Information Circular 8517

How To Mine and Prospect for Placer Gold

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HOW TO MINE AND PROSPECT FOR PLACER GOLD

by

J. M. West [1]

ABSTRACT

Increased leisure time and increased interest in the out-of-doors is leading more and more families to experiment with placer mining of gold, and sometimes even to going on into small-scale production. This Bureau of Mines report supplies basic information on areas of occurrence, equipment needed, prospecting, sampling, mining, and regulations concerning the possession and sale of gold. Selected references are given for further study.

INTRODUCTION

Placer gold has tantalized many a person who has tried his luck and skill in the hope of striking it rich. Separating gold from embedded materials is basically simple, and can be done effectively on nearly any scale, depending upon the deposit and the capital available for investment. The final product is consistently in demand at a relatively stable price. Historically, however, one must be advised that rewards for the majority of small-scale miners--those who operate "on a shoestring"--have been depressingly small.

First of all, the placer miner must know where placer deposits are located and he must have the technical knowledge to extract the gold. Additionally, he must face problems of land ownership, water supply, and water pollution, all of which have grown in complexity with the population. The costs of labor and equipment are relatively high now, although this may not seem significant to an individual mining a small deposit. Secondhand equipment may become available at relatively low cost because of a slowdown in construction or as surplus at the end of a war. By taking advantage of such opportunities, one can sometimes make an otherwise unprofitable operation successful, at least as long as the equipment holds up.

To the novice or "weekend prospector," the more complex features of placer mining may seem hard to comprehend. At any rate, the novice is often more interested in the recreational values offered by gold placering than in its profitability. Thus, the search for and discovery of even a small grain

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or nugget of gold is an achievement worth considerable effort. As a start, the beginner may gain some benefit from visiting one of the many pan-for-a-fee tourist establishments typically found in gold-mining areas.

The small-scale miner may sell his gold, but often he keeps it as a souvenir, or for use in some kind of jewelry, or in the hope that its value will appreciate. Seldom is a placer gold venture truly profitable when all costs are considered under existing circumstances. On the other hand, an individual or a family can gain a great deal of pleasure and satisfaction from the experience of producing your own gold. Producing your own, even on a small scale, involves a number of problems which this publication attempts to discuss. Because the subject is so extensive, the reader is referred to other reports in the bibliography for more detailed information.

ACKNOWLEDGMENT

For many years, three Bureau of Mines Information Circulars written by E. D. Gardner and C. H. Johnson in 1934 and 1935 have been a basic reference on gold placering. However, it was realized after several reprintings of the initial volume of the series that the general presentation had become dated and often went beyond the scope of the usual requests for information. This report has borrowed heavily from the Gardner and Johnson material because of its adaptability, and the author wishes to acknowledge that source in particular, although many other sources have been used in preparation.

HISTORY OF PLACER GOLD MINING

Placer gold mining in the United States spans a period of nearly 200 years. Earliest mining took place in the Eastern States and particularly in the southern Appalachian region during the late 1700's and early 1800's, but the richer deposits were soon exhausted, and interest turned to the West. The earliest production of any note in the West was from the Old and New Placer Diggings near Golden, Santa Fe County, N. Mex. These deposits were worked as early as 1828. A few other deposits were mined in the succeeding years until the first discovery of major importance, that of James Marshall on January 24, 1848, on the American River at Coloma, Calif. This discovery was a major factor in the rapid settlement of the West and triggered the first of the great gold rushes in the United States. Because of the lure and excitement of gold mining, prospectors spread throughout the West and in subsequent years many more rich placer gold deposits were found. A selected listing of discoveries subsequent to Coloma follows:

1848-49....	California..	Trinity and Klamath Rivers.
1849.......	Nevada......	Gold Canyon.
1852.......	Oregon......	Grants Pass district.
	Montana.....	Gold Creek.
1857.......	Nevada......	Six-Mile Creek.
1858.......	Arizona.....	Gila City.
	Colorado....	Cherry Creek, Ralston Creek, Platte River.
1858-60....	Washington..	Blewett Pass (northern and central parts of State).
1859.......	Colorado....	Clear Creek, Blue River, Arkansas River.
1860-61....	Idaho.......	Clearwater River, Pierce City, Oro Fino, Elk City, Florence, Warren.

1862.......	Montana.....	Bannack, Alder Creek.
	Idaho.......	Boise Basin.
	Arizona.....	La Paz district.
1863-64....	Arizona.....	Weaver Creek, Lynch Creek.
	Utah........	Bingham Canyon.
1864.......	Montana.....	Helena.
1867.......	Nevada......	Tuscarora district.
	New Mexico..	Elizabethtown district.
1874-75....	South Dakota	Black Hills, Deadwood Gulch.
1876-77....	Nevada......	Copper Mountain (Charleston district), Osceola.
1881.......	Nevada......	Spring Valley.

In Alaska, gold occurrences were reported as early as 1848, and gold was found in the Yukon region about 1878; but not until the fabulously rich finds in 1897-98 in the Yukon's Klondike (in Canadian territory) did placer miners really begin to exploit the Alaskan deposits. In rapid succession, miners stampeded in 1898 to rich discoveries in the Nome area of Alaska, then in 1902 to the Fairbanks area; the Fairbanks placers were among the last of importance to be discovered.

Any history of placer mining would be incomplete without a word on dredging, which marked a major turn in operational efficiency. Dredging offered a way to handle tremendous quantities of material at a low unit cost and made it possible to mine where gold values were as little as a few cents per cubic yard.

Probably the first successful bucketline dredge in the United States was operated in 1895 on Grasshopper Creek near Bannock in Beaverhead County, southwestern Montana. Others quickly followed, until by 1910, use of dredges had grown so that in California alone about 100 were in existence, of which 63 were reported in operation.

The first gold dredging in Alaska occurred about 1903, and the number of Alaskan dredges grew, until in 1914, 42 were in operation. The peak number of active dredges, 49, was not reached until 1940; World War II then interrupted most operations. Costs rose beyond profitable levels after the war, and only a few of the deactivated dredges were returned to service.

All gold dredges of any significance in the United States have been shut down, and most have been dismantled or sold abroad. Placer gold production today is primarily a byproduct of washing sand and gravel for use as an aggregate in the construction industry. Commercial placer mining by other means continues only at a few locations.

Total placer gold production in the United States from 1792 through 1968 is given in table 1. California and Alaska have accounted for more than three-fourths of the total production of record. A large share of the overall production, it should be added, has come from dredges. The following list includes essentially all States and counties in which placer gold is known to occur (12):[2]

[2]Underlined numbers in parentheses refer to items in the bibliography at the end of this report.

Alabama: Chilton, Clay, Cleburne, Coosa, Randolph, Talladega.

Alaska: For areas of occurrence, see figure 3.

Arizona: Cochise, Mohave, Pima, Pinal, Yavapai, Yuma.

California: Amador, Butte, Calaveras, Del Norte, El Dorado, Fresno, Humboldt, Imperial, Kern, Los Angeles, Madera, Mariposa, Mono, Monterey, Nevada, Placer, Plumas, Sacramento, San Luis Obispo, Shasta, Sierra, Siskiyou, Trinity, Tuolumne, Yuba.

Colorado: Adams, Boulder, Chaffee, Clear Creek, Costilla, Eagle, Gilpin, Hinsdale, Jefferson, Lake, Mineral, Moffat, Montezuma, Park, Routt, San Juan, San Miguel, Summit.

Georgia: Barrow, Bibb, Carroll, Cherokee, Dawson, Douglas, Fannin, Forsyth, Fulton, Gilmer, Greene, Haralson, Hart, Henry, Lincoln, Lumpkin, Madison, Marion, McDuffie, Murray, Newton, Oglethorpe, Paulding, Rabun, Towns, Union, Walton, Warren, White, Wilkes.

Idaho: Ada, Adams, Bannock, Benewah, Boise, Bonneville, Camas, Cassia, Clearwater, Custer, Elmore, Idaho, Latah, Lemhi, Owyhee, Power, Shoshone, Twin Falls, Valley, Washington.

Montana: Beaverhead, Broadwater, Deer Lodge, Fergus, Granite, Jefferson, Judith Basin, Lewis and Clark, Lincoln, Madison, Meagher, Mineral, Missoula, Park, Powell, Silver Bow.

Nevada: Clark, Douglas, Elko, Esmeralda, Eureka, Humboldt, Lander, Mineral, Nye, Ormsby, Pershing, Washoe, White Pine.

New Mexico: Colfax, Grant, Lincoln, Otero, Rio Arriba, Sandoval, Santa Fe, Sierra, Taos.

North Carolina: Anson, Burke, Cabarrus, Caldwell, Catawba, Chatham, Cherokee, Clay, Cleveland, Davidson, Franklin, Gaston, Granville, Guilford, Halifax, Henderson, Iredell, Lincoln, Macon, McDowell, Mecklenberg, Montgomery, Moore, Nash, Orange, Person, Polk, Randolph, Richmond, Rowan, Rutherford, Stanly, Union, Warren, Yadkin.

Oregon: Baker, Coos, Curry, Douglas, Grant, Jackson, Josephine, Union, Wheeler.

South Carolina: Cherokee, Chester, Chesterfield, Kershaw, Lancaster, Spartanburg, Union, York.

South Dakota: Custer, Lawrence, Pennington.

Utah: Beaver, Daggett, Garfield, Grand, Piute, Salt Lake, San Juan, Sevier, Uintah.

Virginia: Albemarle, Buckingham, Culpeper, Cumberland, Fluvanna, Goochland, Louisa, Spotsylvania, Stafford.

Washington: Chelan, Clallam, Ferry, Kittitas, Lincoln, Okanogan, Whatcom.

TABLE 1. - Placer gold production, by States, 1792-1969

State	Placer gold production, thousand troy ounces	Rank as placer producer	Placer share of all gold produced in State, percent	Placer share of all gold produced in country,[1] percent
Alabama............	15	18	30.0	Negligible
Alaska.............	21,130	2	70.2	6.7
Arizona............	500	10	3.7	.2
California.........	68,470	1	64.3	21.7
Colorado...........	1,798	7	4.4	.6
Georgia............	600	8	68.8	.2
Idaho..............	5,625	4	67.7	1.8
Montana............	9,001	3	50.8	2.9
Nevada.............	1,901	6	7.1	.6
New Mexico.........	505	9	22.0	.2
North Carolina.....	245	13	20.5	.1
Oregon.............	3,500	5	60.2	1.1
South Carolina.....	52	15	16.3	Negligible
South Dakota.......	351	11	1.1	.1
Utah...............	75	14	.4	Negligible
Virginia...........	50	16	29.8	Negligible
Washington.........	275	12	7.0	.1
Wyoming............	43	17	97.6	Negligible
Total[2]........	114,136	-	-	([1])

[1]Based on total gold production of 316.77 million ounces, including 4.66 million ounces from undesignated sources. Placer share of all gold produced in country was approximately 37 percent.

[2]Exclusive of small production not identifiable by States.

Source: Based on data in table 6 of Bureau of Mines IC 8331 (24), with addition of production for 1965-69 as reported in the Minerals Yearbooks for those years.

WHERE TO LOOK FOR PLACERS

Figures 1 and 2 show general areas of the conterminous United States and Alaska, respectively, where placer gold has been produced. Placers can be found in virtually any area where gold occurs in hard rock (lode) deposits. The gold is released by weathering and stream or glacier action, carried by gravity and hydraulic action to some favorable point of deposition, and concentrated in the process. Usually the gold does not travel very far from the source, so knowledge of the location of the lode deposits is useful. Gold also can be associated with copper and may form placers in the vicinity of copper deposits, although this occurs less frequently.

Geological events such as uplift and subsidence may cause prolonged and repeated cycles of erosion and concentration, and where these processes have taken place, deposits may be enriched. Ancient river channels (referred to as

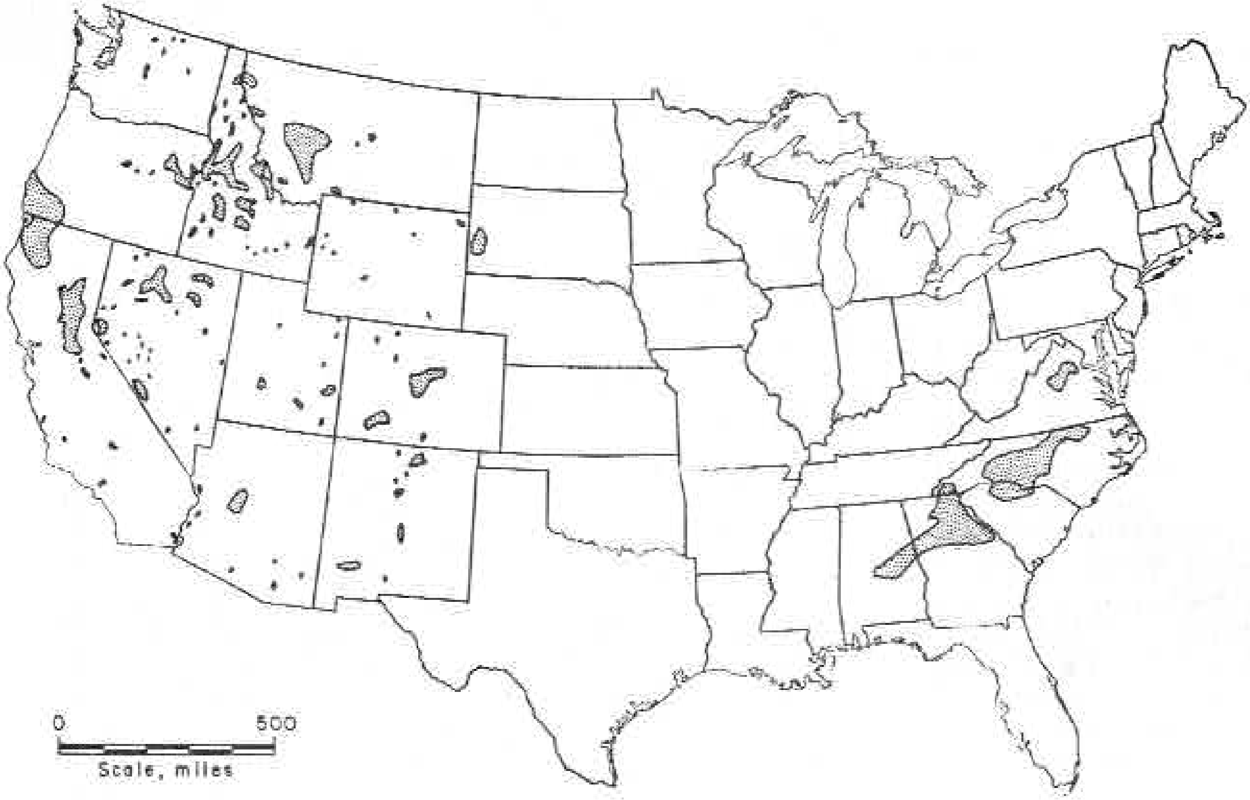

FIGURE 1. - Regions of the Conterminous United States Where Gold Has Been Produced From Placers. Note: See p. 4 for list of producing counties. Source: Reference 12.

the "Tertiary channels" in California) and certain river bench deposits are examples of gold-bearing gravels that have been subjected to a number of such events, followed by at least partial concealment by other deposits, including volcanic materials.

Residual placer deposits formed in the immediate vicinity of source rocks are usually not the most productive, although exceptions occur where veins supplying the gold were unusually rich. Reworking of gold-bearing materials by stream action leads to the concentrations necessary for exploitation. In desert areas deposits may result from sudden flooding and outwash of intermittent streams.

As material gradually washes off the slopes and into streams, it becomes sorted or stratified, and gold concentrates in so-called pay streaks with other heavy minerals, among which magnetite (black, heavy, and magnetic) is almost invariably present. The gold may not be entirely liberated from the original rock but may still have the white-to-gray vein quartz or other rock material attached to or enclosing it. As gold moves downstream, it is gradually freed from the accompanying rock and flattened by the incessant pounding of gravel. Eventually it will become flakes and tiny particles as the flattened pieces break up.

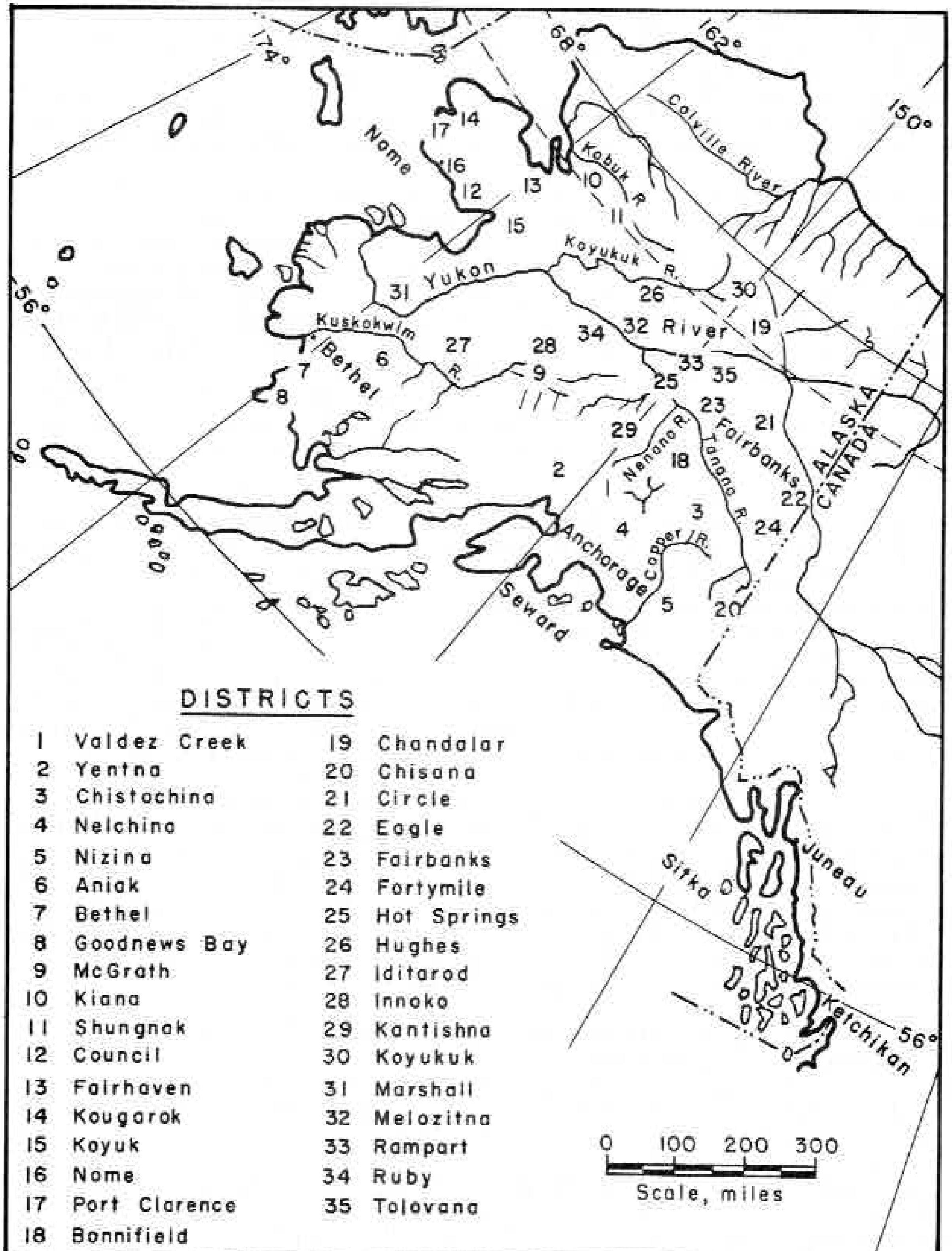

FIGURE 2. - Placer Mining Districts of Alaska. Source: Reference 22.

