Gold in Placer Deposits

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Chapter G

Gold in Placer Deposits

Gold Placers

By WARREN YEEND and DANIEL R. SHAWE

Gold Deposits in the Virginia City-Alder Gulch District, Montana

By DANIEL R. SHAWE and KENNETH L. WIER

U.S. GEOLOGICAL SURVEY BULLETIN 1857

GEOLOGY AND RESOURCES OF GOLD IN THE UNITED STATES

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Gold in Placer Deposits

Gold Placers

By Warren Yeend *and* Daniel R. Shawe

Abstract

Man most likely first obtained gold from placer deposits, more than 6,000 years ago. Placers account for more than two-thirds of the total world gold supply, and roughly half of that mined in the States of California, Alaska, Montana, and Idaho.

Placer deposits result from weathering and release of gold from lode deposits, transportation of the gold, and concentration of the gold dominantly in stream gravels. Unless preserved by burial, a placer subsequently may be eroded, and either dispersed or reconcentrated.

California has produced more than 40 million troy ounces of gold from placers, both modern and fossil (Tertiary). The source of the great bulk of the gold is numerous quartz veins and mineralized zones of the Mother Lode and related systems in the western Sierra Nevada region. The gold-bearing lodes were emplaced in Carboniferous and Jurassic metamorphic rocks intruded by small bodies of Jurassic and Cretaceous igneous rocks. Mineralization occurred probably in Late Cretaceous time. Significant amounts of placer gold also were mined along the Salmon and Trinity Rivers in northern California. Source of the gold is lode deposits in Paleozoic and Mesozoic metamorphic rocks that were intruded by Mesozoic igneous rocks.

Alaska has produced roughly 21 million ounces of gold from placer deposits. Most (about 13 million ounces) has come from the interior region, including 7,600,000 ounces from the Fairbanks district and 1,300,000 ounces from the Iditarod district. Lode sources are believed to be mostly quartz veins in Precambrian or Paleozoic metamorphic rocks intruded by small igneous bodies near Fairbanks, and shear zones in Tertiary(?) quartz monzonite stocks at Iditarod. The Seward Peninsula has produced more than 6 million ounces of placer gold, including about 4,000,000 ounces from the Nome district. Most of the gold was derived from raised beach deposits. Source of the gold probably is Tertiary-mineralized faults and joints in metamorphic rocks of late Precambrian age.

The Helena–Last Chance district, Montana, produced nearly 1 million ounces of gold from placers that were derived from lode deposits in the contact zones of the Cretaceous Boulder batholith granitic rocks intruded into upper Precambrian, Paleozoic, and Mesozoic sedimentary rocks. The Virginia City–Alder Gulch district, Montana, produced more than 2,600,000 ounces of gold, nearly all from placer deposits derived from quartz veins of uncertain age in Archean gneisses and schists. The Boise basin district, Idaho, produced about 2,300,000 ounces of gold, mostly derived from quartz veins in quartz monzonite of the Cretaceous Idaho batholith.

Manuscript approved for publication July 7, 1989.

INTRODUCTION

Man has been mining placer gold for more than 6,000 years, and it is most likely that he first obtained the precious metal from placers. Placers have produced more than two-thirds of the total world gold supply (Boyle, 1979).

The term "placer," probably of Spanish derivation, is typically applied to gold deposits in the sands and gravels of streams. Today we define a placer as a deposit of sand, gravel, and other detrital or residual material containing a valuable mineral that has accumulated through weathering and mechanical concentration. The term placer as used here applies to ancient (Tertiary) as well as to recent (Holocene) gravel deposits, and to underground deposits (drift mines) as well as to surface deposits.

Wells (1969) defined generally applicable principles and processes under which placer deposits form.

The initial stage of formation is weathering and disintegration of lodes or rocks containing one or more valuable heavy resistant minerals such as native gold. The valuable minerals are then concentrated by the winnowing away of lighter minerals, and the deposit is subsequently preserved. Richness and size of a placer deposit depend on supply of source materials, and on conditions favorable for the concentration and preservation of the valuable minerals. Although the location, size, and shape of a placer reflect regional forces of erosion, transportation, and deposition, the final form of a placer is controlled by local conditions. Thus, each placer is unique.

Weathering and release.—The first step in the formation of a gold placer is release of gold particles from a bedrock source. Long periods of exposure of rocks at the Earth's surface result in chemical breakdown of the rocks, and physical disaggregation of the minerals present. Ground and surface water, temperature change, and plant growth all act to decompose and disintegrate rocks. Gold is a very durable mineral both chemically and physically, so that as enclosing minerals are carried off in solution or broken down and removed by physical attrition, the gold fragments show relatively imperceptible change in size and shape (Yeend, 1975). Ultimately, because of pounding during transportation in a streambed load, larger gold particles tend to become rounded, whereas very small particles become flattened (particles as small as a few micrometers in size escape deformation; G.A. Desborough, oral commun., 1988).

Concentration.—Running water of streams and rivers is the dominant agent in the formation of most placers. Most of the work and resultant concentration is done during times of flood and may occur only once a year, once every 10 years, or at even longer intervals. Gold, because of its high specific gravity (19.3 for pure gold), works its way quickly downward in the gravel and into bedrock cracks on the channel floor. In theory, the richest part of a placer is near bedrock, and generally this relation is true. However, deposits in which the gold is scattered throughout a gravel mass without a significant bedrock enrichment are common. Locally, very fine gold will actually be concentrated at the surface; such deposits are termed "flood gold." The ultimate richness of a placer is dependent to a large extent on physical characteristics of the bedrock that tends to trap the gold. Steeply dipping slates and jointed rocks are commonly most effective in trapping gold. Smooth, unweathered granite and serpentine are generally poor gold savers. Because gold commonly works its way down into fractures in the bedrock, as much as a meter of bedrock is mined to recover all the gold.

Preservation.—Unless a placer is preserved by some change in the normal erosion cycle, the very forces that created it will in time destroy it. Burial beneath an impervious cap is one of the surest means of preservation. Lava-capped Tertiary gravel-filled channels in the Sierra Nevada region of California are among the best examples of buried placers. In contrast, elevation of ocean-shoreline deposits has preserved beach placers at Nome, Alaska.

The source of placer gold is generally from lodes (gold-bearing quartz veins) or mineralized zones of other types, and (or) from preexisting placer deposits including auriferous conglomerates (fossil placers).

Lodes.—Although placers commonly occur in lode-mining districts, rarely is there a fixed relation between the richness of the parent lode and the richness of resultant placers. Some noted gold-mining districts, such as Goldfield, Nev., contain no significant placers. Conversely, some highly productive placer areas are not associated with known valuable lodes, such as the Klondike region in Canada and the Circle district in east-central Alaska. In some places, the lode source may have been completely removed by erosion, whereas in others, gold may have been derived from many small mineralized zones scattered through bedrock.

Preexisting placers.—Rich placers may occur in places where there is no apparent nearby bedrock gold source. In these localities gold may have been derived from a fossil placer of which nearly all vestiges have been eroded except for the reconcentrated gold. The western Sierra Nevada region of California is a classic example. In early Tertiary time, extensive river systems flowed westward from ancestral highlands in the vicinity of the present-day Sierra Nevada, and gold derived from a bedrock source in the Mother Lode belt was concentrated in their gravels and sands. Later, as uplift of the Sierra was renewed, new streams flowing westward cut across ancient channels and re-eroded the Tertiary gold-bearing deposits to form new, and in places richer, concentrations of the valuable metal. Similar reconcentrations are found in Alaska and Canada.

Extensive details on the geology of placer gold can be found in Wells (1969), Jenkins (1935), and Boyle (1979).

PRODUCTION

Data on production of placer gold from major producing areas (more than 100,000 oz Au) in the United States, taken mainly from Koschmann and Bergendahl (1968), and Nokleberg and others (1987), are given in table G1.

