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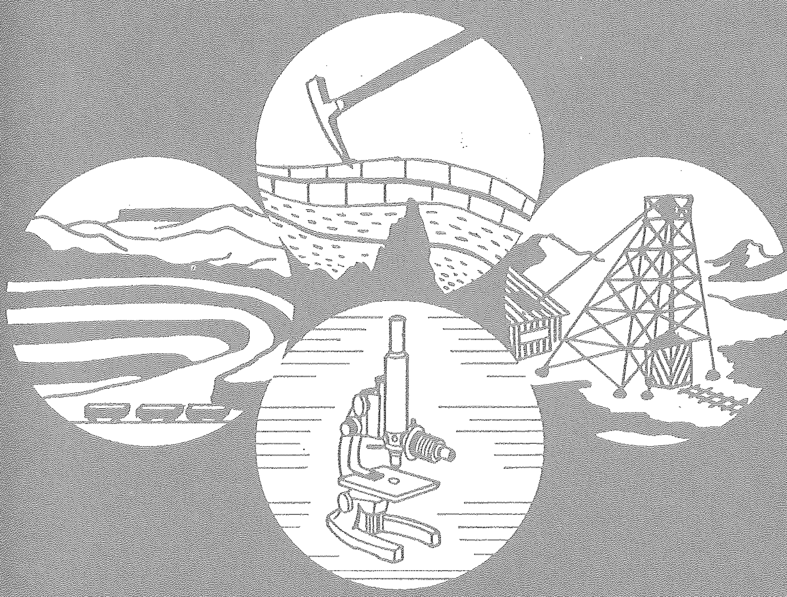

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GOLD

(By Richard T. Moore, Arizona Bureau of Mines, Tucson, Ariz.)

Properties, Use, and Market Conditions

Gold, which is well known to most modern civilized peoples because of the monetary importance it enjoys, has been sought for and prized by man for many centuries. Artifacts unearthed in Egypt and other parts of the eastern Mediterranean region show that the yellow metal was in use at least as long ago as 4,000 B.C. (Rickard, 1932, p. 177–179).

Chemically, gold is rather inert. It does not readily combine with any of the more common solvents or reagents occurring in nature, so is frequently found as a native element. The specific gravity of pure gold is 19.3, but the presence of impurities, principally copper and silver, which are commonly alloyed with the naturally occurring metal, usually lowers it to a range between 15 and 19. Because of its high specific gravity, the native metal concentrates readily in placers and such deposits probably were the source for the gold used by ancient man. The early development of uses for gold in the fashioning of jewelry and simple tools and fastening devices can be directly attributed to its softness, ductility, and malleability, which permitted it to be worked easily by beating and rolling it into desired shapes.

Gold has been used as a medium of exchange since earliest civilizations and the greatest use of gold in modern society is still for monetary purposes. After centuries of use in coinage for transactions between individuals, growth in worldwide commerce and population have placed very heavy demands on the available supply of gold. At present most gold is used to back other forms of money and to satisfy international balances of payments.

Unlike all other commodities, because of its monetary use the price of gold was fixed at $35 per troy ounce from 1934 to early 1968. This price is still maintained for settlement of balance of trade transactions, but the price of gold for industrial and other nonmonetary uses fluctuates in response to demand.

During the past 30 years several industrial uses for gold have been developed. It is used in electronic equipment for transmission and switching components where extreme reliability and resistance to corrosion are required, as coatings on aircraft engine shrouds and earth satellites to provide protection against heat and corrosion, and it is now being used to coat metals and ceramics for architectural applications. Appreciable quantities also are still used for goldleaf, jewelry, laboratory utensils, and for specialized items of glassware and ceramic ware (Ryan, 1965, p. 390). In 1966, our industrial consumption was nearly 6.1 million ounces (U.S. Bur. Mines, 1967).

The problems created by the growing shortage of monetary gold in the United States have been further complicated by these increasing industrial demands, a demand which apparently cannot be met by domestic production. In most mines in this country where gold was the principal metal produced, the costs of mining and treatment have risen above the level where the present (1968) price of gold will permit the profitable extraction of the metal.