Some gold is not readily distinguishable by the normal qualities of orange-yellow to light yellow metallic color and high malleability, where it occurs in a combined form with another element, such as tellurium. Upon weathering, such gold may be coated with a crust, such as iron oxide, and have a rusty appearance. This "rusty gold," which resists amalgamation with mercury, may be overlooked or lost by careless handling in placer operations.

As mentioned before, the richest placers are not necessarily those occurring close to the source. Much depends on how the placer materials were reworked by natural forces. Streambed placers are the most important kind of deposit for the small-scale operator, but the gravel terraces and benches above the streams and the ancient river channels (often concealed by later deposits) are potential sources of gold. Other types of placers include those in outwash areas of streams where they enter other streams or lakes, those at the foot of mountainous areas or in regions where streams enter into broader valleys, or those along the ocean front where beach deposits may form by the sorting action of waves and tidal currents. In desert areas, placers may be present along arroyos or gulches, or in outwash fans or cones below narrow canyons.

Because gold is relatively heavy, it tends to be found close to bedrock, unless intercepted by layers of clay or compacted silts, and it often works its way into cracks in the bedrock itself. Where the surface of the bedrock is highly irregular, the distribution of gold will be spotty, but a natural rifflelike surface favors accumulation. Gold will collect at the head or foot of a stream bar or on curves of streams where the current is slowed or where the stream gradient is reduced. Pockets behind boulders or other obstructions and even moss-covered sections of banks can be places of deposition. Best results usually come from materials taken just above bedrock. The black sands that accumulate with gold are an excellent indicator of where to look.

It should be kept in mind that each year a certain amount of gold is washed down and redeposited during the spring runoffs, so it can be productive to rework some deposits periodically. This applies chiefly to the near-surface materials such as those deposited on the stream bars or in sharp depressions in the channels. The upstream ends of stream bars are particularly good places for such deposits. Where high water has washed across the surface by the shortest route, as across the inside of a bend, enrichment often occurs. A rifflelike surface here will enhance the possibility of gold concentration.

In prospecting areas with a history of mining, try to find places where mechanized mining had to stop because of an inability to follow and mine erratic portions of rich pay streaks without great dilution from nonpaying material. Smaller scale selective mining may still be practical here if a miner is diligent.

Placer gold occurs in so many areas that it would be impractical to try to identify each of them here. One of the best recent publications covering individual districts and areas is U.S. Geological Survey Professional Paper 610, Principal Gold Producing Districts of the United States, published in 1968 (14). Also, a series of reports is being written describing the individual placer gold deposits of various States or portions of States, to be published as Geological Survey Bulletins. For general areas of occurrence the maps in figures 1 and 2 may be consulted. Specific locations and names of mines can often be found on the detailed maps prepared by the U.S. Forest Service, the U.S. Bureau of Land Management, the U.S. Army Corps of Engineers, or the U.S. Geological Survey. Various State agencies may also have appropriate maps on hand.

California

California has led all other States in placer mining and as would be expected has many gold-producing areas of interest, particularly including the deposits on the Feather, Mokelumne, American, Consumnes, Calaveras, and Yuba Rivers and their tributaries (2, 4-6, 9). These rivers reach into the famous Mother Lode area of the Sierra Nevada Mountains from which much of the gold is derived. Deposits are also found in the drainages of the Trinity and Klamath Rivers in northern California and at scattered points in the southern part of the State. Ancient Tertiary channels and gravels of the Sierra Nevada Range have been especially productive sources of gold, and maps have been published by the California Division of Mines and Geology showing approximate routes of these features. Two U.S. Forest Service maps that the prospector would find of particular value in considering the Sierra deposits are of (a) the Downieville, Camptonville, and Nevada City districts, Tahoe National Forest; and (b) the Foresthill and Big Bend districts, also in the Tahoe National Forest. Maps covering the Trinity and Klamath National Forests of northern California might also be of interest.

Alaska

Most of Alaska's gold production has come from placers, principally those in the Yukon River Basin, although deposits are known on nearly all major rivers or their tributaries (11, 19, 22, 33). Beach deposits in the Nome district have been notably productive, as have the river and terrace or bench placers in the drainages of the Copper and Kuskokwim Rivers. Figure 2 shows the main placer districts of the State. Climatic conditions play a great part in mining in Alaska, and the season for hydraulic operations of any kind is relatively short.

Northwest States (Montana, Idaho, Oregon, and Washington)

Montana's principal placer mining districts are in the southwestern part of the State (15). The Helena mining district and the many placers along the Missouri River in the vicinity of Helena and upstream are among the more important areas. The headwaters and tributaries of the Missouri in Madison County, particularly near Virginia City and Bannock, are noted for early placer production. Placer gold has also been produced on the headwaters of the Clark Fork of the Columbia River at a number of points.

The Boise basin, northeast of Boise, Idaho, is most noted for the dredging of placers (21). Other well-known placer areas lie along the Salmon River in Lemhi and Idaho Counties and on the Clearwater River and its tributaries, particularly in the vicinities of Elk City, Pierce, and Orofino. Placer gold is also found along the Snake River, but this is commonly fine-grained or "flour" gold that is difficult to recover.

Oregon's placers are located mainly in the southwestern part of the State, on tributaries of the Rogue River and on streams in the Klamath Mountains (16). Main gold-producing areas are the Greenback district in Josephine County and the Applegate district in Jackson County. Placer gold also occurs in many of the streams that drain the Blue and the Wallowa Mountains in northeast Oregon. The Sumpter area and the upper Powder River have had important production. Other areas include the Burnt River and its tributaries and the John Day River Valley.

Washington is not noted for placers, although gold has been found along a number of its streams, including some on the western slope of the Cascade Mountains. Generally, the few productive placers have been confined to the north-central part of the State.

Nevada

Nevada has not been a large placer gold producer, although lode gold deposits--potential sources--are widely distributed throughout the State (27). The problem has been chiefly one of too little water. In the past, dry washers were used extensively, as well as other methods that were very conservative of water. Producing areas were largely found in the western half of the State and included American Canyon and Spring Valley in the Humboldt Range, Pershing County, and the Manhattan and Round Mountain areas of Nye County. Placers were also worked below Virginia City and in northern Elko County near Charleston. Signs of limited placer diggings may be seen in many parts of the State.

Colorado

A few important Colorado placers of the residual type are found on slopes and hillsides in the immediate vicinity of gold veins. However, placers in Colorado are generally confined to narrow canyons below lode gold mining areas within the Rocky Mountains in a belt which extends northeast across the western part of the State (28). Almost every gold district has had some placer production. Many of the streams emerging from the Front Range, the headwaters of the South Platte River, and the Arkansas River and its tributaries as far upstream as California Gulch contain placer gold. Historically, placers were mined first and led to development of Colorado's rich lode deposits.

Other States

Among the other Western States, placer mining has been limited to only a few localized areas. In South Dakota, the Black Hills (particularly the Deadwood area) and French Creek, near Custer, have been productive sources. Arizona (32) and New Mexico (30) placers are in some instances related to copper deposits that carry gold.

In the Eastern States some of the streams draining the eastern slopes of the southern Appalachian Range have yielded gold (1, 17). Saprolite deposits (rock decomposed at the original site) have been a source of placer gold in Georgia (13) and the Carolinas (3). Generally, the eastern placers are sparsely distributed and the gold is low in grade. Thus, few serious efforts have been made at mining them since the early 1800's. Nevertheless, many locations offer possibilities for small operations intended primarily for recreational purposes.

OTHER THINGS YOU NEED TO KNOW

Staking Claims on Open Lands

Instructions on staking claims and filing for patents can be obtained from the U.S. Bureau of Land Management. In addition to Federal regulations, individual States also have certain requirements pertaining to the location of claims on public lands. Information on these requirements is available from the State agency that deals with mining. Claims for mining can only be staked on lands of the public domain.

Lands in areas generally subject to location for mining, such as National Forests, may be open or closed depending on whether the land has been withdrawn for some special purpose. The status of the land can usually be determined by local inquiry to the U.S. Forest Service, or it can be checked at the Land Offices of the Bureau of Land Management or at the County Assessor's Office. The status of land being considered for mining should be established before any significant investment of money or labor has been made. This will insure that the ground is open to location so that the prospector can stake a valid claim and protect his investment.

When entering any land to examine for or attempt to mine placer gold, a person should determine if it is privately owned, previously located by claim that may still be valid, or possibly held under patent, which conveys the right of private ownership. Under any of these conditions, the unauthorized intruder is trespassing and has no legal rights to the gold he may produce. Usually some sign or indication of ownership is evident, or a local resident can supply the information necessary to determine ownership, but in any event one takes his chances when the status of land is uncertain. At the worst, the land may be protected by a shotgun. Active claims should be clearly marked, and records may be checked in the respective County Courthouse to determine approximately where and when they were located. It should be added that, however necessary, such checking can be tedious.

The basic laws on location of mining claims in the public domain are contained in the General Mining Laws of 1872. Placer claims generally can be located on lands that would be classified as locatable if they contained vein or lode deposits. Neither the beds of navigable lakes and rivers nor lands below high tide are subject to mineral location. However, new claims can be located over abandoned earlier ones, although the new locator may be called upon to establish that the earlier claims were, in fact, abandoned at the time of relocation.

Mining locations may be made by U.S. citizens, by those who have declared their intention to become citizens, by an association of qualified persons, or by a domestic corporation. A location may be made by a minor who has reached "the age of discretion," and without regard to the sex or residence of the locator. A person may make valid locations as an agent for other qualified parties who may not have even seen the ground. No limit is placed by Federal statutes on the number of locations that may be made, and claims may be amended and boundaries changed at any time, provided such changes do not interfere with the rights of others.

Generally, a placer claim is established by posting a notice of location upon a tree, a rock in place, a stone, a post, or a monument. This must contain the name of the claim, name of locator or locators, date of location, number of square feet or acreage claimed, and sufficient description of the claim by reference to some natural object or permanent monument to identify the claim, following which the boundaries of the claim must be marked so they may be readily traced. Requirements for marking of boundaries vary somewhat by State. A location may not exceed 20 acres for any one person nor 160 acres for an association of persons, and claims should conform as nearly as practicable with the rectangular subdivision characteristic of the U.S. system of public land surveys.

At least one discovery of mineralization is required per claim (20 to 160 acres) "that would justify a person of ordinary prudence in the further expenditure of time and money, with reasonable prospect of success in developing a profitable mine."[3] A discovery implies a certain amount of excavation to show that the required mineral is indeed present, although State laws vary somewhat on this point. A minimum annual expenditure in labor and improvements of $100 must be made to hold possession of a mining claim, and evidence to this effect must be duly recorded by the appropriate county recorder. Such work is generally known as "assessment work." Provisions are also made for millsites on nonmineral land. Since September 2, 1958, the requirements for assessment work may be satisfied by conducting geological, geochemical, and geophysical surveys under the supervision of a qualified expert.

Unpatented claims may be bought and sold, but their use is restricted to mining purposes only. Any use of the surface for purposes unrelated or foreign to mining is unauthorized. Ownership of both the minerals and lands prospected and developed is attained by the process of patenting. Prior to patenting, the claim holder has possessory rights only to the minerals.

A number of requirements must be met for a patent, which is obtained through the U.S. Bureau of Land Management. These include proof of discovery of valuable minerals, expenditure of at least $500 in labor and improvements, payment for filing application, publishing costs, and other items. Specific information on placer mining patent applications and on adverse claim procedures in the case of contested rights can be found under parts 3863 and 3870,

[3]For assistance regarding location of mining claims on the public domain, the Bureau of Land Management of the U.S. Department of the Interior should be consulted.

title 43, of the Code of Federal Regulations pertaining to mining claims under the General Mining Laws of 1872.

Public Law 167, enacted July 23, 1955, provides for multiple use of the surface of public lands. This does not alter the validity of gold placer locations based upon sufficient evidence of discovery. It does set up procedures whereby the Government agency responsible for administering surface resources can challenge a mining claimant. In this way the question of surface rights is cleared so that the fullest use can be made of the land.

Under Public Law 359, enacted August 11, 1955, mining is permitted on lands which have been withdrawn from location or reserved for power development and for other purposes, provided certain steps are taken. In this case, permission to mine must be obtained from the Secretary of the Interior. Claims located before the date of the act on a power withdrawal are relocatable.

Lands accorded to Indian Reservations are not subject to claim under U.S. mining laws. (From June 18, 1943, to May 27, 1955, an exception was made for the Papago Indian Reservation, but such free mineral entries were then curtailed (43 CFR 3825, formerly 3635).) One wishing to prospect or mine on Indian lands must obtain a lease from the Secretary of the Interior; application for the lease should be made through the reservation superintendent.

On State-owned lands, application for prospecting or mining lease should be made to the appropriate State authority. Regulations on granting such leases vary by State. Mining claims can be located on private stock-raising homestead lands where the Government has reserved rights to minerals, although certain limitations are specified to protect the homesteader and to provide reimbursement for damage to crops or to tangible improvements. Taylor Grazing Act lands are also subject to location.

Privately owned lands are usually leased or may be purchased outright for mining purposes. Normally a lease will carry a royalty provision on the mineral production as a percentage of the gross or net value received from sales. Many different arrangements are possible, depending upon the requirements or bargaining positions of the potential lessor and lessee.

The recent completion of studies of mining laws by the Public Land Law Review Commission and recommendations by the Commission can be expected to result in changes in regulations that could affect placer location procedures or mining rights. Information on such changes as they occur will become available from the Bureau of Land Management, U.S. Department of the Interior.

Problems With Water Rights, Water Supply, and Stream Pollution

The need for a good, dependable, and plentiful supply of water increases geometrically with the scale of operation in placer mining. Panning gold requires very little water and can be done in a small tub if necessary. At the other extreme, the hydraulic monitor, once in use, employed large flows of water under high pressure, and sluicing at a large operation could consume virtually all the water that might be available. One thing the placer miner must keep in mind is the seasonal nature of stream flow. This affects both the supply of water and also the problems of pollution for downstream users and damage to stream ecology.

Various means are used to divert and impound water. Channels, pipes, and flumes can be constructed to conduct water where it is wanted. If supply at a continuous flow is limited, storage must be provided, and placer operation is then restricted to periodic activity and depends on the capacity of the reservoir. A simple tank may make a suitable reservoir for a small operation. Pumps are commonly used now where power is cheap enough, and the recirculation enables use of a smaller supply of water.

The question of water rights has always been important to the placer miner and is a complex subject in itself. Legal authorities should be consulted in case of any doubts or disputes. It has been common practice in placer mining to measure water requirements in terms of "miner's inches," which can be converted to rate of flow by the approximate factor of 40 inches to 1 cubic foot per second (the legal conversion in Arizona, California, Montana, and Oregon; other States vary). One cubic foot of water is equivalent to about 7.5 gallons. Thus, a miner's inch converts to 11.2 gallons per minute.

Water flows are measured in cubic feet per second and storage is measured in acre-feet, the latter being equivalent to a 1-foot depth of water spread across an area of 1 acre. Measurement of flow is usually done with a calibrated weir, but flows can be estimated by average velocity or by other methods if the quantity is large. A term used to describe the effectiveness of water in hydraulic operations is its "duty," which is usually expressed as the number of cubic yards of gravel washed per miner's inch per 24-hour day. Water duty will vary greatly with the mining situation.

States where placer mining has been important in the past, such as California, have enacted detailed and quite strict laws regarding stream pollution from placer operations. Such laws require the construction of a settling pond or ponds of sufficient size to clarify the water used in mining before it is discharged into the stream. Furthermore, they may require that aluminum sulfate and lime or some similar clarifying substance be added to the effluent to avoid rendering the water in the stream unfit for domestic water supply purposes.

Regulations regarding stream pollution may vary with the stream and the particular portion of the State, so the appropriate control agencies should be consulted. In California, the California Debris Commission and the California Department of Fish and Game regulate discharges from mining operations. The California Fish and Game Code curtails mining operations in the Trinity and Klamath River fish and game district between July 1 and November 30, "except when the debris, substances, tailings, or other effluent from such operations do not and cannot pass into waters in the said district."[4] Federal and State

[4] Quotes in the following sections are obtained from relevant sections of California statutes.

water resource and water quality control agencies may also have something to say about placer mining discharges, and it is wise to check with them before undertaking any sizable project.

