COLORADO
DEPARTMENT OF NATURAL RESOURCES

ROCKTALK

Division of Minerals and Geology
Colorado Geological Survey

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INDUSTRIAL MINERALS

What are they, where are they, and what good are they?

By John Keller and Beth Widmann

The "Industrial Minerals" Category of Mineral Resources

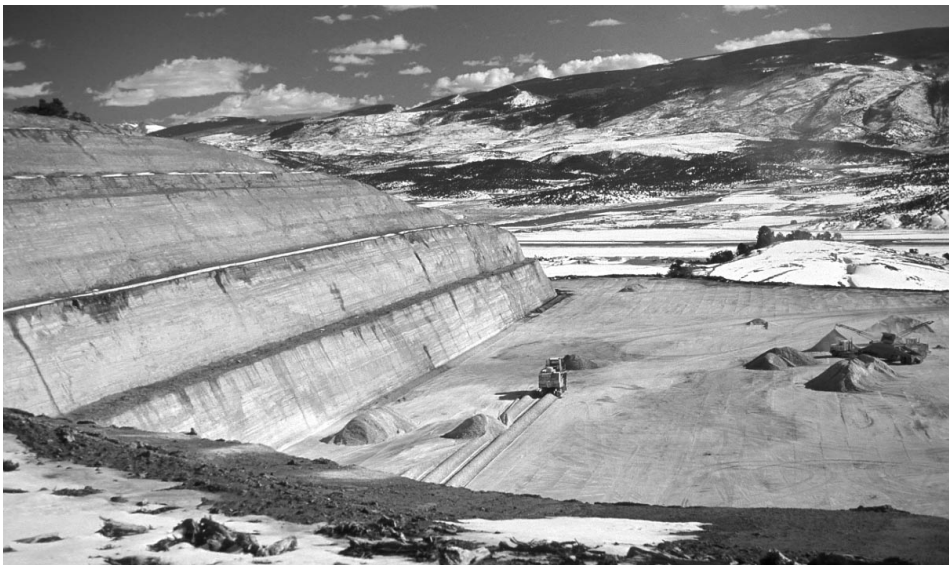
Few people wax nostalgic about the early years of sand and gravel mining, or the fabulous clay "strikes" of Jefferson County, or striking it rich in the nahcolite fields near Meeker. Even coal has more fame and romance attached to it than, for instance, limestone. But industrial minerals and rocks are literally the building blocks of our society, and Colorado possesses abundant resources of several mineral commodities in this category.

Geologists exhibit a strong tendency (some might call it an obsession) to categorize and define, to the *n*th degree, the materials and processes that make up the Earth. Geologists who study mineral resources are no exception to this—but they also have to consider some economic and social values in their categorizations. The "industrial minerals" are one of the main categories of economic mineral resources. The other major classes are metals, oil and gas (hydrocarbons), and coal.

Simply put, industrial minerals are naturally-occurring nonmetallic minerals (and rocks) that have economic value, but are not used as fuels, and are not gems. The name "industrial minerals" is somewhat misleading, because who would deny that, for example, copper, zinc, or coal are used for industrial purposes? But these minerals belong to other categories, and are not lumped together with construction materials such as sand and gravel.

Inevitably, there is some overlap amongst the major mineral resource classes. Titanium minerals, for example, can be mined specifically to produce titanium metal, and in that case the deposit is a "metal resource". However, most titanium minerals are mined not for the metal, but to make titanium dioxide (not metallic) which is used as a pigment to make paint and other products white. In this case, the titanium minerals (mostly rutile and ilmenite) are "industrial minerals."

Some industrial minerals and rocks are categorized as "construction materials" because they are used as they are, with little or no processing, to make things like roads and buildings. Sand and gravel, limestone, sandstone, granite, most clay and shale, perlite, and gypsum belong to this subcategory of industrial minerals. These resources are generally common, and the cost of them is tied less to the mining of the material itself than to the transportation costs to the market; the bulk of the



The American Gypsum Mine in Eagle County produces high-quality qypsum, which is used in the manufacture of drywall.

field notes from the director

Sand, gravel, crushed rock . . . common commodities in Colorado, and important resources in our lives. A typical house uses 400 tons of construction materials. Roads use 38,000 to 50,000 tons per mile. These important rocks and minerals occur all around us, and are relatively inexpensive and easy to develop. But the presence of urban development makes it more difficult to open a new quarry or gravel pit. And the cost of these materials doubles approximately every 25 miles between their source and end use.

Important topics like these were the focus of the National Research Council's Committee on Earth Resources recently convened meeting on "Issues in the Aggregate Industry" at the National Academy of Sciences in Washington, D.C. Participants represented industry, academia, state geological surveys, the USGS, and some of the 35 federal agencies that regulate the industry.

Discussions during this meeting underscored several trends. The U.S. imports 15 million tons of aggregate material annually, from Canada, Mexico, the Bahamas, and the Dominican Republic. Coastal states import some of their materials while they mined and shipped to inland states.

Also, the industry is consolidating. Large, multi-national corporations are buying smaller, locally owned companies. Less acceptance of urban operations, increasingly complex regulations, and the need to ship material longer distances—these factors encourage the trend to larger corporations dominating the industry. The trends described at the Academy's meeting touch Colorado. More changes are in store for Colorado's aggregate industry *and* consumers. What will not change is our need for these earth resources as we continue to build and repair our infrastructure.

cost being in transportation from the mine to the point of use or sale. For example, good sand and gravel deposits in Antarctica presently have no societal or economic value—it would be ridiculously expensive to transport the resource to a new road project in Douglas County. But deposits near large cities like Denver have a high value. Construction materials are usually readily available in large quantities, and therefore have "low unit value"—the cost of a ton or truckload of the material is low.