By far the bulk of placer gold produced in the United States—in the order of 100 million oz (3,000 metric tons)—has come from the States of California, Alaska, Montana, and Idaho. For these States where placer gold has constituted a relatively large proportion of the total quantity of gold produced, the ratios of

Table G1. Gold production from major placer areas in the United States

[Total production (in parentheses) is given for States, and counties or regions, only where data are available. Data mainly from Koschmann and Bergendahl (1968) and Nokleberg and others (1987). Leaders (- - -), no data; ≈, approximate or rounded value]

State-county or region-district	Period	Production (1,000 oz gold)
ALASKA:		(20,957)
Brooks Range	1893-1985	(350)
Wiseman (Koyukuk)	1890-1985	288
Seward Peninsula and Western Yukon-Koyukuk Basin	1897-1985	(7,032)
Nome	1897-1985	4,000
Kougarok	1900-1985	1,500
Council	1900-1985	1,000
Fairhaven	1900-1985	453
West-Central	1907-1985	(2,934)
Aniak	1909-1985	243
Iditarod	1908-1985	1,313
Innoko	1907-1985	537
McGrath	1910-1985	128
Ruby	1907-1985	387
Hughes	1910-1985	200
East-Central	1878-1985	(9,825)
Hot Springs	1904-1985	447
Tolovana	1915-1985	374
Fairbanks	1878-1985	7,603
Circle	1893-1985	725
Fortymile	1883-1985	415
Southern	1880-1985	(695)
Yentna	1905-1985	114
Chistochina	1890-1985	140
Nizina	1898-1985	143
Hope	1900-1985	100
Southeastern	1870-1985	(121)
ARIZONA:		(>≈431)
Yavapai County	1862-1959	(267)
Lynx Creek-Walker	1863-1959	100
Yuma County	1862-1959	(≈164)
La Paz	1862-1959	100
CALIFORNIA[1]:	1848-1965	(68,200)
Amador County	1903-1958	(290)
Volcano	1903-1932	100(?)
Butte County	1880-1959	(3,123)
Oroville	1903-1959	1,964
Calaveras County	1848(?)-1959	(2,996)
Camanche		100-1,000(?)
Jenny Lind	Unknown	100-1,000(?)
Tertiary gravels[2]	1880-1938	>106
El Dorado County	1903-1958	(191)
Tertiary gravels[2]	1903-1958	190
Los Angeles County		----
San Gabriel	1848-1956	≈120
Mariposa County	1880-1959	(584)
Merced County	1880-1959	(516)
CALIFORNIA--Continued:		
Nevada County		----
Grass Valley-Nevada City	1849-1959	≈220
Tertiary gravels[2]	1849(?)-1911	≈3,000(?)
Placer County		----
Dutch Flat-Gold Run	1849-1959	492(?)
Foresthill (Tertiary gravels)	1849(?)-1959	344(?)
Iowa Hill (Tertiary gravels)	1849(?)-1910	500(?)
Michigan Bluff	1853-1959	300
Ophir	1930's-1941(?)	≈100(?)
Plumas County		----
La Porte	1855-1959	2,910
Sacramento County	1880-1959	(5,000)
Folsom (Quaternary gravels)	1899-1959	>3,000
Sloughhouse (in part Tertiary gravels)	? -1959	≈1,700
San Bernardino County		----
Holcomb	1860's-1950	346
San Joaquin County	1885-1959	(126)
Clements	1885-1959	≈100(?)
Shasta County	1905-1959	(375)
Igo	1933-1959	115
Sierra County		----
Alleghany and Downieville (Tertiary gravels)	1852-1888	680
Siskiyou County	1880-1959	(≈1,410)
Klamath River	1933-1959	140
Salmon River	1900(?)-1959	>1,000
Stanislaus County (Quaternary and Tertiary gravels)	1880-1959	---- 364
Trinity County	1880-1959	(≈2,000)
Trinity River basin (Quaternary and Tertiary gravels)	1880-1959	≈1,750
Tuolumne County	1850-1959	(7,551)
Columbia basin-Jamestown-Sonora (mostly Quaternary gravels)	1853-1959	5,874
Yuba County	1880-1959	(4,387)
Hammonton	1903-1959	4,387
COLORADO:		(>≈1,190)
Park County	1859-1959	(≈450)
Fairplay	1859-1952	>202
Summit County	1859-1959	(740)
Breckenridge	1859-1959	735

[1]Neither placer nor lode-gold production figures were accurately recorded in the period 1848-1879.

[2]Tertiary gravels throughout the entire county.

Table G1. Gold production from major placer areas in the United States—Continued

State-county or region-district	Period	Production (1,000 oz gold)
IDAHO:		(>≈4,235)
Boise County		----
Boise Basin	1863-1958	≈2,300
Clearwater County		
Pierce	1860-1959	373
Custer County		
Yankee Fork	1870's-1959	≈100(?)
Elmore County		----
Rocky Bar	1862-1882	≈100(?)
Idaho County		----
Elk City	1861-1959	≈440-690(?)
French Creek-Florence	1860's-1959	≈1,000
Tenmile	1861-1959	≈100(?)
Warren-Marshall	1862-1959	≈800(?)
Lemhi County		(≈350(?))
Mackinaw	1866-1954	≈250(?)
Shoshone County		----
Coeur d'Alene	1880's-1959	≈100(?)
MONTANA:		(>≈7,264)
Beaverhead County		
Bannack	1862-1950	>132
Broadwater County		----
Confederate Gulch	1864-1959	≈590
White Creek	1860's-1959	≈100
Deer Lodge County	1860's-1959	(≈250(?))
French Creek	1864-1940	≈200
Granite County	1865-1959	(≈355)
First Chance	1865-1959	260-355
Jefferson County	1864-1959	(125)
Clancy	1865-1959	101
Lewis and Clark County	1864-1959	(>2,150)
Helena-Last Chance	1864-1959	940
Lincoln	1865-1959	342
McClellan	1864-1959	340
Marysville-Silver Creek	1864-1959	165
Missouri River-York	1864-1959	>265
Madison County	1863-1959	(>2,605)
Virginia City-Alder Gulch	1863-1959	>2,475
Missoula County	1865(?)-1959	(≈250-275)
Elk Creek-Coloma	1865-1959	≈100(?)
Ninemile Creek	1874-1959	100-125
Powell County	1852-1959	(517)
Ophir	1865-1959	>180
Pioneer	1868-1959	246
Silver Bow County		----
Butte	1864-1959	363
NEVADA:		(>≈1,510)
Lander County		----
Battle Mountain	1902-1968	156

Table G1. Gold production from major placer areas in the United States—Continued

State-county or region-district	Period	Production (1,000 oz gold)
NEVADA--Continued:		
Lyon County		----
Silver City	1849-1968	≈100
Nye County		----
Manhattan	1905-1968	210
Round Mountain	1906-1968	232
Pershing County		----
Rochester-Spring Valley	1860's-1968	511
Sierra	1863-1968	201
White Pine County		----
Osceola	1877-1968	≈100
NEW MEXICO:		(>570)
Colfax County		----
Elizabethtown-Mount Baldy	1866-1968	250
Santa Fe County		----
Old Placer	1828-1968	>100
New Placer	1839-1968	>100
Sierra County		----
Hillsboro	1877-1968	120
NORTH CAROLINA:		----
Franklin County	1840-1935	(>100(?))
OREGON:		(>1,461)
Baker County	1862-1957	(>600(?))
Sumpter	1862-1955	>129
Grant County		----
Canyon Creek	1864-1959	817(?)
Jackson County	1852-1959	(≈410)
Upper Applegate	1853-1959	190
Josephine County		----
Galice	1854-1942	100(?)
Waldo	1853-1942	210(?)
SOUTH DAKOTA:		
Lawrence County		----
Deadwood-Two Bit	1876-1959	≈200(?)

placer-gold from major placer areas to total gold produced are as follows: Alaska, 1:1.5; Idaho, 1:2.0; Montana, 1:2.4; and California, 1:2.6. Thus, where placer-gold production has been relatively large, it has amounted to roughly half of the total gold production.

States where placer-gold production has been a relatively small proportion of gold produced are Oregon (1:4.0), Nevada (1:18), Colorado (1:34), Arizona (1:36), and South Dakota (1:156). The reasons for these low ratios are unclear. Local factors may account for low production of placer gold relative to total gold mined. For example, deep lode mines with large production, such as at Lead, S. Dak., and Cripple Creek, Colo., may have been only slightly eroded, and they thus may have provided only minor gold to placers. Bonanza-type gold deposits, as in Nevada and Arizona, are young and likely not greatly eroded, even though close to the surface. In places, arid climate and resultant scarcity of water useful for recovering gold may have inhibited placer mining, as in Nevada and Arizona.

In California, the chance emplacement of volcanic flows above Tertiary auriferous gravels tended to preserve the placers and prevent their dispersion. In Alaska, that placers dominate over discovered lode sources of gold lacks a clear explanation. States where placer-gold:total-mined-gold ratios are small possibly contain substantial undiscovered gold placers.

DESCRIPTIONS OF MAJOR PLACER-GOLD REGIONS AND DISTRICTS

In the following pages, only placer deposits in California and Alaska, as well as those in Montana and Idaho, that have produced about 1 million or more oz gold, are described. The districts in Montana and Idaho, the Helena–Last Chance, Virginia City–Alder Gulch, and the Boise Basin, are described only briefly. The Virginia City–Alder Gulch, district is described in more detail in a separate article (Shawe and Wier, this chapter) as an example of a significant placer-gold district with only minor lode-gold production.