Legislation in California that closed down hydraulic mining on the Sacramento River and its tributaries goes back many years. An act entitled "Protection of Domestic Water Supplies From Pollution of Placer Mining Operations" covering the watersheds of the Sacramento and San Joaquin Rivers (A. B. 2006) was passed in 1941, requiring a permit for placer mining from the California Debris Commission and compliance with a number of provisions specifically aimed at dredging.

Who Can Advise You

There are many sources to which the novice placer miner may turn for information. Probably the first should be the particular State agency dealing with geology, mining, conservation, or development. Universities with geology or mining departments will have knowledgeable people who can be consulted. A readily accessible source of information is the reference section of your public library. Professional engineers and consultants may be contacted through professional organizations or directly, by telephone.

Federal agencies most concerned with the problems of placer mining are the Bureau of Mines, the Geological Survey, and the Bureau of Land Management, Department of the Interior. Generally, the Bureau of Mines is best equipped to handle technical or statistical questions; the Geological Survey provides information on geology and deposits; and the Bureau of Land Management is involved in land ownership and evaluation problems. The Forest Service, Department of Agriculture, is a good source of information on placer mining sites and regulations within the National Forests. Furthermore, the prospector is well advised to inquire at the local ranger station of the National Forest in which he intends to prospect for guidance and to inform the ranger of his intent.

County offices, including that of the County Recorder, can often supply useful information on claim staking and placer locations within that county. Forms for location notices are normally available at the County Courthouse in mining localities or may be purchased at a stationery store. Questions about possession and sale of gold come under the purview of the Department of the Treasury.

HOW TO LOOK FOR PLACERS

Once decided on the area of search and armed with some knowledge of the characteristics of deposits to look for, then you are ready to explore. Most areas are relatively settled today and are accessible by car, or at least lie within a few miles of a road. A possible exception is Alaska, where an aircraft or boat might be needed to reach the site. Regardless of the type of transportation, you will need adequate supplies and equipment to sustain you and your companions for an extended stay in the field. With a gold pan for each and setting out from a base camp it should be possible to determine within several days if the potential for the area is good.

Equipping Yourself

Camping and outdoor recreation in general have become so popular that many commercial sources of equipment and information are now available. Some stores appeal to the budget-minded, while others, such as the specialty shops for camping supplies, have a wider selection of usually more durable products. Books on camping are available at the library, and reliable merchants will recommend the equipment best suited for a particular use. Many of the comforts of home can be found in the ordinary camp today. Backpacking has benefited from developments in lightweight materials and foods. The amounts and types of goods and equipment selected will depend on the remoteness of your location and accessibility of a resupply point. The prospector might wish to travel with a mobile home, trailer, or camper, or he might simply pack his gear on his back and head up the trail. A few suggestions are in order here, but the individual must do much of his own planning, since requirements and tastes vary so greatly.

Basic Equipment

Among the essential implements needed for prospecting are a pick; a long-handled, round-pointed shovel; and a gold pan, preferably a 10- or 12-inch-diameter pan which can usually be purchased at hardware stores in gold-mining areas. A small prospector's pick is also useful, and a magnet and a small amount of mercury should be carried to separate the gold from black sand after panning. Specialty stores and manufacturers can provide the more elaborate equipment, such as skindiving gear, ready-built sluices, and mechanical gold separation devices, if desired.

In some cases, a bucket or wheelbarrow may be needed to transport materials to the washing site, and in addition, a heavy 1/4- to 1/2-inch-mesh screen is handy to separate out coarse materials. A small screen cut to nest in the upper part of a gold pan can be useful for the same purpose in panning. A gold pan the same size as the one used for panning will make a most efficient nesting screen if a close pattern of holes is drilled in the bottom. Holes usually should be 1/4 to 3/8 inch in diameter, depending on the average size of the material being sampled. Distance between holes should be about the same as the diameter of the holes. In some areas these pans can be purchased readymade. For weighing gold, a small balance scale graduated in milligrams may be desirable. A compact, folding type of balance is available for this purpose.

A compass will be needed for establishing claim lines and for finding your way out of the woods if lost. Adequate maps should be carried. A hand magnifying lens is helpful in identifying minerals. Bags may be needed to carry out samples; plastic bags are the best because samples may be damp. A rocker may be transported to the site either assembled or in a knocked-down condition. If mining is planned, lumber and other materials to build a sluice may be carried to the site. (See construction details under respective headings.) More elaborate equipment such as pumps, pipes, hoses, and light plants might be taken in by pack animals if desired.

Personal gear includes a good pair of boots, sturdy clothing, weatherproof gear, sleeping bag, tent, and such other things as one might want for comfort and sanitation. A foam pad or air mattress adds comfort to sleeping. A length of rope is useful for many purposes around camp, from raising the food out of reach of animals to extracting a car from a mudhole. For hiking, all necessary equipment for the period away from camp should fit into a manageable backpack of some kind.

An ax, a flashlight, a knife, and matches are almost indispensable. (Fires in the National Forest should be made only in designated areas or after consulting the local forest ranger.) A water bucket is often required, and a good crosscut saw will be found useful. Guns and fishing equipment can be taken to supplement the food supply and to provide some additional recreation. Guns are seldom necessary for protection from animals. A canteen with a 2-quart or larger capacity is advisable in many areas, depending on dryness of the climate. You will need water-purification tablets where streams are contaminated, whether by grazing stock or for other reasons. A miner's lamp, which consumes calcium carbide, is sold at some hardware stores and can be used for a serviceable light, although most people when away from electricity prefer gasoline or propane lamps. A carbide lamp will also be useful for any underground work. The special miner's safety lamp is recommended wherever air may be bad. Stoves that burn gasoline or pressurized gas are in wide use in camping and even gas refrigerators may be taken along "to cool the beer." (For low-budget operations, a swift-running stream will serve this same purpose well.) For any length of time in the field, an oven for baking is a valuable amenity. A reflector oven for use next to a campfire can be made of light sheet metal and will give excellent results, also serving as a place to keep food warm.

Supplies

Freeze-dried foods are generally good and easy to carry and prepare, although somewhat more expensive than most other foods. For estimating pack weights, about 2 pounds of dehydrated and freeze-dried foods is needed per person per day. Canned foods should be avoided when backpacking because of their weight, but they are otherwise satisfactory. Disposal of empty containers should be done with consideration to others who may follow and wish an uncluttered landscape; burial is usually recommended.

Suggested food supplies for a prospector's camp include the following: bacon, beans, cheese, salt, baking powder and soda, coffee, tea, onions, potatoes, fruits, corn, peas, raisins, rice, flour, crackers, cereals, butter or margarine, powdered milk, eggs, pancake and waffle mix, sugar, syrup, and fresh meat and vegetables as practicable. Many other items can be added to the list, but these are most of the basics. Utensils should include a variety of dishes, silverware, a sharp knife, spatula, can opener, frying pan, coffee pot, and several different sizes of pots and pans. Towels, both paper and cloth, soap, scouring pads, and metal or plastic tubs or basins will be needed for cleaning up.

Extra clothing should be included in your supplies for warmth and for changes. Mosquito netting may be a virtual necessity in some areas, and adequate amounts of a good insect repellent should be packed.

Safety Needs

Probably the most troublesome and at times the greatest hazard in the wilds today is the bear. People may argue which type of bear has the meanest temperament, but any type may leave your camp a shambles when in search of food, and under certain circumstances any bear will attack a person. Placing food out of reach or in a secure container will help reduce the attraction. Fortunately, most bears will turn and run when frightened by loud noises. Other wild animals are seldom dangerous except when provoked, but smaller ones such as packrats can inflict considerable damage on camp gear and foodstuffs. Poisonous snakes, spiders, ticks, scorpions, and the like should be treated with traditional caution; their presence should be anticipated in most areas. Learn to identify and avoid poison oak and poison ivy! Knowledge of first aid is essential for dealing with emergencies that might arise on an outing, and a study or review of the subject should be included in any preparations.

Some of the personal hazards faced in the out-of-doors include twisted ankles, lacerations from falling in brush, falls from slippery rocks or crude bridges when crossing streams, breaking through floors in old building ruins, and falls or cave-ins in old mine workings. Beware of bad air in any old workings! Danger of drowning is always present when working around the deeper streams or pools when placer mining.

Many types of first aid kits and equipment are on the market. The choice of kit is one of size and variety of content. A snakebite kit is usually a separate accessory and should be carried, even though it is rarely put to use. Disinfectants, aspirin, fungicides, bandages, and similar items should be included. For areas of considerable sunshine, tanning lotion, sunglasses, and a hat are needed, and salt tablets should be taken as designated to prevent heat prostration. Wearing a safety hardhat and safety glasses may be advisable at times.

Panning for Gold

The standard gold pan is made of stiff sheet iron and is 16 inches in diameter at the top and 2-1/2 inches deep. The rim is flared outward at an angle of about 50° from the vertical. Smaller pans are used for testing, and it is advisable for most panners to use either a 10- or 12-inch size for handling ease. Probably the 12-inch is the most widely available. Frying pans or other cooking utensils may also be used for washing out gold but are less effective. Before any kind of container is used for panning it should be cleaned thoroughly and all grease should be burned out. New pans generally are greasy and should be heated over a fire until this coating is gone. Even a rusty pan, if clean, can be used satisfactorily. In fact, the roughness due to the pitting of the rust may assist in holding back the gold.

There are different techniques and subtle variations in the art of panning--experience teaches which is best. Those with wide experience and much practice can recover the most gold with the least effort. It is sometimes said that good panning technique lies in the action of the wrists. After much practice the good panner should be able to save even the very fine gold that may be nearly but not quite free from the black sands.

The pan usually is filled level with the top, or slightly rounded, depending somewhat upon the nature of the material being washed and the personal preference of the panner. It is then submerged in water. Still water 6 inches to 1 foot deep is best. While under water the contents of the pan are kneaded with both hands until all clay is dispersed and the lumps of dirt are thoroughly broken. The stones and pebbles are picked out after the fines are washed off. Then the pan is held flat and shaken under water to permit the gold to settle to the bottom. The pan is then tilted and raised quickly--still under water--so that a swirling motion is imparted and some of the lighter top material is washed off. This operation is repeated, occasionally shaking the pan under water or with water in it until only the gold and heavy minerals are left. With proper manipulation, this material concentrates at the edge of the bottom of the pan. Care must be taken that none of the gold climbs to the lip of the pan or gets on top of the dirt.

Nuggets and coarse colors of gold can now be picked out readily with a tweezer or with the point of a knife. Cleaning the black sand from the finer gold is more difficult, but can be carried nearly or entirely to completion by careful swirling of the contents as described above, always watching to see that none of the colors are climbing toward the lip. This part of the operation usually is done over another pan or in a tub so that if any gold is lost it can be recovered by repanning.

The concentrates should be dried, and the black sands (composed largely of magnetite) can then be removed by a magnet or by gently blowing them on a smooth flat surface. If there is an excessive quantity of black sand, the gold usually is amalgamated by putting a portion of a teaspoonful of mercury in the pan. In sampling work, extra care should be taken to see that no fine colors are lost. When mining, however, additional time needed to insure that all colors are saved probably is not justified because the value they add is so small.

A word should be said here about other minerals that you may see in your gold pan. Pyrite ("fool's gold," an iron sulfide) and mica are often mistaken for gold by the novice. Pyrite, which is usually a brassy yellow to white color, will shatter when struck with a hammer and becomes a black powder when finely ground. Mica, which may have a bright, bronzy appearance, is distinguished by its light weight and flat, platy cleavage. Both minerals are common in gold areas. Other minerals that will collect with the gold and black sands because of high specific gravity include ilmenite (iron-titanium oxide), hematite (nonmagnetic iron oxide), marcasite (an iron sulfide), rutile (titanium oxide), scheelite (calcium tungstate), wolframite (iron, manganese tungstate), tourmaline (boron and aluminum silicate), zircon (zirconium silicate), chromite (iron and chromium oxides), and cinnabar (mercury sulfide). If present in sufficient quantity, these latter minerals may have some economic significance, although efforts to recover them as byproducts are seldom worthwhile. Native platinum, elemental mercury, lead shot, and similar materials are also occasionally found in the pan.

EVALUATION: SHOULD YOU INVEST AND MINE?

This question becomes more difficult to answer as the size of the planned operation increases. Estimation of the amount of gold recoverable and the overall costs of investment and mining is no simple matter and calls for highly experienced engineering skills for any moderate- to large-scale project. Elaborate procedures of sampling and evaluation cannot be followed by the small-scale operator because of the cost. Thus, his decisions must be based on a variety of factors, not the least of which is intuition. Needless to say, many mistakes have been made, with much resultant waste of money and effort. Do not let what started out as a recreational activity become your master instead of your servant.

Sampling Techniques

Many methods of sampling are possible, including the simple panning of gravel from surface exposures, churn drilling, test pitting and trenching, shaft sinking, and drifting. As an aid in tracing possible gold-bearing channels, geophysical techniques have been employed with some success, but proper use of the typical instruments involved is generally reserved to experts. Moreover, interpretation of results is seldom adequate to provide any quantitative estimates, although the information gained can be useful in planning an exploration program.

For a thoroughgoing discussion of exploration and sampling techniques the reader is referred to the recent Bureau of Land Management publication by John H. Wells, entitled Placer Examination: Principles and Practice (31). Wells' description of panning is particularly recommended.

Panning and rocking (described later) are the basic means of determining the recoverable gold content of placer materials. A fire assay, sometimes made on a concentrate, provides a relatively complete estimate of the gold content of the material, but a poor estimate of how much gold can actually be extracted by conventional washing methods. Thus, placer gold is seldom assayed, except to determine its fineness (measure of gold purity, see p. 37). In estimating the value of gold in the pan after washing a quantity of gravel, the technique of counting nuggets and "colors" is normally followed. Generally, pieces worth more than 5 or 10 cents are considered as nuggets; smaller particles are colors. When skill is developed in estimating the various sizes of particles, a good degree of consistency can be achieved in the results.

Where samples can be obtained across a section of the bank exposed along a creek, it is good practice to cut a vertical groove or channel of fairly consistent width and depth. The sample may be cut from top to bottom, or in segments comprising several different samples if the bank shows distinct changes in materials. Bars may be sampled by digging a vertical hole, clear to bedrock if possible, and panning the product. For surface mining of "skim bars," sampling consists of simply taking a panful from a favorable point and visually estimating the amount of similar material in the vicinity. Clearly, there is not much accuracy in any of these methods, but the deposition of gold in such locations is bound to be erratic anyway. More representative sampling is usually possible in the larger deposits where deposition and size of gold particles is more uniform or consistent.

Calculating What You Might Have

For the small-scale miner, sampling will usually be limited to taking a panful here and there and possibly running a larger sample through a rocker or sluice if panning discloses any gold. If colors are found, a record should be made of the number and estimated size of colors per pan and the approximate location. The sampling then progresses until one is assured the prospects are good enough to warrant a mining operation of some sort.

A scale of sizes and approximate values of colors based on pure gold at $35 an ounce is as follows: (Note: Mesh = screen size in openings per square inch; minus 10- plus 20-mesh material will pass screen with 10 openings per square inch but be stopped by screen with 20 openings.)

Coarse gold, plus 10 mesh: should be picked out and weighed individually, value about $1 per gram.

Medium gold, minus 10 mesh but plus 20 mesh: 2,200 colors per troy ounce, value about two-thirds of a color to 1 cent.

Fine gold, minus 20 mesh but plus 40 mesh: 12,000 colors per troy ounce, value about 3 colors to 1 cent.

"Flour" gold, minus 40 mesh: 40,000 colors per troy ounce, value about 10 colors to 1 cent.

Differing fineness or price will affect the values somewhat.

It is common to report panning results in cents per pan. So, assuming you have determined that a "pan factor" of about 400 pans per cubic yard (bank measure) for the 12-inch pan is a suitable figure, multiplying the cents-per-pan figure by 400 gives the estimated value per cubic yard.

Another means of estimating is to rank the colors into three groups, as follows:

Number 1: colors weighing over 4 milligrams

Number 2: colors weighing between 1 and 4 milligrams

Number 3: colors weighing less than 1 milligram

(Note: 31,103 milligrams equals 1 troy ounce.)

Scales will be needed to check the weights until the eye can judge the sizes properly. It is recommended that particles over 10 milligrams be weighed individually. A rough measure of value is one-tenth of a cent per milligram. Thus, the value in a pan can be calculated using your visual count and tally of the number of colors of each rank. After sufficient practice, good estimates will come easily. Thickness has a great bearing on weight: For instance, some gold might look large, but actually be flat, flaky, and hence very light.

Determining the overall value of a deposit with any accuracy calls for a knowledge of accepted practices and mathematical procedures for weighting the values and sample intervals. It is important also to understand the statistical principles of variation and distribution, which are beyond the scope of this report. Generally, the practical prospector will take a few measurements, make some crude calculations using his panning results, and decide to stay or move on.

HOW TO GO ABOUT MINING

When a site where gold is known to occur has been found, and after it has been sampled and judged worthy of further effort, the ownership status should be checked to assure that the ground is open for claiming. Then, after staking adequate claims (or arranging to lease if the ground is not open to claim), you are ready to consider mining. Whether mining permits are required by those State agencies involved with fish and game or watersheds should be investigated, because placer operations of any size may drastically change the local water quality. A simple operation may have virtually no effect on a stream or surroundings, but when materials amounting to more than a few cubic yards a day are handled, the possible effects begin to become significant.

Choosing a Method

Among the simpler hand methods of recovering gold are the gold pan, the rocker, the dip-box, the long tom, and the sluice. Panning has been described in a previous section, entitled "How to Look for Placers," and will only be discussed briefly here. The pan is generally too slow to be effective for anything more than prospecting. The rocker is a time-honored device of the small-scale miner with limited means. The dip-box and long tom might be considered more like simplified sluicing methods than distinct methods in themselves. As a method, the long tom has never been very popular but is described here for its possible historical interest. Other methods used in specific circumstances would include the surf washer, the dry washer, and skindiving.

The simpler methods all normally involve hand-mining operations (shoveling and/or picking of the gold-bearing materials). Limited mechanization is sometimes practical for moving and washing gravels in even the smallest operation, and this possibility should not be overlooked. Even motorized devices for panning are marketed by several manufacturers. Pumps and small excavators can often be adapted to the small mining operation by the enterprising miner.

