

ROCKTALK

Division of Minerals and Geology
 Colorado Geological Survey

Volume 6, Number 2

April 2003



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Gold!

Gold! Gold!

GOLD

Just the mention of that word whets the appetite for riches, adventure, and the excitement of discovery. Men have been giving up the comforts of home to search for gold since before recorded history. They have climbed over vast and imposing mountain ranges, suffered the biting blasts of the arctic, fought through disease infested jungles, and wandered across parched and lonely deserts all for gold, the most beautiful and most desired of all metals.

Gold has been treasured since prehistoric times. Gold artifacts are found in some of the earliest archeological sites. The earliest known geological map is Egyptian, and it dates from about 3,300 years ago. The map depicts "mountains of

gold" and shows areas where gold was recovered and where miners lived. No one is sure of the exact location of this ancient mine; however, it may be in the Red Sea Hills near the present day Suez Canal.

What is it about gold that makes it so attractive and so useful? Gold is not very hard; a knife can easily scratch pure gold. Gold is very heavy or dense, having a specific gravity of 19.3+ (extremely heavy even for metallic minerals). Some of the other characteristics of gold are ductility, malleability and sectility, meaning it can be stretched into a wire, pounded into other shapes, and cut into slices. Gold is the most ductile and malleable element on our planet. A single ounce of gold can be drawn into a wire 35 miles long and it can be hammered into sheets less than five millionths of an inch thick. Gold is a great metal for jewelry, as it never tarnishes.

The color and luster of gold are what make this metal so attractive. Gold is almost indestructible and has been used and reused for centuries, to the extent that all of the gold that is currently being used by mankind is almost equal to all the gold that has ever been mined.

When we think of gold our first thoughts go to jewelry and



Twenty-four carat gold leaf glimmers from the Capitol's dome. It symbolizes the pride Colorado's citizens have always taken in the building. But the dome was not always gold. When built in the mid 1890s, it was sheathed in copper, which quickly tarnished to dull green. The dome was first gilded in 1908. The job required 200 ounces of gold, then valued at \$20 per ounce. A dome of gold, said the newspapers, belonged in a gold state, but by the 1940s the gold leaf had worn off, leaving the dome again tarnished. Further applications of gold were done in 1950, 1980, and 1991. (FROM [HTTP://MEWWW.COLORADO.EDU/CENTERS/COMBUSTION/STATECAP.HTML](http://MEWWW.COLORADO.EDU/CENTERS/COMBUSTION/STATECAP.HTML))

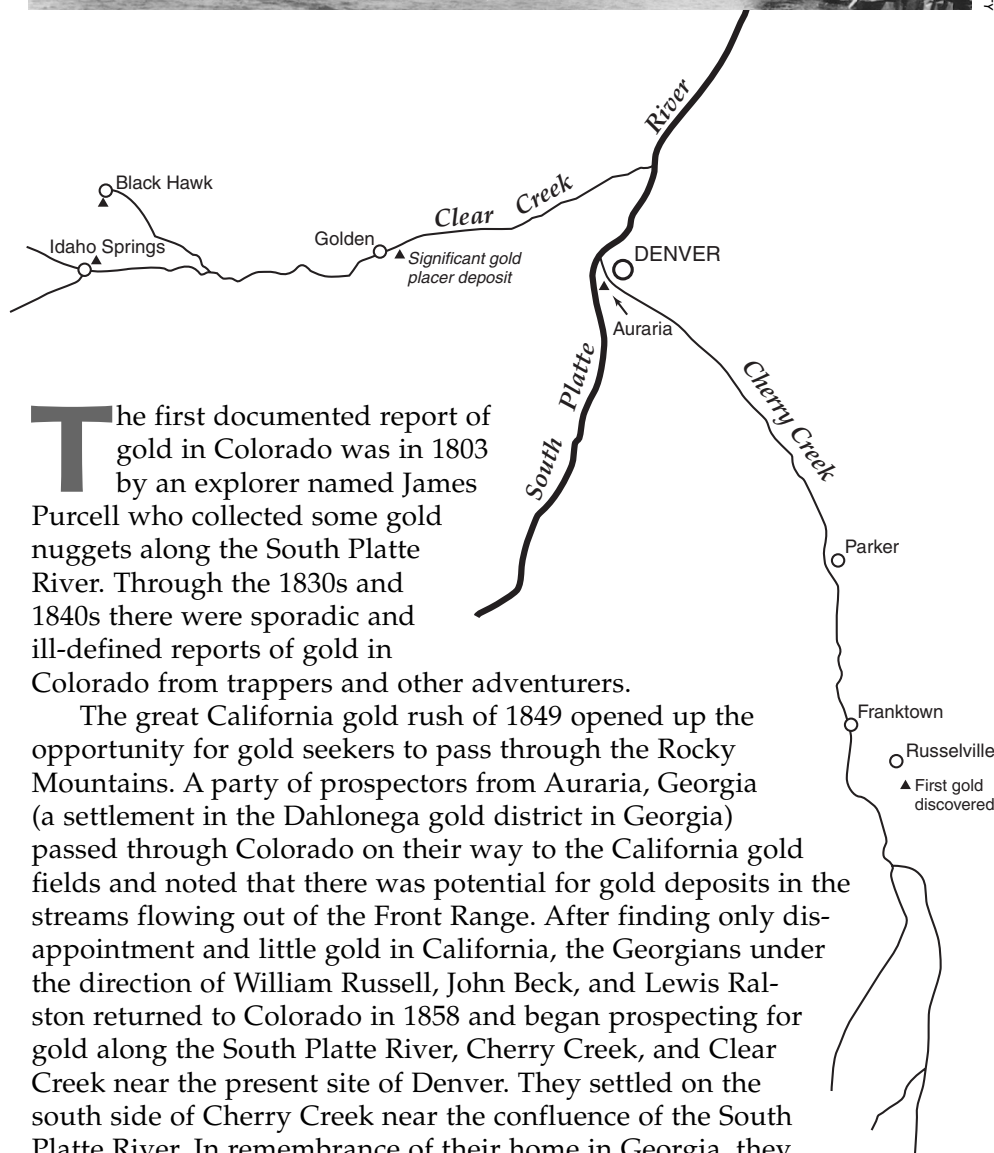
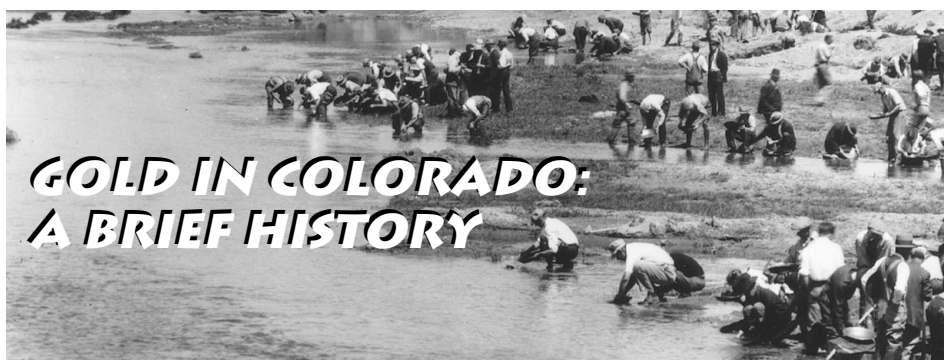
INSIDE

Publications	13
The Rock Doctor Asks	13
San Luis Valley Science Fair	13
Geosciences Critical to Colorado's Future	14
CGS Celebrates a Decade of Excellence	14
Book Review	16

other ornamentations made from gold. In today's modern high tech economy gold has found other uses as well. Gold has superior electrical conductivity, resistance to corrosion, and other desirable combinations of physical and chemical properties that have allowed it to become an essential industrial metal. Gold performs critical functions in computers, communications equipment, spacecraft, jet aircraft engines, airbags in automobiles, and a host of other products. Gold has been used for many years in dentistry, mainly because of its lack of reactivity with other materials. Gold is also used in custom paints; the dome of the Colorado State Capitol building is painted with a special gold paint. Gold is also perceived to be the one commodity that is a long-term store of value. Until recent times, it was considered essentially a monetary metal, and most of the bullion produced each year went into the vaults of government treasuries or central banks.