California Modern and Fossil Placers

More than 40 million oz of gold out of a total production of 106 million oz of gold in California has come from placers. Within 5 years of the discovery of gold in California in 1848, annual production in the State reached an all-time high of nearly 4 million oz (Loyd and Bane, 1981), virtually all of which was from placers. Upon depletion of the gold placers in modern (Quaternary) stream channels in the 1860's, hydraulic mining of fossil (Tertiary) placers commenced, and continued until 1884. Dredging commenced in the Yuba goldfields in 1904 with wooden-hulled bucket-line dredges capable of dipping 60 feet below water level. By the 1930's, 12 dredges were operating, and by 1968, 21 dredges had been built and operated in the goldfields. More than 1 billion cubic yards of gravel containing more than 5 million oz of gold had been mined by these dredges. In late 1976 the last dredge was shut down, but it was subsequently rebuilt with a capacity of digging 140 feet below water level, making it one of the deepest digging gold dredges in the world. In 1981 it commenced mining the gravels at depths below which the earlier dredges were capable. This dredge, the major producer of placer gold in California, continues to operate in the mid-1980's, washing as much as 4,500,000 yd^3, and producing 20,000 to 27,000 oz of gold annually. Locations of California's principal placer mining areas are shown on figure G1.

Most placer gold produced since 1968 has been as byproduct gold from large sand and gravel plants in the Sacramento and San Joaquin Valleys (Great Valley of California). In these operations, primary sources are the Perkins area east of Sacramento and the Friant area northeast of Fresno (Clark, 1978).

Substantial increase in the price of gold in the late 1970's greatly increased placer prospecting throughout California, but most new mining operations are at a small scale. Equipment used ranges from gold pans, picks, and shovels, to various scrapers, screens, sluices, rockers, jigs, tables, power pumps, suction dredges (fig. G2), and dry washers. Efficient and determined prospecting by the early-day placer-gold miners has left very few stream courses that contain virgin placer ground.

Much of the Tertiary gravel is of such low grade that hydraulic mining has been the only economically feasible method of recovering gold. In the late 1870's, vast amounts of gravel could be mined cheaply with the low-cost, plentiful water and labor available then. Hydraulic mining was virtually suspended in 1884 by legal restrictions, particularly the Sawyer Decision

Figure G1. Map of California showing principal placer-gold mining areas.

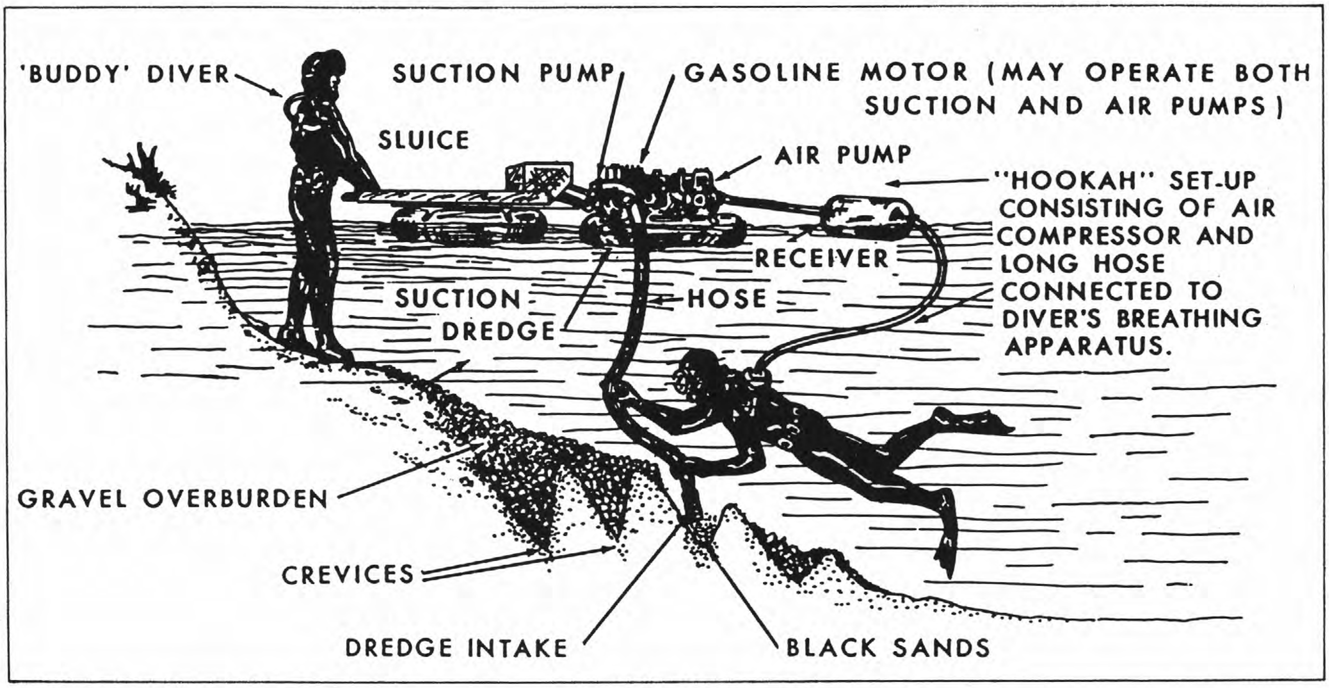

Figure G2. A typical gold-diving operation (from Clark, 1978).

(Kelley, 1959), on the disposal of debris. Attempts to resume exploitation of these deposits by several conventional methods have proved unsuccessful, including expenditure of $4,650,000 of Federal funds for the construction of debris dams (Jarman, 1927). Miners of the gravels today must deal with a multitude of environmental restrictions imposed by several government agencies. These constraints, together with high costs of equipment, water, and labor, pose a major challenge to the mining industry.

Gold-bearing gravels of Tertiary age remain abundant in the central Sierra Nevada region of California. They are believed to contain one of the largest known reserves of gold in the United States (Merwin, 1968). These deposits were studied in the late 1960's by both the U.S. Geological Survey (Peterson and others, 1968; Yeend, 1974), and the U.S. Bureau of Mines (Merwin, 1968; Tibbetts and Scott, 1971). In the past two decades several small mining groups have tested the feasibility of mining the gravels (Yeend, 1974), but no large systematic mining effort has occurred and the resource remains today largely untouched.

The largest single known deposit within the extensive California Tertiary channel system occurs in a part of the ancestral Yuba River (Yeend, 1974). Within the exposed parts of the ancestral Yuba River channel, gold in excess of 5 million oz (about 150 metric tons) is estimated to be distributed within 977.4 million yd^3 of gravel (about 0.0055 oz Au/yd^3). More than three-fourths of this total resource is contained in a vast deposit between the Malakoff and Badger Hill diggings (Yeend, 1974; located at Nevada County Tertiary gravels, fig. G1).

The total gold production from the Tertiary gravels is not known, as large quantities of recovered gold were never reported and not all mining records have been preserved. Estimates range from about 6.6 to 14.3 million oz gold from about 1,585 million yd^3 of gravel (0.004–0.009 oz Au/yd^3) (Clark, 1965; Merwin, 1968).

Reserves of Tertiary gravel are estimated to total 3–4 billion yd^3 with an average grade of 0.007 oz Au/yd^3 (Merwin, 1968). Zones in the lower sections of the gravels are estimated to contain 600–800 million yd^3 with an average value of 0.029 oz Au/yd^3 (Merwin, 1968).

Details regarding the geology, geophysical investigations, and resources of the California Tertiary gold placers have been reported by Whitney (1880), Lindgren (1911), Merwin (1968), Peterson and others (1968), Clark (1970, 1979), and Yeend (1974).

The most productive gold-bearing region of California is the north-central part of the west slope of the Sierra Nevada (fig. G1). Major placer districts (Oroville, Folsom, and Hammonton, fig. G1) in Quaternary flood-plain gravels at the eastern margin of the Great Valley of California have yielded nearly 10 million oz of gold. Additionally, nearly 6 million oz was produced from Quaternary gravels reworked from Tertiary gravels in the Columbia-Jamestown-Sonora district in the western foothills of the Sierra Nevada (fig. G1). Major placer districts (Grass Valley–Nevada City and Sloughhouse, fig. G1) near the western margin of the Sierra foothills produced about 4 million oz of gold from both Quaternary and Tertiary gravels. Major placer districts (Nevada County and La Porte, fig. G1) within the western Sierra Nevada produced nearly 6 million oz of gold from mostly Tertiary gravels.

The source of gold in the Quaternary and Tertiary gravels of the western Sierra Nevada region is numerous quartz veins and mineralized zones of the Mother Lode and related systems, emplaced in Carboniferous black phyllite, quartzite, limestone, chert, and greenstone schist, and in Jurassic slate, graywacke, conglomerate, sericite schist, limestone, and greenstone. Small bodies of peridotite, serpentinite, hornblendite, gabbro, granodiorite, and albitite were intruded into these rocks in Late Jurassic and in Late Cretaceous time. Gold mineralization occurred probably in Late Cretaceous time. (Data here are summarized by Koschmann and Bergendahl, 1968, p. 55, from Knopf, 1929, and Curtis and others, 1958.)