The more complex methods, such as ground sluicing, hydraulicking, drift mining, excavation using powered equipment, and dredging, require considerable investment, knowledge, and experience; a full discussion of these methods is beyond the scope of this report.

The choice of method depends primarily on the scale of operation and the availability of water. These and other characteristics of the different methods are discussed below.

Gold Pan

Panning is the hardest way to wash gold from placer gravels, but it is an inexpensive and completely mobile method. A person can dig with a pick and shovel much faster than he can pan the material dug, so it pays to treat only the highest grade products by panning once one has settled down to mining.

An experienced person can wash about 10 large pans per hour, the equivalent of approximately 1/2 to 1 cubic yard of gravel per day, depending on how clean the gravel is. A level-full, standard 16-inch pan might contain roughly 22 pounds of dry bank gravel; there are approximately 150 to 180 pans per cubic yard of gravel. More than twice as many 12-inch pans would be required per cubic yard. The top dirt or cover is usually cast aside and the few inches of material directly above bedrock and the material scraped from crevices is panned. Places to look and the proper panning technique have been covered in earlier sections.

Rocker

At least twice as much gravel can be worked per day with the rocker as with the pan. The rocker or cradle, as it is sometimes called, must be manipulated carefully to prevent loss of fine gold. With the rocker, the manual labor of washing is less strenuous, but whether panning or rocking, the same method is used for excavating the gravel.

The rocker, like the pan, is used extensively in small-scale placer work, in sampling, and for washing sluice concentrates and material cleaned by hand from bedrock in other placer operations. One to three cubic yards, bank measure, can be dug and washed in a rocker per man-shift, depending upon the distance the gravel or water has to be carried, the character of the gravel, and the size of the rocker. Rockers are usually homemade and display a variety of designs. A favorite design consists essentially of a combination washing box and screen, a canvas or carpet apron under the screen, a short sluice with two or more riffles, and rockers under the sluice (fig. 3). The bottom of the washing box consists of sheet metal with holes about 1/2 inch in diameter punched in it, or a 1/2-inch-mesh screen can be used. Dimensions shown are satisfactory but variations are possible. The bottom of the rocker should be made of a single wide, smooth board, which will greatly facilitate cleanups. The materials for building a rocker cost only a few dollars, depending mainly upon the source of lumber.

After being dampened, the gravel is placed in the box, one or two shovelfuls at a time. Water is then poured on the gravel while the rocker is swayed back and forth. The water usually is dipped up in a simple long-handled dipper made by nailing a tin can to the end of a stick. A small stream from a pipe or hose may be used if available. The gravel is washed clean in the box, and the oversize material is inspected for nuggets, then dumped out. The undersize material goes over the apron, where most of the gold is caught. Care should be taken that not too much water is poured on at one time, as some of the gold may be flushed out. The riffles stop any gold that gets over the apron. In regular mining work, the rocker is cleaned up after every 2 to 3 hours, or

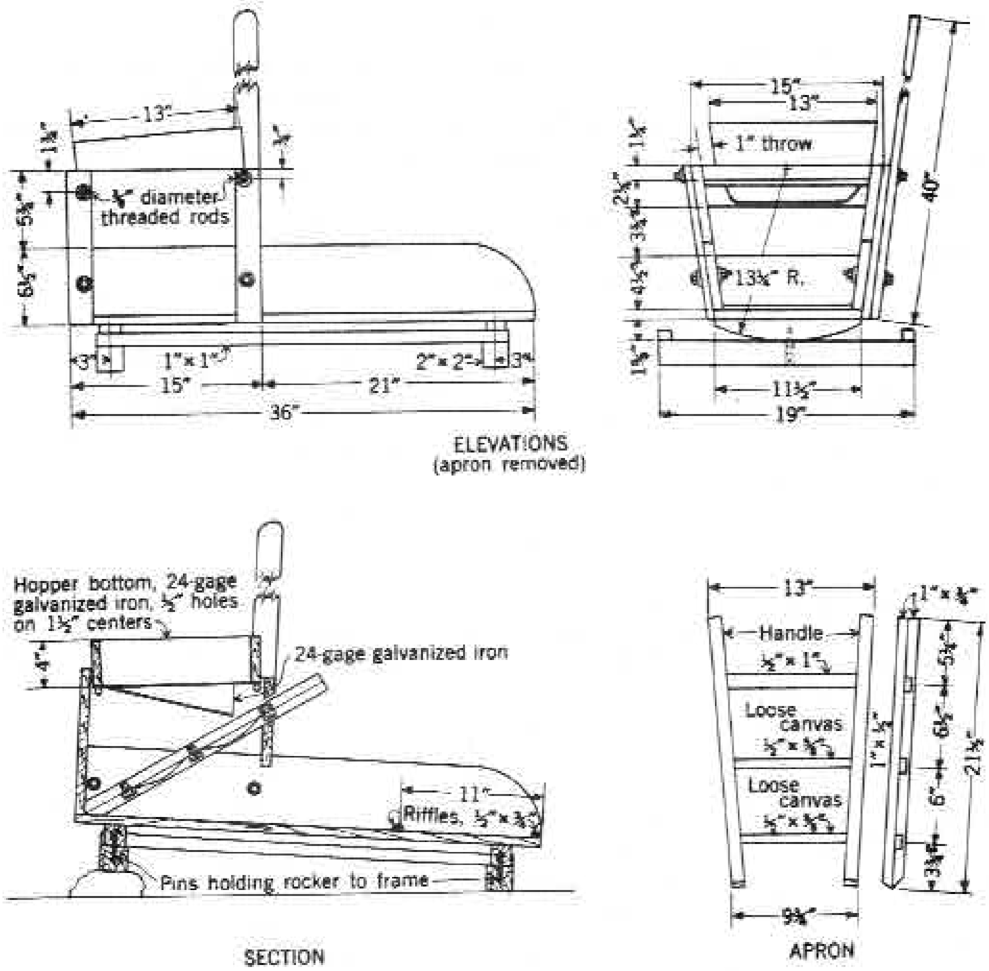

FIGURE 3. - Basic Design for a Prospector's Rocker. (Note that hopper is built to slide back and forth, bumping the sides as unit is rocked.)

oftener when rich ground is worked and gold begins to show on the apron or in the riffles. In cleaning up after a run, water is poured through while the washer is gently rocked, and the top surface sand and dirt are washed away. Then the apron is dumped into a pan. The material back of the riffles in the sluice is taken up by a flat scoop, placed at the head of the sluice, and washed down gently once or twice with clear water. The gold remains behind on the boards, from which it is scraped up and put into the pan with the concentrate from the apron. The few colors left in the sluice will be caught with the next run. The concentrate is cleaned in the pan.

Skillful manipulation of the rocker and a careful cleanup permit recovery of nearly all the gold. Violent rocking should be avoided, so that gold will not splash out of the apron or over the riffles. The sand behind the riffles should be stirred occasionally, if it shows a tendency to pack hard, to prevent loss of gold. If the gravel is very clayey it may be necessary to soak it for some hours in a tub of water before rocking it.

Where water is scarce, two small reservoirs are constructed, one in front and the other to the rear of the rocker. The reservoir at the front serves as a settling basin. The overflow drains back to the one at the rear, and the water is used over again.

The capacity of rockers may be increased by using power drives. Such a device might be rocked by an eccentric arm at the rate of approximately forty 6-inch strokes per minute. The capacity of the typical machine with two men working is 1 cubic yard per hour. Where gravel is free from clay, the capacity may be as great as 3 cubic yards per hour. The cost of the mechanized rocker and a secondhand engine for driving it is estimated at $400.

Dip-Box

The dip-box is useful where water is scarce and where an ordinary sluice cannot be used because of the terrain. It is portable and will handle about the same quantity of material as the rocker.

Construction is relatively simple. The box has a bottom of 1- by 12-inch lumber to which are nailed 1- by 6-inch sides and an end that serves as the back or head. At the other end is nailed a piece approximately 1 inch high. The bottom of the box is covered with burlap, canvas, or thin carpet to catch the gold, and over this, beginning 1 foot below the back end of the box, is laid a 1- by 3-foot strip of heavy wire screen of about 1/4-inch mesh. The fabric and screen are held in place by cleats along the sides of the box. Overall length may be 6 to 8 feet, although nearly all gold will probably collect in the first 3 feet. The box is placed so the back is about waist high; the other end is 1/2 to 1 foot lower. Material is simply dumped or shoveled into the upper end and washed by pouring water over it from a dipper, bucket, hose, or pipe until it passes through the box. The water should not be poured so hard that it washes the gold away. Larger stones (after being washed) are thrown out by hand, or a screenbox can be added to separate them. Riffles may be added to the lower section of the box if it is believed gold is being lost.

Long Tom

A long tom usually has a greater capacity than a rocker and does not require the labor of rocking. It consists essentially of a short receiving launder, an open washing box 6 to 12 feet long with the lower end a perforated plate or a screen set at an angle, and a short sluice with riffles (fig. 4). The component boxes are set on slopes ranging from 1 to 1-1/2 inches per foot. The drop between boxes aids in breaking up lumps of clay and freeing the contained gold.

A good supply of running water is required to operate a long tom successfully. The water is introduced into the receiving box with the gravel, a

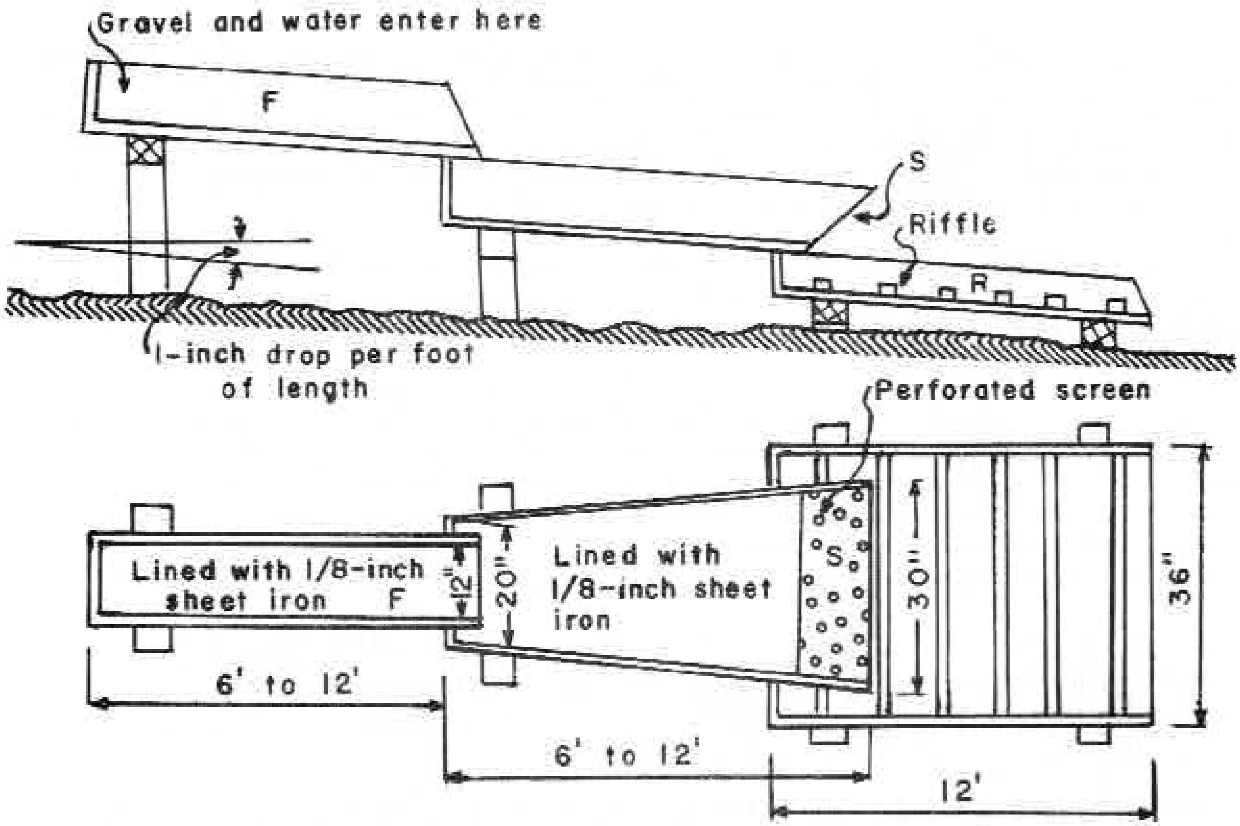

FIGURE 4. - The Long Tom.

both pass into the washing box. The sand and water pass through the screen's 1/2-inch openings and into the sluice. The oversize material is forked out. The gold is caught by the riffles. The riffle concentrates are removed and cleaned in a pan. Quicksilver may be used in the riffles if the gravel contains much fine gold.

The quantity of gravel that can be treated per day will vary with the nature of the gravel, the water supply, and the number of men employed to shovel stones into the tom and then fork them out. For example, two men, one shoveling into the tom and one working on it, might wash 6 cubic yards of ordinary gravel, or 3 to 4 cubic yards of cemented gravel, in 10 hours.

A tom may be operated by four men--two shoveling in, one forking out stones, and one shoveling fine tailings away. Where running water and a grade are available, a simple sluice is generally as effective as the long tom and requires less labor.

Sluice

A sluice is generally defined as an artificial channel through which flows controlled amounts of water. In gold placering, the sluice includes sluice-boxes which collect the gold by means of various configurations of riffles, corrugations, mats, expanded metal, or the like, which trap the heavier particles while allowing the waste to continue through. Figure 5 shows a portable

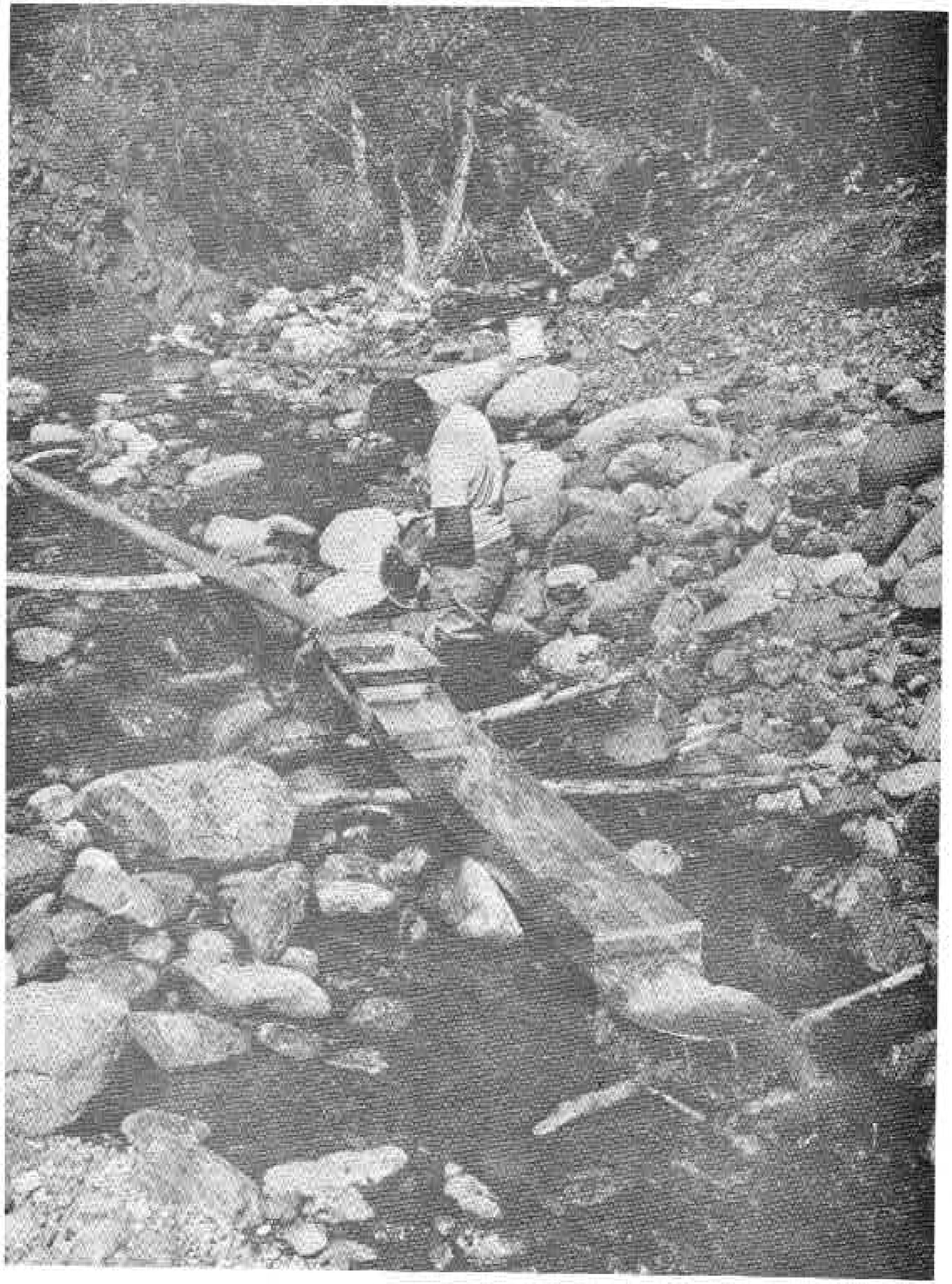

FIGURE 5. - Lightweight Sluicebox in Action. Unit made of aluminum has screen box at the head end, riffle section in the middle, and expanded metal over burlap at the foot. The gold pan would normally be omitted, but is included here to check for losses.

lightweight metal sluicebox suitable for test work or a small-scale placer operation. An important part of any sluicing operation is its water supply, and where water is not plentiful, pumps, pipelines, or even dams with special headgates may be required.

Small-scale sluicing by hand methods has been called quite appropriately shoveling-into-boxes. In contrast, in ground sluicing, usually a more efficient operation, most of the excavation is accomplished by the action of water flowing openly over the materials to be mined. In either case, the materials pass through a sluice, where gold is collected behind riffles. A variation of the sluicing technique, where water is stored and released against or across the materials intermittently, is called booming.

