to produce trona).

Wyoming produced 90% of all U. S. soda ash in 1990. The remaining 10% was produced from surficial trona deposits in California. In early 1991, the California operation shut down. About one-third of Wyoming's production is exported (Kostick, 1989b), mostly to Pacific Rim countries. New uses for soda ash are continuously developed, and Wyoming has enough mineable trona to supply the world's demand for soda ash for a very long time.

Vermiculite

Vermiculite is the name of a group of hydrated magnesium aluminosilicate minerals that expand when heated. Vermiculite is not considered a single mineral but rather a family of related minerals (Stewart, 1983; Deer and others, 1966). The expanded product is also called vermiculite. It is used as insulating material, in construction as a lightweight aggregate, in agriculture and horticulture as a soil conditioner, and in other industrial products (Meisinger, 1989b).

Vermiculite forms by weathering or hydrothermal alteration of biotite and phlogopite in mafic and ultramafic igneous or metamorphic rocks, usually at or near the contact with intrusive acidic igneous rocks (Meisinger, 1985; Bothner, 1967; Hagner, 1944).

Vermiculite occurs in Wyoming in several areas in biotite schist, hornblende schist, diorite and metadiorite, hornblendite, and serpentinite at or near a contact with granite, granite gneiss, granite pegmatite, or vein quartz. Vermiculite was produced in the past in Wyoming from deposits near Encampment, west of Casper, and in the central Laramie Mountains. There are probably sufficient vermiculite resources in the southern Saratoga Valley near Encampment to support renewed production (Harris, 1990c).

Natural zeolites

Zeolites are a group of chemical compounds characterized by a ring silicate structure and a high cation-exchange capacity. They have a wide variety of uses from petroleum refining to kitty litter. Natural zeolites are most commonly found in a variety of igneous rocks and in sedimentary rocks containing a high percentage of volcanic glass. They form by devitrification and diagenetic alteration of glass and aluminosilicate minerals. [For technical discussions on the origin of zeolites see Hay and Sheppard (1977), Hay (1978), Surdam and Sheppard (1978), Boles and Surdam (1979), and Iijima (1980).]

Currently, most industrial zeolites are produced synthetically. Natural zeolites may prove to be less expensive to produce than those produced synthetically. Since Wyoming has extensive zeolite occurrences (see Harris and King, 1990; King and Harris, this volume), this resource represents an opportunity for development.

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