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PRODUCTION POTENTIAL OF KNOWN GOLD DEPOSITS IN THE UNITED STATES

By Field Staff, Bureau of Mines

UNITED STATES DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

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Walter R Hibbard Jr
Director

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UNITED STATES DEPARTMENT OF THE INTERIOR
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CONTENTS

ILLUSTRATIONS

TABLES

PRODUCTION POTENTIAL OF KNOWN GOLD DEPOSITS IN THE UNITED STATES

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Field Staff, Bureau of Mines

ABSTRACT

As part of its regular program to provide timely information on domestic mineral commodities, the Bureau of Mines conducted an engineering appraisal of more than 1,300 lode and placer gold deposits in the United States to determine their gold production potential. While these deposits were estimated to contain over 400 million ounces of gold, only 9 million ounces, or slightly more than 2 percent, was found to be producible at $35 per ounce under prevailing mining and metallurgical technologies.

The study revealed that any significant increase in available gold in the United States is most likely to come from the discovery of new sources, intensive exploration and development of the more promising known mineralized areas, and development of new or improved mining and metallurgical techniques.

INTRODUCTION

As part of its regular program to provide timely information on domestic mineral commodities, the Bureau of Mines conducted an engineering appraisal of domestic active and inactive gold mines and undeveloped sources. Although every effort was made to include all deposits with gold production potential, regardless of cost, some significant sources may have been overlooked. Sources of byproduct gold--such as copper, lead, zinc, and silver deposits--where gold yield is dependent upon production of other metals, were not considered.

Gold mineralization is widespread and tens of thousands of gold prospects have been recorded in the United States. Of these, about 9,000 (5,000 lode and 4,000 placer) properties have produced enough gold to be classed as mines. About 1,300 of these mines (814 lodes and 494 placers), were selected for detailed study. These properties represent almost all of the Nation's gold reserves.

Evaluation of these reserves and their production potential was made on the basis of existing data and under mining and metallurgical technologies prevailing at the time of the study. Information relative to the geology and origin of gold deposits was drawn largely from the literature which is referenced in a bibliography at the end of the report.

Except for active mines and a few of the larger inactive properties for which a portion of the ore could be classified as measured and indicated reserves, virtually all of the reserves are inferred. The distribution of values in gold mines usually is erratic; hence, the lack of substantial developed reserves is a leading characteristic. Measured ore reserves usually are depleted as a final effort on the part of management before closing a mine, to recover as much as possible of the money expended for their development.

From 1792 through 1964, U.S. gold production totaled 308.5 million troy ounces, of which approximately 88 percent came from gold ores and placers and only 12 percent from byproduct sources. In recent years, the proportion of byproduct gold has been increasing and in 1964 it was 37 percent of the total.

The present study revealed an availability of about 408 million ounces of gold (not including byproduct potential) from sources in 18 States. However, only 9 million ounces or slightly more than 2 percent, was found to be producible at $35 or less per ounce. More than 96 percent of the commercial reserves are in deposits in two major producing States--South Dakota and Nevada.

More than 99 percent of the U.S. gold production, exclusive of byproduct gold, has come from 12 gold-producing districts, only one of which the Piedmont district, is east of the Mississippi River. The Pacific Border district, which extends from Alaska through California, has accounted for more than 40 percent of total U.S. gold output.

Five States--Idaho, Alaska, Washington, California, and Montana, in decreasing order--contain almost four-fifths of the gold reserves producible at more than $35 per ounce. More than 55 percent of the total is in Idaho and Alaska.

Ninety-seven percent of the commercial reserves and almost three-fourths of the noncommercial reserves are in lode deposits.

ACKNOWLEDGMENTS

Many mining company officials, mining consultants, and others provided information that contributed greatly to the completeness of the study. All of them cannot be acknowledge individually, but contributions deserving special mention were made by Gene Nelson and William Byington, A. J. Industries; officials of U.S. Smelting, Refining, and Mining Co.; James O. Harder, Homestake Mining Co.; Paul Miller, Bald Mountain Mining Co.; George C. Orton, Bradley Mining Co.; Walter A. Stinson, Original Sixteen to One Mine; Cecil D. Brophy and V. A. Hoak, Yuba Consolidated Goldfields Co.; R. G. Smith, The Natomas Co.; William B. Clark, California Division of Mines and Geology; and Max H. Bergendahl, U.S. Geological Survey.

Leonard C. Clark, formerly mining engineer with the Bureau of Mines Area VI Mineral Resource Office, San Francisco, Calif., developed the cost-level method and coordinated the work of the professional staff that included J. A. Herdlick, B. I. Thomas, Kevin Malone, and A. L. Kimball, Juneau, Alaska;

S. W. Zoldok and D. P. Banister, Spokane, Wash.; R. P. Darnell, Denver, Colo.; W. E. Burleson, Socorro, N. Mex.; J. H. Soulé, Tucson, Ariz.; and A. R. Kinkel, San Francisco, Calif.

DOMESTIC GOLD SOURCES

Types of Deposits

Major U.S. sources of gold are lode gold deposits, placer deposits, and base-metal and silver lode deposits. Only the first two types, which supplied 87 percent of the domestic gold output in 1940 and 63 percent in 1964, are the concern of this report. The level of gold production from base-metal and silver deposits is dependent upon the economics of copper, lead, zinc, and silver.

Lode gold deposits in the United States occur as single veins, fracture zones consisting of many parallel veins, or as stockworks of small irregular veins. Most of the highly productive deposits have been strongly tabular in shape, with a large lateral extent and a relatively narrow width.

Gold is one of the most persistent of minerals, and occurs in geologic environments ranging from high-temperature deposits extending to depths of 10,000 feet or more to low-temperature deposits which persist to only a few hundred feet. Ore grades are highly variable. Some large deposits are extremely uniform in grade; in others most of the gold is concentrated in high-grade pockets in otherwise low-grade ore zones. Average grades of ore hoisted from large commercial mines have ranged from 0.03 to 1.0 or more ounces per ton. Gold usually occurs as native metal but tellurides are common in some districts. Coarse visible gold is characteristic of some deposits, but more frequently gold is fine grained.

Mineral associations are variable. The most common gangue mineral is quartz, usually containing a few percent of pyrite and other sulfides. Other deposits contain larger quantities of base-metal sulfides, particularly pyrite, chalcopyrite, arsenopyrite, and galena. Low-temperature gold deposits often contain rhodochrosite and adularia.

Placer deposits are formed by natural stream concentrations of the metal after its liberation from host rocks by deep weathering and erosion. As the liberated gold moves downstream it eventually sifts through the loose stream bed to rest on bedrock. Many important placer fields have been derived from erosion of deposits whose primary gold content was too small to sustain lode production. Concentrations are found both in active watercourses and in ancient streams which have been replaced by new drainage routes. In many cases, these ancient placers have been covered with later sediments or lavas. Placers may be classified into river channel, bench, buried channel, residual, dry, beach, and offshore types.

Mineral Producing Districts

Mineral deposits have no genetic relationships to political boundaries and their most logical geographic grouping is on the basis of specific mineral producing districts. Gold occurrences in each district have in most cases a similar history. The districts which have made significant gold production are shown in figure 1. In Alaska the gold-producing districts are in the Central Uplands and Plains, the Seward Peninsula, and the Pacific Border areas.