There are very few true gold minerals besides native gold. Gold forms a major part of only a few rare minerals; it is found as little more than a trace in a few others, or it is alloyed to a small extent with other metals such as silver and copper. A few of the minerals that bear gold in their respective formulae are in a class of minerals called the tellurides. The element gold seems to have an affinity for tellurium and is one of the only elements that gold can bond with easily.

Gold-silver alloys usually have a whiter color than pure gold, and gold-copper alloys tend to have a slight reddish tint. The gold content of a gold alloy is measured in karats; 24 karat is 100 percent, 18 karat is 75 percent gold and 25 percent other metals, and 14 karat is 58 percent gold and 42 percent other metals.



The first documented report of gold in Colorado was in 1803 by an explorer named James Purcell who collected some gold nuggets along the South Platte River. Through the 1830s and 1840s there were sporadic and ill-defined reports of gold in Colorado from trappers and other adventurers.

The great California gold rush of 1849 opened up the opportunity for gold seekers to pass through the Rocky Mountains. A party of prospectors from Auraria, Georgia (a settlement in the Dahlonega gold district in Georgia) passed through Colorado on their way to the California gold fields and noted that there was potential for gold deposits in the streams flowing out of the Front Range. After finding only disappointment and little gold in California, the Georgians under the direction of William Russell, John Beck, and Lewis Ralston returned to Colorado in 1858 and began prospecting for gold along the South Platte River, Cherry Creek, and Clear Creek near the present site of Denver. They settled on the south side of Cherry Creek near the confluence of the South Platte River. In remembrance of their home in Georgia, they named the settlement Auraria (today the home of the Auraria campus of CU Denver, Metropolitan State College, and the Tivoli Brewery). Through 1858 and early 1859 these prospectors and others found gold in these streams but never a rich amount—always just a tease. The local prospectors and their financial backers in the east were beginning to think that the Pikes Peak Gold Rush (as it was called, even though it was nowhere near Pikes Peak) was a bust!!

In the late summer of 1859, George Jackson, another prospector from Georgia, began prospecting along Clear Creek near the present site of the city of Golden (oddly Golden is not named for gold, but for a man named

Tom Golden, an early prospector). Jackson found significant amounts of gold as he continued up Clear Creek until he discovered and starting mining the rich placer* deposits where Chicago Creek joins Clear Creek near Idaho Springs.

Later that same year, another Georgia prospector, John Gregory, prospected for gold along Clear Creek and then up the North Fork to the present site of Blackhawk. There he found an outcropping quartz vein with gold, the first "lode"* gold discovery in Colorado, which led to the development of the Blackhawk–Central City mining district. During that year and in 1860, gold was discovered in many locations throughout the state including Boulder Creek, Nederland, Breckenridge, Silverton, Telluride, Leadville, and other famous Colorado mining sites.

Leadville

The discovery of gold near Leadville in the gravel deposits of California Gulch lead to a short lived placer gold boom in that area. The discovery of veins with large masses of free gold at the Printer Boy Mine in 1868 helped extend the life of the camp, but did not reverse the trend of declining production. One of the problems

the placer miners encountered was a strange brown material that kept clogging up the gold placer mining operations. In 1874 the brown material was recognized as a silver-lead ore and the great lead–zinc–silver–gold deposits of the Leadville district were quickly discovered and developed.

During the 1860s, most all of Colorado's easily mined gold deposits, placer and oxidized gold lode deposits were exploited. As the 1870s and 1880s came to a close, new processing techniques allowed the development of underground lode gold mines throughout the state. During these years silver, especially in the Alma district, Leadville district, and San Juan Mountains, became the dominant commodity mined in Colorado. Gold mining suffered and the huge bonanza gold district eluded detection, that is until 1891.

Cripple Creek

Early reports of gold in the area around Pikes Peak in 1874 and 1884 never "panned out"(a common expression related to gold prospecting). In 1891, a local rancher named Robert Womack made a gold discovery in Poverty Gulch, just east of the present day town of Cripple Creek, and located the El Paso claim. This claim was later developed into the Gold King

Mine, the first of a series of gold discoveries that led to the rapid development of the Cripple Creek district. The rich underground mines in the early years of the district's history had an average grade of 1 to 2 ounces of gold per ton.

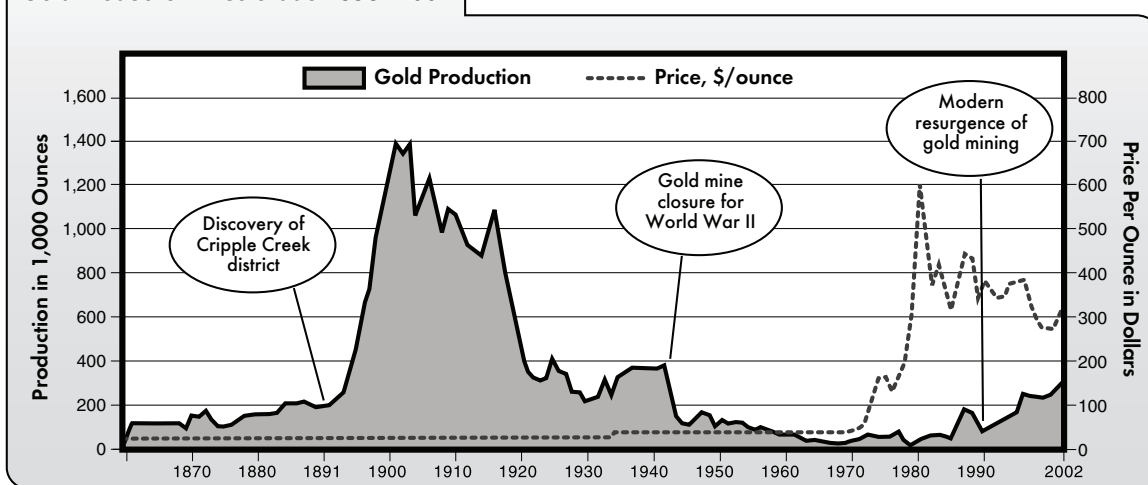
The Cripple Creek District has produced more than 23 million ounces of gold, about half of Colorado's total production of 45 million ounces. In the peak year of production, 1900, 879,000 ounces of gold were produced. By 1920 production from the district had started to decline because of labor shortages, wage disputes, and water problems.

In 1933, the price of gold increased from \$20.67 to \$35.00 an ounce, which fostered a small mining boom in the state until the outbreak of World War II and the closure of all non-essential mines by the War Production Board. Gold mining in Colorado languished in the years after World War II, primarily because of the low price of gold.

All restrictions on the price of gold were lifted during the mid-1970s and interest focused on low grade (0.03 to 0.2 ounces of gold per ton) bulk-tonnage gold deposits. Gold production began to steadily increase during the 1980s and 1990s from deposits located near Silverton at the Sunnyside

* See **Definitions** on page 12

Gold Production in Colorado 1858–2001



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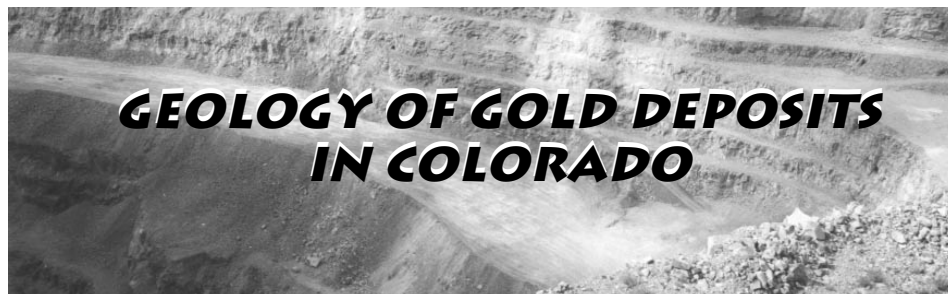
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Ground Water Atlas of Colorado \$40.00

Mine, near Ouray at the Camp Bird Mine, the Summitville Mine in the San Juan Mountains, the Globe Hill and Iron Clad mines in the Cripple Creek district, and the San Luis Gold Mine in the Sangre de Cristo Mountains.