The sluicebox in its simplest form might be a 12-foot-long plank of 1- by 12-inch pine lumber, to which sides about 10 to 12 inches high are nailed, with braces secured at several places across the top. Larger sluices can be made with battens to cover joints between boards where gold might slip out, and with braces built around the outsides of the box for greater rigidity. To provide for a series of boxes, the ends should be beveled or the units tapered so that one will slip into the other in descending order and form a tight joint. Four to eight such boxes in series would be a typical installation. Two men hand-shoveling into sluiceboxes can wash 5 to 10 times as much gravel as could be put through a rocker in a day. The slope of the sluice and the supply of water must be adjusted so that the gravel, including larger cobbles, will keep moving through the boxes and on out. Slopes of 4 to 12 inches per 12-foot box are normal, but if water is in short supply the slope may be increased. Trestles are necessary to support the boxes over excavated ground, gulleys, or swales.

Inside the boxes, various kinds of riffles may be employed, depending upon availability of material and personal preference. The riffles, which go on the bottom, are usually set crosswise in the box, but they can also be effective when placed lengthwise, the concentrates settling between them. They may be of wood, or of strap or angle iron, or a combination of the two. Straight, round poles or a pattern of square blocks or stones can serve for riffles. Rubber or plastic strips have even been used. Durability is important for prolonged operations, so wood may be armored with metal. Expanded metal, heavy wire screen, or cocoa mats make good riffles for collecting fine gold.

A common height for riffles is 1-1/2 inches; they may be placed from one-half to several inches apart. Fastening the riffles to a rack, which is then wedged into place in the box, permits their removal. A tapered shape on the cross riffle, with the thinnest edge to the bottom, tends to create an eddying action that is favorable for concentration. Another way to achieve this eddying action is to cant the riffle or even just the top of the riffle. Burlap or blanket material is commonly placed under the riffles to help in collecting fine gold. Mercury may be added to some sections of the sluice if there is much fine gold, but care must be taken to prevent escape of the mercury.

Sluice cleanups should be made at fairly regular intervals. After running clear water until the sluice is free of gravel, riffles are removed in sections starting at the upper end. With a thin stream of water, the lighter of the remaining material is washed to the sections below. The gold, heavy sands, and amalgam, if mercury has been used, are scraped up and placed in buckets. This mixture then can be panned or cleaned up in a rocker to obtain a final concentrate or amalgam.

Feeding the Sluice

It is common in a small operation, when feeding the sluice, to place a heavy screen or closely spaced bars of some sort across the section where the gravels enter, to eliminate the larger particles, which are probably barren anyway. The screen or bars (a "grizzly") should be sloped so the oversize material rolls off to the side. The size of mesh or spacing will depend upon the gradation of feed, but would generally be in the range of 1/4 to 1 inch, with 3/8 inch being a common size. In larger operations a rotating screen, or trommel, might be used. In a ground sluicing operation, possibly all materials would be run through the sluiceboxes. Provisions must be made for removing the oversize material, and, if required, stacking it away from the work area.

If the gravel contains much clay it may be desirable to use a puddling box at the head of the string of sluiceboxes. This may be any convenient size--for instance, 3 feet wide by 6 feet long, with 6- to 8-inch sides. The clayey material is shoveled into this box and broken up with a hoe or rake before being allowed to pass into the sluice. The importance of this step is that if allowed through the sluice, the unbroken clay lumps may pick up and carry away gold particles already deposited.

Usually, the shoveling-in method proceeds as follows: After the boxes are set, shoveling begins at an advantageous point. Experienced miners work out the ground in regular cuts and in an orderly fashion. Enough faces are provided so that shovelers will not interfere with one another. Provision is made to keep bedrock drained, and boulders and stumps are moved a minimum number of times. Cuts are taken of such a width and length that shoveling is made as easy as possible. The boxes are kept as low as possible so a minimum lift of gravel is necessary. At the same time an adequate slope must be maintained for the gravel to run through the boxes under the limitations of the available water. Allowance for dump room must also be provided at the tail end of the sluice. Leaks in the sluice are stopped promptly, and shoveling is done in such a manner that the sluice does not become clogged nor does water splash out. (Water in the pit hampers shoveling.)

All material of a size that will run through the sluice is shoveled in, and the oversize material is thrown to one side. Boulders from the first cut should be stacked outside the pit, on barren ground if possible. The width of a cut is usually limited to the distance a man can shovel in one operation. When shoveling from more than several feet away, it is best to set boards above and on the opposite side of the box; this increases the efficiency of the shovelers. The greatest height a man can shovel into a box is 7 to 8 feet, and above 5 or 6 feet the efficiency of the shoveler is markedly reduced. If the gravel is over 3 or 4 feet deep, it usually is excavated in benches to facilitate digging and to permit the upper layers to be raised a minimum shoveling height. Where the gravel is shallow, wheelbarrows may be used. Another way is to shovel the gravel onto a conveyor belt that discharges into a trommel, discarding the oversize material and running the undersize material through the sluice. Where two or more persons are working in the same cut, the height of succeeding benches is governed by the character of the material being dug and the distance the gravel has to be lifted.

The sluice may be maintained on the surface of unworked ground or supported on bents on the opposite side of the cut. After the first cut the boulders are thrown onto the cleaned-up bedrock. Where cuts are run on both sides of the sluice, the boxes are supported on bents as the ground underneath them is dug out. At other places the boxes may be set on bedrock and the dirt may be shoveled into the head of the sluice from short transverse cuts at the upper end of the pit. Work usually begins at the lower end of a deposit so that bedrock may be kept drained, and then proceeds across the deposit by regular cuts. The length and order of the cuts will depend upon local conditions. As heavy sands and gravel build up deposits between the riffles in the sluice, it may be necessary to stir these up to prevent packing and the consequent override of gold particles. A tined implement such as a pitchfork is often convenient for this. Larger stones that lodge in the sluiceway may be similarly removed.

Supplying Water

The quantity of water available will influence the scale of operations and the size of sluice used. A minimum flow of 15 to 20 miner's inches (170 to 225 gallons per minute) is required for a 12-inch-wide sluicebox with a steep grade. Smaller flows than this can be utilized by storing the water in some kind of reservoir and using the supply intermittently. A common practice followed where the quantity of water is limited is to use a grizzly or screen over the sluice to eliminate oversize material and thus increase the duty of the water. Reduction in the amount of material to be treated by first running it through a trommel to wash and screen out the coarse size is another effective way to lower the water requirements.

Water usually is conducted via ditch to the sluice. However, if the ground is rich enough it may be practicable to pump water for the sluice. The feasibility of obtaining a gravity flow should first be investigated, as the expense of pumping may be more than the cost of a long ditch, when the cost is distributed over the yardage of gravel moved. A suitable number of sluiceboxes or some other removal system may be used to transport the tailings to a dumping ground away from the working area. A tailings or settling pond may be required to maintain downstream water quality.

Ground sluicing utilizes the cascading effect of water to break down the gravel; hence, the requirements for water are much greater. The chief application of ground sluicing is to streambed deposits. Pipelines, flumes, or ditches would be necessary if ground sluicing were applied to gravels higher up on banks or terraces, and the larger scale hydraulic methods would then become more favorable. If booming is to be done, a dam and reservoir are needed. The dam is usually equipped with a gate mechanism that permits either automatic or manual control and quick release of the impounded water for maximum washing effect. The water may be passed over the upper face of a gravel bank or diverted against the bottom in order to undercut and carry away the gravel as the face of the bank breaks down. All materials are channeled toward the sluice.

The natural flow of a stream can be used by diverting the current with boards or simply with piled boulders. "Shears" can be constructed of 1- or 2-inch-thick boards 12 feet long nailed to pairs of tripods so that the boards slope back from the water flow at an angle of about 60°. The tripods are built in such a way that boulders can be piled inside the base to hold them in place. A row of these shears may be used to divert the force of the water against a bank, or two rows may be used to form a flume.

The seasonal nature of stream flow in different areas must be kept in mind when planning any placer operation. State and Federal agencies can provide information on stream runoff for many of the more important streams, information which will indicate the limitations in water supply that might be expected due to seasonal changes.

Additional Methods Sometimes Used

The methods described below, particularly the surf washer, are limited in application, but interest in them revives from time to time, so they are included here. Many kinds of dry washers have been developed, some very elaborate. Most dry-washing operations have a short lifespan, owing to the erratic character if the deposits. Skindiving for gold is not new, but development of better diving equipment in recent years has stimulated interest in the method, although restricted in practice to a few select stream areas. Shaft and drift mining are also among methods used in extracting placer gold gravels, but because techniques are more related to other types of mining, discussion is not included in this report.

Dry Washer (for Desert Areas)

Dry washers have been used for many years in the Southwestern United States, where water is scarce, and especially in New Mexico where several million dollars in gold has been produced during the last century by dry washing. The Cerrillos, Golden, and Hillsboro districts are among those having produced gold by dry washing. In years when other employment is scarce such production may take place widely. In the 1930's a considerable number of men also used dry washers in Nevada, southern California, and Arizona.

If gravel is to be treated successfully by dry washing, it must be completely dry and disintegrated. For instance, after rainstorms, operations must be stopped until the ground dries out again. Even in very dry climates the gravel is slightly damp below the surface, and must be dried before it can be treated in a dry washer. Spreading the material to sun-dry or putting it through dryers adds to the cost of mining. In small-scale work, however, the gravel will dry out about as fast as it can be treated.

Dry washers are usually run by hand and have about the same capacity as rockers of corresponding size, but the work of operating the dry washer is much harder. The workers select the material they are to treat with regard to both dryness and probable gold content. It is difficult to do this on a large scale with hired labor. Plants with mechanical excavators and complex power-driven dry-washing machinery have been tried, but in the United States, at least, virtually all were commercial failures, primarily because the gravel was dug faster than the sun could dry it out. Also, in large-scale work, particularly with mechanical excavation, the cost of sizing the material is quite great. Clay and cemented gravel introduce even further difficulties.

When the gold-bearing material is completely dry and disintegrated, panning tests of the tailings should show that a good saving can be made, except perhaps with extremely fine or flaky gold. Completely disintegrated material, however, is seldom obtained. The tops of clay streaks in the gravel are likely to be richer in gold than the gravel itself. Clay or cemented gravel seldom can be broken up sufficiently by hand to free all the gold without the use of some form of pulverizer. In a dry washer all gold included in a lump of waste passes out of the machine. As water usually will break up all the gravel and separate the gold from the other material, a better saving usually can be effected with the rocker or sluiceboxes than with a dry washer.

Basically, the dry washer separates gold from sand by pulsations of air through a porous medium. The screened gravel passes down an inclined riffle box with cross riffles. The bottom of the box consists of canvas or some other fabric. Under the riffle box is a bellows, by which air in short, strong puffs is blown through the canvas. This gives a combined shaking and classifying action to the material. The gold gravitates to the canvas and is held by the riffles, while the waste passes out of the machine.

The gravel is shoveled into a box holding a few shovelfuls at the head of the washer, from which it runs by gravity through the machine. A screen with about 1/2-inch openings is used over the box. All stones over about 1 inch in diameter generally are discarded in mining. A dry washer usually is run by a small gasoline engine which saves the labor of one man. The capacity of such machines is considerably greater than that of hand-operated ones. For instance, one man working alone must fill the box, then turn a crank which runs the bellows until the gravel runs through. The process is then repeated. With two men working, one shovels and the other turns the crank. One man can treat 1/2 to 1 cubic yard per day with a hand-operated washer, where the gravel lies close to the machine.

When cleaning up, the material behind the riffles usually is dumped into a pan and washed out in water. If water is very scarce, the accumulated material from the riffles may be run through the machine a second time and then further cleaned by blowing away the lighter grains of sand in a pan.

Dry washers are usually handmade and have been built in a large number of designs and sizes. Figure 6 shows an example of one type. The bellows of the

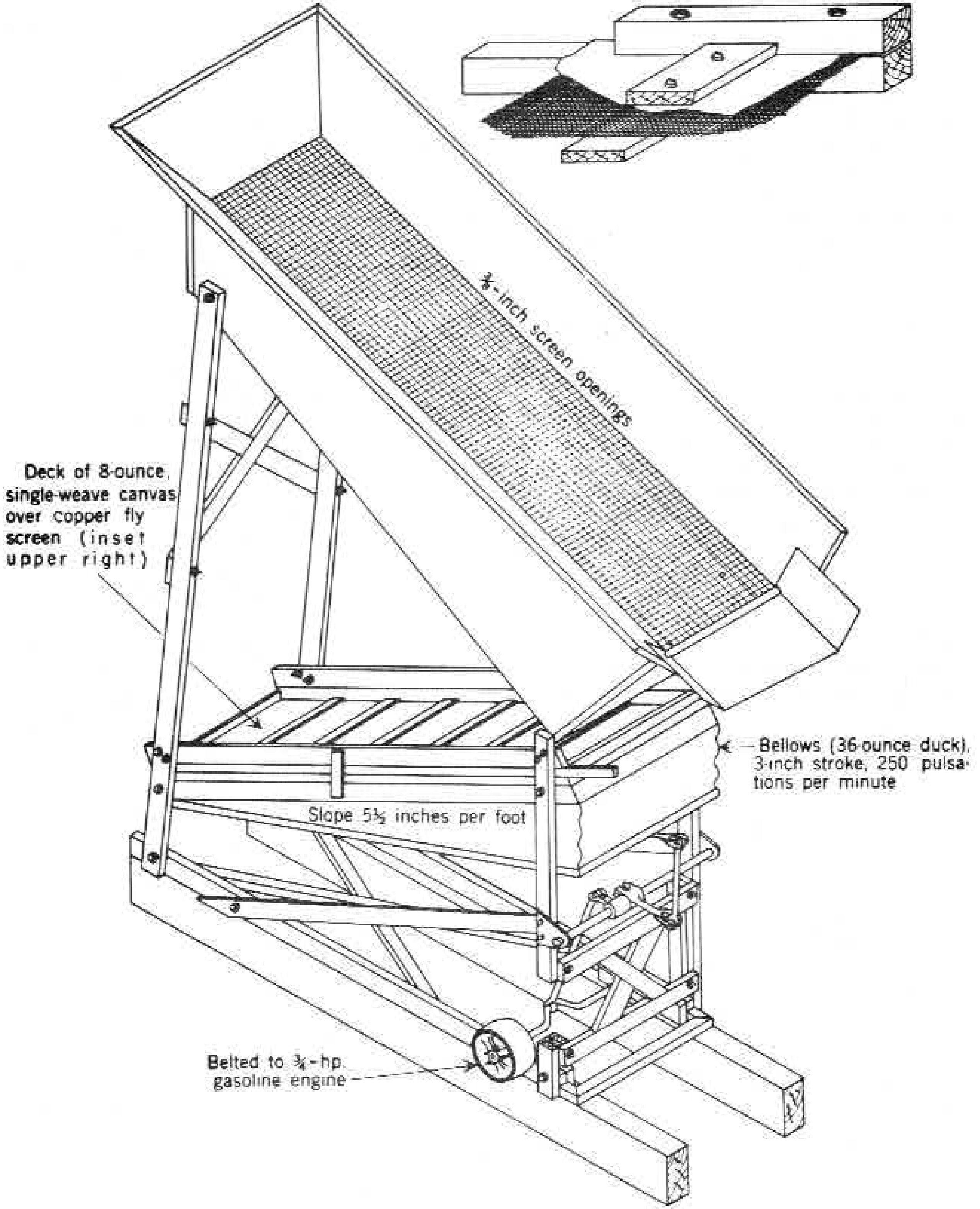

FIGURE 6. - A Dry Washer. (May be hand- or machine-powered.)

machine is made of 36-ounce duck and the bottom of the riffle box of 8-ounce, single-weave canvas. In contrast to the single-weave canvas, silk or rayon permits a good extraction of gold, but too much dust goes through into the bellows. Heavier canvas is too tight for good separation. Copper-wire fly screen is used under the canvas. The riffle box is 11 inches wide and 40 inches long and contains six riffles. The slope of the riffle box is 5-1/2 inches to the foot. (Hand-operated machines are usually much smaller and the riffle box is set at a steeper angle than with powered machines.) The gravel and sand are shoveled onto a screen with 3/8-inch openings at the top of the washer. The bellows is operated at 250 pulsations per minute; the stroke is 3 inches. The capacity of the machine is about 4/5 yard per hour, which probably would correspond to 1-1/2 or 2 cubic yards, bank measure. (The plus 1-inch material was previously discarded.)

In cleaning up after treating approximately 1 cubic yard in the washer, the riffle box is lifted out and turned over on a large, flat surface, such as a baking tin. The concentrate from the upper three riffles is first panned, and the gold is removed. Usually both the coarse and the fine gold can be saved here. The lower riffles may contain a few colors, but nearly all the gold is normally caught in the upper riffles.

Surf Washer (for Beach Deposits)

Few sea-beach-type placer gold deposits have been mined successfully. The most important producers have been in the vicinity of Nome, Alaska, but gold is also known to occur in a few other shoreline locations of States bordering the Pacific Ocean. Special techniques have been developed to utilize the action of the surf in recovering gold from these deposits.

Surf washers are similar to long toms, but wider and shorter. They can be used only when the surf is of proper height. They are set so the incoming surf rushes up the sluice, washes material from the screen box or hopper, and retreating, carries it over the riffles and plates. One man can attend to two surf washers, and about 8 cubic yards can be handled per 10 hours.

An example of a simple surf washer is a riffled sluice 3 to 4 feet wide and 8 to 10 feet long, set on the sand at the water's edge so that the incoming waves wash through it to the upper end, and retreat below the lower end. The sluice is made of boards nailed to sills at either end which can be weighed down with rocks or otherwise. The sides are 4 or 5 inches high. The riffles in the example are made in sections of about 1- by 1-inch strips spaced about 1 inch apart. The end sections are transverse riffles, the center section longitudinal. The box preferably is set on a grade of 8 to 10 inches per 12 feet. Best results are obtained by using mercury in the riffles. When the surf is strong, the washer treats as much as two men can shovel, but at other times it has to be fed very slowly.