Other industrial minerals are more rare and have specific industrial applications. They generally have a much higher unit value than the construction materials. Such industrial minerals and rocks have a multitude of uses, including chemicals, abrasives, ceramics, glass, refractories (heat-resistant products like the lining of steel furnaces, etc.), fertilizers, absorbents, insulating materials, even food additives. Many are used for more than one purpose and defy easy categorization. Clay, for example, occurs in several varieties and can be used to make construction bricks, ceramics and pottery, to line artificial ponds to prevent water leakage, as a drilling agent, and even to clean horses! Ball clay is an absorbent, and is the main ingredient in kitty litter, among other things. Kaolin clay is one of the main ingredients in glossy paper like that used in magazines. The table on page 11 is a partial list of industrial minerals found in Colorado, and some of their uses. Some of the more economically important of these are described in greater detail in the following pages.

Aggregate—Sand, Gravel, and Crushed Stone

Sand, gravel, and crushed stone, often collectively referred to as aggregate, are most widely used as an ingredient in concrete, asphalt, and road base. Sand and gravel deposits are commonly found along major streams and rivers such as the Colorado River. Till, material deposited by glaciers more than 12,000 years ago, also may contain good sand and gravel resources. Crushed stone can be derived from many different sources such as granite, gneiss, sandstone, limestone, marble, and volcanic rock, all of which are readily available in various parts of the state.

The alluvial gravel being examined by geologist Jim Cappa has been screened to meet the size specifications of a customer who will use the material to line fish hatchery ponds.

It is estimated that each person in the Front Range is responsible for consuming about 14 tons of

aggregate per year—our use of roads, buildings, foundations, driveways, sidewalks, parking lots, and dams contributing the most to this yearly total. The construction of our relatively new airport (Denver International) devoured immense amounts of aggregate and serves as a good example of how much concrete is actually used in a single large-scale construction event. More than 2.5 million cubic yards of concrete were used solely in the construction of the runways, taxiways, and aprons. This is the equivalent of an 100-story building the length and width of a football field filled with concrete! The concrete-paved runways are 17 inches thick and are underlain by nearly eight feet of well-compacted soil, aggregate, and cement. An additionally staggering amount of aggregate was used in the concrete foundation of the terminal and the parking structures, and the road base and asphalt of the roadways, parking lots, rental car lots, and Peña Boulevard. In fact, so much aggregate was needed in such a short period of time that Colorado's aggregate industry did not have the operational capability to produce the material fast enough. Aggregate actually had to be imported from Wyoming in order to complete construction at DIA.

Aggregate has many other uses besides concrete, asphalt, and road base. Sand with specific qualities is used in water purification, in the manufacture of glass (including fiberglass), as an abrasive, in snow and ice control, and it invariably provides a nice resting spot for golf balls on Sunday afternoons (to the dismay of many golfers!). Gravel containing smooth cobbles and pebbles is used to line ponds at fish hatcheries so that spawning fish won't tear their scales or fins when they burrow to lay eggs (photo on previous page). Crushed stone is a common landscaping material (photo below), as is volcanic cinder, or scoria, which is also used in gas barbecue grills.

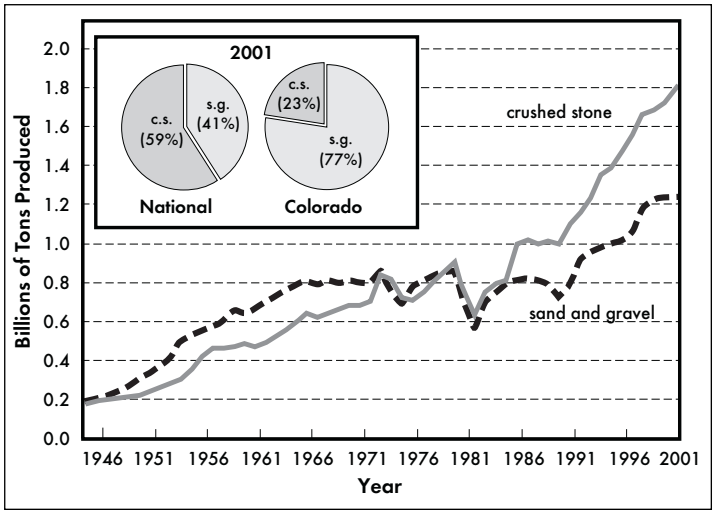
Colorado produced nearly 50 million tons of aggregate in 2001 and ranked seventh in the nation for sand and gravel production. Booming land development statewide results in a need for more locally produced materials. This, in turn, leads to more frequent controversy among local residents, land-use planners, regulators, and aggregate producers. New homes and businesses require aggregate for construction and development of roadways. The broad, flat terraces adjacent to many rivers are ideal sites for residential, commercial, and agricultural development because of their natural beauty, scenic views, ease of development, and proximity to water. However, the best sand and gravel resources often underlie these same terraces. Once there has been housing or commercial development on a sand and gravel deposit, the mineral resource is essentially lost, and it becomes more difficult to exploit other nearby resources because most folks don't want their communities disturbed by the noise, dust, visual affects, or potential environmental problems that may be generated by aggregate operations.

Crushed stone is commonly used as a decorative landscaping material. It is especially popular where water is scarce.