Gold mining still continues today in the Cripple Creek District with the 1995 development of the Cresson surface mine by the

Cripple Creek & Victor Gold Mining Company (CC&V), which is a joint venture between AngloGold (Colorado) Corp. (67%) and Golden Cycle Gold Corporation (33%). The operation has produced 1.62 million gold ounces since early 1995. The project employs over 300 people and is currently accelerating production to over 400,000 gold ounces per year.



The Colorado Mineral Belt played an important role in the distribution of the different types mineral deposits in Colorado. Most of Colorado's gold deposits are within the Colorado Mineral Belt with one rather important exception. The Colorado Mineral Belt (page 5) was recognized early in the development of Colorado's mineral exploration history. Josiah Spurr, in his 1908 study of the Georgetown—Silver Plume area, was the first scientist to recognize and publish the observation that mining districts in Colorado tended to line up in a northeasterly direction.

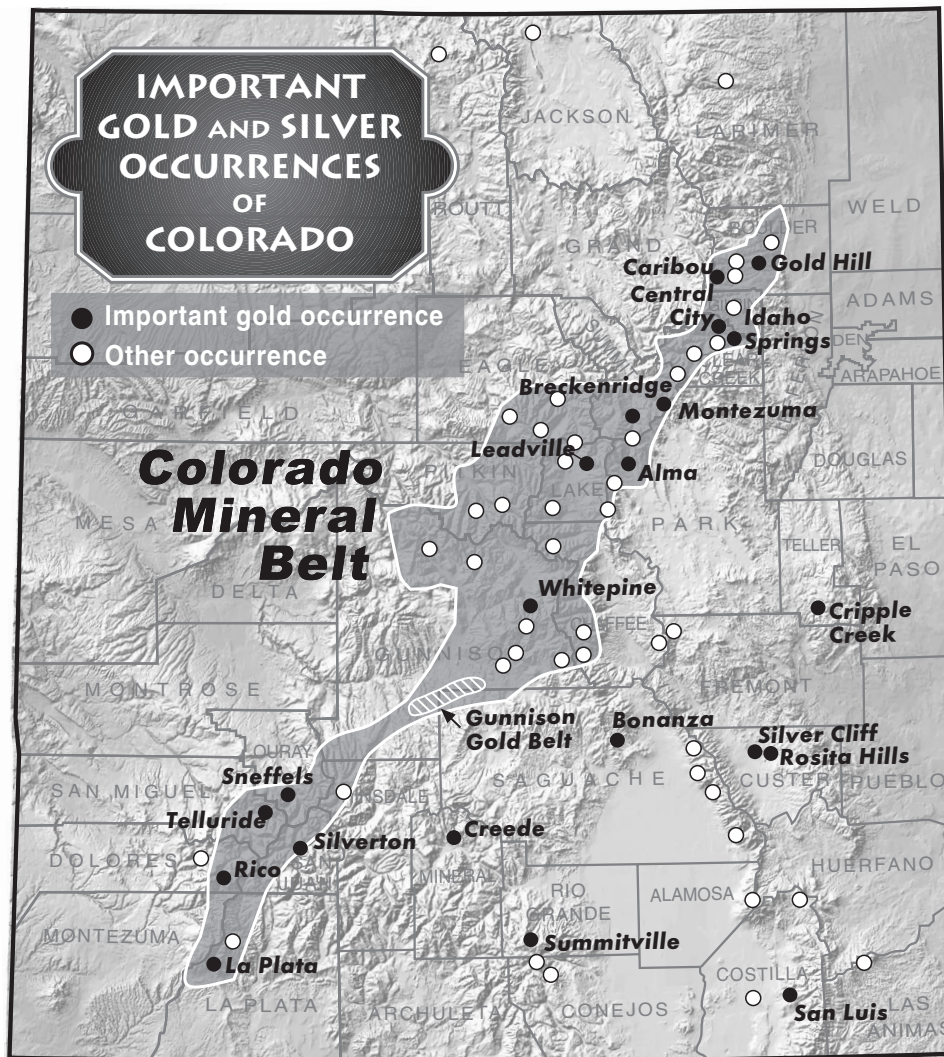
Later workers came to realize that this northeasterly-trending zone was, in fact, a zone of fracturing and igneous intrusion that formed during the Laramide Orogeny* (about 75 million years to 40 million years ago). These intrusions and fractures are thought to follow a much older, Precambrian age zone of crustal weakness and shearing. Most of Colorado's vein, placer, and replacement ore bodies occur within the bounds of the Colorado Mineral Belt. However, it should be noted that Colorado's greatest gold producing district, the Cripple Creek district, is well outside of the Colorado Mineral Belt and is some 10 million years younger than the mineral deposits related to the Laramide Orogeny.

All of the lode* gold deposits described below commonly contain more than one type of gold deposit; for example, the massive sulfide replacement deposits of the Leadville district also contain vein deposits.

Vein Deposits

Ore-bearing veins are open-space fillings along fractures or fault zones in the country rock. Veins usually consist of some non-ore mineral material (gangue), like quartz or calcite, and ore minerals like gold, silver, and base metal (lead, zinc, copper, and iron) sulfides.

Quartz-base metal-gold veins are the most common type of ore body in the mining districts of the Front Range of Colorado. Here, the veins generally fill north-northeast to east-trending fractures and faults in Precambrian igneous and metamorphic rocks and, locally, a type of Laramide Orogeny-age, igneous rock called porphyry*. Veins generally



include Silverton, Creede, Summitville, Telluride, Lake City, and Imogene Basin (near Ouray). Most of the mining camps of the San Juan Mountains produced considerably more silver than gold; however, gold was the most important mineral, economically.

Veins in the San Juan Mountains have lengths up to about 9,000 feet, with depths to over 2,500 feet. Vein widths average three to six feet; the largest are up to 50 feet wide.

Gangue minerals in the veins of the San Juans include quartz, calcite, barite, fluorite, and a rich variety of manganese minerals including rhodochrosite (the new State Mineral), rhodonite, and others.

Ore minerals include the base metal sulfides: pyrite, sphalerite, galena, tennantite, and chalcopryrite. Gold is generally associated with the pyrite and chalcopryrite and most of the silver is associated with tennantite.