In northern California about 1.75 million oz of gold came from Quaternary and Tertiary gravels in the Trinity River basin, and more than 1 million oz of gold was mined from Quaternary gravels along the Salmon River (fig. G1).

Country rocks in the Klamath Mountains, which the Trinity River system drains, are marine sedimentary and metasedimentary rocks of Carboniferous age; Paleozoic and Mesozoic schist; serpentinite, peridotite, gabbro, diorite, and diabase of chiefly Mesozoic age; and granitic-quartz dioritic plutons of Mesozoic age intruded into the older rocks (Jennings, 1977). Gold-bearing quartz veins in the region (J.P. Albers and W.P. Irwin, written commun., 1982), which probably formed at the time of emplacement of the Mesozoic granitic plutons, apparently were the source of the gold concentrated in the placer deposits.

Country rocks drained by the Salmon River consist of Paleozoic and Mesozoic metasedimentary and metavolcanic rocks, serpentinite, and gabbro, intruded by plutons of granitic–quartz dioritic composition (Jennings, 1977). Source of the gold in the Quaternary gravels along the Salmon River likely is quartz veins similar to those in the Klamath Mountains around the Trinity River basin.

Alaska Modern Placers

More than 30 million oz (900 metric tons) of gold has been produced from Alaska mines since gold was first mined there in 1870. Of this amount, two-thirds, or roughly 20 million oz (600 metric tons) has come from placers. Alaska's interior region has produced the bulk of this placer gold, about 12 million oz, of which about 7,600,000 oz came from the Fairbanks district and about 1,300,000 oz from the Iditarod district (fig. G3). The Seward Peninsula has produced more than 6 million oz of Alaska's placer gold, of which about 4,000,000 oz came from the Nome district (fig. G3).

Most of the gold from the Fairbanks district (fig. G3) has been produced by large dredges working the unconsolidated auriferous gravels of major creeks tributary to the Tanana River west of Fairbanks. An excellent videotape is available showing the large-scale thawing and mining of these gravels in the 1930's and 1940's (Univ. of Alaska, 1981, videotape). The bulk of placer gold came from gravel from just above to nearly 3 m above bedrock. Bedrock consists of three metamorphic rock sequences—part of the old Yukon-Tanana upland schist belt. The middle unit, a 900-foot-thick sequence of schists termed the Cleary sequence, is considered to be the host to most of the lode gold occurrences. It is mostly mafic and felsic schist, and greenschist which may represent rocks of distal volcanic origin. The schists have been intruded by 90-million-year-old intrusive quartz monzonites, and granodiorites. Sulfide lenses and disseminations in the metavolcanics contain free gold that contributed to the placers. Gold-quartz veins, the source of the lode gold production in the district, are probably the main source of placer gold. (Data here are summarized from Koschmann and Bergendahl, 1968, p. 16–27; Mertie, 1937; Prindle and Katz, 1913; Hill, 1933; Anonymous, 1985; and Metz, 1987.)

Gold production from the Iditarod district (fig. G3) has been almost wholly from placers. Bedrock of the district is mostly sandstone, shale, and conglomerate of the Kuskokwim Group of late Early to Late Cretaceous age; metamorphic rocks of Paleozoic and Precambrian ages are present in the west. Volcanoplutonic complexes of Late Cretaceous–early Tertiary age intrude and overlie the Kuskokwim Group. These rocks and related dikes are the major sources of the placer gold. The gold distribution is a result of structural controls, geomorphic evolution of stream drainages in a preglacial environment, and stream piracy (Miller and Bundtzen, 1987).

Most of the gold produced in the Nome district (fig. G3) has come from residual, stream, bench, and beach placers (Moffit, 1913). Beach placers formed at several levels during successive episodes of uplift, and they have been preserved beneath coastal-plain deposits and deposits of the present beaches. The beach placers have been the most productive at Nome. Several successive events of reconcentration may have occurred prior to formation of the rich Nome beach placers. Country rocks in the Nome area consist of schist, slate, and volcanic rocks of late Precambrian age that were deformed in Mesozoic and Tertiary times (Hummel,

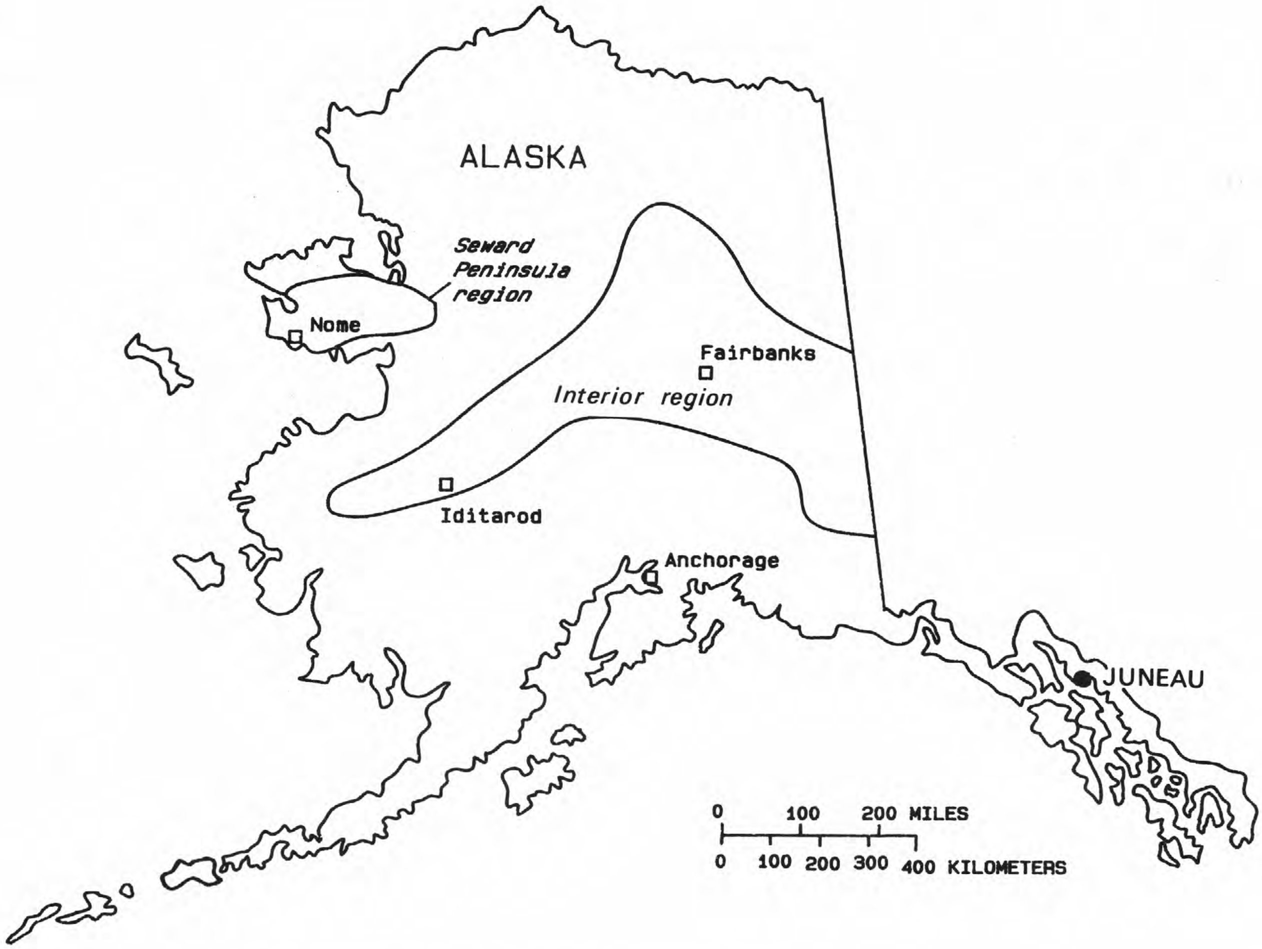

Figure G3. Map of Alaska showing principal placer-gold mining areas.

1960). Faults and joints that formed during the Tertiary deformation are in part mineralized, "and these lodes are probably the source of the gold in the Nome Placers" (Koschmann and Bergendahl, 1968, p. 19). The world's largest offshore dredge, the Bima, began operating in Norton Sound, near Nome, in 1986. Capable of washing 1,000 yds/hr, the Bima recovered 36,000 oz of gold during 1987. Mining is currently restricted to 100 acres of sea floor per year (Petroleum Information, Alaska Report, Jan. 13, 1988).