Gold deposits are found in 12 districts of the conterminous United States. They are the Pacific Border (which extends from Alaska), Columbia Plateau, Basin-Range, Colorado Plateau, Northern Rocky Mountains, Middle Rocky Mountains, Wyoming Basin, and Southern Rocky Mountains districts in the Pacific and Rocky Mountain States; the Black Hills district in the northern Great Plains; and the Piedmont district in the southeastern seaboard States.

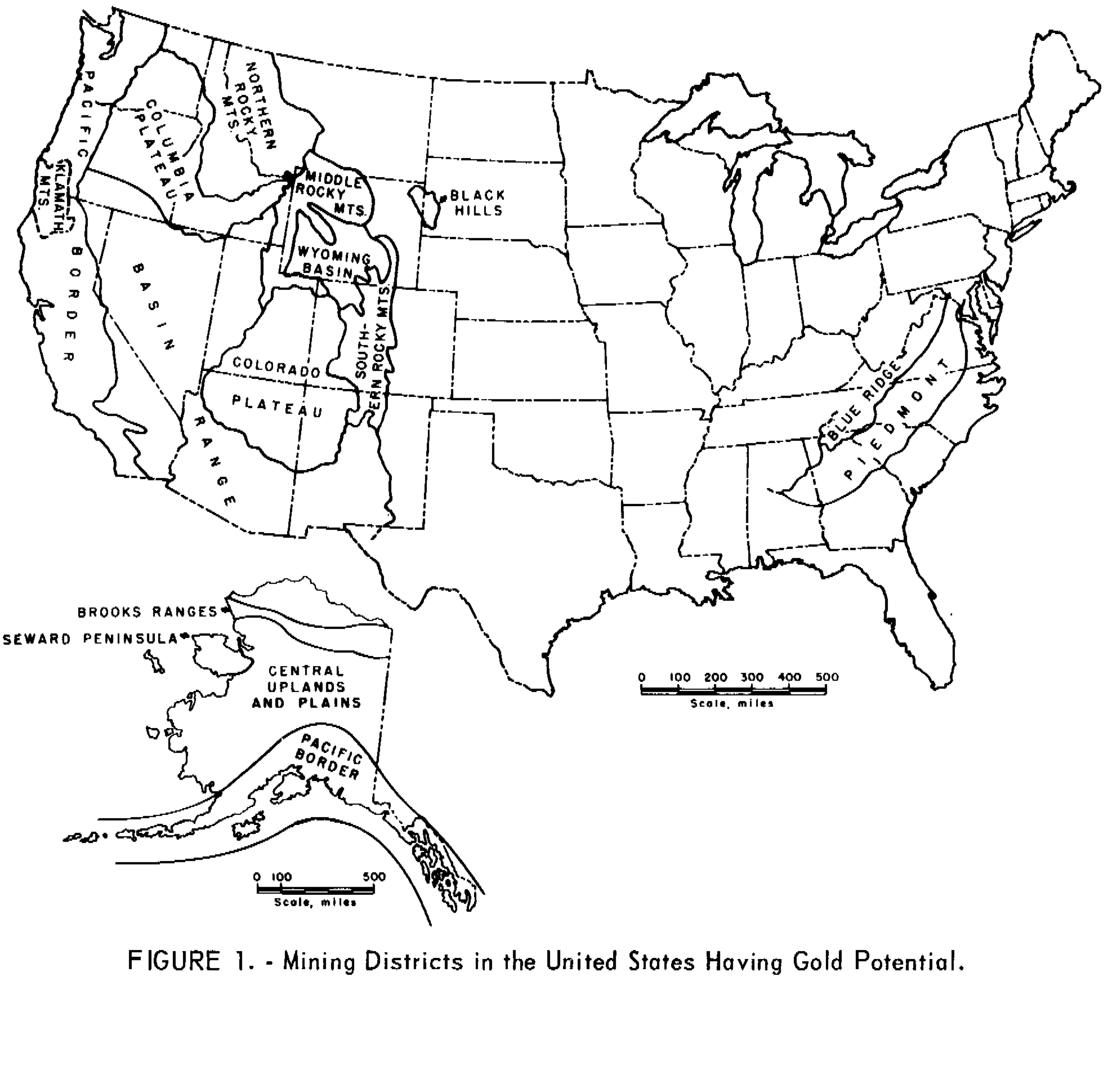

FIGURE 1. - Mining Districts in the United States Having Gold Potential.

These 12 districts through 1964 yielded 265.2 million ounces of gold (more than 99 percent of the U.S. total), mostly from about 5,000 lode gold and 4,000 placer mines. Tens of thousands of small prospects contributed to the total. (Total U.S. output, including byproduct gold, was 308.5 million ounces through 1964.) Some 1,300 lode and placer mines in these 12 districts are estimated to contain an additional 407.8 million ounces of gold, distributed, as shown in table 1.

TABLE 1. - United States production and potential production from gold mines by districts

(Millions of troy ounces)

District	Production	Potential
Pacific Border (including Alaska)	110.5	102.3
Southern Rocky Mountain	39.3	8.0
Basin-Range	34.5	31.7
Black Hills	30.6	16.1
Northern Rocky Mountain	22.3	162.0
Central Uplands and Plains (Alaska)	15.0	65.7
Columbia Plateau	6.3	5.1
Seward Peninsula (Alaska)	5.0	([1])
Piedmont	1.7	2.8
Wyoming Basin	([2])	13.4
Colorado Plateau	([2])	.5
Middle Rocky Mountain	([2])	.2
Total	265.2	407.8

[1] Included with Central Uplands and Plains.
[2] Less than 50,000 troy ounces.

Central Uplands and Plains District

The Central Uplands and Plains district of Alaska lies between the Brooks Range and the Pacific Border district and consists of a great expanse of plains interrupted by the lowlands of several large rivers, separated in the west by occasional upland areas.

Placer deposits, chiefly those of the Fairbanks area, have supplied most of the gold produced in this district and about 25 percent of the State total. The auriferous gravels of the Fairbanks area are largely ancient buried placers and constitute the largest production potential in the area. In places they attain great width and depth. Lode gold occurs in the Fairbanks area, in quartz veins in schist, usually near intrusive granite rock. Narrow veins, 2 inches to 3 feet in width, have been the most productive, but locally ore zones 8 to 12 feet wide have been sufficiently high grade to mine. These wide ore zones consist of closely spaced auriferous veinlets. Much of the gold is free. Gold also occurs in the sulfides, particularly in arsenopyrite and stibnite.

Seward Peninsula District

The Seward Peninsula district ranks as the third largest gold-producing region in Alaska (following the Fairbanks area and the Juneau gold belt). The ancient beach placers near Nome and the stream channels extending inland from the southern shore have been the most productive. Recent stream placers have been of little importance. Residual placers occasionally contain significant concentrations of gold.

There are two ancient auriferous beach lines, one about 1 mile inland and another about 5 miles inland. These deposits, first worked by drift mining, then by hydraulicking where adequate water was available, are largely exhausted. Recent beach placers, never notably rich, are also largely exhausted. The remaining placer deposits were worked intensively until 1962 when dredging operations in the Nome area ceased.