Aggregate development is a temporary land use, and properly done, can lead to long-term benefits for a community. Many lakes and open-space parks along rivers and creeks in the Front Range and elsewhere were once sand and gravel mining operations that have since been reclaimed. Besides making good public places for recreation, some of these lakes have become the centerpieces of residential housing projects. In the Front Range there are high quality sand and gravel resources associated with the South Platte, Cache La Poudre, and Arkansas Rivers, but a large part of these resources will never be recovered because development has sealed them off.

In an ideal situation, important mineral resources are recovered before development occurs. County planners must, therefore, weigh the benefits of encouraging development, which may block access to valuable mineral resources, allowing mining operations along scenic river valleys, which undoubtedly means facing political and environmental opposition, or developing inferior quality resources and importing aggregate from afar, the cost of which may be economically impractical.

In an effort to meet growing aggregate needs while maintaining accord between local residents and aggregate producers, planning officials must search for alternatives to sand and gravel resources in politically and environmentally contentious areas. Although sand and gravel production dominates in Colorado, crushed stone



U.S. sand and gravel vs. crushed stone production, 1945–2001. Pie diagrams illustrate percentage of sand and gravel versus crushed stone aggregate produced nationwide and in Colorado in 2001.

production nationwide has consistently outweighed sand and gravel production since 1980 (see graph above). There are several reasons for this shift in the national trend. Sand and gravel operations disturb a relatively large surface area to depths typically less than a hundred feet. Although sand and gravel deposits can be easily excavated using cheaper mining processes such as bulldozing and front-end loading, the location of most of the deposits in ecologically sensitive environments adjacent to streams and rivers may raise environmental and political issues that can become very costly to address. Furthermore, these areas are often prime agricultural lands and are increasingly viewed as premium sites for residential development. Conversely, crushed stone quarries produce more aggregate from a smaller disturbed area because the aggregate material extends to a much greater depth. These mines are able to operate vertically, as opposed to sand and gravel operations which mine laterally. An added benefit is that crushed stone quarries can be located in mountainous areas that, so far, have less pressure for residential development. Of course, crushed stone operations incur the additional cost of drilling, blasting, and transportation (the further the quarry is from developed areas, the greater the transportation costs), so it is not necessarily always the better option. In addition, developing a quarry in mountainous areas may present its own set of environmental issues, such as increased noise, dust, truck traffic, and aesthetic damage to scenic views.

Dimension Stone

Stone cut or shaped to a specific dimension is termed "dimension stone." Dimension stone is most often used as a building stone, but has also been used to create sidewalks and curbs, and more recently, has become a fashionable choice for kitchen countertops. In Colorado, dimension stone is derived primarily from marble, granite, sandstone, rhyolite (a volcanic rock), and travertine. Granite and sandstone are particularly abundant throughout Colorado.

Marble is simply limestone or dolomite that has been recrystallized, typically by an nearby heat source such as a magmatic intrusion. The Yule Marble of Gunnison County is recrystallized Mississippian-age Leadville Limestone (photos below and on next page). It has the beautiful soft white color and very even texture that is much sought after for fine architecture and monuments. The Yule Marble has been used in the construction of many prominent structures, most notable of which are the Tomb of the Unknown Soldier (see next page), Lincoln Memorial, Colorado State Capitol Annex, U.S. Customs House in Denver, and Denver International Airport. The Beulah Marble is an intricately banded rose-colored marble of Mississippian age that was quarried near Beulah in Pueblo County. The marble was utilized as a decorative stone on the walls and pillars in the Colorado State Capitol (photo on next page). The entirety of this small but beautiful marble deposit was quarried for this purpose.

Sandstone is a sedimentary rock made up mostly of quartz and feldspar grains that have been nat-

Inside the Yule Marble Quarry in Gunnison County.

Flatbed truck hauling largest block of marble ever taken out of the Yule Quarry. Block weighed 58 tons.

PHOTO COURTESY OF SIERRA MINERALS CORP.

urally cemented together,usually by silica. Sandstone is widely distributed in Colorado, but not all of it is good enough to use as a building stone. The Permian-age Lyons Sandstone of Boulder and Larimer counties has been used as dimension stone since the mid- to late-1800s. It has a light salmon color, consistent texture, and breaks easily along cross-bedding surfaces that are diagonal to the original bedding. The cross-bedding structures in this formation indicate that it originated as a sand dune deposit similar to present-day dunes found at the Great Sand Dunes National Monument in San Luis Valley. Ancient ripple marks attest to streams that meandered between the dunes. The large slabs of sandstone are used as flagstone on walkways and as building stone. Most of the buildings on the University of Colorado campus in Boulder are constructed of the Lyons Sandstone (photo on page 6). Other sandstones have also been used for building stones in Colorado, but to a lesser extent than the Lyons. The Dakota Sandstone of Cretaceous age has been used in the Front Range area when large dimensions stones with high-bear-

The Tomb of the Unknown Soldier in Washington, D.C. was sculpted from Yule Marble quarried in Gunnison County, Colorado.

Pillar base at the Colorado State Capitol faced with Beulah Marble from Pueblo County.