The Seward Peninsula is the site of other locations that have been rich in placer gold in addition to Nome. Eight areas have produced approximately 2,500,000 oz of placer gold, roughly 12 percent of the total from Alaskan placer mines. The placers in all these areas seem to have a close spatial association with certain metamorphic rocks of the Nome Group that are quartz-graphite schist, and marble with occasional boudins of metabasite. Five of the placer gold-rich areas contain outcrops of the Casadepega Schist, a chlorite-albite and mafic schist with boudins of metabasite that could also have provided some of the gold to the placers (Yeend and others, 1988).

Alaska is probably the only State where placer-gold production is significantly increasing (Pittman, 1981): A recent hydraulic operation in the Circle district is shown in figure G4. In the early 1970's, gold mining in Alaska was almost extinct. The depressed price of gold, together with the high cost of labor and equipment, limited production in those years to perhaps about 10,000 oz from about a dozen gold-mining operations. The dramatic increase in the price of gold in the late 1970's and early 1980's resulted in a second gold rush to Alaska. By 1981, there were about 400 placer mines in the State employing about 3,000 miners. Placer gold production of about 30,000 oz in 1979 and 50,000–70,000 oz in 1980, increased to 160,000 oz in 1986, and about 200,000 oz in 1987.

Placer mining within Alaska presents certain problems not encountered in other areas of the United States. Most of the placer deposits are perennially frozen and many are overlain by a thick layer of organic-rich muck that must be thawed by surface stripping, exposure to summer air temperatures, and periodic removal of thawed material to keep frozen material exposed. In

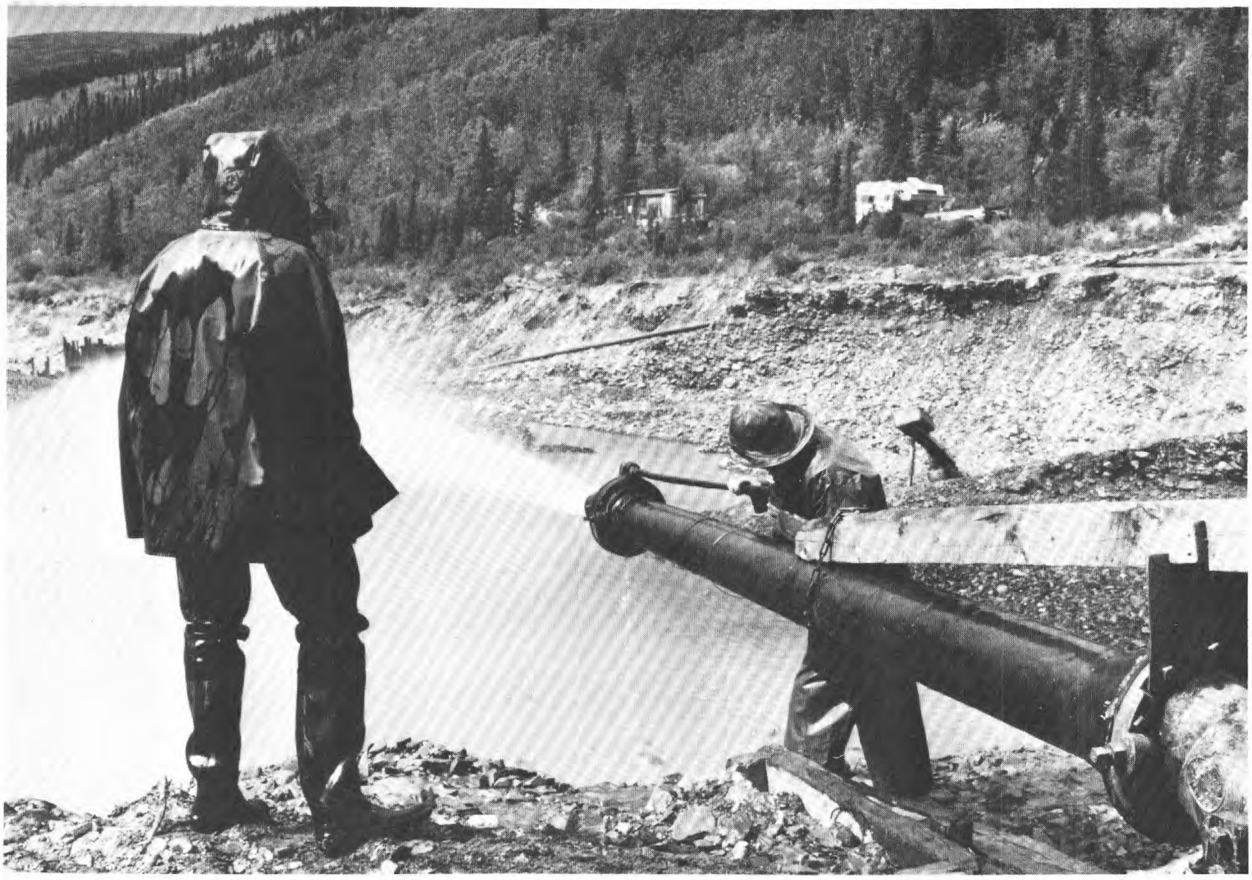

Figure G4. Hydraulic mining on the North Fork of Harrison Creek, Circle quadrangle, Alaska, 1980.

some large-scale dredging operations, large volumes of ground must be thawed to bedrock by cold water prior to dredging. Water injected through pipes to the bottom of closely spaced holes drilled to bedrock circulates back to the surface. Injection continues until the ground between the holes is thawed. Cold-water thaw fields typically require preparation and operation at least 2 years ahead of the mining operation. Because of widespread disruption of the land surface, siltation of streams and rivers is a common problem.

Pertinent data on presently active gold placer mining areas in Alaska are given in table G2. Some of these areas appear to have significant resources of gold that promise large future production. Additional details of the history of placer mining in Alaska, and extensive descriptions of the placer deposits are presented by Cobb (1973) and by the University of Alaska (1979–1987).

Helena–Last Chance District, Montana

The Helena–Last Chance district in southern Lewis and Clark County, Mont. (fig. G5) produced about 940,000 oz of placer gold and at least 345,000 oz of lode gold during the period 1864–1955. The rich placers were formed by erosion of lode deposits in hornfels, tactite, and granitic rocks near the contact of the Boulder batholith of Cretaceous age with sedimentary rocks of late Precambrian, Paleozoic, and Mesozoic age. The lode deposits are aggregates of lime-silicate minerals, tourmaline, quartz, ankerite, and chlorite gangue that contain pyrite, pyrrhotite, chalcopyrite, galena, and native gold. (Data here are summarized by Koschmann and Bergendahl, 1968, p. 155, from Lyden, 1948; Knopf, 1913; and Pardee and Schrader, 1933.)

Virginia City–Alder Gulch District, Montana

The Virginia City–Alder Gulch district in Madison County, Mont. (fig. G5) produced more than 2,600,000 oz of gold during the period 1863–1963, nearly all of which was derived from placers. Lode deposits in the district that are the apparent source of the placer gold are quartz veins and stringers in Archean gneisses and schists. The primary veins contain auriferous pyrite, galena, sphalerite, and chalcopyrite, and lesser amounts

Table G2. Major active 1980's gold placer mining areas of Alaska

[Leaders (- - -), no data]

Area	Total production (1,000 oz Au)	Resources (yd^3)	Grade (oz/yd^3)	Gold occurrence	and source of gold	Mining method	No. miners, operations	References
Chistochina River	140 (early 1900's-1980)	-----	0.0125-.0275	Poorly sorted alluvium, fans, colluvium, drift. Nuggets to 6 mm; mostly thin plates 1 mm diameter; large quantities of black sand.	Tertiary(?) conglomerate.	Sluice	4 properties (1980).	Yeend, 1981.
Circle district	730 (1893-1980)	Large	0.001-0.034 (commonly 0.006-0.016)	Alluvial; colluvial	Precambrian quartzite, quartzitic schists, and Upper Cretaceous and lower Tertiary granite; mafic schist with quartz-veins possible source.	Sluice box; hydraulic (see fig. G1).	400-750 miners, 20-90 operations.	Yeend, 1982, 1987; Bundtzen and others, 1987.
Fortymile district	417 (1888-1961)	-----	-----	Stream and bench placers; loess mantles much of the area.	Gneiss, schist, marble; felsic batholiths; gold source may be small mineralized quartz veins in metamorphic rocks near contacts with felsic intrusive bodies.	Floating dredge, sluice.	26 active mines (1982).	Cobb, 1973; Eakins and others, 1983.
Ophir	300 (1906-1980)	-----	0.01-0.02 (modern alluvium); to 0.024 bench gravels)	2-6 m gravel beneath 1-5 m frozen muck; gold concentrated in lower 1 m of gravel and in fractures in upper 1 m of bedrock; gold as fine-grained flattened grains; some grains iron stained; some grains composite with quartz and magnetite.	Cretaceous shale, siltstone, sandstone, cut by aplite and porphyry dikes; some mineralized dikes and faults in the area contain gold; as yet unrecognized fossil placers may have been a source.	Bucket drag line; suction dredge.	6 mines (1980).	Yeend, unpub. data, 1980.
Seward Peninsula	6,500 (1897-1986)	900,000,000 (3,000,000 oz gold)	0.0033	Raised submarine beach placers near Nome; Pleistocene gravels in Kougarok district; offshore submarine sediments.	Upper Precambrian schist, slate, volcanic rocks; mineralized faults and joints probable source gold.	Pan, rocker, sluice, suction dredge, floating dredge.	200-300 miners, 25-35 operations (1986).	Eakins, 1981; Bundtzen and others, 1987.
Tolovana district	374 (1915-1959)	20,000,000	0.024	Stream and bench placers; placers; rich buried bedrock benches.	Schist, Paleozoic clastic, volcanic and carbonate; quartz & carbonate; quartz and calcite veins in bedrock contain gold.	Floating dredge, underground drift.	200 miners, 6 mines (1981).	Eakins, 1981; Cobb, 1973; Bundtzen and others, 1987.
Valdez Creek district	120 (1903-1986)	35,000,000	0.0125-0.20	Buried gravel-filled channels.	Metamorphic, sedimentary and volcanic rocks; gold and sulfide-bearing quartz veins.	Washing plant.	85-136 miners, 1 company (1986).	Smith, 1970; Cobb, 1973; Bundtzen and others, 1987.
Yentna-Cache Creek district	115 (1905-1959)	-----	-----	Stream and bench gravels, Pleistocene glaciofluvial and Tertiary conglomerate.	Graywacke, Tertiary gold-rich conglomerate.	Floating dredge.	12 properties.	Eakins, 1981; Cobb, 1973.

