Excerpts from ROCKTALK vol. 6 no. 2
Colorado Geological Survey

Gold – Jim Cappa

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.

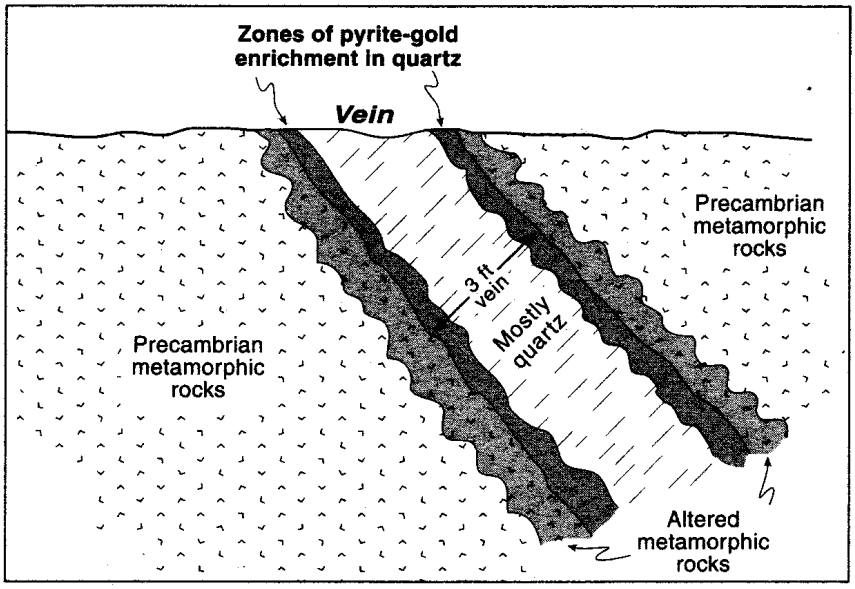
The color and luster of gold are what make this metal so attractive. Gold is almost indestructible and has been used and reused for centuries, to the extent that all of the gold that is currently being used by mankind is almost equal to all the gold that has ever been mined. When we think of gold our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

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.

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 Colorado's Leadville district also contain vein deposits.

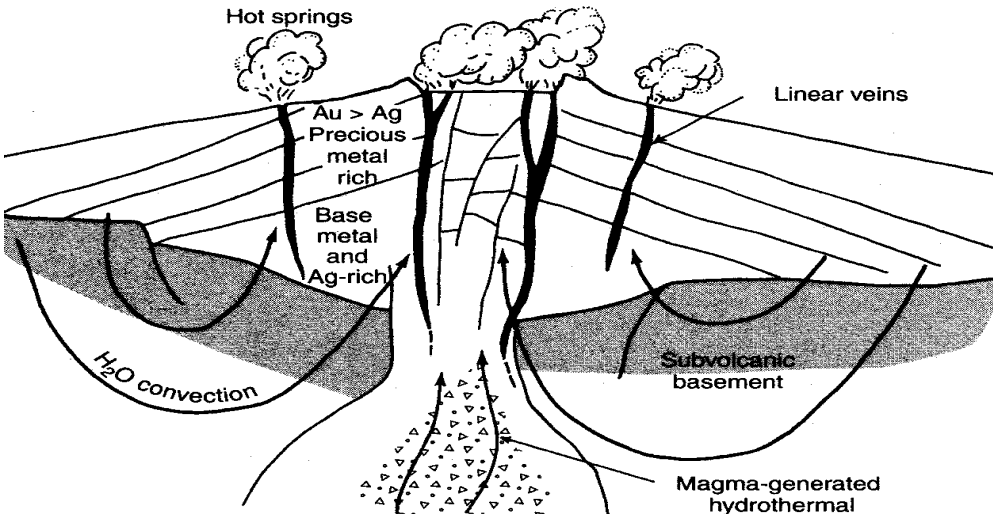
Vein Deposits



Typical gold vein.

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 distracts 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 are a few thousand feet in length, the longest vein in the Central City distract 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. 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. Some of the better known mining districts of the San Juan Mountains 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;



Cross section of a volcano showing a collapsing caldera and the relationship of precious metal vein deposits.

however, gold was the most important material, economically. Veins in the San Juan Mountains have lengths up to about 9,000 feet, with depths to over 2,500 feet. Veins widths average three to six feet, the largest are up to 50 feet wide. Gangue minerals in the veins of the San Juan's 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 chalcopyrite. Gold is generally associated with the pyrite and chalcopyrite and most of the silver is associated with tennantite.

Replacement Deposits

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

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	$3CuS_2 \cdot As_2S_3$	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

A few of the many minerals associated with gold deposits.

Strata - bound 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 breccias 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 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 tellurium minerals: calaverite, and rarely sylvanite and petzite. Calaverite from district mines contain 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, and 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 mines 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.

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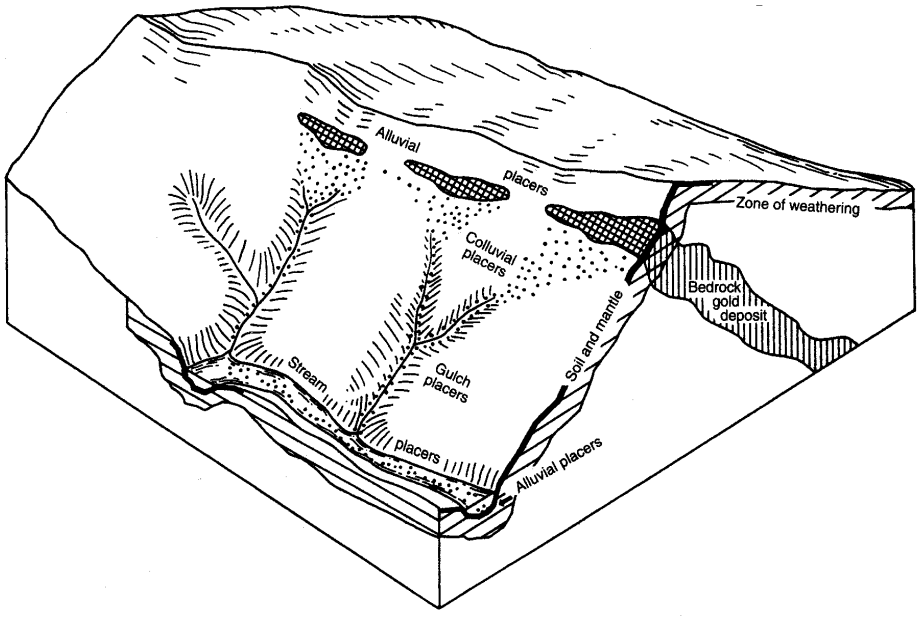
Placer Deposits

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. The largest gold lode deposits in the world, the Witswatersrand 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.



Different types of placer deposits.

Gold from placer deposits has been recovered by a variety of methods including panning, sluice boxes, hydraulic mining, and dredging and drift mining. For a more complete description of these placer-mining methods please refer to Parker (1992). Economically significant placer mining in Colorado ended in 1951 with the shutdown of the "Fairplay Dredge" 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.

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. AngloGold (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 remaining 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 50 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 of gold ceased in Cripple Creek in 1961, 70 years after the discovery of gold in the district. In 2002, the Cripple Creek & Victor Gold Mining Company 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. The trucks deliver the raw ore to a crushing plant that crushes the rock to a specified mesh size, about 5/8 inches in diameter. The crushed ore is then placed on a heap leach pad. 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 macroscopic 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 the gold out of the solution. The gold (along with a little silver) is then smelted into dore bars of crude metal, which is sent to a gold refinery in another state for purification.

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