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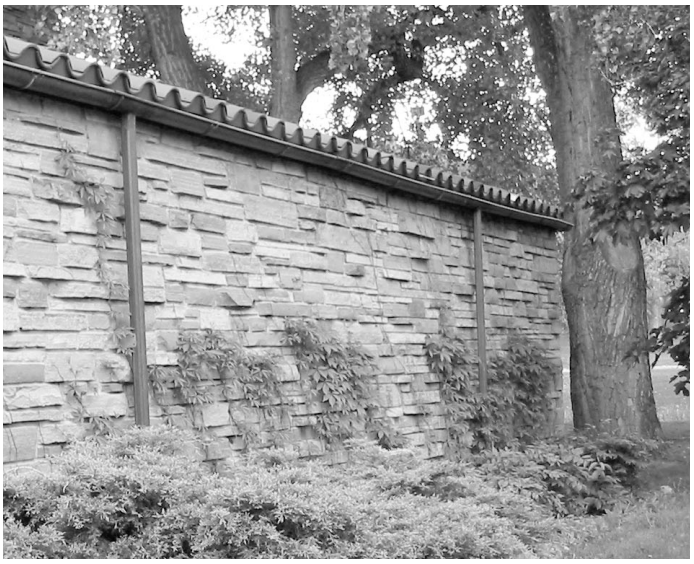


Sandstone from the Lyons Formation in Boulder and Larimer Counties was used in the construction of many buildings on the University of Colorado Campus in Boulder.

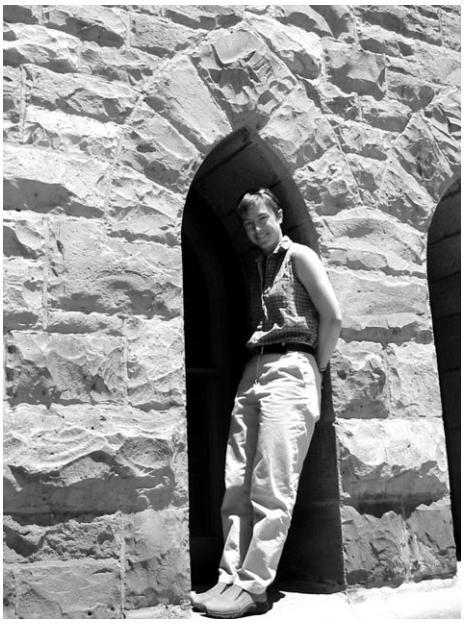
ing strength were needed. The Ordovician-age Harding Sandstone has been used mainly around Colorado Springs and southern Colorado.

The Aberdeen Granite of Gunnison County is one of the most widely used granites in the state. It is a medium-grained, mottled, gray rock made up of quartz, feldspar, and mica. It has a preferred rift orientation that allows it to be quarried easily into large slabs. More than 283,500 cubic feet of this granite was used to build the state capitol and the grayish steps leading up to the entrance (photo below, left). Several other granitic bodies in the state have been used for dimension stone as well as for monumental stone. The pink granite of Salida in Chaffee County was exported to Salt Lake City, Utah, where it was carved to create the Mormon Battalion Monument. The Cotopaxi Granite of Fremont County was used in the construction of the base of Denver City Hall. The Pikes Peak Granite of Douglas County and the Silver Plume Granite of Clear Creek County are other notable sources of granite dimension stone.

Colorado State Capitol is constructed with Aberdeen Granite from Gunnison County. The Veterans Memorial monument is made of polished Lyons Sandstone from the northern Front Range foothills.

The most significant travertine deposit in Colorado is located near Wellsville in Fremont County. Travertine forms through precipitation of calcium carbonate from mineral-spring waters. It is usually light pink to buff in color and may be banded with darker streaks. Because it is very durable it has been used in the construction of many buildings both within the state and without. Denver General Hospital, the Gates Rubber Company, and the Bus Terminal Building are just some of the buildings in the Denver Metro area that have utilized Colorado travertine.

The light gray, Eocene-age Wall Mountain Tuff of Douglas County, more commonly known in the building industry as the Castle Rock Rhyolite, has been widely used as building stone in the Front Range. Rhyolite is a light colored volcanic rock originating from hot ash and gaseous lava that has settled and partially re-melted to become a very compact hardened layer. The Trinity United Methodist Church in Denver was built using this rock (below).



The Wall Mountain Tuff , also known as the "Castle Rock Rhyolite", was used to build the Trinity United Methodist Church in Denver. CGS geologist Beth Widmann provides scale.

Limestone

Limestone is an accumulation of sea shells, calcium carbonate precipitate, and fine sediment deposited on the sea floor, most often in a shallow, warm environment. In Colorado, limestone deposits are fairly widespread, but not all deposits are thick enough or of high enough quality to be mined commercially. In the late 1800s to mid-1900s, limestone deposits near metallic mining districts were used

as fluxing agents in the smelting process. More recently, the Cretaceous-age Niobrara Formation has become one of the leading sources of limestone and is used primarily in cement manufacture (photo at right). Crushed limestone may also be used as an aggregate in concrete. Limestone is an important industrial mineral because it has such a wide variety of uses. It is valued both for its physical properties and its chemical properties. Cut limestone is well suited as building stone and often may be used in monuments or statues. Crushed limestone can fulfill many aggregate needs such as fill, road base material, decorative rock, and is the key ingredient in portland cement. Ground limestone may be used as pigments or fillers in manufactured products such as paint, caulks and sealants, paper, and plastics. Powdered limestone is also used in coal mines to prevent combustion of coal dust. Limestone is also an important source of chemical lime (CaO) and magnesia (MgO). Lime and magnesia are widely used in the metallurgical and ceramics industry as a fluxing agent in the processing of metals, refractories, ceramics, glass, and fiber optics. Lime is used in agriculture as a soil additive to help neutralize acidic soils and break up clayey soils. It is also used as a feed stock additive and is one of the principal elements essential to plant growth. It is a standard ingredient in plant food.