Production from lode deposits has been minor compared to that from placers but there are many occurrences of primary gold ore. The most prominent deposits are filled veins and fracture zones containing a gangue of quartz and some sulfides. In some deposits the gold is associated with the sulfides, in others it occurs as free gold in quartz. Small quantities of gold also occur with disseminations of quartz and sulfides throughout wide zones of metamorphic rocks.

Pacific Border District

The Pacific Border district, which encompasses the entire western coastal region of North America from Alaska to California has been the premier lode and placer gold-producing region in the nation, accounting for more than 40 percent of the output.

Alaska

The Alaskan section of the Pacific Border district is a narrow, arcuate, mountainous region extending from southeastern Alaska through the Aleutian Islands. Its southeastern portion contains one of the State's major gold-producing areas, the Juneau gold belt, which is marked by occurrences for a length of 100 miles. The Alaska-Juneau and Alaska Treadwell mines, both near Juneau, are the principal properties and together have yielded about 30 percent of Alaska's gold output. These two mines reportedly contain large tonnages of low-grade gold ore. Other significant deposits include those on Chichagof Island, those in the Berners Bay, Ketchikan, and Eagle River areas in southeastern Alaska, and those in the Nabesna, Valdez, and Willow Creek areas to the northwest. Only about 1 percent of the gold produced in Alaska was derived from placer deposits.

The Juneau gold belt is bounded by the diorite batholith core of the Coast Range on the east and by greenstone and chloritic schists on the west. At the Alaska-Juneau mine, the rocks of the belt consist of a sequence of metamorphosed sediments (slate, phyllite, quartzite, and schist) interspersed with irregular intrusions of metagabbro. The gold occurs chiefly in numerous irregularly distributed quartz stringers and gash veins in slate and metagabbro. The gold is irregularly distributed in the quartz and has a wide range in particle size. Sulfide minerals are present, but the gold essentially is free.

In the Alaska Treadwell mine, mineralized albite-diorite dikes are intruded along the structure of a black slate. The ore-bearing dikes are thoroughly impregnated with sulfides, principally pyrite, and in part are shattered and filled by reticulating veins of calcite and quartz, which also carry sulfides. The gold is so evenly distributed throughout the dikes that no well-defined ore zones can be distinguished as ore shoots. Often the whole rock mass was mined as ore.

Conterminous United States

Since 1848, about 102 million ounces of gold have been mined in Washington, Oregon, and California, of which California produced over 90 percent. Lode gold occurs mainly in deep-seated veins associated with Tertiary and Mesozoic granitic intrusives. Vein walls are of many rock types, with slate the most common. Quartz is the predominant gangue mineral and veins usually contain a few percent of sulfide minerals. Native gold is the principal ore mineral. It occurs both in microscopic and visible particles, occasionally in masses. Gold occurs both in the sulfides and throughout the quartz.

Over two-thirds of the gold production in the Pacific Border district has come from placers. Stream and river channel, bench, and buried placers all have been important sources.

Columbia Plateau District

The Columbia Plateau district includes southeastern Washington, eastern Oregon, and most of southern Idaho. Placer mines have supplied most of the 6 million ounces of gold produced. Lode deposits consist of veins and fracture zones containing gold in a gangue of quartz and sulfides. Most of the area is overlain by thick late Tertiary lavas which are barren of gold and which cover possible gold-containing horizons.

Basin-Range District

The Basin-Range district includes western Utah, Nevada, southeastern California, southern Arizona, and southwestern New Mexico. Production from gold deposits has been 35 million ounces, mainly from lode mines in Nevada. There are more than 500 mining districts in the area. In most of them gold was produced as a byproduct or a coproduct, but in many district, notably Goldfield, Nev., Bodie, Calif., and San Francisco, Ariz., gold was the predominant mineral. The deposits characteristically occur in low-temperature veins which for the most part bottomed at depths of 2,000 feet or less. Gangue minerals are quartz, adularia, calcite, and sulfides of base metals and silver. The host rocks are many different sediments and volcanics. Most deposits have a close spatial relation to intrusive rocks.

Placers are numerous but have yielded only a small gold output. The prevailing arid climate has both limited the formation of placer deposits and hampered attempts to exploit those that do occur. Another factor has been the condition of the gold which most frequently occurs in sulfides as very fine particles which the intermittent streams of the area have not concentrated effectively.

Colorado Plateau District

The Colorado Plateau district covers eastern Utah, extreme western Colorado, northern Arizona, and northwestern New Mexico. There has been no production from lode mines and only a small output from placers.

Northern Rocky Mountain District

The Northern Rocky Mountain district includes the northeast corner of Washington, most of northern Idaho, and western Montana. Gold deposits have yielded about 22 million ounces since their discovery in the 1850's. Gold occurs in quartz-filled veins and fracture zones, mainly in volcanic and intrusive rocks. The deposits are related to area-wide igneous activity during late Mesozoic or early Tertiary time. A large amount of low-grade gold-bearing material in the form of mineralized dikes is reported to be present.

Significant production was made from high-grade placers, but these resources are now depleted.

Middle Rocky Mountain District

The Middle Rocky Mountain district lies in parts of Montana, Wyoming, Idaho, Utah, and Colorado. Most of the gold has been produced as a byproduct of base-metal and silver ores from the Park City district in Utah and the Jardine district in Montana and from gold horizons in these districts.

The Atlantic City gold district at the southern end of the Wind River uplift in Wyoming has yielded a moderate quantity of gold from quartz veins in Precambrian metamorphic rocks. Productive placer deposits also occur in this district.

Wyoming Basin District

The Wyoming Basin district, which covers a large area of southwestern Wyoming and a small part of northwestern Colorado, has recorded only a small gold production, nearly all from placers. Extensive gravels containing low-gold values occur in Moffat County, Colo.

Southern Rocky Mountain District

The Southern Rocky Mountain district lies mainly in Colorado with small extensions in Wyoming and New Mexico. Production has been about 39 million ounces, chiefly from the Cripple Creek area and the San Juan Mountains area, both in Colorado. Gold occurs in low-temperature veins along belts of Tertiary intrusives. Gold occurs in quartz and pyrite and occasionally with silver minerals, but most frequently with varying amounts of lead, zinc, and copper sulfides. A large proportion of the gold occurs as a telluride.

Placer deposits are important. Production has come from bench placers in Park and Summit Counties, Colo., and from stream and river placers draining the Front Range and San Juan Mountains. Large buried placers are probably present although they have been little worked and enormous amounts of very low-grade material are in the outwash plains below the gold areas.

Black Hills District

The Black Hills district is confined to the immediate Black Hills area in western South Dakota. Most of the area's production of 30.6 million ounces of gold has come from replacement deposits in Precambrian schist, as replacements in silicified areas in Paleozoic limestone, and as vein deposits in Tertiary eruptive rocks. Placer deposits in the district also have been productive.