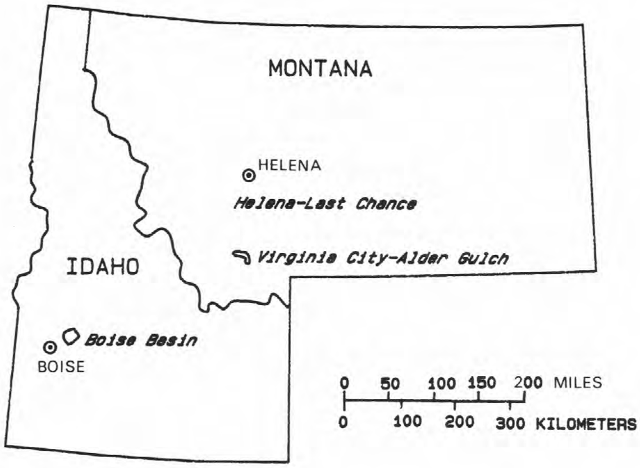

Figure G5. Map of Idaho and Montana showing locations of the Boise Basin, Virginia City–Alder Gulch, and Helena–Last Chance placer-gold districts.

of gold tellurides, tetrahedrite, argentite, and stibnite (Koschmann and Bergendahl, 1968, p. 163; summarized from Winchell, 1914, p. 159–165; and Hart, in Tansley and others, 1933, p. 47–50).

Boise Basin District, Idaho

The Boise Basin district in Boise County, Idaho (fig. G5) produced about 2,300,000 oz of gold during the period 1862–1958, mostly from placers. The placers were derived from lode deposits that are quartz veins in fracture zones in quartz monzonite of the Idaho batholith of Cretaceous age (Kiilsgaard and others, 1989). The quartz fissure fillings contain small amounts of pyrite, arsenopyrite, sphalerite, tetrahedrite, chalcopyrite, galena, stibnite, and native gold. (Data here are summarized by Koschmann and Bergendahl, 1968, p. 124–125, from Lindgren, 1898, and Anderson, 1947.)

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Gold Deposits in the Virginia City–Alder Gulch District, Montana

By Daniel R. Shawe *and* Kenneth L. Wier

Abstract

The Virginia City–Alder Gulch district was discovered in 1863 and has produced more than 2,600,000 ounces of gold, mostly from placer deposits. Placer workings sustained production during early years; dredging dominated production after the turn of the century. Gold of about 850 fineness is distributed along 25 kilometers of Alder Gulch, being of coarse and ragged character in the upper reaches of the drainage, and finer grained, brighter, and well worn in the lower reaches, indicating a proximal source. Steeply dipping quartz veins of varied strikes in the surrounding Precambrian gneisses and schists are the evident sources of the placer gold; the veins have yielded somewhat less than 200,000 ounces of gold. The veins contain auriferous pyrite, minor galena, sphalerite, and chalcopyrite, and lesser amounts of gold tellurides, tetrahedrite, argentite, and stibnite. Vein ores averaged about 0.33 oz Au/ton and 7.2 oz Ag/ton. The district is zoned; deposits in the south part produced ores with Au:Ag ratios as high as 5:1; deposits northward and to the east and west margins of the district produced ores with lower Au:Ag ratios, ranging progressively to as low as 1:75. Age and source of the ores are unknown.

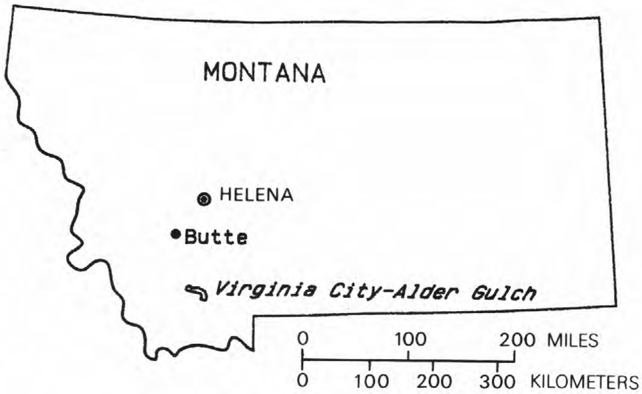


Figure G6. Map of Montana showing the location of the Virginia City–Alder Gulch district.

INTRODUCTION

The Virginia City–Alder Gulch district is in central Madison County, Mont., about 90 km south-southeast of Butte (fig. G6), at an elevation of 1,585–2,375 m (5,200–7,800 ft) at the south end of the Tobacco Root Mountains. Gold was discovered in Alder Gulch, a tributary of the Ruby River, on May 26, 1863, by a group of six prospectors outfitted in Bannack and LaBarge City (Deer Lodge), Mont. Bill Fairweather and Henry Edgar panned gold from a stream bar along the gulch where rich concentrations lay just below the surface (Edgar, 1900). A precipitous rush followed the discovery, and within 18 months the area had a population of about 10,000.

Placer workings sustained the bulk of gold production from the district during the latter part of the 19th century and the early part of the 20th century (Jennings, 1916). Dredging dominated production of gold after about 1900. Significant lode-gold production commenced about the turn of the century and has continued intermittently ever since, but it has contributed only a small amount of the district's total yield.

Total gold production from the Virginia City district through 1963 is estimated (Koschmann and Bergendahl, 1968, p. 163; K.L. Wier, unpub. data) to be at least 2,646,000 oz, of which 2,475,000 oz was from placer operations. Other estimates have placed the placer yield somewhat higher. Some early reports suggested that more than 1,000,000 oz of gold was recovered during the first 3 years of placer mining. On the basis of the known fineness (about 850) of placer gold mined during the period 1934–1963, the placers are estimated to have also yielded about 350,000 oz silver. Lode mining yielded a total of about 170,800 oz of gold (1867–1890, 48,400 oz; 1891–1900, 13,000 oz; 1901–1967, 109,400 oz). During the period 1901–1967 the lode deposits yielded a total of 2,388,800 oz silver (K.L. Wier, unpub. data). Placer ground through the 25-km length of Alder Gulch has been thoroughly and repeatedly worked, and all known lode deposits are small. Gold-ore reserves both in placer and in lode deposits in the district are small, although gold resources may be large in placer ground downstream from previously worked gravels. Alder Gulch, like few other places in the United States, has shown rich and large placer-gold accumulations despite apparently small lode sources.

GEOLOGY

The Virginia City district is situated in Precambrian (Archean) rocks (Vitaliano and others, 1979) which, south of the district, underlie a moderately thick section of Paleozoic marine-shelf quartzite, limestone, and shale (Hadley, 1969; fig. G7). The Precambrian rocks consist of interlayered units of garnet-bearing gneiss, amphibolite schist, dolomitic marble, and metamorphosed ultramafic rocks that strike generally northeast to north-northeast. Numerous thin subparallel pegmatitic dikes that strike west to west-northwest cut the layered units. A few northwest-trending faults of minor displacement offset the layered Precambrian units. Tertiary basalt and silicic tuff, not known to be gold mineralized, cap older rocks at the east side of the district.

A Tertiary diatreme of mainly basalt and some Precambrian rock fragments in a clay matrix appears to be overlain by Tertiary volcanic rocks about 1 km south of the town of Virginia City. A few oval-shaped plugs(?) of Tertiary volcanic rocks, maximum length about 300 m, lie 1–2 km south-southwest of Virginia City within the area of Precambrian rocks (K.L. Wier, unpub. data).