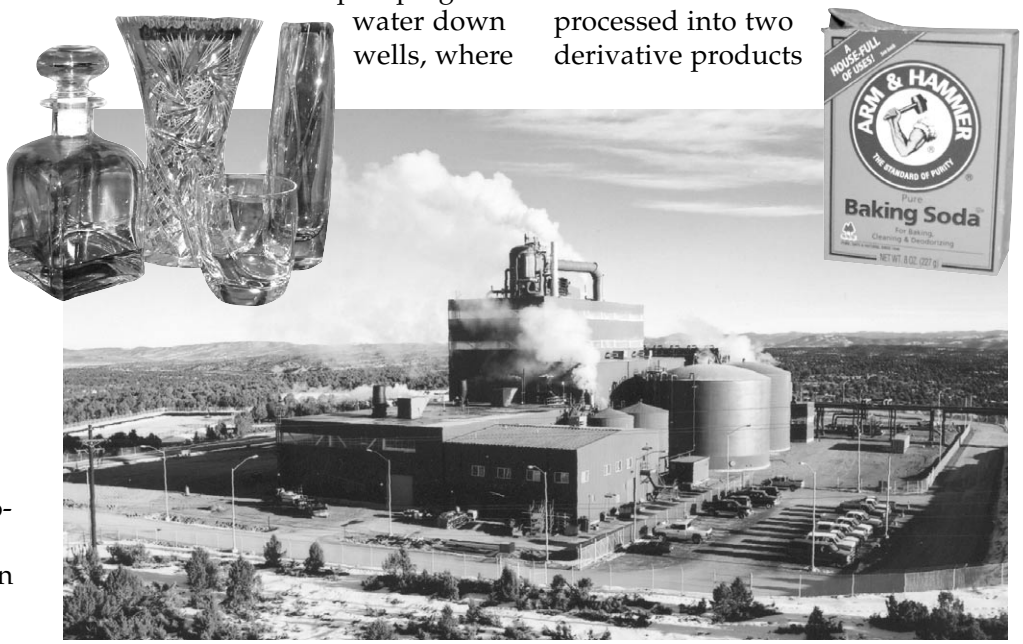
This concrete mixer truck is loaded with industrial minerals! Aggregate (crushed stone or sand and gravel) plus cement (limestone, clay or shale, and gypsum).

Nahcolite

Nahcolite is a sodium carbonate mineral ($NaHCO_3$), and has in recent years become one of the most economically important industrial minerals mined in Colorado. The world's largest known deposits of nahcolite are located in northwest Colorado. Nahcolite occurs in bedded sedimentary deposits of the Green River Formation, which is the same formation that hosts enormous and potentially valuable oil shale deposits. Currently, two companies mine nahcolite in Rio Blanco County southwest of Meeker: American Soda (see photos below) and White River Nahcolite. A third company, Natural Soda, Inc., is interested in developing a new mine in the same area. It is estimated that the Piceance Creek Basin contains 30 billion tons of nahcolite.

In Colorado, nahcolite is extracted from the deeply buried deposits by a method known as "solution mining". Solution mining of nahcolite is accomplished by pumping hot water down wells, where it dissolves the nahcolite. The nahcolite-rich water solution is then pumped back to the surface and sent through pipelines to processing facilities, where the nahcolite is taken out of solution and converted to soda ash or sodium bicarbonate. There is no need for open-pits or traditional shafts and tunnels to be dug, and no large piles of waste rock or tailings. Solution mining is not only cheaper than traditional mining methods, but preferable for many environmental reasons as well. In 2001, roughly 500,000 tons of nahcolite was recovered by the solution mines in Rio Blanco County.

Nahcolite is processed into two derivative products



American Soda's plant at the nahcolite solution mine in Rio Blanco County. Materials derived from nahcolite are used to make glass, soap and detergents, and baking soda. PHOTO COURTESY OF AMERICAN SODA, LLP

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Title: Waste Not. Want Not. Can a Leaf Mulch Improve Soil?