Piedmont District

The Piedmont district lies between the Appalachian Mountains and the Atlantic coastal plain in Virginia, North Carolina, South Carolina, Georgia, and Alabama. The gold lodes, which with few exceptions parallel the trend of the country rock, are irregular and contain relatively small lenticular ore shoots. However these are often high grade. The wall rock is a Precambrian or early Paleozoic schist. Visible gold occurs in the quartz and much fine-grained gold is in the pyrite. Gangue minerals are principally quartz, pyrite, arsenopyrite, pyrrhotite, and less commonly, galena, sphalerite, and chalcopyrite.

Considerable gold has been recovered by hydraulic methods from the saprolite overlying the lode deposits and large resources of this material remain. There has been substantial production of placer gold.

METHOD EMPLOYED IN MAKING ENGINEERING APPRAISALS

The Cost-Level Method

Appraisal of gold properties based solely on past production was considered inadequate to evaluate the many variables affecting reactivation of long-dormant mines. Consequently, a cost-level method of mine evaluation based on engineering techniques was devised to provide realistic data from which the production potential for each individual mine could be derived. This calculated potential included an optimum annual rate of production, total recoverable metals, years of life, capital requirements, and the estimated cost per troy ounce of gold produced after crediting byproduct metals. Economic and geologic factors, such as return of capital, profit, grade of ore, and geologic characteristics, influenced the production potential.

The evaluation of individual mines was made entirely on the basis of existing data. Sources of the data included: (1) Published reports on the geology of mining districts and individual deposits; (2) production records for individual properties; (3) published reports of past mining and milling procedures; (4) field examinations by Bureau of Mines engineers of the most important gold districts and major mines to determine present condition; (5) examination of unpublished data, including company-confidential reserve estimates, operating reports, and mine maps, made available to Bureau of Mines engineers by producers and former producers; and (6) interviews with present and former mine owners, operators, and engineers, with knowledgeable Federal and State officials, and with manufacturers of mining and milling equipment.

All pertinent data from these sources were used to estimate physical requirements necessary for production at each of the more than 1,300 mines selected for detailed study. An appropriate operating rate was assigned to each, followed by estimation of the capital required for rehabilitation, exploration and development, plant, and operating costs.

Costs

The derivation of appropriate costs was of major importance in applying the cost-level method. Capital cost included the expense of rehabilitation, exploration, mine development, and plant; operating cost included mine and mill operating expenses and overhead. Some of the elements considered in developing these costs are explained below.

Rehabilitation

The expense of rehabilitating buildings, equipment, and surface and underground openings was estimated on the basis of actual needs, so far as they could be determined. Quantity requirements were estimated and assigned a dollar value at cost rates applicable to the type of rehabilitation.

Exploration and Development

Exploration cost was determined by applying appropriate unit cost rates to the estimated footage, or other appropriate unit, for drilling, surface trenching, or underground work. Unit rates were adjusted to accommodate working conditions.

Plant

Plant (mill) capital costs were determined by rule-of-thumb methods based on current costs of similar plants, by formula applied to the cost of a similar plant built in previous years, or by distribution of the percentage of cost when equipment cost was known.

The relatively unchanged economy during the period 1958-64 allowed the cost of plants constructed during this period to be used directly without modification for rule-of-thumb estimates based on plant type and tons-per-day of capacity. By this method, the cost of a 500-ton-per-day cyanide mill in

1964 was approximately $3,000 per ton of daily capacity; one with 1,000 tons-per-day capacity was $2,850; 2,000 tons-per-day, $2,400; and 5,000 tons-per-day, $1,800. Flotation plant cost was estimated at two-thirds of cyanide plant cost.

Current mill cost also was estimated from the known cost of a similar plant constructed in a prior economic period, when such data were available, by the following formula:

$$\text{New plant cost} = \text{Original plant cost} \times \frac{\text{Current construction cost index}}{\text{Prior construction cost index}} \times \left(\frac{\text{New plant daily capacity}}{\text{Original plant daily capacity}}\right)^{0.7}$$

The cost of small plants, 25 to 300 tons-per-day capacity, was estimated at equipment cost multiplied by 3.4.

Used equipment, and its appropriate cost, was assigned in some instances when total estimated resources were not large enough to amortize the purchase price of new equipment during the contemplated life of the mine. In other instances, salvage value of equipment was credited to short-lived properties.

Operating Cost

Lode Mines

Operating cost per unit of raw material produced was governed by the type of mine and the circumstances of the ore occurrence. It was assumed that most lode mines would need mills for ore beneficiation; others, usually small operations incapable of amortizing mill cost, were assumed to be shippers of raw ore to custom mills or smelters. Mining and milling costs were estimated on the basis of costs experienced in comparable operations; 10 to 20 percent was added to the sum of mining and milling cost for overhead.

Placer Mines

Operating cost per yard of placer gravel treated at dragline dredge and bucketline dredge mines was estimated from the costs achieved at similar currently operating mines, or costs were escalated from past operations by use of appropriate index.

Reliable operating costs for drift, hydraulic, and stationary plant operations were not available; costs used in the study for these mines were derived by estimating the required labor and supplies. An index of principal mine operating expense, 1950-64 is shown in table 2.

TABLE 2. - Index of principal mining expenses, 1950-1964

(1957-59 = 100)

Year	Total	Labor	Supplies	Fuels	Electricity
1950..........	70	64	78	95	([1])
1951..........	78	69	88	94	([1])
1952..........	85	77	96	93	([1])
1953..........	89	87	88	96	([1])
1954..........	94	95	89	95	([1])
1955..........	88	84	91	94	([1])
1956..........	94	93	95	97	([1])
1957..........	97	95	99	103	([1])
1958..........	100	99	100	99	([1])
1959..........	105	106	102	99	([1])
1960..........	102	101	102	100	102
1961..........	101	100	101	101	103
1962..........	99	96	101	100	103
1963..........	98	95	102	100	102
1964..........	97	94	102	97	101

[1]Not available.

Source: U.S. Bureau of Mines, Minerals Yearbook.

The range of costs applied in estimating exploration, development, mining, and operating expenses are shown in table 3. Selection of costs within the indicated ranges was made by the appraising engineer on the basis of experience and known local conditions. Bucketline dredge cost is shown in table 4; floating gravel washing plant cost is shown in table 5.

Other Considerations

In any such analysis a number of perturbation factors are involved. Their impacts can only be estimated in the light of historical records. Among the economic factors are price adjustments, priority ratings, and monetary inflation. Labor negotiations and labor supply are important considerations. Technological innovation is a powerful factor that cannot be fully anticipated. As mentioned earlier, this study was based on the concept of full utilization of existing (1964) technology.

Because ownership costs could not readily be determined, all properties were assumed to be owned by the mine operators, and royalty or other property payments were excluded from the calculations of cost of operation. Taxes other than Federal were not included.