Skindiving (Combining Recreation)

In recent years skindiving enthusiasts have taken up small-scale placering as both a hobby and a sometimes, though seldom, profitable venture.

Various kinds of apparel and equipment are used, but the investment is usually not great. Wet suits and canvas shoes are almost a necessity for entering cold mountain streams to search the streambed for pockets that might contain gold. Beginners should be equipped with a snorkel, a face mask, gloves, a weighted belt, fins, a gold pan, and a crevicing tool. More experienced divers may use the popular scuba equipment, but this calls for special knowledge to insure safety. Crevicing tools include large spoons, tire irons, crowbars, etc.--almost anything that can reach into tight places and dislodge nuggets from the stream bottom. The pan should be used to test sands from various places where gold would be expected to settle, such as the downstream sides of obstructions. Where colors in the pan indicate a favorable area of the stream, a more intense search may be made.

Mining equipment may include various combinations of pumps, miniature dredges, and riffle boxes that can be built from salvage by the operator or purchased from commercial sources. A number of manufacturers have produced special equipment for the purpose. One of the popular kinds is the jet dredge, a pipelike device made of sheet metal curved at the intake end and with a water jet entry to propel the water and gravel through the straight portion. The jet is supplied from a portable pump and in effect causes gravel and sand to be sucked into and through the pipe. A riffle box built into the end section collects the gold and other heavy particles while the rest of the material discharges. The riffle box may be enclosed so it can function while submerged. Usually, a 6- to 10-horsepower pump is adequate; the hose to the jet may be 1-1/2 to 2 inches in diameter.

Manipulating the device underwater requires skill and patience, since the riffle section must be kept nearly horizontal during the mining operation. Floating platforms are sometimes used to support equipment. In this case, riffle boxes and other units may be installed on the platform. The usual operation includes moving many large boulders to get at the trapped gold underneath or alongside. Conventional equipment such as a rocker or a sluice may be employed to carry selected material from the streambed to a shoreline site for processing. Concentrates are then panned to recover the gold.

PROBLEMS YOU SHOULD ANTICIPATE IN PLACER MINING

Besides the many problems already discussed, such as where and how to find a placer deposit, how to locate a claim, and how to sample and mine, a few special operational problems should be considered. These relate to the physical nature of placer materials and the climatic conditions under which they may be found.

Streams with steep gradients often have poorly sorted sands and gravels, meaning a wide range of size will be encountered, up to cobbles and large, irregularly shaped boulders. Other debris and tree roots may be present too. Materials that have lain in place for long periods become indurated (that is, bound up tightly with clay, or cemented sometimes almost to the point of being solid rock), which makes them exceedingly difficult to break up with water. Irregularities in the rock surface underlying placer materials become important in mining because this is the zone where the richest values usually are found. A very uneven surface can be particularly difficult to work on. In addition, there is difficulty in Alaska where ground may be frozen a large part of the year. It may be impractical for the weekend or vacation prospector to tackle placers where such adverse conditions prevail. How these problems are normally dealt with in larger operations is discussed briefly under the headings to follow.

Handling Boulders

Boulders are best left in place if it is at all possible to work around them. Sometimes, particularly in sluicing, it becomes necessary to move the boulders out of the way. A derrick operated by a hand winch or steam, gasoline, or electric power may be used for this purpose. Possibly several such derricks will be needed if many boulders are present. Boulders may be drilled with a jackhammer and blasted using dynamite, or more simply blasted with an explosive plastered onto the rock, a technique called "mudcapping." Platform skips may be swung from a derrick boom or cableway; the larger rocks are then pried out and rolled into the skip for removal. A small bucket-loader vehicle may be useful for handling boulders, provided it can operate over the type of surface exposed on the pit floor. Sections of the pit where bedrock has been cleaned up may be reserved for stacking large rocks. Future operations should be planned so repeated handling is avoided.

Trouble With Clays and Cemented Gravels

Clays and cemented gravels usually require the cutting force of the hydraulic giant for effective mining. In some nonfloating washing plants the gravel is delivered to the head of the sluice where a giant is used to break up the clay. Indurated or clayey materials are normally dredged with little difficulty, but if gravels are tightly cemented, they may best be mined by shaft or drift methods using explosives and timbering as required. This presumes they are rich enough to stand the high cost of such mining and are not exposed enough for open pit mining. Clay lumps must be broken up quite thoroughly before passing through gold-recovery equipment because of their capacity to imbed gold particles and carry the gold out with the discharge. The breaking of clays can be accomplished using the puddling box (previously described on p. 29) or with a trommel, which quickly reduces the lumps by its rotation and abrading action. Exposure of clays to air is also effective in breaking them down, although the time required may be a matter of days or weeks.

Cleaning Bedrock

Cleanup of the last remaining materials from bedrock is an important step in gold placering, and if the surface is soft, fractured, or uneven, this can be a painstaking chore. Where bedrock is soft and fractured, gold particles can be embedded as much as several feet, so it often is advisable to also excavate this kind of bedrock material for its gold content. Usually, it is best to clean the bedrock as the work progresses upstream. A final cleaning of the surface may be left until the end of the season, when there is more time to spend on this activity and when the water is short for other work.

Where bedrock is hard it must be cleaned largely by hand, and the soft seams and cracks invariably present should be cleaned out with handtools. A hose and small pump are almost necessities for a good cleanup. Sometimes a separate sluicebox smaller than that used in the main operation will be employed for handling materials from a cleanup operation.

RECOVERING YOUR GOLD AND SELLING IT

As you reach the final stage in turning arduous labors into a product, the gold should be in either of two forms--a nearly pure concentrate or an amalgam with mercury--depending upon whether the latter was used to implement the collection of gold. Placer gold in its natural form is almost always alloyed with a certain amount of silver, which decreases its fineness. The silver, being much lower in value or price per ounce, lowers the value of the gold by a corresponding amount. Fineness is based on a scale of 0 to 1,000. As an example, gold 750 fine would be three-fourths gold and probably close to one-fourth silver. The important thing is that the gold until it is refined will be worth somewhat less than the market price for pure gold. The exception to this, of course, is specimen material that may have special value in its natural form.

Gold in an amalgam can be heated or retorted to drive off the mercury, leaving a gold sponge. Great care should be taken when this is done to avoid inhalation of the mercury fumes, which are highly toxic and which can cause a variety of ailments or even death. Small quantities of amalgam may be heated on an iron surface, such as a shovel face, out-of-doors where the vapors will be quickly dispersed. Preferably, a retort is used for environmental reasons and personal safety. Mercury, which partially vaporizes at ordinary room temperatures, will vaporize completely at about 675° F, so an ordinary fire or propane burner will suffice. Small retorts are commercially available, or they can be constructed out of a small cast iron pot with a tight-fitting cover to which a short length of water-jacketed condenser pipe is connected. A typical setup may have a sloping pipe 2 to 4 feet long encased in a larger diameter pipe through which water is circulated. A coating of chalk or clay inside the pot will prevent the gold from adhering to the iron. The pot is heated gently at first, raising the temperature gradually until mercury stops coming from the condenser outlet. Mercury thus recovered is ready to reuse for amalgamation, and the spongy mass of gold can be sold. Because amalgams are difficult to sell, it is usually best to retort your own and market the gold.

Gold is priced and sold by the troy ounce, which should not be confused with the better known avoirdupois ounce. A troy pound consists of 12 troy ounces and is equivalent to 0.8229 pound avoirdupois. A button of gold that weighed 1 pound avoirdupois would contain about 14.6 troy ounces. Normally, gold is weighed on special troy scales so the confusion in this odd conversion is eliminated.

When selling gold, the owner must comply with a number of requirements laid down by the Federal Government and administered by the Department of the Treasury. The following statement relating to gold in its natural state, gold amalgam, and retort sponge was issued by Treasury's Office of Domestic Gold and Silver Operations in January 1969 and sums up the pertinent gold regulations then in effect:

> "Gold in its natural state" is defined in the Gold Regulations as being gold recovered from natural sources, which has not been melted, smelted or refined, or otherwise treated by heating or by a chemical or electrical process. This gold may be purchased, held, sold, transported within the United States, imported or held in custody for domestic account only without a Treasury Department license under the provisions of Section 54.19 of the Regulations, regardless of the amount involved.
>
> Gold in its natural state which has been recovered from natural sources in the United States and which has not entered into industrial or monetary use, may be exported without a license. In connection with the exportation of such gold, the exporter is required to execute and file in duplicate a certification on Form TG-34 on which information is required concerning the amount, source and description of the gold, and the consignee. Copies of this form are available from the Office of Domestic Gold and Silver Operations, Department of the Treasury, Washington, D.C. 20220. The executed form should be filed in duplicate--the original with the customs office at the port of export and the copy with the Office of Domestic Gold and Silver Operations.
>
> Pursuant to amendments to the Gold Regulations which were effective March 18, 1968, the U.S. mints and assay offices no longer purchase gold from private sources.
>
> Gold in its natural state and gold amalgam may be melted, smelted or refined or otherwise treated by heating or by a chemical or electrical process only pursuant to a Treasury license or without a license within the limitations contained in Section 54.19 of the Gold Regulations, as explained below.
>
> Gold amalgam results from the addition of mercury to gold in its natural state. Gold amalgam produced from domestic sources may be dealt with in the same manner as gold in its natural state.
>
> In addition, gold amalgam may be heated to a temperature sufficient to separate the mercury from the gold (but not to the melting temperature of gold), without a license by the person, or his duly authorized agent or employee, who recovered the gold from natural deposits in the United States or a place subject to the jurisdiction thereof. The retort sponge (amalgam cake) resulting from the heating of the amalgam may be held and transported by the person who mined or panned the gold, without a license, except that he may not hold at any one time an amount of retort sponge produced by him which exceeds in fine gold content 200 fine troy ounces.

Retort sponge produced by a miner or panner may be sold to a person holding a Treasury Department gold license authorizing the purchase of such gold, or to unlicensed persons provided that such unlicensed persons do not hold, at any one time, more than 200 fine troy ounces of gold. Persons other than the miner or panner, who acquire retort sponge, may sell the gold only to the holder of a Treasury license.

An unlicensed person may not retort gold purchased by him from miners or other persons, nor may he sell the retort sponge resulting therefrom.

Gold in melted or treated form may be sold or disposed of only by persons and concerns operating under a Treasury gold license authorizing the disposition of gold in such form.

In addition, buyers of gold may also be required in some States to hold a State license.

The dollar value received for gold will vary somewhat since the introduction of a two-level price system in 1968. Previously the U.S. Treasury had purchased gold for $35 an ounce, less a small charge for service and melting. Currently, one price exists for official monetary transactions at $35 an ounce while another exists for private transactions based on open-market demands. The price paid to the private seller of gold will depend not only upon the fineness and purity of the gold but on day-to-day market fluctuations. Financial pages of most newspapers and industry trade journals should be consulted for latest price quotations.

Finding a buyer for small lots of gold is not as easy as one might expect. Normally, an assay is necessary to establish the purity, and a sample must be taken in such a way that it is representative of the whole amount. A typical smelter accepting gold (American Smelting & Refining Co. at Selby, Calif.)[5] quoted a refining charge of $30 per lot (1970) for such services plus a small melting charge that varied according to the quantity (the smaller the quantity, the greater the rate per ounce; for 1,000 ounces this charge was $6). Also, there were reductions from quoted market prices for other reasons such as impurities or special handling. When a sale is completed, the seller receives a settlement sheet which specifies gold and silver content, sales value, and the charges, and a check for the amount due.

A producer may prefer to sell to a dealer, of whom there are only a few that will purchase in small lots. Names of prospective buyers can usually be found in the classified section of the telephone book for larger cities under Gold and Silver Buyers. Such a buyer may require sampling and assay, adding the appropriate charges, or may buy simply on inspection, although discounting his offer to allow for errors in estimation. Since he will often end up selling to a smelter, his price must be low enough to permit him a profit after

[5]Reference to specific company names is made for identification only and does not imply endorsement by the Bureau of Mines.

covering the smelter charges and handling costs. A limited market exists in selling directly to a collector or jeweler, either for speculation on a future price increase or for use in special jewelry that requires crude gold.

After receiving payment, or after placing your gold in a display case or strong box, hopefully you will feel the effort was all worthwhile, even if your venture would not be considered a financial success. Perhaps because of the exercise and fresh air your health will be better than when you started.

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3. Bryson, H. J. Gold Deposits in North Carolina. North Carolina Dept. of Cons. and Dev. Bull. 38, 1936, 157 pp. Mostly about gold quartz vein deposits; contains brief summary on placers, particularly the saprolite type (gold with host rock decomposed in place).

4. California Division of Mines and Geology. Legal Guide for California Prospectors and Miners. 1962, 128 pp. Particularly written for California but contains much information of general value to mineral locators in other States.

5. Clark, W. B. Skin Diving for Gold in California. Calif. Div. of Mines and Geol. Min. Inf. Serv., v. 13, June 1960, 8 pp.

6. ____. Gold Districts of California. Calif. Div. of Mines and Geol. Bull. 193, 1970, 186 pp. Provides information and references on history, geology, and ore deposits by regions and districts.

7. Gardner, E. D., and P. T. Allsman. Power Shovel and Dragline Placer Mining. BuMines Inf. Circ. 7013, 1938, 68 pp. Many tables listing examples of operations.

8. Gardner, E. D., and C. H. Johnson. Placer Mining in the Western United States: Part I. General Information, Hand Shoveling and Ground Sluicing. BuMines Inf. Circ. 6786, 1934, 74 pp.; Part II. Hydraulicking, Treatment of Placer Concentrates, and Marketing of Gold. BuMines Inf. Circ. 6787, 1934, 89 pp.; Part III. Dredging and Other Forms of Mechanical Handling of Gravel, and Drift Mining. BuMines Inf. Circ. 6788, 1935, 82 pp. One of the most complete reviews of the overall subject of placer mining; contains many specific examples of operations.

9. Haley, C. S. Gold Placers of California. Calif. State Min. Bur. Bull. 92, 1923, 167 pp. Review of placer mining methods; productive rivers, creeks, and areas in California.

10. Jackson, C. F., and J. B. Knaebel. Small-Scale Placer-Mining Methods. BuMines Inf. Circ. 6611, 1932, 17 pp. Contains State maps showing locations of placer mining districts; discusses simple placer methods.

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[6] Many of these reports are out-of-print and may only be available now through libraries.

11. Janin, C. Recent Progress in the Thawing of Frozen Gravel in Placer Mining. BuMines Tech. Paper 309, 1922, 34 pp. Examples and operational data.

12. Johnson, F. W., and C. F. Jackson. Federal Placer-Mining Laws and Regulations; Small-Scale Placer-Mining Methods. BuMines Tech. Paper 591, 1938, 49 pp.

13. Jones, S. P. Second Report on the Gold Deposits of Georgia. Georgia Geol. Survey Bull. 19, 1909, 283 pp. Lode and placer mines described together; many details about individual properties and past operations.

14. Koschmann, A. H., and M. H. Bergendahl. Principal Gold-Producing Districts of the United States. U.S. Geol. Survey Prof. Paper 610, 1968, 283 pp. One of the most complete reviews of gold mines and districts published to date; includes locations of placer areas and production information; bibliography of geological reports.

15. Lyden, C. J. The Gold Placers of Montana. Montana Bur. of Mines and Geol. Mem. 26, 1948, 151 pp. Many details of specific operations, described by county and river or creek; good series of location maps.

16. Oregon Department of Geology and Mineral Industries (staff). Oregon's Gold Placers. Misc. Paper No. 5, 1954, 14 pp. Briefly describes past gold placer activities by stream drainages in southwestern and northeastern Oregon.

17. Pardee, J. T., and C. F. Park, Jr. Gold Deposits of the Southern Piedmont. Geol. Survey Prof. Paper 213, 1948, 156 pp. Relatively technical, but one of the best reviews available on gold along the eastern flank of the Appalachian Mountains from Virginia to east-central Alabama; contains detailed lists of gold localities.

18. Peele, Robert. Mining Engineer's Handbook. John Wiley & Sons, Inc., New York, 1947, 2 volumes. Technical and authoritative; divided into sections covering all phases of mining.

19. Purington, C. W. Methods and Costs of Gravel and Placer Mining in Alaska. U.S. Geol. Survey Bull. 263, 1905, 473 pp. Written during period of great activity in Alaskan goldfields; information on hydraulic mining, special problems with frozen ground, and description of early dredging.

20. Romanowitz, C. M., H. J. Bennett, and W. L. Dare. Gold Placer Mining. Placer Evaluation and Dredge Selection. BuMines Inf. Circ. 8462, 1970, 56 pp. Covers dredging from "doodle-bug" to large bucket-line and offshore operations, things to consider in exploration and evaluation of deposits, typical operating costs.

21. Staley, W. W. Gold in Idaho. Idaho Bur. of Mines and Geol. Pamph. 68, 1946, 32 pp. Gives placer production by county; includes district maps showing locations of gold veins, mines, and prospects.

22. Thomas, B. I., D. J. Cook, E. Wolff, and W. H. Kerns. Placer Mining in Alaska: Methods and Costs at Operations Using Hydraulic and Mechanical Excavation Equipment With Nonfloating Washing Plants. BuMines Inf. Circ. 7926, 1959, 34 pp. Some typical operations in recent years. Describes "sluiceplate" mining.

23. U.S. Bureau of Land Management. Regulations Pertaining to Mining Claims Under the General Mining Laws of 1872, Multiple Use, and Special Disposal Provisions. Circ. 2149, 1964, 45 pp. Covers regulations on placer location and patenting.

24. U.S. Bureau of Mines. Production Potential of Known Gold Deposits in the United States. BuMines Inf. Circ. 8331, 1967, 24 pp.

25. U.S. Department of the Air Force. Search and Rescue Survival. Air Force Manual, AFM 64-5, August 1969, 136 pp. Contains a brief, concise section on first aid and has many suggestions on how to survive in a variety of situations.

26. U.S. Department of the Treasury. Gold Regulations.(Revised May 1, 1969), 17 pp. States regulations regarding possession, transport, foreign trade, and sale of gold in all forms.