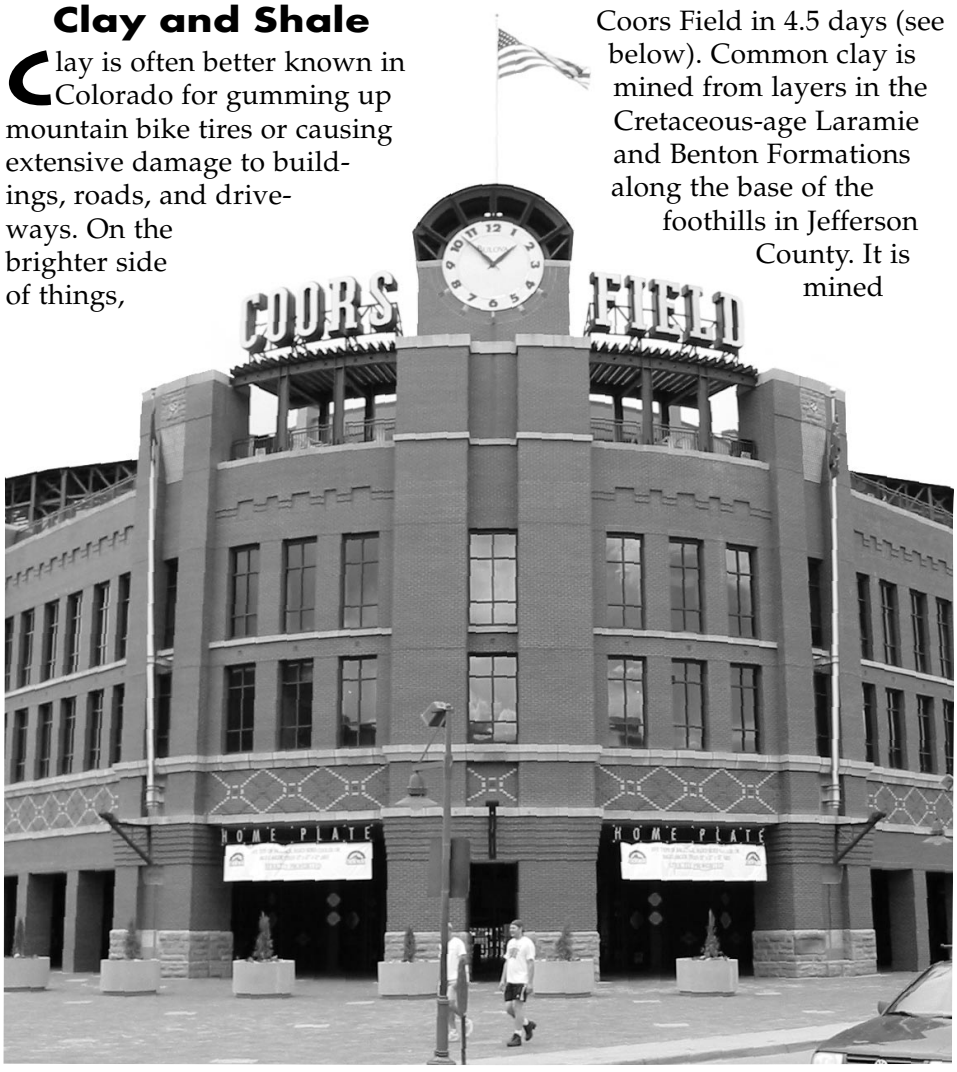
High School Winner
Christine Knoblauch,
Monte Vista High School
Title: Where's It Coming From? Hydropollution in the Alamosa River Drainage

that have a variety of industrial and consumer uses: soda ash (Na_2CO_3) and sodium bicarbonate (same chemical formula as nahcolite, ($NaHCO_3$). Soda ash is one of the main ingredients in the manufacturing of glass, soaps, detergents, and other chemicals. Another major use is to remove sulfur dioxide from power plant emissions, and is in this regard an "environment-friendly" industrial mineral. Sodium bicarbonate, also known as baking soda, is used in food products, animal feed, cleaning products, and pharmaceuticals. It can also be used as a "sandblasting" agent, and is used in some toothpastes. Colorado nahcolite solution mines compete with trona, another sodium mineral, which is mined in Wyoming and California.

Clay and Shale

Clay is often better known in Colorado for gumming up mountain bike tires or causing extensive damage to buildings, roads, and driveways. On the brighter side of things, however, clay is also a very useful mineral resource. Three main types of clay are mined in Colorado: common clay, refractory clay, and bentonite. Shale, a rock that contains an abundance of clay minerals, is also mined and is used for some of the same purposes as clay.

Common clay is used mainly to manufacture construction bricks and tiles. This type of clay is mined primarily in eastern Colorado, especially along the Front Range in Jefferson, Pueblo, and Fremont Counties. To make bricks, clay is mixed with water, strengthening agents, and colorants before being fired in a kiln at about 2,000° F. It takes about 2 tons of raw material to make 1,000 typical building bricks. The Robinson Brick Company in Denver manufactured all 1.4 million bricks for Coors Field in 4.5 days (see below). Common clay is mined from layers in the Cretaceous-age Laramie and Benton Formations along the base of the foothills in Jefferson County. It is mined



Coors Field was constructed using 1.2 million bricks made from Colorado clay.

from the Cretaceous-age Dakota Formation in Fremont and Pueblo Counties, and to a lesser extent in Jefferson County. A few clay mines are also present on the eastern plains, where it is mined mainly from small pits in the Dawson Formation of Tertiary age.

Refractory clay (or "fire clay") is still mined in the old clay mining area of Stone City, northwest of the city of Pueblo. It is mined from beds in the Dakota Sandstone of Cretaceous age. This clay is used to make industrial ceramics such as fire assay crucibles, foundry pouring systems, and laboratory furnaces. Refractory clay and pottery clay was mined in the past from the Dakota Sandstone near Golden (see photo below). Numerous clay pits and extensive tunnels along the Dakota Hogback in that area are testament to the good quality of this clay. Refractory clay deposits were also mined in the past northeast of Walsenburg in Huerfano County, and near Husted in El Paso County.

Bentonite is known in Colorado for causing damage to buildings and roads due to its ability to swell greatly when wet. When pure enough, bentonite is mined and used in oil drilling muds, to seal canals or ponds, as an absorbent such as in kitty litter, and for many other purposes. In Colorado, bentonite clay has most recently been mined from a small pit near Howard in Fremont County. There, the bentonite is present within an area of chemically weathered volcanic ash. Bentonite has also been intermittently produced from the Jurassic-age Morrison Formation near Grand Junction.