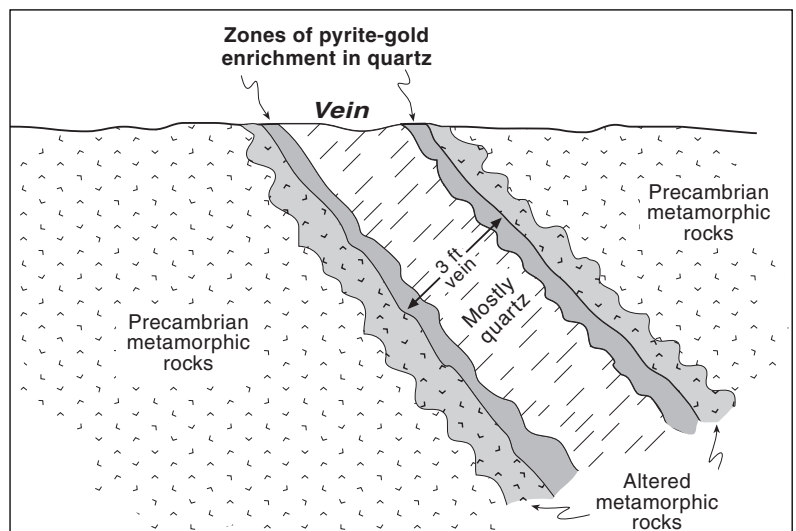
Replacement Deposits

Replacement deposits are, for the most part, hosted by Paleozoic-age

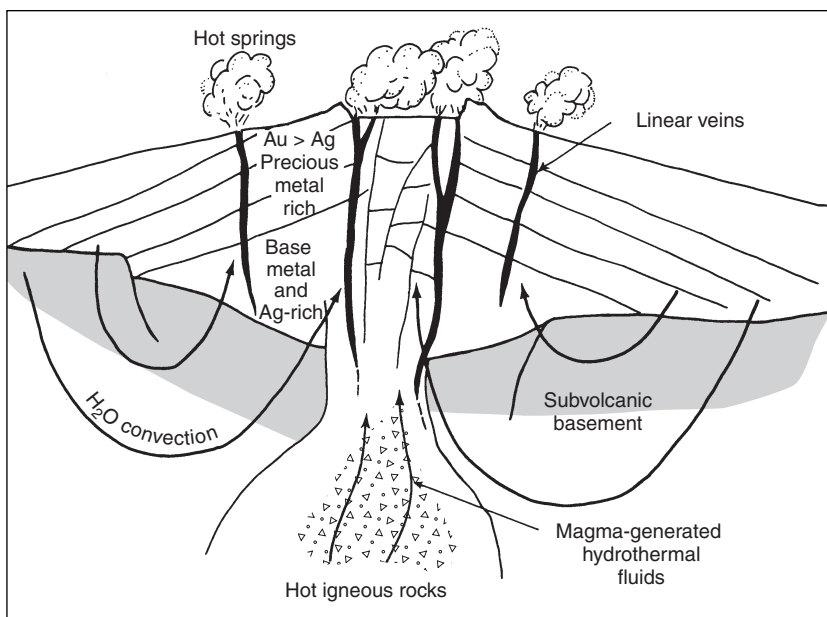
are a few thousand feet in length; the longest vein in the Central City district is the California-Mammoth vein, which is over two miles in length. Veins in the Central City district vary in width from a few inches to about 40 feet (at right). The veins "pinch out" at depths of 1,000 to 2,000 feet below the surface. Ore from the Mammoth Vein is typical of the district; gold contents ranged from 0.5 to 26 ounces per ton; silver ranged from 1.5 to hundreds of ounces per ton. Most of the gold-bearing veins of the Front Range mining districts also produced considerable amounts of lead, zinc, and copper.

The spectacular San Juan Mountains of southwestern Colorado also contain several mining districts that have gold-base metal veins; however, in this area the veins are related to the development of a post-Laramide Orogeny-age volcanic field. Most of the veins are related to post-eruption subsidence of volcanoes, called calderas (next page). Some of the better known mining districts of the San Juan Mountains

carbonate rocks, limestone and dolomites. The replacement ore bodies are composed of zones of almost entirely sulfide minerals (called massive sulfide deposits), usually galena, sphalerite, pyrite,



Typical gold vein



Cross section of a volcano showing collapsing caldera and relationship of precious metal vein deposits —ADAPTED FROM GUILBERT AND PARK, 1985, P. 537

and others. Gangue minerals are minor and consist mostly of quartz and calcite. Silver is commonly associated with galena and gold is commonly associated with pyrite. Most of the replacement deposits in Colorado are associated with Laramide Orogeny-age porphyry intrusions. They include the Leadville district, the Aspen district, the Gilman district, and the La Plata district in the southwestern corner of Colorado. Only the Leadville district and the Gilman district produced significant amounts of gold from replacement deposits..

The Leadville district is noted for six types of mineral deposits:

- 1) Zinc-lead-silver-gold replacement bodies have typical grades of 0.05–0.2 ounces of gold per ton, 2–6 ounces of silver per ton, 3–8 percent lead, 6–30 percent zinc, and 0.1–0.3 percent copper;
- 2) Quartz-base metal veins have typical grades of 0.1–0.5 ounces of gold per ton, 2–13 ounces of silver per ton, 5–15 percent lead, and 4–10 percent zinc;
- 3) Magnetite-serpentine-gold replacement bodies have average grades of 0.06–0.17 ounces of gold per ton, 2–4 ounces of silver per ton, and some copper;
- 4) Quartz-pyrite-gold veins have average grades of 0.5 ounces of gold per ton, 30–40 ounces of silver per ton;
- 5) Disseminated pyrite-gold in igneous intrusions, mainly porphyritic rocks, have historic grades of 0.15–0.9 ounces of gold per ton;
- 6) Placer gold.

Stratabound Gold-Sulfide Deposits

Disseminated gold and base metal mineralization occurs along structures or other zones that are parallel to foliation or original bedding in Precambrian age metamorphic rocks in several areas of the state, including the Pearl district in Jackson County, the Salida area of Chaffee County, and the “Gunnison Gold Belt” in Gunnison County.

These types of deposits never produced much gold in Colorado; however, they remain an intriguing target for gold prospectors, especially in other parts of the world.

Gold Deposits in Alkalic Volcanic Rocks

Alkalic igneous rocks form a unique suite of rocks that are depleted in silica and relatively enriched in sodium and potassium compared to other igneous rocks. The Cripple Creek

district is located within a small (approximately six square miles) 32–28 million year old alkalic intrusive-diatreme complex emplaced at the junction of four Precambrian igneous and metamorphic units.

Diatremes are neck-like volcanic features composed of breccia formed by the explosive activity that results when molten rock interacts with abundant groundwater near the surface. The complex consists primarily of a large mass of phonolite, an alkalic igneous rock, and

Just a few of the many minerals associated with gold deposits in Colorado and elsewhere.

Mineral Name	Chemical Composition	Chemical Name
Quartz	SiO ₂	Silicon dioxide
Calcite	CaCO ₃	Calcium carbonate
Fluorite	CaF ₂	Calcium fluoride
Rhodonite	MnSiO ₃	Manganese silicate
Rhodochrosite	MnCO ₃	Manganese carbonate
Pyrite	FeS ₂	Iron sulfide
Sphalerite	ZnS	Zinc sulfide
Galena	PbS	Lead sulfide
Chalcopyrite	CuFeS ₂	Copper-iron sulfide
Tennantite	3CuS ₂ ·As ₂ S ₃	Copper sulfide–arsenic sulfide
Calaverite	AuTe ₂	Gold telluride
Sylvanite	(Au,Ag)Te ₂	Gold-silver telluride
Petzite	(Ag,Au)Te ₂	Silver-gold telluride

phonolite breccia. There are also lake sediments, tree trunks, and coal layers within parts of the complex, which indicate that these igneous rocks formed a small volcanic center at the surface.

Because of their unique composition, ore deposits associated with alkalic igneous rocks have distinctive set of gangue and ore minerals. The principal ore minerals in the Cripple Creek district are gold telluride minerals: calaverite, and rarely sylvanite and petzite. Calaverite from district mines contains 39 percent to 43 percent gold and minor amounts of silver.

The Cripple Creek district is in Teller County, well south of the Colorado Mineral Belt. The district is the most important gold-producing camp in the state; it has produced more than 23 million ounces of gold since its discovery in 1891. In comparison, the entire state of Colorado has produced about 45 million ounces.

Four main types of ore deposits are found within the Cripple Creek district: vein deposits, diatreme-hosted deposits, hydrothermal breccia-hosted deposits, and bedded rock-hosted deposits.