The seriousness of these problems has prompted the Federal Government to initiate several programs designed to help alleviate them. In April 1966, the Heavy Metals program was started as a joint project of the U.S. Geological Survey and U.S. Bureau of Mines to stimulate domestic production of a group of metals in short supply; during the first 18 months of the program about 90 percent of the project effort was expended on gold. In addition to the Heavy Metals program, assistance is available to industry in the form of loans for gold exploration projects, through the Office of Minerals Exploration. In March 1968, the Treasury Department, in an additional step to alleviate the situation, announced that, under agreements made with other interested nations, it would no longer buy or sell gold in the private market.

Under these agreements the $35 per ounce price for governmental gold stocks would be retained, but the Treasury would no longer supply gold to the speculative markets. The effect these actions will have on the domestic gold mining industry is not predictable.

Production and History

In 1966, domestic mine production was slightly more than 1.8 million ounces, or only about 10 percent of our industrial consumption plus net exports. Of that production, 58 percent came from dry and siliceous ores, 37 percent from base-metal ores, and 5 percent from placer deposits. Listed in the order of importance, just four states, South Dakota, Utah, Nevada, and Arizona, produced a total of more than 1.5 million ounces of gold in 1966, or about 86 percent of the total domestic production for that year (U.S. Bur. Mines, 1967, p. 236).

Since 1945, Arizona has ranked seventh or higher among the states in yearly production of gold, and since 1960 it has annually ranked either third or fourth. In 1966, of the 25 leading gold-producing mines in the United States, 7 were in Arizona and for the period 1858–1967, the State's total recorded production of gold is more than 13.7 million ounces valued at almost $365.5 million (Elsing and Heineman, 1936; U.S. Bur. Mines, 1935–67; Larson and Henkes, 1968). Over 95 percent of the gold produced in Arizona since 1950 has been derived as a by-product of base-metal mining, with copper mining accounting for about 80 percent and lead-zinc mining about 15 percent. Siliceous and dry ores and placer production have not contributed more than 5 percent to Arizona's gold production since 1950. This is in marked contrast with the period before 1933 when the siliceous and dry ores and placer deposits accounted for at least 50 percent of the production.

The search for gold has played an important part in the development of Arizona. The history of the early period of Arizona's gold mining industry has been well summarized by Wilson (1961), Wilson and others (1934), and Heineman (1938), from which the following sketch has been largely abstracted.

The Spanish explorers, although more frequently identified with the mining of silver, were, nonetheless, continually on the watch for gold, and it is reported that a Castilian priest, Padre Lopez, had by 1774, extensively worked the placer deposits in the Quijotoa district (fig. 21, No. 17). It was not until after the Gadsden Purchase, in 1853, that Americans began entering the area to prospect, but within 10 years a large number of prospectors had arrived and several placer deposits had been discovered. The Chemehuevis district (fig. 21, No. 13), near the confluence of Sacramento Wash with the Colorado River, was found in 1857; the Gila City or Dome placers (fig. 21, No. 50), near Yuma, were discovered in 1858; Capt. Pauline Weaver opened the La Paz diggings (fig. 21, No. 43) in 1862; and several small but rich gold placer deposits, such as those in the Lynx Creek (fig. 21, No. 27) and Big Bug (No. 28) districts in the Bradshaw Mountains, near Prescott, were being exploited in 1863. The districts containing these and other placer deposits in Arizona are listed below in table 13.