Shale is mined from the Pierre Shale of Cretaceous age in northern Jefferson County by TXI for use as lightweight aggregate. The shale is kiln-fired to the point where it expands in size and becomes low in density and weight. Lightweight aggregate is used in place of regular sand, gravel, or crushed stone in applications where excessive weight is undesirable, such as floors and walls in multi-story buildings. Cinder blocks are commonly made with lightweight aggregate. In the past, the Mancos Shale was commonly mined in western Colorado for use as common clay (making bricks and tiles).

Stacks of wallboard made from gypsum at the local home improvement mega-store.

Gypsum

Gypsum is a hydrated calcium sulfate mineral ($CaSO_4 \cdot 2H_2O$) that most commonly is found in bedded sedimentary deposits. Gypsum is an "evaporite" mineral. Evaporites are formed in shallow, protected marine bays or inland seas that are cut off from supplies of fresh water. The salty, heavy water becomes so saturated with mineral constituents that salts and other solid minerals, like gypsum, precipitate out of the water. The Great Salt Lake in Utah is a present-day example of an environment where evaporite minerals are accumulating. Thick deposits of these chemical precipitates can develop if the evaporite basins are active for a long period of geologic time. Commercial quantities of gypsum are present in a number of sedimentary formations throughout Colorado.

The largest industrial use of gypsum is in the manufacture of gypsum wallboard (see photo above). Gypsum wallboard is used everywhere in home and building construction because of its fire-resistance, low cost, and durability. Gypsum is also an important ingredient in plaster and cement. A fine-grained, dense variety of gypsum known as alabaster is used to make sculptures and ornamental objects.

In Colorado, the most economically important gypsum deposits are found in the Pennsylvanian-age

Clay miners posing for a photo in the underground clay mine of the Coors Porcelain Company, near Golden, Colorado, circa 1947.

PHOTO COURTESY OF COLORADO SCHOOL OF MINES

Pavement-profiler machine mining gypsum at the American Gypsum Mine in Eagle County, Colorado. The gypsum is used to make drywall at a plant in the nearby town of Gypsum.

rocks of the Eagle Valley Formation, most notably in Eagle County around the appropriately-named town of Gypsum. There, gypsum is mined at the surface using pavement-profiler machines (photo above) and is processed at a nearby plant into wallboard.

Gypsum is also currently mined from the Pennsylvanian-age Lykins Formation northwest of Fort Collins in Larimer County, and from the Jurassic-age Ralston Creek Formation northeast of Canon City in Fremont County. Gypsum from these areas is mined for use in cement production and as soil conditioners. Some gypsum from these sites has been used to make plaster as well. Gypsum deposits that were mined in the past, and that may become sources again in the future, are present in Jefferson, Douglas, El Paso, Mesa, San Miguel, and Las Animas Counties. Alabaster is mined on a small scale in Larimer and Pitkin Counties. The alabaster is used to make stylish ornamental items and artistic sculptures.

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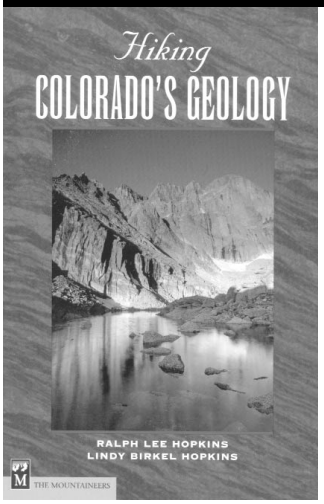
Principal Industrial Minerals of Colorado and Their Uses