TABLE 3. - Range of cost applied for exploration, development, mining, and operating items, 1964

Cost item	Range, dollars
Exploration, development, mining:	
Drilling:	
Churn....foot..	3 - 10
Diamond....do...	6 - 12
Rotary....do...	1 - 4
Trenching:	
Back-hoe....hour..	5 - 15
Dragline....do...	15 - 40
Tractor....do...	15 - 25
Surface stripping:	
Truck....do...	5.00 - 25.00
Shovel....do...	20.00 - 45.00
Scraper....do...	10.00 - 25.00
Slusher....cubic yard..	0.06 - 0.12
Underground:	
Cross-cut....foot..	30 - 50
Drift....do...	30 - 50
Drift, rehabilitation....do...	5 - 50
Shaft sinking....do...	100 - 500
Shaft, rehabilitation....do...	25 - 400
Raising....do...	10 - 30
Operating:[1]	
Mining:	
Lode:	
Open pit....short ton milled..	1 - 5
Underground....do...	5 - 25
Placer:	
Dragline dredge....cubic yard..	0.22 - 0.45
Bucketline dredge....do...	0.11 - 0.22
Drift....do...	9.00 - 18.00
Hydraulic....do...	0.25 - 0.45
Milling:	
Cyanidation....short ton..	2.00 - 7.00
Flotation....do...	2.00 - 6.00
Flotation-cyanidation....do...	2.50 - 8.00
Gravel washing plants....cubic yard..	0.10 - 0.25

[1]Milling capacities range between 25 and 25,000 tons per day; custom ore shipments ranged between 10 and 50 tons per day.

TABLE 4. - Bucketline dredge cost, 1964

Annual capacity, million cubic yards	Bucket size, cubic feet	Maximum digging depth below water level, feet	Weight, tons	Cost per ton, erected, dollars	Cost, erected, dollars (million)
8.4	22	[1]150	5,000	1,300	6.5
10.4	27	120	4,000	1,370	5.5
6.9	18	100	3,000	1,400	4.2
3.8	10	80	2,000	1,600	3.2
3.0	8	50	1,300	1,850	2.4
2.3	6	40	700	2,000	1.4
1.6	4¼	25	460	2,175	1.0

[1]A bucketline dredge of this digging capacity has not been built; bucket size may be restricted by engineering requirements.

Source: Yuba Manufacturing Co.

TABLE 5. - Floating gravel washing plant cost, 1964

Annual capacity, million cubic yards	Trommel size	Weight, short tons	Cost per ton, erected, dollars	Cost, erected, thousand dollars
0.6	54-inch diameter, by 30 feet.	76	1,380	105
1.5	72-inch diameter, by 47 feet.	207	1,210	248
3.0	120-inch diameter, by 63 feet.	488	1,270	620

Source: Bodinson Manufacturing Co.

U.S. GOLD POTENTIAL--OVERALL APPRAISAL

Historical Production

From 1792 through 1964, the United States produced almost 308.5 million ounces of gold from all sources (table 6). A large share of the gold was produced before accurate statistical collection procedures were in effect; for that reason, many authoritative estimates of early gold production were accepted to arrive at the State and National totals. Historical gold production, shown graphically in figure 2, identifies the major gold producing States and cites significant economic, technologic, and historical events since 1848 that influenced gold production.

Almost all of the 308.5 million ounces of gold produced in the United States came from 18 States--Alabama, Alaska, Arizona, California, Colorado, Georgia, Idaho, Montana, Nevada, New Mexico, North Carolina, Oregon, South Carolina, South Dakota, Utah, Virginia, Washington, and Wyoming. Of the total, 99 percent was identifiable by source (State and type of deposit); 88 percent came from gold ores (51 percent from lodes and 37 percent from placers) and 12 percent was a byproduct of other metal mines. In 1964, byproduct production had risen to 37 percent of total output.

TABLE 6. - United States gold production from major gold-producing States, 1792-1964

(Thousand troy ounces)

State	Production from gold ores			Byproduct production	Grand total
	Lodes[1]	Placers	Total		
Alabama	30	15	45	5	50
Alaska	8,800	21,000	29,800	110	29,910
Arizona	5,500	500	6,000	7,200	13,200
California	32,474	68,293	100,767	5,300	106,067
Colorado	36,891	1,790	38,681	2,058	40,739
Georgia	266	600	866	5	871
Idaho	2,475	5,625	8,100	200	8,300
Montana	6,500	9,000	15,500	2,200	17,700
Nevada	20,700	1,900	22,600	3,000	25,600
New Mexico	1,230	505	1,735	525	2,260
North Carolina	938	245	1,183	12	1,195
Oregon	2,300	3,500	5,800	10	5,810
South Carolina	262	52	314	5	319
South Dakota	30,223	350	30,573	-	30,573
Utah	2,155	75	2,230	15,110	17,340
Virginia	115	50	165	3	168
Washington	2,750	275	3,025	600	3,625
Wyoming	37	43	80	2	82
Total identifiable by States	153,646	113,818	267,464	36,345	303,809
Other[2]	-	-	-	-	4,661
Grand total	([3])	([3])	([3])	([3])	308,470

[1] Includes some gold from silver ores, but only those States and years in which silver ores were not reported separately.

[2] Largely the undistributed production from the above States, but also includes minor production from Michigan, Pennsylvania, Tennessee, and others.

[3] Not available.

Source: U.S. Bureau of Mines, Minerals Yearbook.

Historically, the five major gold producing States have been, in decreasing order of output, California, Colorado, South Dakota, Alaska, and Nevada; their combined output was more than three-quarters of the total. In 1964, 82 percent of the gold output (excluding that from byproduct sources) came from three States--South Dakota, California, and Nevada. Utah and Arizona produced 82 percent of the Nation's byproduct gold.