Some K-Ar ages have been determined for volcanic rocks in the vicinity of Virginia City (Marvin and others, 1974). Two samples collected from a unit that ranges from andesite to dacite porphyry in the volcanic rocks exposed just northeast of the town of Virginia City yielded ages of 49 and 51 Ma. Porphyritic rhyolite collected near the Ruby River Reservoir southwest of Virginia City yielded an age of 45 Ma. Samples of basalt collected at two localities south and southeast of the town were determined as 33 and 34 Ma, respectively, and a basalt sample collected southeast of the town of Alder (small outcrop not shown on fig. G7) was determined to be 30 Ma.

GOLD DEPOSITS

Age of the Deposits

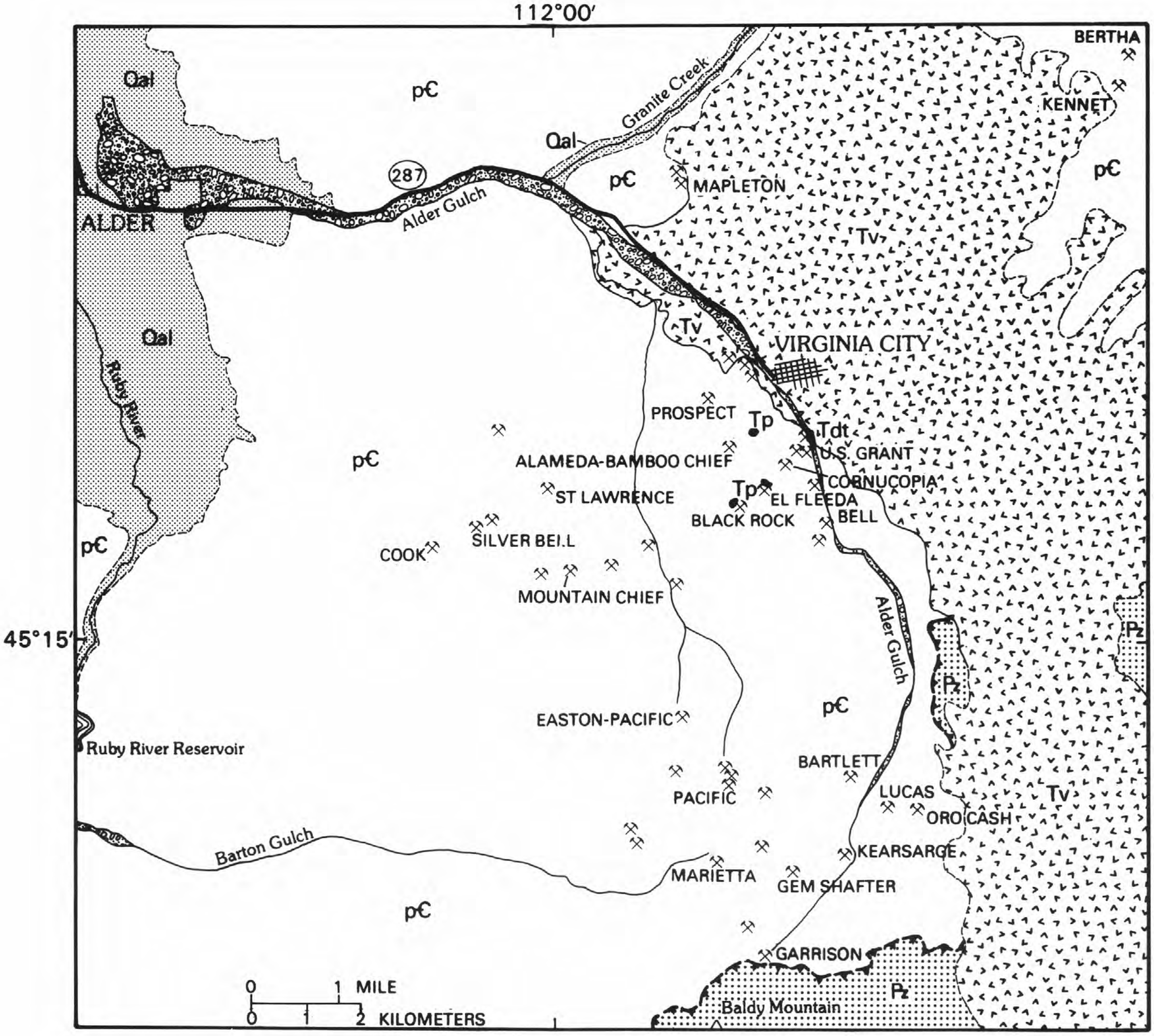
The age of the vein deposits of the district has not been established. Their origin may have been related to emplacement of the volcanic rocks (30–50 Ma) in the vicinity of the district or to the volcanic diatreme and plugs (age unknown) south and southwest of Virginia City. The gold veins may have formed during an earlier widespread regional mineralizing event about 60 Ma, at the time that veins were formed at Butte, which is about 90 km north-northwest of Virginia City. This possibility is strengthened by the fact that the Tobacco Root batholith of Late Cretaceous age that intrudes Archean rocks about 20 km north of Virginia City is surrounded by numerous small lode-gold deposits. These small gold deposits, similar in vein mineralogy and host rocks to those near Virginia City (R.C. Pearson, written commun., 1984; Vitaliano and Cordua, 1979), appear genetically related to the batholith and its satellitic stocks. On the other hand, the gold veins at Virginia City may be as old as Precambrian.

Volcanic rocks that date at 50 Ma lie in the bottom of Alder Gulch near Virginia City, showing that the gulch had formed prior to 50 Ma. Whether or not the gulch contained placer gold at that time is uncertain. However, once concentration of gold in the gulch started, it has continued to the present.

Placer Gold

The placer gold of Alder Gulch appears to have been derived from erosion of a few moderately sized and numerous small quartz veins in the surrounding Precambrian country rock, particularly in the upper reaches of the gulch. However, the source of the gold has long been disputed because of the apparently insufficient size and richness of the known quartz veins. In the upper part of Alder Gulch, much of the placer gold was "coarse, ragged, and little or not at all water worn" (Douglass, 1905, p. 354). Douglass also reported that a "decomposed vein" (the Lucas lode) below the upper placer ground yielded gold, and placer ground downstream from the vein was very rich, implying that the vein was surely the source of the placer gold. Douglass further stated that gold became progressively finer grained downstream to the mouth of the gulch, although some "fair-sized nuggets" were recovered near the mouth of the gulch. According to Browne (1868, p. 506), placer gold at the head of Alder Gulch is "coarse and rough, with portions of quartz adhering to it; further down the stream it becomes finer and brighter, showing unmistakable evidence of having been worn by the action of water. Near the mouth it is exceedingly fine [grained] ***." These relations are convincing evidence of a local source for much of the gold.

Fineness of the placer gold increased downstream. Jennings (1916, p. 23) reported that, in the early 1900's, gold recovered from dredging farthest up Alder Gulch was 822 fine and that recovered from dredging farthest



EXPLANATION

- Qal — Quaternary alluvium
- Quaternary (?) placer ground
- Tp — Tertiary plug
- Tdt — Tertiary diatreme
- Tv — Tertiary volcanic rocks
- Pz — Paleozoic marine sedimentary rocks
- pC — Precambrian metamorphic rocks
- Contact—Dashed where approximately located
- Thrust fault—Teeth on upper plate
- Mine—Name shown where known

Figure G7. Generalized geology of the Virginia City–Alder Gulch district. Compiled from Wier (1982) and other sources. Names of mines are shown where known.

below the mouth of the gulch was 873 fine. The average fineness of placer gold mined during the period 1934–1963 was 849 (Au:Ag ratio 5.6:1) (K.L. Wier, unpub. data).

Lode Gold

During the early years of gold mining in Alder Gulch, the Kearsarge and Oro Cash lodes along the upper reaches of Alder Creek were mined, and "much gold" was said to have been produced (Douglass, 1905, p. 355). Nevertheless, there is no record of large production. Mining ceased at the Kearsarge mine following a fire in 1903, and mining ceased in the Oro Cash following removal of the near-surface oxidized ores. Most lode-gold production in the 20th century was from mines nearer to Virginia City, mainly the Prospect (1933–1936) and U.S. Grant (1945–1948) and from the Easton-Pacific (1902–1915) near the head of Browns Gulch. Many other mines throughout the district sporadically produced substantial amounts of gold (1,000 oz/yr or more), but none sustained a large production. Locations of these and other mines referred to in the text are shown on figure G7.