Vein Deposits

The vein and fissure vein deposits of the Cripple Creek district were the first discovered. The veins generally dip steeply and show a general radial pattern within the district. The veins of the district range from simple fissure fillings less than an inch thick to sheeted zones that are several feet, and as much as 100 feet, in width. The Ajax vein system is typical of the district; the Ajax vein is exposed throughout a vertical range of greater than 3,000 feet with virtually no change in ore grade or mineralogy. The Ajax Mine began production in

1895 and produced more than 700,000 ounces of gold at grades of 0.6 to 1.04 ounces per ton.

Diatreme-hosted Deposits

The most economically significant diatreme-hosted deposit in the Cripple Creek district was the Cresson Mine. It yielded 28.3 million tons of ore at a grade of 0.55 ounces of gold per ton from 1904 to 1959. The mine's production of over 15 million ounces of gold was about 70 percent of the district's total production. In 1914 a very rich part of the deposit known as the Cresson Vug was discovered and during a period of four weeks it yielded approximately 58,000 ounces of gold from an open cavity 23 feet by 13 feet by 40 feet high.

Hydrothermal Breccia Deposits

The northern part of the Cripple Creek district is dominated by hydrothermal breccia gold deposits. These deposits consist of low grade, native gold ores within strongly altered and hydrothermal brecciated alkalic porphyry. The hydrothermal breccias of the Globe Hill and Ironclad deposits were mined during the period from 1992 to 1995 using modern surface mining techniques.

Sedimentary Rock-hosted Deposits

Lake and river sediments are common in the eastern part of the Cripple Creek intrusive-diatreme complex. Sedimentary rocks are found at the surface and in the deepest mine workings, 3,200 feet below the surface, indicating a substantial amount of subsidence within the complex. The Cameron Mine contains disseminated gold in sediments.

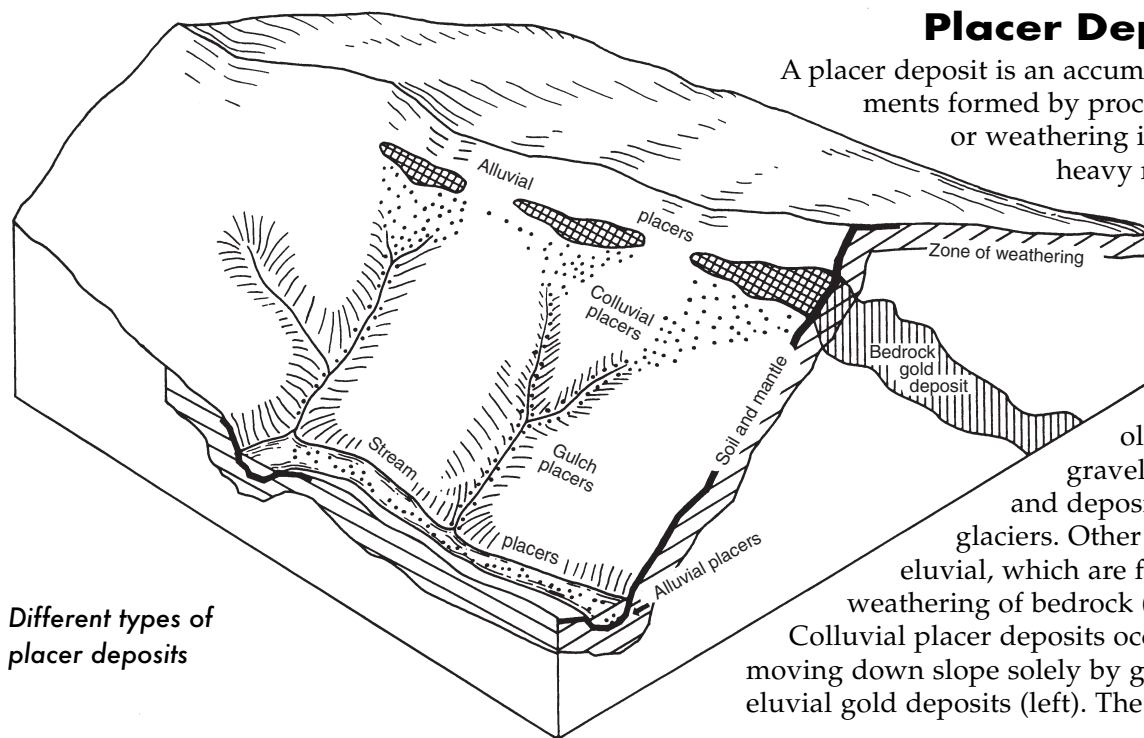
Placer Deposits

A placer deposit is an accumulation of rock fragments formed by processes of sedimentation or weathering in which gold or other heavy minerals are concentrated by mechanical

processes, such as gravity. Placer deposits occur in alluvial deposits of sand and gravel in modern day streams,

older bench or terrace gravel deposits, alluvial fans, and deposits left or modified by glaciers. Other placer deposits include eluvial, which are formed in soils by the weathering of bedrock (lode) gold deposits.

Colluvial placer deposits occur by gold particles moving down slope solely by gravity, generally from eluvial gold deposits (left). The largest gold lode



**Different types of
placer deposits**

deposits in the world, the Witwatersrand in South Africa, were originally formed in alluvial beach placers during the early Precambrian (about 2,200 to 3,000 million years ago). These gravels were subsequently turned into hard rock by heat and pressure.

In Colorado the most common type of gold placer deposits are alluvial deposits formed in the sand and gravel of modern day streams. In many cases older stream deposits called benches or terraces, which formed during the Quaternary Period (the last two million years) are also good hosts for placer gold deposits. The first gold discoveries in Colorado were placer deposits in and around the present site of Denver. Other notable placer mining areas in Colorado include Clear Creek from Golden to Idaho Springs, the Blue River near Breckenridge, and the South Platte River near Fairplay.

Gold from placer deposits has been recovered by a variety of methods including panning (below), sluice boxes, hydraulic mining, and dredging and drift mining. For a more complete description of these placer-mining methods please refer to Parker (1992).



Prospector panning for gold —PHOTO
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Fairplay Dredge No. 1 —PHOTO COURTESY COLORADO HISTORICAL SOCIETY, ZELLARS COLLECTION

Economically significant placer mining in Colorado ended in 1951 with the shutdown of the “Fairplay Dredge,” (above) a large dredging machine that recovered gold from the South Platte River near Fairplay.

Even today, small amounts of gold are recovered from sand and gravel quarries along the South Platte River. Also, many people come to Colorado to do recreational gold panning; these modern day prospectors recover small amounts of gold.

— Jim Cappa



The Cripple Creek & Victor Gold Mining Company is presently the only active large scale gold mining operation in Colorado. It is located 52 miles west of Colorado Springs near the historic gold mining towns of Cripple Creek and Victor. Anglo-Gold (Colorado) Corp. operates this large surface mine, which employs about 300 people and is the largest private employer in Teller County.

Whereas the old-time miners in the area searched for and mined rich “high grade” gold ore from narrow veins, the modern mine takes advantage of new mining technology to extract gold remain-

ing in the “low grade” ore that was left untouched by the old-timers. Although the ore is not rich, there is a lot of it. At the beginning of 2002, geologists at the mine estimated a reserve of 157 million tons of gold-bearing ore containing 5.0 million ounces of gold. The ore has an estimated average grade of only about 0.032 ounces of gold per ton. Modern-era surface mining began in the Cripple Creek district in 1991. Underground mining ceased in Cripple Creek in 1961, 70 years after the discovery of gold in the district. (left)

In 2002, the Cripple Creek & Victor Gold Mining Company



The Cripple Creek & Victor gold mine. Note the drilling rigs forming a blasthole pattern in the bottom of the mine.