27. Vandenburg, W. O. Placer Mining in Nevada. Univ. of Nev. Bull., v. 30, No. 4, May 15, 1936, 180 pp. Particularly good discussion of placer mining where water is short. Nevada deposits discussed by county and district.

28. Vanderwilt, J. W., and others. Minerals Resources of Colorado. Denver, Colo., Min. Resources Board, 1947, 547 pp. Contains good maps showing locations of Colorado placers.

29. von Bernewitz, M. W. Treatment and Sale of Black Sands. BuMines Inf. Circ. 7000, 1938, 21 pp. Concentration, amalgamation, and extraction of gold from heavy sands.

30. Wells, E. H., and T. P. Wooten. Gold Mining and Gold Deposits in New Mexico. New Mexico Bur. of Mines and Min. Resources Circ. 5 (revised ed.), 1940 (report reissued in 1957), 24 pp. Limited information on placers; deposits described by counties and districts.

31. Wells, J. H. Placer Examination: Principles and Practice. Bur. of Land Management Tech. Bull. 4, 1969, 155 pp. Excellent technical report on sampling procedure and estimation of gold values in placer deposits; contains glossary of terms used in placer mining.

32. Wilson, F. D. Arizona Gold Placers, Part 1 of Arizona Gold Placers and Placering. Arizona Bur. of Mines Bull. 160, Min. Tech. Series 45, 1952, pp. 11-86. Placers described in good detail by county and district; many individual operations cited.

33. Wimmler, N. L. Placer-Mining Methods and Costs in Alaska. BuMines Bull. 259, 1927, 236 pp. Useful information on all methods of placer mining; emphasis on Alaskan problems with seasonal activities.

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I. C. 6787 October 1934

DEPARTMENT OF THE INTERIOR

UNITED STATES BUREAU OF MINES
JOHN W. FINCH, DIRECTOR

INFORMATION CIRCULAR

PLACER MINING IN THE WESTERN UNITED STATES

PART II. HYDRAULICKING, TREATMENT OF PLACER CONCENTRATES, AND MARKETING OF GOLD

Sluice Box and Riffle section Only.

BY

E. D. GARDNER AND C. H. JOHNSON

Sluice Boxes

Construction

Sluice boxes are rectangular in section and are nearly always built of lumber; steel or iron sluices, however, were used at a few washing plants operated in 1932.

The construction of a wooden sluice box depends somewhat upon the size and service expected of the box; a number of types, however, may be used satisfactorily. Common types of construction for large and small boxes are illustrated in figure 13.

The important features in design are sturdiness and simplicity of construction. Large flumes may have to withstand severe battering and vibration from the passage of heavy boulders, hence they must be strongly constructed and well braced. In small flumes this feature is less important, but the use of lighter lumber increases the difficulties of maintenance and prevention of leaks.

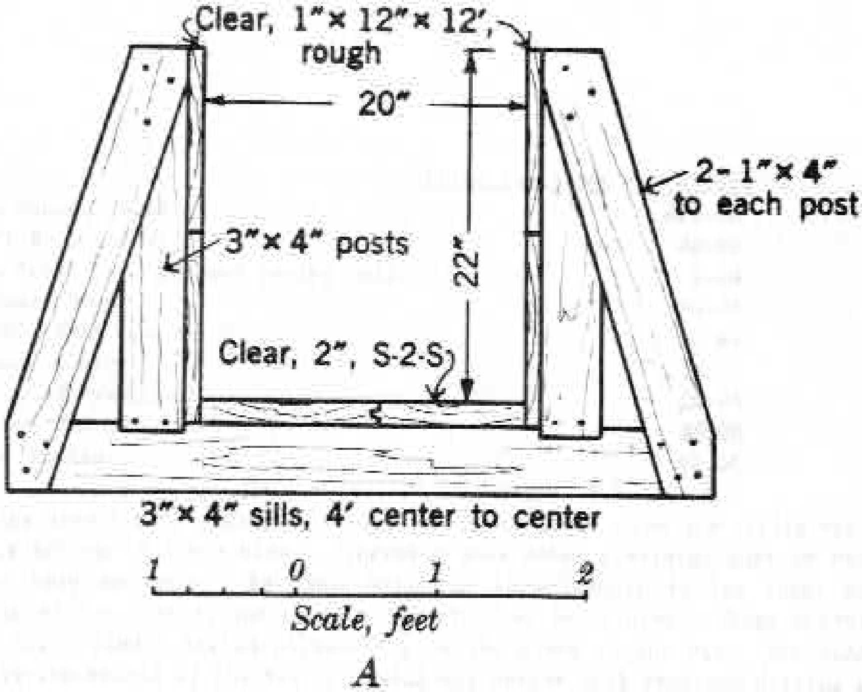
The bottom of a narrow sluice should be a single plank if lumber of the desired width is obtainable; for wider boxes two or more bottom planks must be used. The bottom joints may be made tight by the use of soft-pine splines, by batten strips nailed on the outside, or by caulking with oakum or other material. Bowie[30] recommends half-seasoned lumber as most suitable for the construction of boxes. Where local timber is used it is common practice to cut the plank during the dry season or before snow is off the ground. It is not customary to use surfaced lumber for boxes, although a smooth bottom facilitates the clean-up. The lumber should be clear and of uniform size.

For any but small, temporary installations the sides of sluice boxes should be lined with a wearing surface of rough lumber or sheet iron. Otherwise the entire box must be replaced when the sides are worn out. Board lining is easier to place and replace than sheet iron. In early Californian practice some of the side linings were made of wide, thin blocks nailed on so as to present the endgrain to the wear. Worn iron or steel riffles are used for side lining at some places. Usually only the lower half or third of the side of the box needs this protection, and a single 2-inch board may serve not only for lining but as a cleat to hold down the riffles. False bottoms of planed or rough boards may be used to save wear on the box proper.

Each box should rest on three or four sills, equally spaced. The sills and upright members at the ends of the box serve as battens to prevent leakage at joints. The practice of tapering the box enough to permit a telescope joint is very convenient in small sluices, especially if the boxes must be moved occasionally. Small, three-board boxes may be braced with ties across the top, although this hampers shoveling and clean-up operations. Larger boxes should be braced externally from the ends of the sills, as illustrated in figure 13, A and B. Sills should be weighted with rocks to check any tendency of the sluice to rise. If the sluice is placed in a bedrock or other cut, water under it or at the sides has a strong lifting effect. Moreover, the vibration caused by boulders rolling through the sluice permits fine gravel to be washed under the sills placed on the ground.

The following table shows the price of lumber suitable for building sluices at various places in the summer of 1932:

30 Bowie, A. J., Hydraulic Mining in California: Van Nostrand Co., New York, 3d ed., 1889, p. 220.



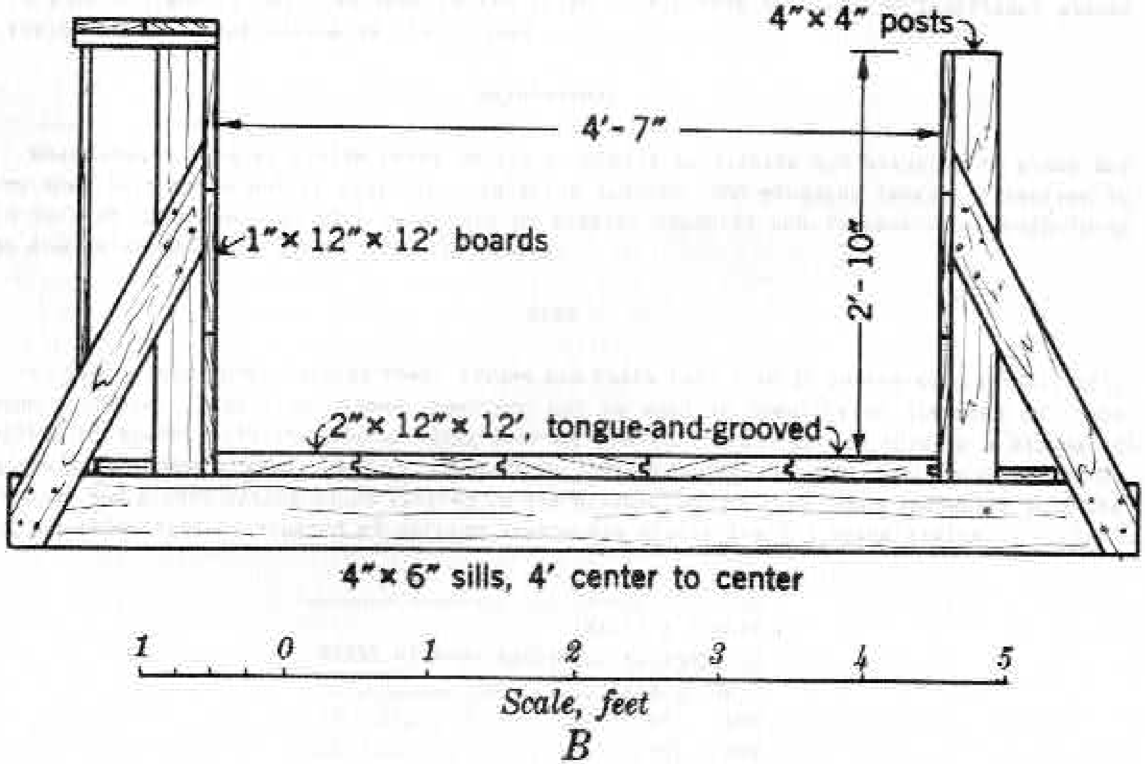


Figure 13.—Sluice-box construction: *A*, Twenty-inch box at Henderson mine, Gold Creek, Mont.; *B*, five-foot sluice box.

	Price per 1,000 board-feet
Oregon House, Calif.	$25.00
Sawyers Bar, Calif.	30.00
Waldo, Oreg. (cutting and sawing only)	8.00
Wenatchee, Wash.	20.00
Emigrant, Mont.	20.00
Townsend, Mont.:	
1- by 12-foot	28.00
2- by 16-foot	35.00
Therma, N. Mex.	22.00

As mentioned, the side lining plank may serve as a cleat under which the riffle sections can be wedged to the bottom of the sluice. Otherwise some other provision must be made as the riffles must be held securely. In small boxes it is customary to lay long, narrow boards on edge on top of the riffles and against the sides of the sluice. These boards are wedged down tightly under cleats nailed permanently to the sides of the box. The practice of nailing riffles to the bottom of the box, or using any device that requires driving nails in the bottom or sides, should be avoided as it results in leaks and eventually damages both sluice and riffles. Wooden blocks are the most difficult to secure in place but can be held by the method described in the following section. Rock pavement depends on its weight, on being packed tightly, and sometimes on the slight downstream tilt of the individual stones to resist the shifting action of the current.

Maintenance

Maintenance work on sluice boxes consists chiefly in alining and bringing to grade any boxes that have moved out of position, replacing linings, and plugging leaks. Attention to this work at clean-up time will be repaid by greater capacity and freedom from break-downs when the water again is turned into the sluice.

Size

As previously shown, sluice boxes seldom are built less than 10 inches wide for strictly mining purposes. Eight-inch boxes, however, may be used in sampling or cleaning up. The quantity of water, with its accompanying load of gravel, that will run through a sluice of a given size depends upon a number of factors. The practice at the majority of about 75 hydraulic and ground-sluice mines visited in the preparation of this paper indicates that the carrying capacities of sluices of various widths are within the following limits:

Width of box, inches	Miner's inches of water	
	From	To
12	25	100
18	100	300
24	200	600
36	500	1,300
48 to 60	1,000	3,000

These limits probably represent good practice.

More trouble is experienced from clogging of boxes that are too wide, because the depth and velocity of water are insufficient, than from failure of boxes to carry their load because they are too narrow.

The current velocities required to transport different sizes of material have been studied; works of various authorities are cited by Gilbert.[31] The following table is based chiefly on Dubuat's figures for competent velocity; the figures are adjusted to approximate mean velocity instead of bed velocity. The last three figures are taken from Van Wagenen.[32]

Size of material moved	Mean velocity, approximate feet per second
Sand:	
Fine	0.5
Coarse	1.0
Gravel:	
Fine	1.5
1-inch	2.5
Egg-size	4.0
Boulders:	
3- and 4-inch	5.3
6- to 8-inch	6.7
12- to 18-inch	10.0

Well-rounded pebbles are easier to move than angular ones, and rock of low specific gravity is appreciably easier to wash than heavy, dense rock such as greenstone or basalt. Gold has a better opportunity to settle and be caught in riffles in a wide, shallow stream than in a deeper and narrower stream of the same volume; the wider sluice, however, usually must be set on a steeper grade.

Small- or medium-size boxes generally are roughly square in cross-section; large boxes usually are one half to two thirds as deep as they are wide. The water in a sluice should always be more than deep enough to cover the largest boulder that may be sent through. In practice, the depth of the stream in the main sluice at hydraulic mines usually is a fifth to a half the width of the box so as to prevent spills if the box is temporarily plugged by boulders or sand. Where screened gravel is being washed, as in undercurrents or on dredges, wide and shallow streams are necessary for the recovery of fine gold. In "booming" operations the boxes usually are run full in order to handle the relatively large volumes of water that flow for short periods only, and the sluices commonly are about as deep as they are wide. It would be desirable but impracticable to decrease the depth of water by using wider sluices, as flows of 5,000 to 10,000 miner's inches are not unusual when the gate of the reservoir suddenly is opened wide.

Grade

Usually the grade of the sluice depends upon the slope and contour of the bedrock. If the gradient of bedrock, however, is to low to permit sufficient fall for the sluice, cuts or tunnels may be run in the bedrock to overcome this difficulty. Very short sluices of only

31 Gilbert, G. K., The Transportation of Debris by Running Water: U.S. Geol. Survey, Prof. Paper 86, 1914, p. 218.
32 Van Wagenen, T. F., Manual of Hydraulic Mining: Van Nostrand Co., New York, 1880, p. 88.

1 or 2 boxes sometimes are set nearly flat where there is a drop at the end of the box, the gravel being forced through the sluice by the initial velocity and the head of water in the pit.

The opinion of most operators is that about 6 inches in 12 feet is the best grade for average conditions. As shown, grades as flat as 3 inches in 16 feet can be used but only at great loss of capacity. At the Depot Hill mine, where a grade of 3 inches in 14 feet is used, all rocks over 5 or 6 inches in diameter must be left in the pit. Because of the greater friction and the consequent lowering of velocity, steeper grades are needed for small sluices than for large ones; some operators favor grades of 12 inches to a 12-foot box. For maximum gold-saving efficiency, as well as for economy in dump room, grades should be as flat as possible without lowering the velocity to such an extent that the riffles pack with sand. Any increase in slope from that adjustment will increase the capacity of the sluice, increase the wear on the sluice, and decrease the efficiency of the riffles, resulting in gold losses if carried to extremes or if the gold is very fine. If water is scarce, gold recovery may well be sacrificed to capacity. Bowie[33] states that grades of 10 to 24 inches were used in some Forest Hill Divide (Calif.) mines for this reason. Increasing the proportion of water to solids decreases the tendency of riffles to pack with sand.

Sluice capacity increases with grade but more rapidly; that is, doubling the grade of sluice boxes will more than double the quantity of gravel that can be put through the boxes by a given flow of water. The absolute increase cannot be predicted closely as coarseness of gravel, velocity, and shape of the box appear to have some bearing on the relation of capacity to slope. For instance, Bowie[34] cites a mine at which changing the grade from 3 to 3 1/2 inches in 16 feet increased the quantity of gravel sluiced through the same boxes with the same flow of water by about one third.

The established grade should not be decreased anywhere along a sluice, otherwise gravel may accumulate where the current loses velocity. If the water and gravel, however, enter the first box with considerable speed, say, from the discharge of a hydraulic elevator, the first boxes may be placed on less than the regular grade. Bends or curves are undesirable as they complicate construction and induce clogging and running over. When a curve is unavoidable it should be as gradual as possible, the outside of the sluice should be elevated a fraction of an inch, and the grade should be increased perhaps an inch per box at and immediately below the curve. Similar rules apply to turn-outs or branches, and drops of 3 or 4 inches should be provided at junctions to check the deposition of gravel at these points. Such drops occasionally are inserted in straight sluices if the grade is available, particularly if the gravel is a difficult one to wash or if heavy sand tends to settle to the bottom. A drop of even a few inches from one box to the next has a disintegrating effect and mixes the material passing through the sluice, thus assisting gold recovery. At one place where drops were provided at intervals between different types of riffles, 25 percent of the gold recovered in the sluice was found at the drops.[35]

Riffles

Theory of gold-saving by riffles

The function of riffles is to hold back the gold particles that have settled to the bottom of a flowing stream of water and gravel. Any "dead" space in the bottom of a sluice

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33 Bowie, A. J., A Practical Treatise on Hydraulic Mining in California: Van Nostrand Co., New York, 3d ed., 1889, p. 220.

34 Bowie, A. J., work cited, p. 266.

35 Theller, J. H., Hydraulicking on the Klamath River: Min. and Sci. Press, vol. 108, Mar. 28, 1914, pp. 523-526.

box, where there is no current, fills quickly with sand and thereupon loses most of its value as a gold saver, unless the sand remains loose enough to permit gold to settle into it; therefore, the shape of riffles is important, regardless of the fact that under some conditions, as with coarse gold and free-washing gravel, all forms of riffles are almost equally efficient. The riffle should be shaped so as to agitate the passing current and produce a moderately strong eddy or "boil" in the space behind or below it, thus preventing sand from settling there and at the same time holding the gold from sliding farther down the sluice. In other words, riffles, for maximum efficiency, should provide a rough bottom that will disturb the even flow of sand and gravel, will retain the gold, and will not become packed with sand. Where grade is lacking the riffles must be relatively smooth, so as not to retard the current unduly; under these conditions the sluice must be long enough to compensate for the loss in gold-saving efficiency of the individual riffles.

Natural stream beds act as gold-saving sluices, not because they are particularly efficient as such but because most gold is "hard to lose" and the streams are long.