Mined quartz veins in the district are moderately to steeply dipping and strike northwest (Prospect mine, Easton-Pacific mine), north-northwest (Pacific mine), north-northeast to northeast (Oro Cash lode, Lucas lode, Kearsarge lode, St. Lawrence mine, U.S. Grant mine), and east-northeast (Alameda mine). The veins tend to be localized along thin units of dolomitic marble in the Precambrian rocks (Wier, 1982).

The gold-bearing lodes "are quartz veins and stringers that contain auriferous pyrite, galena, sphalerite, and chalcopyrite, and lesser amounts of gold tellurides, tetrahedrite, argentite, and stibnite. Most of the ore shipped was oxidized and consisted of gold and free [native?] silver in quartz, iron oxides, manganese oxides, and a little locally occurring copper stain" (Koschmann and Bergendahl, 1968, p. 163; summarized from Winchell, 1914, p. 159–165, and Hart, in Tansley and others, 1933, p. 47–50). The larger veins average about 1 m in width.

The tenor of lode ores mined in the early days was about 0.5 oz Au/ton (Browne, 1868, p. 507). On the basis of production figures for the period 1901–1967 (K.L. Wier, unpub. data), which show a total lode production of 109,415 oz Au and 2,388,802 oz Ag, the tenor of the ores was 0.33 oz Au/ton and 7.2 oz Ag/ton (Au:Ag ratio 1:21.8).

Au:Ag ratios in mined veins varied widely but somewhat systematically throughout the Virginia City district. At the south end of the district, the Kearsarge and Oro Cash veins yielded ores with Au:Ag ratios of 5:1 and 3:1, respectively; because these were the earliest mined deposits, however, mining and metal recovery may have been selective for gold. Northwest and west of the Kearsarge and Oro Cash mines, the Gem Shafter, Bartlett, and Marietta mines produced ores with Au:Ag ratios of 1:2 to 1:7. Farther north, most of the rest of the mines of the district yielded ores with Au:Ag ratios of 1:13 to 1:35, with the exception of the Prospect mine (Au:Ag ratio 1:6), and at the district's east and west margins respectively the U.S. Grant mine (Au:Ag ratio 1:67) and the Silver Bell mine (Au:Ag ratio 1:75). Thus, the district is strongly zoned from high-gold ores at the south end, with increasing silver northward, and very high silver ores at the east and west margins (fig. G8). No geologic element is recognized that may have caused the zoning. The cluster of a Tertiary diatreme and plugs south and southwest of the town of Virginia City shows no relation to the zonal pattern of Au:Ag ratios. Possibly a stock satellitic to the Tobacco Root batholith underlies Paleozoic rocks south of Virginia City, and the zoning might be related to such a postulated stock.

The veins mined in the Virginia City district primarily for gold and silver yielded a very small amount of copper (0.00014 percent of the mined ore), lead (0.00039 percent), and zinc (0.00004 percent). Of course, base metals were not recovered from many ore shipments, as much of the early production was from stamp mills and only "free" gold with included silver (electrum) was recovered. Until about 1941, zinc was not recovered at all, and the composite base-metal content of the vein ores was undoubtedly higher than indicated by the smelter returns. Nevertheless, it is clear that copper, lead, and zinc contents of the ores were quite low.

Cu:Pb ratios of metals recovered from the mined veins varied widely throughout the Virginia City district, but were not as systematically zoned as were the Au:Ag ratios. Some mines yielded only copper (Cu:Pb ratio ∞), in a few the Cu:Pb ratio was as high as 6:1, and the ratio ranged downward to as low as 1:175. In a general sense, high-copper ores were from mines with high Au:Ag ratios, and high-lead ores were from mines with low Au:Ag ratios.

Genesis of the Gold Ores

Because the age of the gold-bearing quartz veins of the Virginia City district is unknown, we can only speculate on the genesis of the ores. Emplacement of the Tertiary diatreme and plugs perhaps provided the heat, fluids, and metals responsible for the formation of the hydrothermal veins. On the other hand, the strong metal zoning—gold- and copper-rich ores at the south end of the district and silver- and lead-rich ores farther north—suggests a center of hydrothermal activity to the south, possibly related to an unexposed stock satellitic to the Tobacco Root batholith. If this activity did emanate from

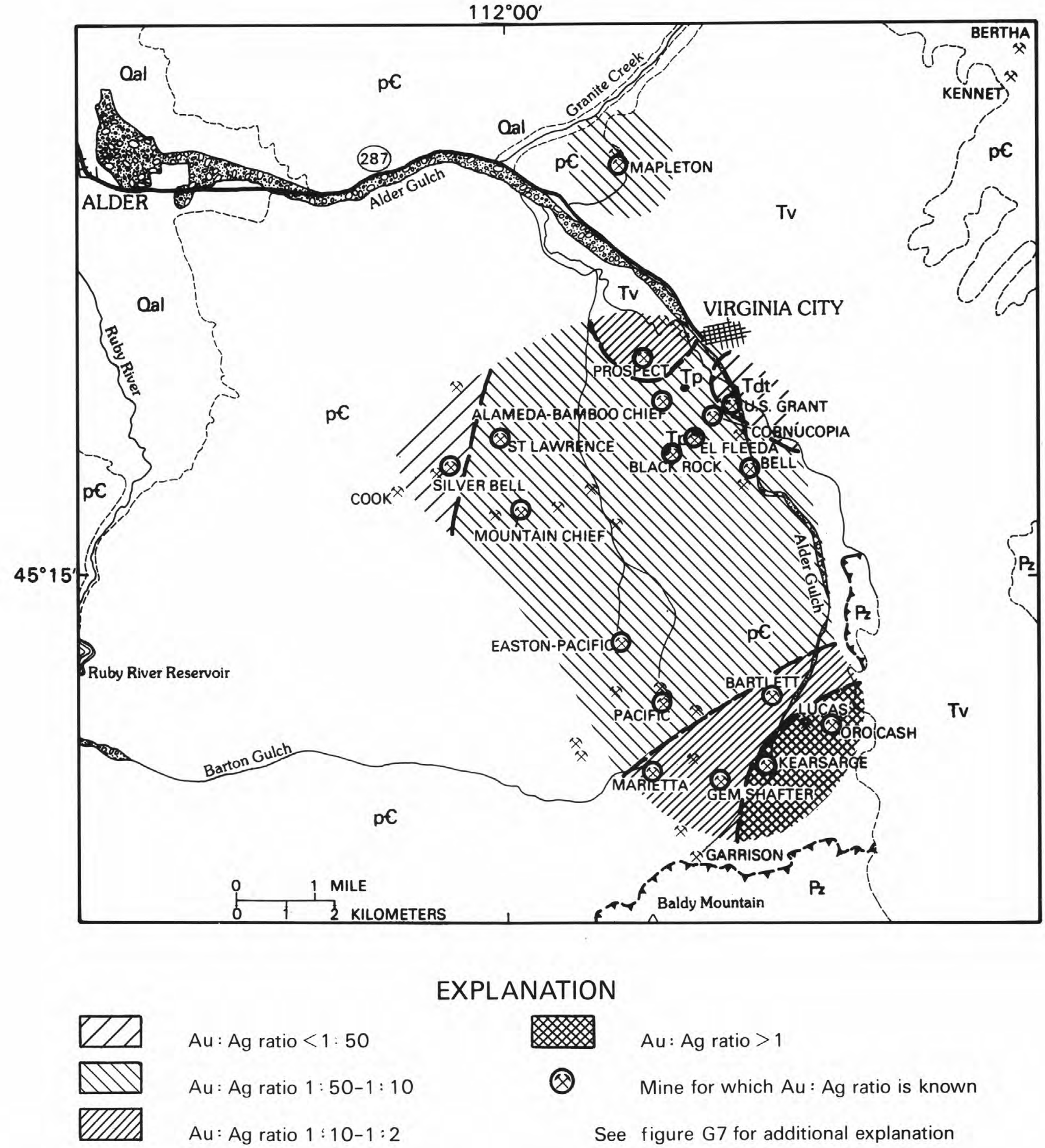


Figure G8. The Virginia City–Alder Gulch district showing zoning of the Au:Ag ratios of gold ores.

such a center, it is not evident why ore deposits are not found in Paleozoic and Mesozoic rocks farther south, barring substantial post-ore displacement of the sedimentary rocks by thrusting. If Precambrian rocks beneath the Paleozoic and Mesozoic rocks were mineralized south of the district, whether or not possible deposits would be large or rich enough to warrant exploration is unknown. Also, lack of understanding of the relative ages of the veins and the volcanic rocks makes the potential for possible ores under the volcanic rocks east of the district quite speculative.

The placer-gold deposits of Alder Gulch are remarkable for their extreme richness and large yield compared to the relatively small extent of the known vein deposits that may have been their source. Explanations for this relation might include: a much richer vein system above the present level of erosion; or preconcentration of placers on an older surface, such as that underlying the layered volcanics east of the district, presuming that the vein deposits predated the volcanic rocks.

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