Crushing and sorting facility, Cripple Creek & Victor Gold Mine

produced 224,000 ounces of gold. In October 2002, the company completed a major expansion of its production capability that will permit the mine production to ramp-up to 400,000 ounces of gold per year. At the expanded rate of production, the ore reserve base will support mining through 2012.

Mining and Processing

The low-grade gold ore at Cripple Creek & Victor is mined at a rate of about 55,000 tons per day. The ore is blasted from active mining "benches" within the open pit and loaded by enormous shovels into giant trucks that can haul 310 tons of rock in a single load (below). The trucks deliver the raw ore to a crushing plant that



Massive new truck at the Cripple Creek & Victor with the capacity to haul 310 tons of ore per load.

crushes the rock to a specified mesh size, about $\frac{5}{8}$ inch in diameter. The crushed ore is then placed on a heap leach pad (page 10). A slow-drip system applies a solution of water and sodium cyanide to the ore. The cyanide solution soaks into the pad and dissolves the microscopic particles of gold within the ore. The cyanide solution is then collected at the base of the pad by a system of pipes and heavy liners. Care is taken to avoid any leaks of cyanide solution, not only to protect the groundwater, but to protect profits. Losing cyanide solution at this point means losing gold. After being collected, the gold-bearing cyanide solution is treated with activated carbon, which acts like a chemical sponge and reduces

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THIS ISSUE

Editors: Jim Cappa, John Keller,
Cheryl Brchan

Production: Cheryl Brchan



Heap leach pad with a drip system that gently applies a solution of water and sodium cyanide to crushed and screened gold ore at the Cripple Creek & Victor Gold Mine.



Getting ready to pour gold at Cripple Creek & Victor Gold Mine

the gold out of the solution. The gold (along with a little silver) is then smelted into doré bars of crude metal, which is sent to a gold refinery in another state for purification.

— John Keller

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Parker, B.H., Jr., 1992, Gold panning and placering in Colorado: Colorado Geological Survey Information Series 33, 83 p.
Vanderwilt, J.W., 1947, Mineral resources of Colorado: Denver, State of Colorado Mineral Resources Board, 547 p.
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DEFINITIONS

(From Glossary of Geology,
American Geological Institute)

Ore deposit—Ore is defined as a naturally occurring material from which a mineral, or minerals, of economic value can be extracted.

Grade—The relative quantity or percentage of ore mineral content in a body of rock. For gold usually expressed as ounces of gold per ton.

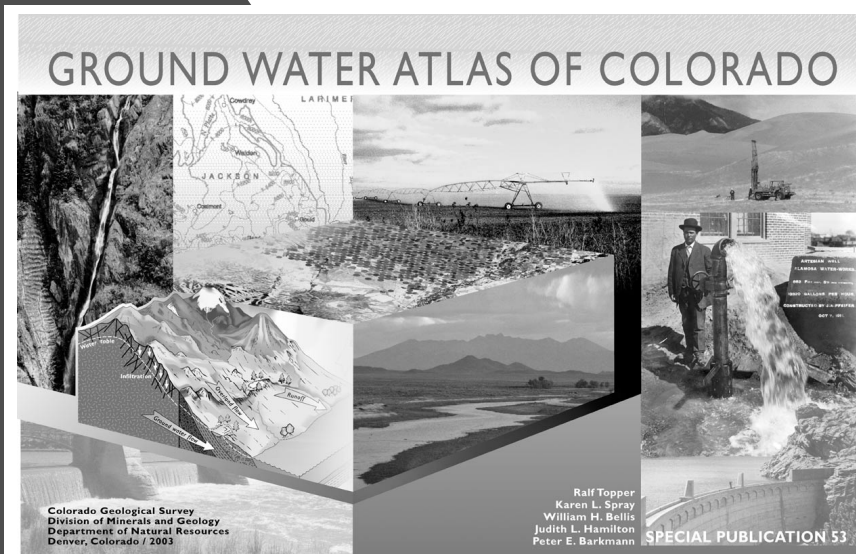
Lode deposit—A mineral deposit in consolidated rock as opposed to most placer deposits which are in unconsolidated materials.

With the worst drought on record in 2002, water is a topic that gets a bit more attention throughout Colorado these days. Information on this subject is more sought after than ever. Now, the Colorado Geological Survey delivers a benchmark publication, compiling basic ground-water information from an abundance of sources into one volume, the *Ground Water Atlas of Colorado*.

The *Ground Water Atlas of Colorado* is a comprehensive, map-based look at ground water in our state, an important part of the water resource picture. It summarizes the location, geography, geology, water quality, and hydrologic characteristics of the prominent aquifers in each part of Colorado. The large-format, full-color atlas was produced in cooperation with the Colorado Water Conservation Board and the Division of Water Resources.

The *Ground Water Atlas of Colorado* presents ground water information in a way that is approachable by laypersons as well as those well-versed in the subject. A multitude of maps, diagrams, pictures, tables, and graphs help make the technical aspects of ground water more understandable. With over 200 pages, the basic ground water information you need is probably covered.

The *Ground Water Atlas of Colorado* (Special Publication 53) is now available at the Colorado Geological Survey at a cost of \$40.00. Call (303) 866-2611 and order yours today!



COLORADO MINING AND MINERAL MUSEUMS AND MINE TOURS

Colorado's mining history has left a rich legacy. But, this legacy also includes 23,000 inactive and abandoned mines that can be as dangerous as they are picturesque. Mine sites may look safe to explore, but they often contain unstable soil, unsafe roofs and ladders, deadly gasses, poisonous snakes and dangerous explosives. The Colorado Division of Minerals and Geology asks you to "Stay Out and Stay Alive" and not explore abandoned mines but encourages you to learn more about mining and Colorado's historic mining past by visiting a mining museum or tourist mine in Colorado.

Argo Gold Mine and Mill (tour)

Idaho Springs, Colorado
(303) 567 2421
<http://www.historicargotours.com/>

Bachelor Syracuse Mine (tour)

Ouray
970-325-0220
<http://www.ouraycolorado.com/activits.html>

Clear Creek Mining and Milling Museum

23rd Avenue and Riverside Drive
Idaho Springs

Colo. School of Mines Geology Museum

Currently in Berthoud Hall, CSM campus.
Soon in new building!
Phone: (303) 273-3823
<http://www.mines.edu/academic/geology/museum/>

Country Boy Mine (tour)

542 French Gulch Road, Breckenridge
970-453-4405
<http://www.summitnet.com/countryboymine/>

Cripple Creek District Museum

5th and Bennett Avenues, Cripple Creek
(719) 689-2634
<http://www.cripple-creek.co.us/ccdm.html>

Creede Underground Mining Museum (and tour)

Creede
719-658-0811
<http://www.museumtrail.org/CreedeUndergroundMiningMuseum.asp>

Denver Museum of Nature and Science

2001 Colorado Blvd., Denver
(303) 322-7009
<http://www.dmnh.org/>

Edgar Mine (tour)

Colorado Avenue & 8th Street
Idaho Springs
(303) 567 2911
<http://www.mines.edu/Academic/mining/edgar.html>

Gilpin County Historical Society and Museum

228 High Street
Central City, CO 80427
(303) 582 5283
<http://www.coloradomuseums.org/gilpin.htm>

Hard Tack Mine (tour)

Lake City
970-944-2506
<http://www.lakecityco.com/lakecityRecreation.html>

Hidee Gold Mine (tour, appointment only)

County Rd. 6, Central City/Blackhawk
303-989-2861

Lafayette Miners' Museum

1087 E. Simpson Street
Lafayette, CO 80026
(303) 665 7030

Lowell Thomas Museum

3rd and Victor Avenue, Victor
http://www.byways.org/image_library/media_details.html?CX_MEDIA=26638

Lebanon Mine (tour) and Georgetown Loop Railroad

Georgetown
(303) 569 2403
<http://gtownloop.com/mine.html>

Matchless Mine (tour)

414 W. 7th Street, Leadville
(719) 486-3900
<http://www.matchlessmine.com/>

Mayflower Mill (tour)

2 miles north of Silverton, Hwy 110
County Rd 2
(970) 387 0294

Mollie Kathleen Gold Mine (tour)

Cripple Creek
(719) 689 2466
<http://www.goldminetours.com/>

National Mining Hall of Fame & Museum

120 W. 9th, Leadville
(719) 486-1229
<http://www.leadville.com/miningmuseum/>

Definitions from p. 11

Orogeny—The process by which structures in mountain areas are formed including brittle folding and faulting in the outer layers of the earth and plastic folding, metamorphism, and igneous intrusions in the inner layers of the earth.