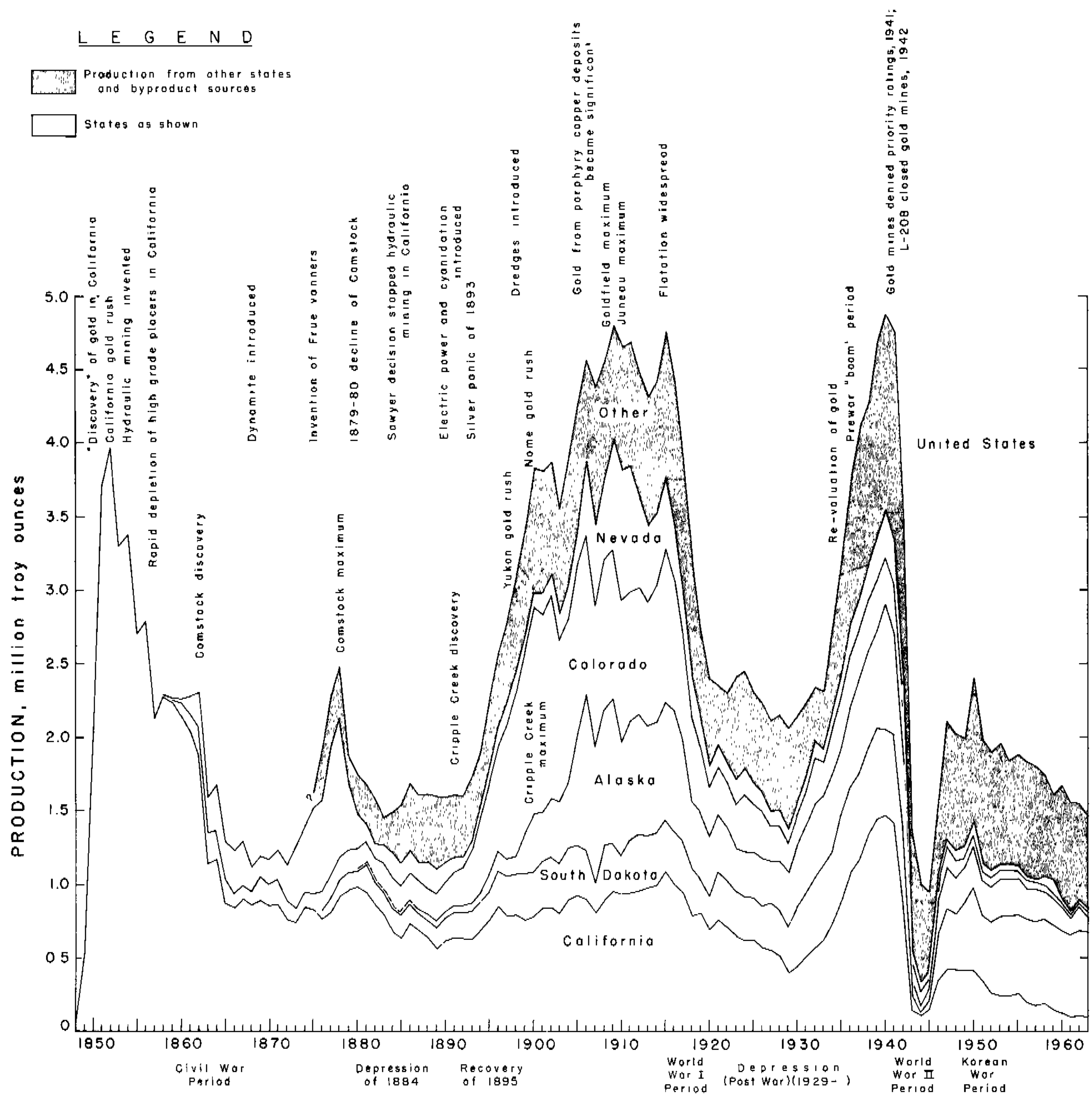

FIGURE 2. - Historical Production of Gold in the United States and Selected Major Producing States, 1848-1963.

Production Potential

This study of U.S. potentially producible gold deposits was made under the conditions prescribed in the section, Methods Employed in Making Engineering Appraisals. It revealed a potential of 407.8 million ounces (table 7), made up of 302.2 million ounces from 814 lode deposits, and 105.6 million ounces from 494 placer deposits. (Small-scale hand-operated deposits were not considered because of lack of data and their very small total potential.)

TABLE 7. - U.S. gold resources

(Thousand troy ounces)

State	Gold reserves potentially producible at $35 per ounce or less		Gold reserves potentially producible at more than $35 per ounce		Total potentially producible gold reserves
	Lode	Placer	Lode	Placer	
Alabama	-	-	129	114	-
Alaska	28	(1)	35,168	54,724	-
Arizona	(1)	(1)	2,086	5,153	-
California	35	(1)	12,736	12,904	-
Colorado	(1)	(1)	5,561	14,278	-
Georgia	-	-	359	272	-
Idaho	(1)	(1)	133,542	3,018	-
Montana	(1)	(1)	24,130	1,365	-
Nevada	3,351	(1)	6,416	1,690	-
New Mexico	(1)	(1)	1,610	7,601	-
North Carolina	-	-	318	417	-
Oregon	(1)	(1)	15,401	1,233	-
South Carolina	-	-	471	22	-
South Dakota	5,400	(1)	10,356	319	-
Utah	(1)	(1)	26	466	-
Virginia	-	-	378	274	-
Washington	(1)	-	44,323	-	-
Wyoming	-	(1)	98	1,470	-
Total United States	9,100	290	293,108	105,320	407,818

[1]Withheld to avoid disclosing individual company confidential data.

The study further indicated that only 9.4 million ounces or slightly more than 2 percent of the total could be classified as commercially producible (those recoverable at a cost not to exceed $35 per ounce). Of the commercially producible gold, 9.1 million ounces (97 percent) is contained in lode deposits and 0.3 million ounces (3 percent) in placers.

The commercially producible deposits are in 13 western States where gold now is being produced, and virtually all are in presently producing properties. Most of these reserves are measured or indicated. Nevada and South Dakota account for 96 percent of the lode reserves; Alaska and California for more than 97 percent of the placer reserves.

The few inactive commercial deposits are not being exploited for a number of reasons. These include: Unclear titles to property or mineral rights or the involvement of these interests in litigation; zoning regulations and other land-use restrictions which prohibit or restrict mining activity (the Sawyer decision in 1884, prohibiting the dumping of debris in the Sacramento-San Joaquin River systems, is a case in point); situations where gold mining would conflict with a more lucrative or critical use of the property in question;

the difficulty of obtaining water rights where hydraulicking may be otherwise feasible; the difficulty sometimes encountered in getting a number of property or claim owners to agree to consolidate their holdings and to offer them to mining interests at a reasonable price; the existence of peculiar environmental factors which would seriously inhibit mine development.

The noncommercial resources--those producible at more than $35 per ounce--are contained in lode deposits (74 percent) and placer deposits (26 percent) in 13 western States--Alaska, Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, South Dakota, Utah, Washington, and Wyoming--and 5 southeastern States--Alabama, Georgia, North Carolina, South Carolina, and Virginia. Almost four-fifths of the total are in deposits in 5 States--Idaho, Alaska, Washington, California and Montana, in decreasing order, and 55 percent are in 2 States, Idaho and Alaska. Virtually all of the noncommercial reserves are in known deposits, and are inferred on the basis of historical production and geological data.

CONCLUSIONS

This study has revealed the following significant facts concerning the U.S. gold potential:

(1) The portion of the total gold reserves of the United States producible at $35 per ounce is relatively small, and virtually all in presently producing mines.

(2) U.S. gold reserves producible at more than $35 per ounce are almost entirely in the inferred category.

(3) Any significant increase in available gold in the United States is most likely to come from the discovery of new sources, intensive exploration and development of the more promising known mineralized areas, and development of new or improved mining and metallurgical techniques.

(4) Most of the literature on gold deposits was published before 1920.

BIBLIOGRAPHY

1. Allsman, Paul T. Reconnaissance of Gold Mining Districts in the Black Hills, S. Dak. BuMines Bull. 427, 1940, 146 pp.

2. American Institute of Mining, Metallurgical, and Petroleum Engineers. Economics of the Mineral Industries. New York, 2d ed., 1964, 787 pp.

3. Arizona Bureau of Mines. Gold Placers and Placering in Arizona. Univ. Arizona Press Bull. 168, 1961, 124 pp.

4. Aubury, Lewis E. Gold Dredging in California. California Div. Mines Bull. 57, 1910, 312 pp.

5. Averill, Charles Volney. Placer Mining for Gold in California. California Div. Mines Bull. 135, 1946, 377 pp.

6. _____. Gold Dredging in Shasta, Siskiyou, and Trinity Counties, Calif. California J. Mines and Geol. v. 34, No. 1, 1938.