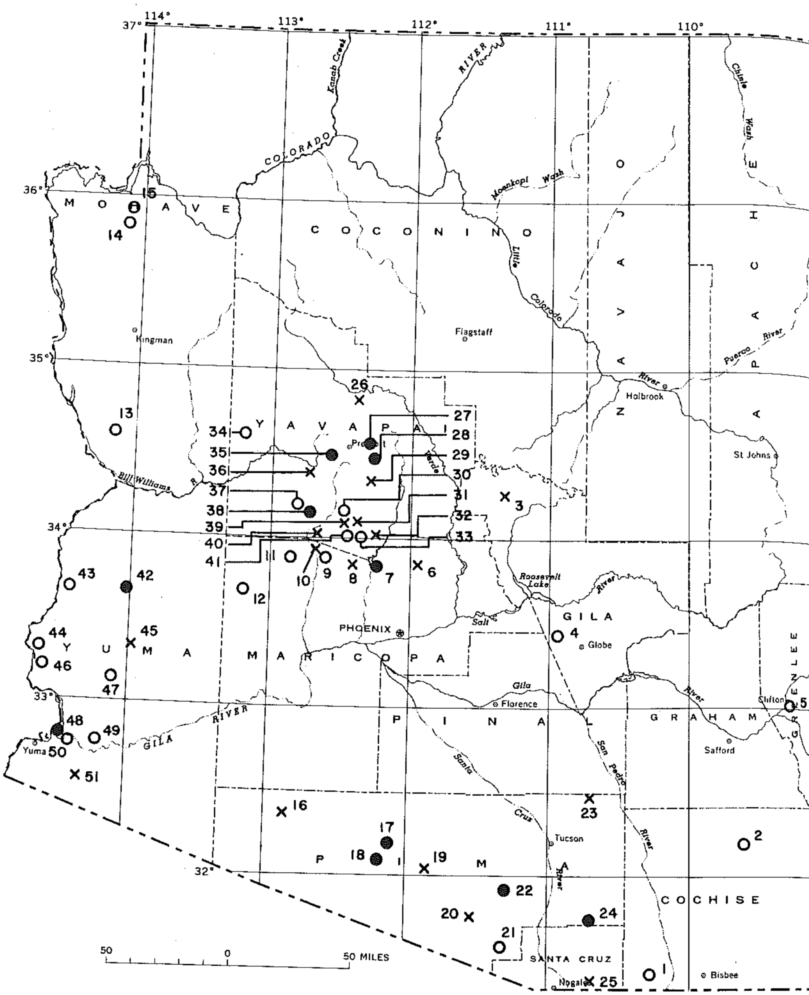
While the placer deposits were being developed, many lode deposits also were found in adjacent areas, and between 1853 and 1863 several mines were opened in what are now Maricopa, Mohave, Yavapai, and Yuma Counties. Lode deposits in the Castle Dome district (fig. 22, No. 95), near Yuma, and the Moss deposit in the Oatman district (fig. 22, No. 34), Mohave County, were discovered in about 1860, and the famous Vulture deposit in the Vulture district (fig. 22, No. 24), near Wickenburg, Maricopa County, was found in 1863. Numerous lode deposits were also found in the Prescott region, and in 1863 Prescott was named the Capitol of the newly established Arizona Territory, largely on the strength of the mining developments in the vicinity. The districts containing the lode gold deposits in Arizona are listed below in table 14.

By 1875, most of the placer deposits known in Arizona today had been discovered, and by 1885 the bulk of the placer gold production recorded for the State had been made. In the lode deposits most of the free-milling gold was found to be superficial and, with few exceptions, the deposits were shortly abandoned and mining interests turned to silver and the base metals.

A few large, rich gold deposits were still being found, however, and in 1887, the Congress deposit in the Martinez district (fig. 22, No. 84), Yavapai County, was discovered, and in 1888, development work on the Harquahala gold deposit in the Ellsworth district (fig. 22, No. 91), Yuma County, was started. The demonetization of silver in 1893 was followed by a sharp business recession, and many prospectors regained their interest in gold. The development of the cyanide process for the recovery of gold, in 1887, contributed greatly to the reestablishment of the gold mining industry because this made it possible to reopen many of the lode deposits in which the free-milling gold had been exhausted, but in which gold remained in base-metal sulfides or in very finely divided form.

During the next few years the gold industry in Arizona thrived, and several large deposits were opened. In Yuma County, the Fortuna deposit (fig. 22, No. 97) was discovered in 1895 and the King of Arizona mine in the Kofa district (No. 94) was opened in 1896. Between 1900 and 1917 several large gold lodes were discovered in the Oatman-Katherine district (fig. 22, No. 34), Mohave County, including the Gold Road in 1903, the Tom Reed in 1908, the United Eastern in 1915, and the Big Jim in 1916. During its years of peak production, 1917–23, this district produced gold valued at between $2.3 million and $2.8 million per year, (Wilson and others, 1934, facing p. 80), and its total production has exceeded 2.04 million ounces valued at about $46.9 million (Elsing and Heineman, 1936; U.S. Bur. Mines, 1935–67).