Porphyry—An igneous rock in which larger crystals (phenocrysts) are set in a finer groundmass, which may be crystalline or glassy, or both.

Placer deposit—An accumulation of rock fragments formed by processes of sedimentation or weathering in which gold or other heavy minerals are concentrated by mechanical processes such as gravity.

Nederland Historical Society and Museum
4th and Bridge Streets, Nederland,
Boulder County
(303) 285-3575

Ouray County Historical Society and Museum

420 Sixth Street, Ouray
<http://www.ouraycountyhistoricalsociety.org/>

Old Hundred Gold Mine (tour)

Silverton
(970) 387-5444 or 1-800-872-3009
<http://www.minetour.com/>

Phoenix Mine (tour)

Idaho Springs
(303) 567 0422
<http://www.phoenixgoldmine.com/>

Smuggler Mine and Compromise Mine (tour, reservations required)

Aspen
970-925-2049

Walsenburg Mining Museum

101 E. 5th Street, Walsenburg
719-738-1992
<http://www.hchstsoc.org/Walsenburg%20Mining%20Museum.html>

Western Museum of Mining and Industry
1025 Northgate Road, Colorado Springs
(719) 488-0880 or 1-800-752-6558
<http://www.wmmi.org/>

THE ROCK DOCTOR ASKS

“Did You Know?”

Did you know how important Colorado is to the Cretaceous/Tertiary (K/T) boundary story? In the 1940s South Table Mountain (near Golden) was the first place in the world where the K/T boundary was described in terrestrial rocks; with dinosaur bones below, only mammals above. This site is so significant that the National Science Foundation held its 50th birthday party on the outcrop at South Table Mountain in 2000.

In 1980 scientists proposed that the Cretaceous Period ended on Earth with the impact of an asteroid or comet traveling at 100,000 miles per hour. Colorado sites and geologists played key roles in proving the impact hypothesis, locating the crater at Chicxulub on the Yucatan Peninsula of Mexico, and proving that Chicxulub was the source of the impact debris. The existence of an iridium anomaly at the K/T boundary in coal-swamp deposits in Colorado proved

that the iridium anomaly was not just some phenomenon created by seawater, but was fallout from an extraterrestrial event. Indeed, Colorado has the highest iridium anomaly ever measured in terrestrial rocks. Colorado sites also showed the presence of shocked quartz grains that could only be caused by impact. The size of the shocked quartz fragments and the existence of two layers of fallout debris in Colorado sites also indicated to crater searchers that the impact must have been located near North America.

Once Chicxulub was proposed as the site of impact, Colorado once again provided key evidence confirming it. The nail was put in the coffin by comparing the lead-loss of zircons from Chicxulub's rocks with the lead-loss of zircons in the K/T boundary layer from a number of sites. Most of these samples were from Colorado. Colorado also provided the world with its first known, shocked zircon grains.

Southern Colorado's dozen sites that preserve the K/T boundary layer are so important that the Smithsonian Institution archived a 2.5-ton sample of the K/T boundary from south of Trinidad and has it on display in Washington, D.C. A good place to observe the K/T layer is in Trinidad Lake State Park where a new information sign was recently



erected on the Long Canyon Trail. An excellent book about the development of the asteroid-impact theory is *Night Comes to the Cretaceous* by James Powell.

Congratulations 2003 CGS AWARDS FOR THE SAN LUIS VALLEY REGIONAL SCIENCE FAIR

Elementary level: Shelly Moeller, “Break That Rock,” Manassa Elementary School. Shelby collected samples of scoria, soaked them in water, and froze them. She measured the width of the cracks caused by freezing and compared them to physical properties of the samples.

Junior level: Beth Garcia, “Rock-N-Roll,” Sargent Middle School (located between Monte Vista and Center in Rio Grande County). Beth examined several rock outcrops around San Luis Valley. Assisted by published geologic

mapping, she identified the rocks exposed in her study sites, which included tuff, rhyolite, breccia, basalt, and granite.

Senior level: Ricardo Devine, “Sangre de Cristo Fault: Is It A Sleeping Giant?,” Sierra Grande High School in Blanca. Ricardo researched information of earthquakes and faults in San Luis Valley, and concluded that the Sangre de Cristo Fault could cause a large earthquake. Ricardo lost his mother in the 1987 El Salvador earthquake.

GEOSCIENCES CRITICAL TO COLORADO'S FUTURE

**By Greg E. Walcher, Executive Director
Department of Natural Resources**

The present-day Colorado Geological Survey (CGS) and Department of Natural Resources (DNR) were both formed in the late 1960s, and both continue to provide outstanding service to the citizens of Colorado. The legislation establishing the Geological Survey listed nine objectives, including:

- 1) Assist, consult with, and advise existing state and local governmental agencies on geologic problems;
- 2) promote economic development of mineral resource;
- 3) conduct studies to develop geologic information;
- 4) inventory and analyze the state's mineral resources as to quantity, chemical composition, physical properties, location, and possible use;
- 5) collect and preserve geologic information;
- 6) advise the state and act as liaison agency on transactions dealing with natural resources between state agencies and with other states and the federal government on common problems and studies;
- 7) evaluate the physical features of Colorado with reference to present and potential human and animal use;
- 8) prepare, publish, and distribute reports, maps and bulletins when necessary to achieve these purposes; and
- 9) determine areas of natural geologic hazards that could affect the safety of, or economic loss to, the citizens of Colorado.

CGS has done an outstanding job of meeting these objectives, and with the support of the Colorado Severance Tax and it is well-positioned to continue their excellent performance into the future.

The Geologic Mapping Program is providing detailed geologic maps for use by local government, state and federal agencies, scientists, consultants, and the public. The Minerals Program provides data, maps, studies, and statistics on the mining and oil and gas industries that contributed an estimated \$14 billion to Colorado's economy in 2002. The Land-Use Review Program conducts more than 500 reviews per year for local governments to ensure safe mitigation of geologic hazards in the nation's third-fastest-growing state. The Colorado Avalanche Information Center provides avalanche warnings and education programs that have helped reduce the incidences of deaths from avalanches. The Environmental Program applies geology to understanding environmental and water-resource issues including water quality, ground water, abandoned mine lands,

and wetlands. The Critical Hazards Program conducts studies, issues reports, and responds to emergency incidents involving hazardous soils, landslides, mudslides, earthquakes, and rockfalls.

Governor Owens joins me in congratulating the Survey on 35 years of excellence in providing sound science as the basis for many of the economic and social issues facing the state.



Greg Walcher was appointed by Colorado Governor Bill Owens as Executive Director of the Department of Natural Resources in January 1999. He brings to the position 20 years experience in natural resource issues. From 1989–99 Walcher served as president of CLUB 20. During his tenure CLUB 20 membership and budget nearly tripled, and he was credited with bringing a new level of activity, visibility and effectiveness to the Western Slope. Prior to that, Walcher spent 10 years in Washington, D.C., on the staff of U.S. Sen. Bill Armstrong, including 5 years as executive director. He handled issues as diverse as transportation, agriculture, governmental affairs, and natural resources. He is currently the chair of the Natural Resource Leadership Council.