7. Bergendahl, M. H. Gold. Mineral and Water Resources of Nevada. Nevada BuMines Bull. 65, 1964, pp. 99-100.

8. Boutwell, John Mason. Geology and Ore Deposits of the Park City District, Utah. With contributions by Lester Hood Woolsey. Geol. Survey Professional Paper 77, 1912, 231 pp.

9. Bowen, Oliver E., Jr., and Clifton H. Gray, Jr. Mines and Mineral Deposits of Mariposa County, Calif. California J. Mines and Geol. v. 53, Nos. 1 and 2, 1957, pp. 35-343.

10. Brooks, Alfred H., and others. Mineral Resources of Alaska. Report on Progress of Investigations in 1916. Geol. Survey Bull. 662, 1918, pp. 221-227, 403-449, and 451-458.

11. Burbank, W. S. Geology and Ore Deposits of the Bonanza Mining District, Colo. With a section on history and production, by Charles W. Henderson. Geol. Survey Prof. Paper 169, 1932, 166 pp.

12. Bureau of Mines Staff. Black Hills Mineral Atlas, South Dakota: Part 1. BuMines Inf. Circ. 7688, 1954, 123 pp.

13. _____. Black Hills Mineral Atlas, South Dakota: Part 2. BuMines Inf. Circ. 7707, 1955, 208 pp.

14. _____. Minerals Yearbook, annual volumes.

15. Butler, B. S., G. F. Loughlin, V. C. Heikes, and others. The Ore Deposits of Utah. Geol. Survey Professional Paper 111, 1920, 672 pp.

16. California Division of Mines. Mineral Commodities of California. Bull. 176, 1957, pp. 215-226.

17. Calkins, Frank C. Gold Deposits of Slumbering Hills, Nevada. Univ. Nevada Bull. v. 32, No. 3, 1938, 26 pp.

18. Diller, J. S. Auriferous Gravels in the Weaverville Quadrangle, Calif. Geol. Survey Bull. 540-A, 1914, pp. 11-21.

19. _____. Geology of the Taylorsville Region, Calif. Geol. Survey Bull. 353, 1908, pp. 1-13, and 61-72.

20. _____. Mineral Resources of Southwestern Oregon. Geol. Survey Bull. 546, 1914, 147 pp.

21. _____. The Auriferous Gravels of the Trinity River Basin, Calif. Geol. Survey Bull. 470-B, 1911, pp. 11-29.

22. Dolbear, Samuel H. Economic Mineral Resources and Production of California. A Survey With Reference to Postwar Employment. California Div. Mines Bull. 130, 1945, 219 pp.

23. Dunn, Russell, L. Drift Mining in California. Eighth Ann. Rept. of the State Mineralogist, 1888, pp. 736-770.

24. Edman, J. A. The Auriferous Black Sands of California. California Div. Mines Bull. 45, 1907, 22 pp.

25. Emmons, W. H. Gold Deposits of the World. McGraw-Hill Book Co., Inc., New York, 1937, 562 pp.

26. Ferguson, Henry G. The Round Mountain District, Nev. Geol. Survey Bull. 725-I, 1922, pp. 383-406.

27. Gayle, Hoyt S. Gold Placer Deposits Near Lay, Routt County, Colo. Geol. Survey Bull. 340-A, 1908, pp. 84-95.

28. _____. The Hahns Peak Gold Field, Colo. Geol. Survey Bull. 285-A, 1906, pp. 28-34.

29. Gardner, E. D., and Paul T. Allsman. Power-Shovel and Dragline Placer Mining. BuMines Inf. Circ. 7013, 1938, 68 pp.

30. Gardner, E. D., and C. H. Johnson. Placer Mining in the Western United States. I. General Information, Hand-Shoveling, and Ground Sluicing. BuMines Inf. Circ. 6786, 1934, 73 pp.

31. _____. Placer Mining in the Western United States. II. Hydraulicking, Treatment of Placers Concentrates, and Marketing of Gold. BuMines Inf. Circ. 6787, 1934, 88 pp.

32. _____. Placer Mining in the Western United States. III. Dredging and Other Forms of Mechanical Handling of Gravel, and Drift Mining. BuMines Inf. Circ. 6788, 1935, 81 pp.

33. Gianella, Vincent P. Geology of the Silver City District and the Southern Portion of the Comstock Lode, Nevada. Univ. Nevada Bull. v. 30, No. 9, 1936, 108 pp.

34. Graton, L. C. Reconnaissance of Some Gold and Tin Deposits of the Southern Appalachians. With Notes on the Dahlonega Mines by Waldemar Lindgren. Geol. Survey Bull. 293, 1906, 134 pp.

35. Haley, Charles Scott. Gold Placers in California. California Div. Mines Bull. 92, 1923, 167 pp.

36. Hammond, John Hays. The Auriferous Gravels of California. Geology of Their Occurrence and Methods of Their Exploitation. Ninth Ann. Rept. of the State Mineralogist, 1890, pp. 105-138.

37. Horner, R. R. Notes on the Black Sand Deposits of Southern Oregon and Northern California. BuMines Tech. Paper 196, 1918, 42 pp.

38. Hulin, Carlton, D. Geology and Ore Deposits of the Randsburg Quadrangle. California Div. Mines Bull. 95, 1925, 152 pp.

39. Jackson, Charles F., and John B. Knaebel. Gold Mining and Milling in the United States and Canada, Current Practices and Costs. BuMines Bull. 363, 1932, 151 pp.

40. _____. Sampling and Estimation of Ore Deposits. BuMines Bull. 356, 1934, pp. 129-130.

41. _____. Small-Scale Placer-Mining Methods. BuMines Inf. Circ. 6611, 1932, 17 pp.

42. Jenkins, Olaf P. New Techniques Applicable to the Study of Placers. California J. Mines and Geol., v. 31, No. 2, 1935, pp. 143-210.

43. _____. Report Accompanying Geologic Map of Northern Sierra Nevada. Mining in California Chapter. Rept. of the State Mineralogist v. 28, Nos. 3 and 4, 1932, pp. 279-298. (Quarterly.)

44. Johnson, Bertrand L. Gold Deposits of the Seward-Sunrise Region, Kenai Peninsula. Geol. Survey Bull. 520-E, 1912, pp. 131-173.

45. Julihn, C. E., and F. W. Horton. Mineral Industries Survey of the United States. California, Calaveras County, Mother Lode District (south). Mines of the Southern Mother Lode Region. Part I--Calaveras County. BuMines Bull. 413, 1938, 140 pp.

46. Knopf, Adolph. The Mother Lode System of California. Geol. Survey Prof. Paper 157, 1929, 88 pp.

47. Koschmann, A. H. The Historical Pattern of Mineral Exploitation in Colorado. Minerals and Energy. Problems, Practices, and Goals. (Western Resource Conf., 1962.) Colorado Sch. Mines Quarterly, v. 57, No. 4, 1962, pp. 8-10.

48. Koschmann, A. H., and M. H. Bergendahl. Gold in the United States Exclusive of Alaska and Hawaii. Geol. Survey Mineral Investigations Resource Map MR-24, 1962, 22 pp.