After several years of moderately high gold production (see fig. 23), the metals market began to collapse, and gold production dropped from a high of nearly 300,000 ounces in 1923 to a low of about 65,000 ounces in 1932. With the revaluation of the dollar in 1934, when the price of gold was raised from $20.67 to $35 per troy ounce, production again soared, and until 1941, averaged about 300,000 ounces per year. Because of a wartime labor shortage in 1942, Government Order L–



EXPLANATION

● 7
Production more than 1,000 troy ounces

○ 4
Production 100 - 1,000 troy ounces

× 6
Production less than 100 troy ounces

(Numbers refer to districts listed in table 13 and mentioned in text)

FIGURE 21.—Placer gold in Arizona.

TABLE 13.—*County listing of placer gold districts*

[Locations are shown in fig. 21]

Locality No. in fig. 21	County and District	Locality No. in fig. 21	County and District
	Cochise:		Santa Cruz:
1.	Hartford	25.	Patagonia
2.	Dos Cabezas-Teviston		Yavapai:
	Gila:	26.	Granite Creek
3.	Green Valley	27.	Lynx Creek
4.	Globe-Miami	28.	Big Bug
	Greenlee:	29.	Peck
5.	Chase Creek-San Francisco River	30.	Walnut Grove
		31.	Silver Mountain
	Maricopa:	32.	Tip Top
6.	Cave Creek	33.	Humbug
7.	Agua Fria	34.	Eureka
8.	Pikes Peak	35.	Copper Basin
9.	San Domingo	36.	Kirkland
10.	Hassayampa River	37.	Martinez
11.	Vulture	38.	Weaver
12.	Big Horn	39.	Black Rock
	Mohave:	40.	Blue Tank
13.	Chemehuevis	41.	Castle Creek
14.	Gold Basin		Yuma:
15.	Lost Basin	42.	Plomosa
	Pima:	43.	La Paz
16.	Ajo	44.	Trigo Mountain
17.	Quijotoa	45.	Kofa
18.	Horseshoe Basin	46.	Colorado River
19.	Cobabi	47.	Castle Dome
20.	Baboquivari	48.	Laguna
21.	Arivaca	49.	Muggins Mountain
22.	Papago	50.	Dome
23.	Old Hat	51.	Fortuna
24.	Greaterville		

208 closed essentially all of the gold mines in Arizona; since then gold production has been primarily a byproduct of base-metal mining.

TYPES OF DEPOSITS

The lode deposits in Arizona can be grouped into four main categories: (1) hydrothermal gold-quartz veins, (2) siliceous fissure veins containing gold-bearing base-metal sulfides, (3) massive sulfide replacement deposits carrying gold as an accessory, and (4) gold-bearing disseminated copper deposits. Nearly all of the known deposits in categories 1 and 2 in Arizona have been described in detail by Wilson (Wilson and others, 1934) from which the following summaries largely have been compiled.

GOLD-QUARTZ VEINS

In several districts notable quantities of gold have been produced from quartz veins in which gold, along with some silver, is the most valuable constituent. These veins are of the epithermal type, as defined by Lindgren (1933, p. 444), and in Arizona are best developed in Ter-