A fifth-generation native of Colorado, Walcher was born and raised in Grand Junction and received his degree from Mesa State College, where he served as student body president and became a national college debate champion. He and his wife Diana operate a 15-acre peach orchard in Palisade.



COLORADO GEOLOGICAL SURVEY CELEBRATES A DECADE OF EXCELLENCE

**By Ronald W. Cattany
Director, Division of Minerals and Geology**

In 1872 the Legislature empowered the Territorial Governor to appoint a Territorial Geologist. Seven scientists occupied the position until 1907. The Colorado Geological Survey (CGS) was established in 1907 with the Chair of the Geology Department at the University of Colorado serving as State Geologist until 1927, when it was deactivated. The CGS was re-established in 1967 with John

W. Rold serving as State Geologist until 1992, and Vicki Cowart until 2003. Under their excellent leadership, the Survey has gained an international reputation of scientific excellence.

The survey was incorporated in the Department of Natural Resources (DNR) in 1968 and the Division of Minerals and Geology (DMG) in 1992. Since then, it has produced over 170 publications, beginning with the very popular *Colorado's Dinosaurs*. In 1994, CGS began reporting on the *Mineral and Mineral Fuel Activity of Colorado*, in response to the legislative mandate of the Mineral, Energy, and Geology Policy Advisory Board. The first 1:24,000 geologic map—the 1995 Shoshone quadrangle in Garfield County—was the first of what will be 50 new geologic quadrangle maps produced by CGS mappers by the end of the 2003 field season.

The Colorado Avalanche Information Center (CAIC) produced *The Snowy Torrents*. In 1996 because of heightened avalanche awareness. The next year, CAIC began publishing *The Beacon* for the Friends of the Center.

The Survey has sold over 165,000 copies of the 1997 publication, *The Guide to Swelling Soils for Colorado Homebuyers and Homeowners*—making it the most widely distributed book ever produced by a state geological survey. In January 1998 *RockTalk* began; with 20 editions in publication and available for information and education purposes.

Today, CGS has five science sections—each one producing excellent information in a variety of media. The first water quality directory was produced in 1999, followed by the digital publication of Colorado's earthquake information, the *Handbook of Colorado's Meteorites*, and the first of the county report series—*Geology and Mineral Resources of Gunnison County*, and a new oil and gas fields map as well as the Colorado coal directory. A significant achievement last year was the production of the Department of Natural Resources' first Web site publication, the *Colorado Late Cenozoic Fault and Fold Database and Internet Map Server*. Just recently, the CAIC unveiled a set of avalanche advisory tools that are user-friendly and available on the web, the Engineering Geology Section produced significant studies of collapsible soils in the Roaring Fork Valley and landslides in Colorado Springs, and the Minerals and Mineral Fuels section published a CD-ROM compilation about historic coal mines.

These are a small sampling of the reports, maps and books, many award-winning, that the Colorado Geological Survey has produced in the last few years. All this while answering citizen phone calls and questions, leading public, educational, and professional field trips, and producing a successful series of geologic hazards technology transfer conferences. Since June 1993, CGS has provided approximately 6,000 land use reviews for local governments, created inventories and reports on abandoned mine sites of the state's mineral areas, and given hundreds of geologic talks to schools, community groups and professional societies.

The CGS has a host of exciting activities and publications that are underway—a new digital atlas of the Paradox Basin, nearest neighbor models for avalanche forecasting, important studies of recent faults, and two world-class books—the *Ground-Water Atlas of Colorado* and *Natural Acid Rock Drainage Associated with Hydrothermally Altered Terrane in Colorado*. Since 1993 the budget of the Survey has nearly doubled and the professional staff has increased nearly a third—making 2002–2003 the fiscal year with the largest number of grants and contracts from client agencies in the history of the Survey.

The mission of the CGS 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. The work of the people of the Colorado Geological Survey and the Colorado Avalanche Information Center is important to Colorado's economy and to Colorado's citizens. I congratulate the Survey in its commitment to excellence.



In August 2002, Governor Bill Owens and DNR Executive Director Greg Walcher appointed **Ronald W. Cattany** director of the Division of Minerals and Geology. He also serves as one of three Natural Resource Trustees appointed by the Governor to oversee natural resource damage issues under CERCLA, and as a member of the Colorado Commission of Indian Affairs. He is also currently serving as the interim Director of the Colorado Geological Survey and State Geologist. From 1991 to 2002 he served as the Deputy Director of the Colorado Department of Natural Resources. From 1981 to 1991 he served as Assistant Director of the Department, focusing on activities related to natural hazard management, economic impacts of energy development on local communities, Indian reserved water rights, mineral and energy regulation and promotion, and public land management. In 1977 he co-founded the Colorado Office of Energy Conservation, serving as its director of policy and planning. He was an energy economist for the Colorado Energy Research Institute from 1974 to 1977. He is the author of over 50 publications. He holds a B.S. in Mineral Engineering and an M.S. in Mineral Economics from the Colorado School of Mines, and was a Senior Executive Fellow at the Kennedy School at Harvard in 1985.



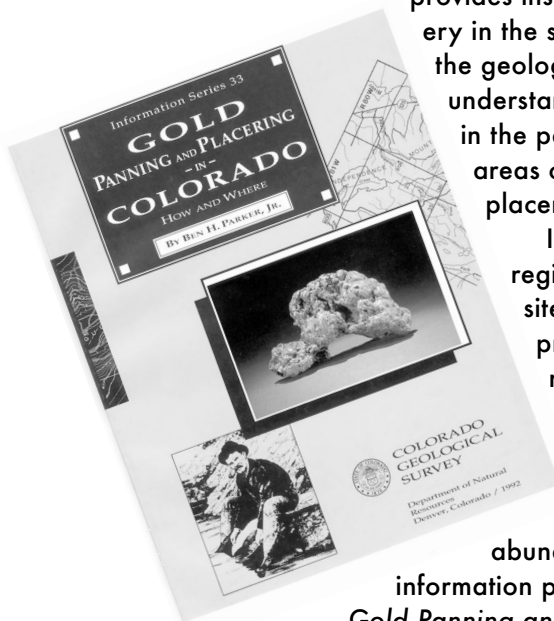
Mr. Cattany is a native of Colorado.

BOOK REVIEW

Information Series 33

Gold Panning and Placering in Colorado: How and Where

By Ben H. Parker, Jr.



Gold Panning and Placering in Colorado: How and Where is a great reference text for the recreational gold panner. Ben Parker's book provides insight on how to pan for gold, the history of placer recovery in the state, techniques commonly used for gold recovery, and the geology of placer deposits. This detailed history aids your understanding how thoroughly a stream may have been worked in the past and whether the techniques used may have left some areas overlooked. The book also describes the recharge of placer deposits and how they may be fruitful in the future.

I especially enjoyed the detail given to the various regions depicted in this book. Specific warnings about mill sites, erodible banks, and the responsibility of panning on private lands gives the reader fair warning about field realities. The geologic explanation of gold-bearing landforms can greatly increase your understanding and identification of the best places to pan. Tips on panning these areas are given for each section such as not using magnetite in your pan as an indicator of gold abundance. Consider it a place to start and gather additional information prior to your gold panning trip.

Gold Panning and Placering in Colorado is an enjoyable book with colorful characters making the story of Colorado's gold rush more interesting. I enjoyed the story of the great diamond hoax that snagged investors from across the country and the depiction of elaborate hydraulic mining operations that moved incredible amounts of earth. Historical photographs throughout the text show the amazing ingenuity of these miners who made their living recovering gold from placer deposits. Personally, I would enjoy funding my next vacation to the Rocky Mountains by panning for gold.

—Reviewed by Melissa Ingrisano

ROCKTALK

Colorado Geological Survey
Division of Minerals and Geology
1313 Sherman Street, Room 715
Denver, CO 80203

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