49. Krumlauf, H. E. Exploration Costs of Small Mines. Eng. and Min. J., v. 162, No. 6, 1961, pp. 195-197.

50. _____. The Open Pit: Low Cost and High Production. Eng. and Min. J., v. 162, No. 6, 1961, pp. 198-202.

51. _____. Underground: High Cost, but Richer Ore. Eng. and Min. J., v. 162, No. 6, 1961, pp. 221-226.

52. Laizure, C. M. Elementary Placer Mining in California and Notes on the Milling of Gold Ores. California J. Mines and Geol. v. 30, Nos. 2 and 3, 1934, pp. 242-251.

53. Lausen, Carl. Geology and Ore Deposits of the Oatman and Katherine Districts, Arizona. Arizona BuMines Bull. 131, 1931, 126 pp.

54. Lincoln, Francis Church. Mining Districts and Mineral Resources of Nevada. Nevada Newsletter Pub. Co., Reno, 1923, 295 pp.

55. Lindgren, Waldemar. Gold and Petroleum in California. California J. Mines and Geol., v. 34, No. 1, 1938, pp. 27-32.

56. _____. Mineral Deposits. McGraw-Hill Book Co., Inc., New York, 4th ed., 1933, pp. 19, 233, 444, 470, and 473.

57. _____. The Gold-Quartz Veins of Nevada City and Grass Valley Districts, Calif. Ch. in Economic Geology and Hydrography, 1896. Geol. Survey 17th Ann. Rept., pt. 2, 1895-96, pp. 13-262.

58. _____. The Tertiary Gravels of the Sierra Nevada of California. Geol. Survey Prof. Paper 73, 1911, 226 pp.

59. Logan, Clarence A. Mother Lode Gold Belt of California. California Div. Mines Bull. 108, 1934, 240 pp.

60. _____. Platinum and Allied Metals in California. California Div. Mines Bull. 85, 1918, 120 pp.

61. MacDonald, Donald Francis. The Weaverville-Trinity Center Gold Gravels, Trinity County, Calif. Geol. Survey Bull. 430-A, 1910, pp. 48-58.

62. Maddren, A. G. Gold Placer Mining Developments in the Innoko-Iditarod Region. Geol. Survey Bull. 480-I, 1911, pp. 245-270.

63. McCanley, Maryclaire. The Closing of the Gold Mines--August 1941 to March 1944. Historical Repts. on War Administration: War Production Board Special Study No. 9, First issued June 1, 1944. Reissued April 5, 1946, 77 pp.

64. Moffit, Fred H. Geology of the Nome and Grand Central Quadrangles, Alaska. Geol. Survey Bull. 533, 1913, pp. 109-123.

65. Nolan, Thomas B. The Tuscarora Mining District, Elko County, Nevada. Univ. Nev. Bull. v. 30, No. 1, 1936, 38 pp.

66. _____. The Underground Geology of the Tonopah Mining District, Nevada. Univ. Nev. Bull. v. 29, No. 5, 1935, 49 pp.

67. Pardee, J. T., and C. F. Park, Jr. Gold Deposits of the Southern Piedmont. Geol. Survey Prof. Paper 213, 1948, 156 pp.

68. Patmon, Charles G. Methods and Costs of Dredging Auriferous Gravels at Lancha Plana, Amador County, Calif. BuMines Inf. Circ. 6659, 1932, 16 pp.

69. Preston, E. B. Plumas County, California. Tenth Ann. Rept. of the State Mineralogist, 1890, pp. 466-495.

70. Prindle, Louis M. Auriferous Quartz Veins in the Fairbanks District. Geol. Survey Bull. 442-F, 1910, pp. 210-229.

71. _____. The Gold Placers of the Fortymile, Birch Creek, and Fairbanks Regions, Alaska. Geol. Survey Bull. 251, 1905, 89 pp.

72. Ransome, F. L. The Geology and Ore Deposits of Goldfield, Nev. Geol. Survey Prof. Paper 66, 1909, 258 pp.

73. _____. Geology of the Oatman Gold District, Ariz., A Preliminary Report. Geol. Survey Bull. 743, 1923, 58 pp.

74. _____. Preliminary Account of Goldfield, Bullfrog, and Other Mining Districts in Southern Nevada. With Notes on the Manhattan District, by G. H. Garrey, and W. H. Emmons. Geol. Survey Bull. 303, 1907, 98 pp.

75. Root, Lloyd, L. An Investigation of the Feasibility of any Plan or Plans Whereby Hydraulic Mining Can be Resumed in California. Rept. of the State Mineralogist, v. 23, No. 1, 1927, p. 47.

76. Sampson, R. J. Placers of Southern California. Rept. of the State Mineralogist, v. 28, No. 1, 1932, pp. 245-255.

77. Schrader, Frank C. Gold Placers on Wind and Bighorn Rivers, Wyo. Geol. Survey Bull. 580-G, 1915, pp. 133-145.

78. Singewald, Quentin D. Gold Placers and Their Geologic Environment in Northwestern Park County, Colo. Geol. Survey Bull. 955-D, 1950, pp. 103-172.

79. Smith, Alfred Merritt. The Mines and Mills of Silver City, Nevada. Univ. Nevada Bull. v. 36, No. 5, 1932, 28 pp.

80. Spencer, Arthur C. The Atlantic Gold District and the North Laramie Mountains, Fremont, Converse, and Albany Counties, Wyo., Geol. Survey Bull. 626, 1916, 85 pp.

81. _____. The Juneau Gold Belt, Alaska. Geol. Survey Bull. 287, 1906, pp. 1-137.

82. Spurr, Josiah Edward. Geology of the Tonopah Mining District, Nev. Geol. Survey Prof. Paper 42, 1905, 295 pp.

83. Storms, W. H. Ancient Channel System of Calvares County, Calif. Twelfth Rept. of the State Mineralogist, 1893-1894, pp. 482-492.

84. Taylor, George F. Brandy City Hydraulic Mines, Sierra County, Calif. Eng. and Min. J., v. 89, 1910, pp. 1152-1153.

85. U.S. Senate. Mineral and Water Resources of New Mexico. Committee on Interior and Insular Affairs. U.S. Senate, 89th Cong., 1st sess., 1965, 437 pp.

86. _____. Mineral and Water Resources of Utah. Committee on Interior and Insular Affairs. U.S. Senate, 88th Cong., 2d sess., 1964, 275 pp.

87. University of Nevada. Nevada's Metal and Mineral Production, 1859-1940, Inclusive. Geology and Mining Series, Bull. 38, v. 37, No. 4, 1943, 159 pp.

88. Vanderburg, William O. Placer Mining in Nevada. Univ. Nevada Bull. v. 30, No. 4, 1936, 178 pp.

89. Wilson, E. D. Arizona Lode Gold Mines. Arizona BuMines Bull. 137, 1934, 194 pp.

90. Wright, Lauren A., Richard M. Stewart, Thomas E. Gay, Jr., and George C. Hazenbush. Mines and Mineral Deposits of San Bernardino County, Calif. California J. Mines and Geol. v. 49, Nos. 1 and 2, 1953, pp. 69-86.

91. Yale, Charles G. Dry Placers in California. Mineral Resources of the United States, Part 1. Metals. Geol. Survey, 1912, pp. 262-263.

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