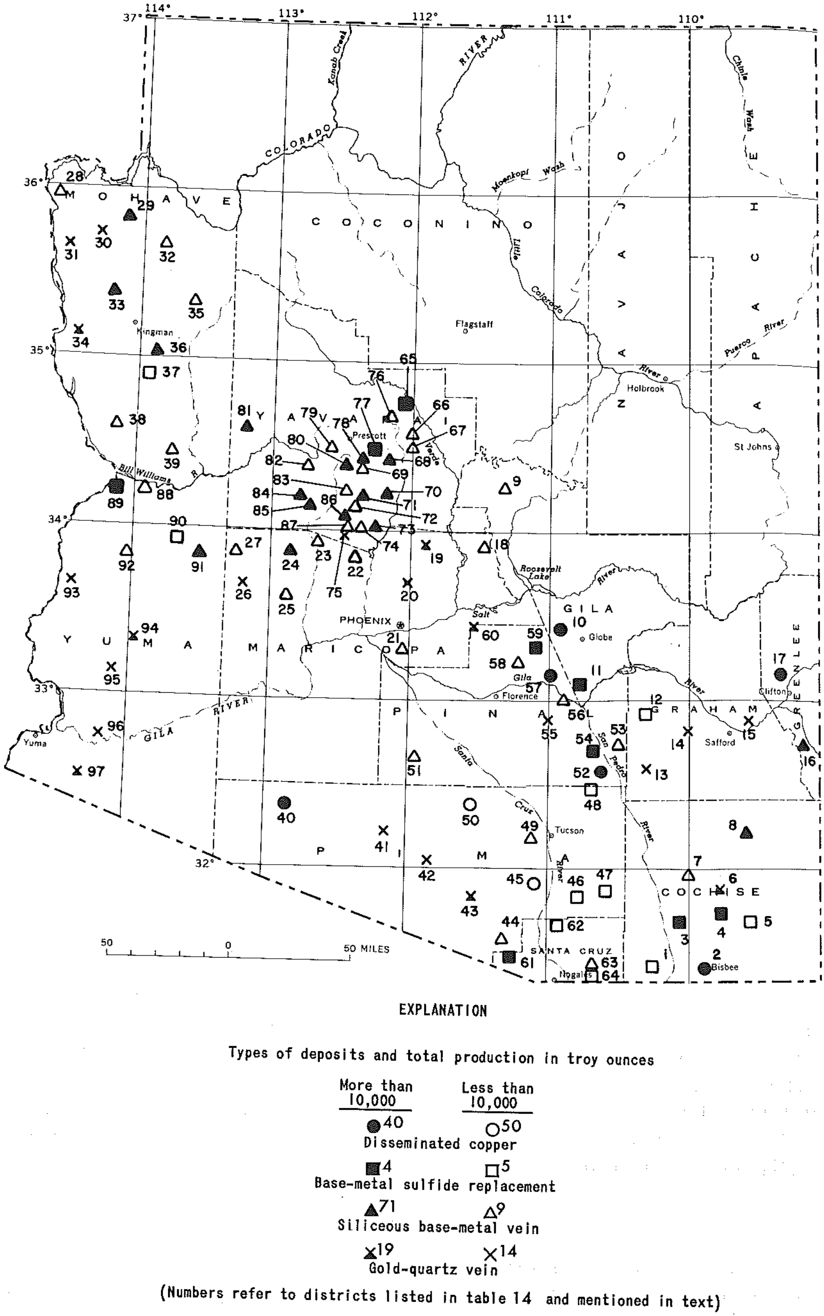


FIGURE 22.—Lode gold in Arizona.

TABLE 14.—*County listing of lode gold districts*

[Locations are shown in fig. 22]