Commodity	Main Uses	Some Other Uses	Significant Resource Areas in Colorado
Barite	Drilling mud for petroleum exploration	Automotive paint; chemicals	Not currently mined in Colorado, but occurs as vein deposits in the Wet Mountains of Fremont and Custer Counties, and in Boulder County
Clays and shale	Brick-making, tiles, ceramics, paper-making (kaolin only)	Kitty litter, lightweight aggregate	Currently mined mainly in eastern Colorado, along the flank of the Front Range in Jefferson, Pueblo, and Fremont Counties
Feldspar	A main ingredient in glass and ceramics	Used as a sandblasting agent and as an abrasive	No longer mined in Colorado, but formerly produced from numerous granitic pegmatites in mountainous areas, especially in Larimer, Chaffee, Fremont, Park, Jefferson, Gunnison, Boulder, and El Paso Counties
Fluorspar	Used to make hydrofluoric acid, which is used to make fluorocarbon chemicals (used in most air conditioners and refrigerators); aerosols	Aluminum smelting; steel-making	No mines currently operating in the entire U.S. The U.S. imports fluorspar, mainly from China. In Colorado, mines operated in the past in Boulder County, Jackson County, and in Browns Canyon in Chaffee County. Fluorspar was at one time Colorado's most economically important industrial mineral.
Gypsum	Gypsum wallboard (drywall) manufacture	An ingredient in cement, soil conditioner, slope stabilizer	Large mine in Eagle County produces gypsum for wallboard. Smaller mines in Fremont and Larimer Counties produce gypsum for other uses
Limestone	Cement production and as a construction aggregate	Food products, soil conditioners, environmental clean-up of acidic water	Mined for cement-making in Fremont and Larimer Counties. Occurs in many locations of the state
Mica	House paints, drywall joint compound, and insulators in electric motors	Insulation material in toasters; adds "sparkle" or "shimmer" in cosmetics	Very little U.S. production currently. Formerly produced in Colorado from pegmatites (often with feldspar), especially in Fremont County
Nahcolite	Used to manufacture soda ash, which is used to make glass, soap, detergents, and other chemicals. Also used to make sodium bicarbonate	Sodium bicarbonate is baking soda. Soda ash is also used to remove sulfur from smokestack emissions	Nahcolite is mined from wells in Rio Blanco County. The mineral occurs in bedded deposits within the Green River Formation. After construction aggregates, it is the most economically important industrial mineral produced in Colorado
Perlite (a volcanic rock)	When expanded by high heat, used as lightweight concrete construction aggregate and in acoustic ceiling tiles	Used in plant potting mixtures to keep soil loose	Formerly mined near Rosita in Custer County. Now U.S. production is mainly from New Mexico
Sand and gravel	Construction aggregate (concrete and asphalt), road base and fill	Decorative "river rock", golf course sand traps, trout spawning habitat for hatcheries	Found in all areas of the state. Deposits are located along rivers and major creeks, and in former glacial valleys
Silica Sand (industrial sand)	Hydro-fracturing of oil wells, gravel packs for groundwater monitoring wells, used in pack stucco	Advanced ceramics, optical fiber, non-skid flooring, golf course sand traps, steel foundry sand	Eolian sand deposits in Colorado Springs are quarried mainly for use in hydro-fracturing oil wells, and for gravel packs for environmental monitoring wells
Stone (crushed)	Construction aggregate (concrete and asphalt), road base and fill	Barbecue grill rock (volcanic cinder), decorative stone for landscaping	Granite and metamorphic rock in the Front Range and other mountains, volcanic rock in southwest and south-central Colorado, limestone, sandstone, and quartzite in eastern Colorado, marble in Chaffee County, volcanic cinder in Costilla and Eagle Counties
Stone (dimension)	Building construction	Walkways, countertops, monuments	Marble (Gunnison County), sandstone (Boulder, Larimer, El Paso, Pueblo, and Fremont Counties), granite (Larimer, Teller, Fremont, Gunnison, and Chaffee Counties), rhyolite (Douglas and Fremont Counties), travertine (Fremont County)
Sulfur	For manufacturing sulfuric acid used to make fertilizer, and in petroleum refining	Elemental sulfur used in synthetic rubber production	No longer mined in Colorado, but formerly produced from small mines in Delta, Gunnison, and Mineral Counties. Most U.S. sulfur is now produced as a byproduct of petroleum refining
Titanium minerals	White pigment in paints, plastics, and paper	High-end bicycle frames and golf clubs	No mines currently operating, but large potential resources exist in Gunnison County and on the plains near Limon
Vermiculite	Like perlite, useful when greatly expanded by heat; used as fire-proof insulation material, and as a soil conditioner	Protective base material for swimming pools	Found only in Precambrian and Cambrian rocks in the mountains of Colorado. Not presently being mined in the state. Best deposits are in Gunnison, Custer, Fremont, Pueblo, Chaffee, and Jackson Counties
Zeolite (clinoptilolite and other minerals)	Because of its capacity for cation-exchange, used in water treatment plants. Removes ammonia and other impurities	Used in kitty litter to remove odor; other odor elimination products	Clinoptilolite was mined in the past near Creede in Mineral County, from an altered volcanic ash layer. Also occurs in Moffat County in Tertiary-age alkaline lake bed deposits

Review of *Hiking Colorado's Geology*

By Vince Matthews, Senior Science Advisor



"These mountains of fire were ultimately chilled in the Ice Age freezer that worked its magic on their peaks during the past 1.8 million years, carving mountaintops and valleys into the dramatic shapes of today's San Juan Mountains."

—is an example of the delightful writing found in *Hiking Colorado's Geology* by Ralph and Lindy Hopkins. The Hopkins have created a book that is much more than a guide to interesting geological locales. Indeed, it is worth reading for the geology even if one never attempts any of the fifty trails described in the book.

The well-written text is succinct and well researched. One is hard pressed to find geological descriptions or interpretations in it with which to quibble. Ralph's beautiful photographs artistically illustrate the geologic features of interest. The drafted graphics are excellent—uncluttered, pertinent, and useful.

The hikes cover a broad cross section of Colorado's geology and geography, from the prairie of eastern Colorado across the mountains to the plateau of western Colorado. The trails lead to such diverse features as glaciers, fossils, granite batholiths, volcanic breccia, metamorphic rocks, landslides, sand dunes, volcanic ash and flows, hot springs, a "fourteener," mining districts, arches, dikes, dinosaur footprints, faults, unconformities and much more.

The Introduction contains a general summary of geologic principles for the non-geologist. Topics include Colorado's landscapes, the major rock types, sedimentary structures, geologic structures, plate tectonics, topographic and geologic maps, and tips on hiking Colorado's mountains.

The hikes are grouped into eleven geologic areas. Introducing each area is a précis of the general geology. The description of each hike within the areas covers the specific geology encountered. At the beginning of the section on each hike is a listing of distance, elevation, difficulty, topographic maps, geologic maps, key references, precautions, and who to contact for information. The text for the individual hikes begins with a short summary of the principal attractions entitled, "About the Landscape." The "Trail Guide" begins with an excellent description of how to reach the trailhead from the nearest population center. The trail descriptions are so well done that the reader is a vicarious hiking companion who is missing only the aches and pains.

I enjoyed reading the book and recommend it for anyone interested in the geology of Colorado. For those interested in hitting the trails in search of interesting geologic features, this book is a "must." See the Publications section on page 5 for purchasing information.

CGS Mission Statement

The CGS mission is to serve and inform the people of Colorado by providing sound geologic information and evaluation and to educate the public about the important role of earth science in everyday life in Colorado.

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