Locality No. in fig. 22	County and District
	Cochise:
1.	Huachuca
2.	Warren
3.	Tombstone
4.	Turquoise
5.	Swisshelm
6.	Pearce
7.	Dragoon
8.	Dos Cabezas
	Gila:
9.	Green Valley (Payson)
10.	Globe-Miami
11.	Banner-Dripping Spring
	Graham:
12.	Aravaipa
13.	Rattlesnake
14.	Clark
15.	Lone Star
	Greenlee:
16.	Ash Peak
17.	Morenci-Metcalf
	Maricopa:
18.	Sunflower
19.	Cave Creek-Magazine
20.	Winifred
21.	Salt River Mountain
22.	Pikes Peak
23.	Wickenburg
24.	Vulture
25.	Osborn
26.	Big Horn
27.	Ellsworth
	Mohave:
28.	Minnesota
29.	Gold Basin
30.	White Hills
31.	Weaver
32.	Music Mountain
33.	Wallapai
34.	Oatman-Katherine
35.	Cottonwood
36.	Maynard-McConnico
37.	Cedar Valley
38.	Chemehuevis
39.	Owens
	Pima:
40.	Ajo
41.	Quijotoa
42.	Cobabi
43.	Baboquivari
44.	Arivaca
45.	Pima
46.	Helvetia
47.	Empire
48.	Control
49.	Amole
50.	Silver Bell
	Pinal:
51.	Casa Grande
52.	San Manuel
53.	Bunker Hill
54.	Mammoth
55.	Cottonwood
56.	Ripsey
57.	Mineral Creek (Ray)
58.	Mineral Hill
59.	Pioneer (Superior)
60.	Goldfield
	Santa Cruz:
61.	Oro Blanco
62.	Tyndall
63.	Harshaw
64.	Patagonia
	Yavapai:
65.	Verde
66.	Cherry Creek
67.	Ash Creek
68.	Agua Fria
69.	Turkey Creek
70.	Black Canyon
71.	Pine Grove-Tiger
72.	Silver Mountain
73.	Tip Top
74.	Humbug
75.	White Picacho
76.	Black Hills
77.	Big Bug
78.	Walker
79.	Copper Basin
80.	Hassayampa
81.	Eureka
82.	Kirkland
83.	Walnut Grove
84.	Martinez
85.	Weaver
86.	Black Rock
87.	Castle Creek
	Yuma:
88.	Planet
89.	Cienega
90.	Harcuvar
91.	Ellsworth
92.	Plomosa
93.	La Paz
94.	Kofa
95.	Castle Dome
96.	Muggins Mountain
97.	Fortuna

tiary volcanic rocks. They generally occur as irregularly shaped, tabular or lenticular masses, and consist of finely crystalline, greenish-yellow quartz, displaying marked banding or crustiform layering.

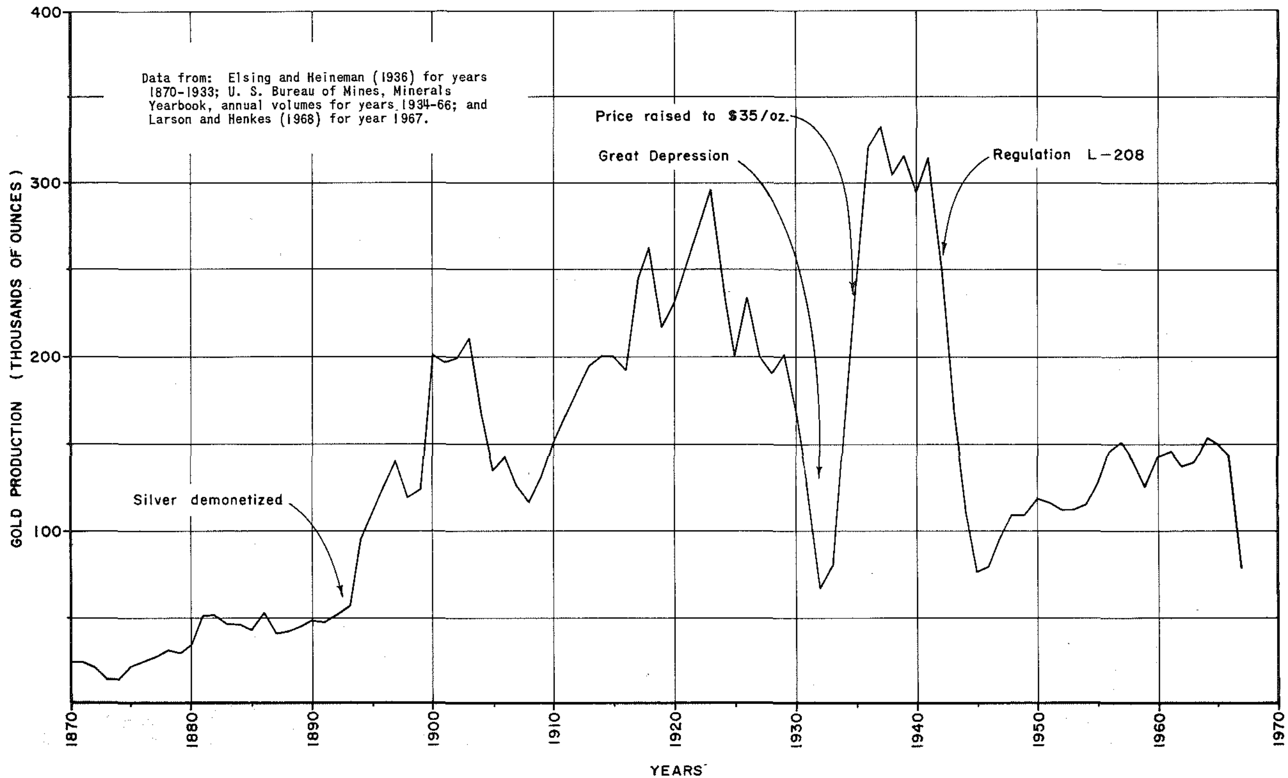


FIGURE 23.—Arizona gold production, 1870–1967.

Calcite and microscopic adularia commonly accompany the quartz, and the gold occurs as finely divided, pale yellow particles, alloyed with silver. Wall rock alteration is common, and chlorite, various carbonate minerals, quartz, and fine-grained sericite are developed in zones ranging from a fraction of an inch to several inches thick in the walls of veins.

The best known and most productive deposits of this type in Arizona are found in the Oatman-Katherine district (fig. 22, No. 34). Other districts containing epithermal gold-quartz veins include the Kofa district (No. 94), Yuma County, the Winifred (No. 20), and Big Horn (No. 26) districts in Maricopa County, and the Cobabi (No. 42) and Baboquivari (No. 43) districts in Pima County.

SILICEOUS BASE-METAL VEINS

Siliceous base-metal vein deposits are classified as mesothermal veins, as defined by Lindgren (1933, p. 529) and the characteristics of the Arizona deposits have been summarized by Wilson (Wilson and others, 1934, p. 22) as follows:

> In general, these veins, though locally lenticular, are persistent, straight, and narrow, with definite walls. Their gangue is massive to drusy milky-white quartz, with or without ankeritic carbonates. Their ore shoots, below the zone of oxidation, contain abundant sulphides, principally pyrite, galena, sphalerite, chalcopyrite, arsenopyrite, and tetrahedrite. Most of them are silver bearing, and may contain more silver than gold by weight. In the primary zone, some of their gold is free, but most of it occurs as sub-microscopic intergrowths with the sulphides, particularly the finer-grained galena, chalcopyrite, and pyrite. Their oxidized zone was rich in free gold but generally shallow. They have yielded placers only where their primary zone carried considerable free gold. The vein wall rocks generally show sericitization and carbonatization. High-temperature minerals are absent.

Important veins of this type are found in the Humbug (fig. 22, No. 74), Pine Grove-Tiger (No. 71), Walker (No. 78), Weaver (No. 85), and Martinez (No. 84) districts, Yavapai County.

BASE-METAL SULFIDE REPLACEMENT DEPOSITS

Since 1955 between 10 and 20 percent of the gold produced in Arizona has been derived from base-metal sulfide replacement deposits, principally lead and zinc producers, such as in the Big Bug (fig. 22, No. 77) and Verde (No. 65) districts in Yavapai County, and the Tombstone (No. 3) and Turquoise (No. 4) districts in Cochise County. The gold content of ore bodies of this group ranges widely but averages between 0.01 and 0.3 ounce per ton of ore. In 1966 nearly 14,000 ounces was recovered from the treatment of a little more than 322,000 tons of ore from about 13 lead and zinc producing mines (Larson and Henkes, 1967, p. 95, table 8).

The gold-bearing base-metal sulfide replacement deposits generally contain galena, sphalerite, chalcopyrite, and pyrite in varying proportions, and the gold is usually contained in one or more of these sulfide minerals. The sulfide replacement masses occur as irregular lenticular or tabular bodies in favorable limestone masses, as pipelike bodies along the intersections of favorable structures, and as ore shoots in vein-filling material. The following brief geologic descriptions are representative of the replacement type deposit.

In the Tombstone district (fig. 22, No. 3), gold is associated with argentiferous galena, sphalerite, and chalcopyrite. Sulfide replacement bodies occur along northeast-trending fissures in Paleozoic and Mesozoic limestone and in dikes of Laramide age. Anticlinal rolls in favorable host rocks act as local traps for the mineralizing solutions. The gold values vary greatly from one part of the district to another. In some areas values as high as 5 ounces per ton have been found and in others the gold content is as low as 0.3 ounce per ton (Butler and others, 1938).

In the Turquoise district (No. 4), oxidized lead-silver and zinc ore bodies, and some sulfide bodies occur as replacements in impure Carboniferous limestone along steeply dipping faults and beneath low-angle faults, particularly where intersected by northeasterly trending fissures. Gold commonly accompanies the lead-silver minerals and ranges from 0.03 to 0.2 ounce per ton (Wilson, 1951).

The lead-zinc deposits in the Mammoth (No. 54) and Oro Blanco (No. 61) districts are examples of gold-bearing base-metal sulfide deposits occurring as fissure-filling and wall-rock replacements in shear zones. In the Montana mine in the Oro Blanco district (Fowler, 1951), galena and sphalerite form massive sulfide ore shoots in the Montana shear zone, and form replacement masses in conglomerate in the hanging wall of the shear. The Mammoth-St. Anthony deposit, Mammoth district, is more complicated in that it involved at least two stages of gold mineralization (Creasey, 1950). The first stage involved the deposition of gold-quartz fissure veins, similar to the epithermal vein type described above, and in the second stage the gold was deposited in association with galena in massive vein and wall rock replacement bodies.

DISSEMINATED COPPER DEPOSITS

The major gold-producing mines in Arizona are the large disseminated copper deposits, such as those at Ajo, Bisbee, San Manuel, and Morenci. Since 1953, over 80 percent of the State's production has come from the treatment of copper ores and, in 1966, 89 percent was recovered as a byproduct of copper refining (Larson and Henkes, 1967, p. 9). The average gold content of the disseminated copper ores is between 0.001 and 0.002 ounce per ton, but because of the large tonnage of ore handled annually—over 101.5 million tons in 1966—large quantities of gold are recovered from them.

Descriptions of the disseminated copper deposits are given in "Copper" (p. 139).

PLACER DEPOSITS

As mentioned above, the first gold produced in Arizona came from placer deposits. These deposits are located generally in the southwestern half of the State (fig. 21), and a detailed account of them has been given by Wilson (1961).

Although some placer gold can be derived from almost any lode gold deposit, the more productive placers in Arizona, and those in which the larger nuggets have been found, were derived mainly from the oxidized parts of the deeper-seated, mesothermal vein deposits

(Wilson 1961, p. 14). This association is apparent when the distribution of placer and lode deposits, as shown in figures 21 and 22, is compared. The main concentration of placer deposits, including five of the eleven that have a recorded production exceeding 1,000 ounces, are located in the Bradshaw Mountain area, Yavapai County, in close proximity to the major concentration of mesothermal vein deposits.

Summary and Conclusions

During the past several years Arizona has produced between 130,000 and 150,000 ounces of gold per year, the greater percentage of which was a byproduct of copper mining. As long as the State's copper production remains at its current level, as seems most likely, gold production should continue at least at present levels.

Some chance for an expansion in the gold-mining industry in Arizona, though, is possible in light of two recent developments. First, under the Heavy Metals program, the U.S. Geological Survey has examined placer deposits in the Gold Basin (fig. 21, No. 14) and Lost Basin (No. 15) districts, Mohave County, and preliminary tests indicate resources that may exceed 500 million cubic yards of gravel containing 0.01–0.02 ounce of gold per cubic yard (U.S. Geol. Survey, 1968, p. 6). Second, with the freeing of the gold price effected by the Treasury Department's action of March 17, 1968, some increases in the price of gold have occurred which may make it feasible for some gold mines to reopen.

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