Types of riffles

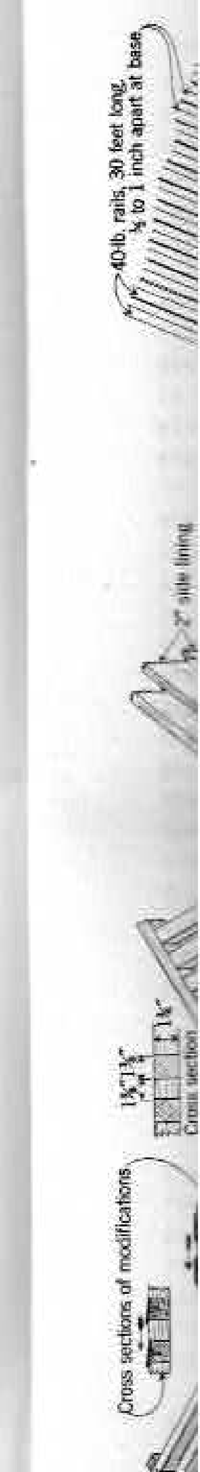
Riffles, of course, should be designed so as to save the gold under the existing conditions. They should also be cheap, durable, and easy to place and remove. Not all these qualities are found in any one type.

Sluice-box riffles may be classified roughly as transverse, longitudinal, block, blanket, and miscellaneous roughly surfaced ones, or, according to material, as wood block, pole, stone, cast iron, rail, angle iron, fabric, and miscellaneous. Usually more than one type of riffle is used, although in California very long sluices have been paved entirely with wood-block riffles, and on dredges the type illustrated in figure 14,A, is used almost exclusively.

Of about 80 hydraulic, ground-sluice, and mechanically worked placer mines visited in 1932 by the authors, approximately 25 percent used riffles of the transverse variety, loosely termed "Hungarian", consisting generally of wooden crossbars fixed in a frame and sometimes capped with iron straps. About 20 percent used the longitudinal pole type, 15 percent wooden blocks, and 15 percent rails, the last being placed crosswise or lengthwise. Angle-iron riffles, wire-mesh screen or expanded metal on carpet, blankets, or burlap, rock paving, and cast-iron sections together made up the remaining 25 percent. The only general rule observed was that the size of the riffles was roughly proportional to the size of the material to be handled and that for fine material, particularly the screened gravel washed in most of the mechanically operated plants, the dredge-type riffle found most favor.

For a small or medium-size sluice (if lumber is costly and a plentiful supply of small timber, such as the lodge-pole pine so common in many Western States, is available) peeled pole riffles (fig. 14 B and C) are perhaps the most economical and satisfactory of the various types. Their construction is evident from the drawing. Those of transverse variety may have a somewhat higher gold-saving efficiency, but undoubtedly they retard the current more and wear out faster. Poles 2 to 6 inches in diameter may be used, spaced 1 or 2 inches apart. Such riffles are cheap but wear out rapidly. The sections should be a third or half the box length for convenience and 1 or 2 inches narrower than the sluice. At the Golden Rule mine 6-inch pole riffles had to be replaced every 10 days or after each 1,200 cubic yards had been sluiced. The sluice was 30 inches wide and had a grade of 8 inches in 12 feet. At other mines poles last several times as long.

If sawed lumber can be obtained cheaply, riffles similar to the one described may be made of 1- by 2-, 2- by 2-, or 2- by 4-inch material, as shown in figure 14, D and E. The top surfaces of the riffles may be plated with strap iron (fig. 14, F and G). Transverse



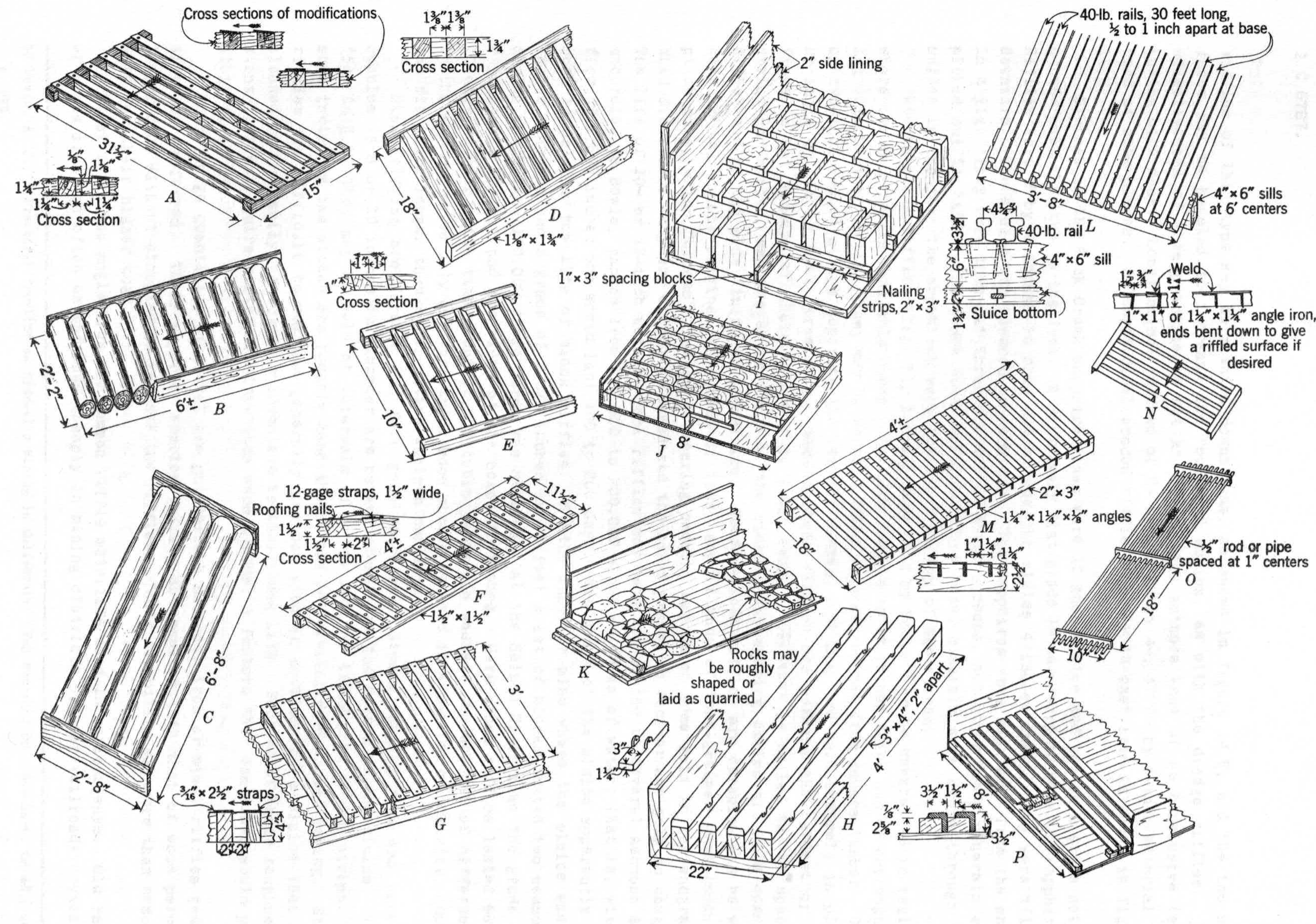


Figure 14.- Types of riffles: A, Transverse wooden, steel-capped riffles used on dredges; B, transverse pole riffles; C, longitudinal pole riffles; D, transverse wooden riffles, square section; E, transverse wooden riffles, beveled section; F, transverse wooden riffle, steel-capped, inclined section; G, transverse wooden riffles, steel-clad, with overhang; H, longitudinal wooden riffles capped with cast-iron plates; I, wooden-block riffles for large sluices; J, wooden-block riffles for undercurrents; K, stone riffles; L, longitudinal rail riffles on wooden sills; M, transverse angle-iron riffles; N, transverse angle-iron riffles with top tilted upward; O, longitudinal riffles made of iron pipe; P, transverse cast-iron riffles used in undercurrents.

riffles of this type may be slanted downstream, as shown in figure 14,F, and the top surfaces may be beveled to increase the "boiling" action, as with the dredge riffles. The effectiveness of this practice is not known, and the authors know of no conclusive tests having been made. Longitudinal riffles of 2- by 4-, 3- by 4-, or 2- by 6-inch material are used at some places. A longitudinal wooden riffle capped with cast iron is shown in figure 14,H.

Sluices in the Rock Creek sapphire mines were 12 inches wide and set on a grade not to exceed one half inch to the foot. A relatively flat grade is necessary to save the sapphires. Riffles were 2 by 4 inches in size set across the sluice 4 inches apart; they were tilted downward. The sluice was cleaned up each day. The sapphires were separated from the sands in a jig. They were then put through a set of seven screens, and other heavy minerals were picked out by hand. The black sand and other fine heavy minerals were drawn through the screen in the jig; the sapphires were taken off on top of the screen.

Wooden-block riffles (fig. 14, I and J) are held by Bowie[36] to be unexcelled in regions where the material is available cheap. The blocks are 4 to 12 inches thick and of corresponding diameters or widths. They may be round, partly squared, or cut from square timber. One- or two-inch wooden strips separate the rows of blocks, and they are held securely in place by nails driven in both directions. Wooden-block riffles are perhaps the hardest of all types to set because of their tendency to float away. They must be nailed to the spacing strips, as stated, and wedged securely at the sides. The spacing strips are held down at either end by the side lining of the sluice. Wooden-block riffles are durable, can be worn down to half their original thickness or less, and if made of long-grained wood (such as pitch pine, which "brooms" instead of wearing smooth) may catch some gold in the endgrain. When discarded, they are commonly burned and the ashes panned to recover any gold so caught. The life of 10- or 12-inch wooden-block riffles may be a few months to several seasons and, according to Bowie, ranges from 100,000 to 200,000 miner's inches of water; that is, with a flow of 1,000 inches one would last 100 to 200 days. The grade of the sluice apparently has much to do with the life of block riffles. At the Superior mine where the sluice was 48 inches wide and had a grade of 2 3/4 inches in 12 feet a set of blocks lasted two seasons, during which time 140,000 cubic yards was sluiced. At the Salmon River mine the grade was 7 inches in 12 feet and the width of the boxes 30 inches. Here block riffles lasted 60 to 70 days, during which time about 18,000 cubic yards was washed. On account of differences in the wearing rates only one variety of wood should be used in a section of a sluice. Douglas fir wears longer than other native western conifers.

Stone riffles are durable and fair gold catchers. Stones ranging from the size of cobbles to 8 or 10 inches in diameter are packed closely on the bottom of the sluice. (See fig. 14,K.) They may be held at intervals of a few feet by transverse wooden strips. In some instances the stones are roughly hand-shaped and set similarly to street paving. Stone riffles are difficult to set and generally are not used in portions of a sluice that are cleaned up frequently. Their main advantage is their long life. Because of their roughness, stone riffles require a steeper slope than wood blocks, a feature that sometimes would prohibit their use.

Where large quantities of gravel are put through sluices, iron or steel riffles generally are preferred. Their superior wearing quality as compared with that of wood permits longer runs without stopping to replace the riffles. Their durability may more than compensate for their higher cost.

Steel rails and angle iron are common riffle materials used in various ways. Old rails or angle iron can often be obtained cheaply in mining districts or near railroads. Various

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36 Bowie, A. J., A Practical Treatise on Hydraulic Mining in California: Van Nostrand Co., New York, 3d ed., 1889, p. 225.

other steel products such as pipe and channels have been utilized for riffles. Cast iron is also used and has the advantage of a lower first cost than steel rail or angle iron.

Iron or steel riffles should not be used in units too long to be handled readily. Rope blocks on movable tripods have found favor at some places for lifting heavy riffle sections.

When used as transverse riffles lengths of steel rail usually are set upright, the flanges almost touching or not more than 1 or 2 inches apart. Where grade is lacking and gold saving is not particularly difficult, longitudinal rail riffles make excellent paving for a sluice as they provide a smooth-sliding bottom for the gravel and boulders. The rails ordinarily are bolted together by tierods passing through wood, pipe, or cast-iron spacing blocks, forming riffle sections the width of the sluice and any convenient length. At the La Grange mine in Trinity County, Calif., 40-pound rails costing about $125 per ton proved more satisfactory than wood riffles.[37] When 16- by 16- by 13-inch wood blocks were used the riffles tended to "sand up." Moreover, the blocks had to be replaced every 2 or 3 weeks. Lengthwise rails 8 inches apart lasted 2 months and rails 5 inches apart, 4 months. Strangely enough, transverse rails 5 inches apart lasted 6 months. The rails were spaced by cast-iron lugs and set right side up on timber sills. When the head of the rail was worn off the remainder was used for side lining. This sluice was handling a flow of about 4,000 inches of water and 1,000 cubic yards of material per hour, boulders as large as 7 tons being washed through. The eddies behind the rails were believed to be the cause of the improved recovery as compared with that using block riffles. The lower part of the branching sluice line was cleaned up every other season only.

The combination of steel rails and wooden sills used at the La Grange mine appears to make an excellent gold saver, and modifications have been used at many large mines. Figure 14,L, illustrates a combination of longitudinal rails and transverse timber sills.

At the Round Mountain mine 25-pound rails were placed longitudinally in a 36-inch sluice with a grade of 4 inches in 12 feet. After about 150,000 cubic yards had been run through the sluice the center rails showed considerable wear and were removed to the outside. At the Lewis mine on Rogue River a set of riffles made of 40-pound rails lasted 15 seasons. The sluice was 30 inches wide and had a grade of 8 inches in 12 feet. About 7,000 cubic yards was washed yearly. Only material under 5 inches in diameter was run through the sluices.

Angle iron is commonly used for making riffles, as illustrated in figure 14, M and N. Many methods of assembling the lengths of angle iron into riffle sections are in use, and no one method can be said to excel. The irons may be set with flat upper surfaces or inclined slightly to increase the riffling action. Usually the gap between the riffle bars is 1/2 to 1 inch. The effectiveness of this type of riffle is believed by some operators to depend largely on the vibration of the riffles under the impact of boulders which keeps the sand trapped under the angles in a loose condition favorable to gold saving.

Figure 14,O, illustrates an unusual all-metal riffle used at a Colorado drift mine, which was said to be giving satisfaction and appears to be simple to construct and convenient to use. The riffling effect could be increased, with some loss of velocity, by spacing the transverse bars closer.

Cast-iron riffles of all shapes and sizes have been used. If available at low cost they are very economical, as they wear slowly, can be quickly and securely placed, and are efficient gold savers if designed so as not to pack with sand. In an undercurrent at the Indian Hill mine, Calif., cast-iron riffles were in use that were 4 feet long, shaped like angle irons, and had equal 3 1/2-inch legs 7/8 inch thick. (See fig. 14,P.)

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37 MacDonald, D. F., The Weaverville-Trinity Center Gold Gravels, Trinity County, Calif.: U.S. Geol. Survey Bull. 430, 1910, pp. 48-58.

One property in California was reported to be using old car wheels for sluice paving. They were laid close together, flange side up, in a box just wide enough to hold one row of wheels. The riffling action caused by the hubs, webbing, and spaces between adjacent wheels and under the flanges was said to have resulted in a satisfactory gold recovery. A gravel-washing plant in Arizona was provided with riffles made of standard 2-inch pipe and 2 1/2-inch angle iron welded into riffle sections resembling pole riffles. This riffle should be fast-running and as efficient as any longitudinal type of riffle, relatively light, and easy to handle. It would not be durable enough for very heavy gravel and would be relatively expensive unless salvaged material and welding equipment were available.

For shallow sluice streams carrying only fine material various gold-saving materials are used, including brussels carpet, coco matting, corduroy, and burlap. These may be held down by cleats or by wire screen. Fabrics often are used in combination with riffles to catch fine gold and hinder its being washed out of the riffles by eddies. A corduroy woven specially for a riffle surface is used by some large Canadian lode-gold mines to catch their "coarse" gold before flotation or cyanidation. As such gold would be considered fine by most placer miners it seems probable that such a fabric would be useful for treating finely screened placer sands. The corduroy in question has piles about 1/4 inch wide and 1/8 inch high, spaced about 1/4 inch apart. The piles are beveled slightly on one side. The cost in Canada is about $1.00 per square yard.

Heavy wire screen such as that used for screening gravel makes an excellent riffle for fine or medium-size gravel in fairly shallow sluice streams, and generally it is used with burlap or other fabric underneath.

Expanded metal lathing and woven metal matting are common types of riffles for fine material and are used with carpet or burlap. If the thin strands of metal slant considerably in one direction, the material should be placed with this direction downstream. Eddies in back of the strands will then form gold catchers, whereas if the recesses face upstream they will at once fill with a tight bed of sand and lose their effectiveness.

A matting woven of twigs or cane is recommended by Idriess[39] as an efficient gold catcher for a small, portable sluice box for shoveling-in operations or prospecting. Turf, as used at the Hockensmith placer in Idaho, is said to make an efficient trap for fine gold.

Solid-rubber riffles were noted at one washing plant. Sponge-rubber riffle material is on the market, but it was not observed in use and nothing is known by the authors of its merits or cost.

Another form of riffle often used as an auxiliary to other types is a mercury trap, consisting of a board the full width of the sluice with 1- or 1 1/2-inch auger holes in which mercury is placed. Instead of round holes, transverse grooves or half-moon-shaped depressions, 2 to 4 inches wide and with the rounded, deep side downstream, may be cut in a wide board and partly filled with mercury. These riffles have no apparent advantage over the ordinary transverse-bar type and are suitable only for fine gravel, as large pebbles would splash the mercury out of the traps.

Many ingenious and odd kinds of riffles are encountered in the field, some of which have been patented. It is very unlikely, however, that the advantage of any unusual or freakish design of riffle is sufficient to offset the cost of royalties on patented inventions.

Undercurrents

An undercurrent, as defined before, is a device for sluicing separately a finer part of the gravel passing through the main sluice. The fine material and a regulated quantity of

39 Idriess, I. L., Prospecting for Gold: Angus & Robertson, Sydney, 3d ed., 1932, pp. 64-65.

water pass through a stationary grizzly in the bottom and usually near the end of the sluice to one or more wide sluice boxes, commonly called tables, paved with suitable riffles. If the main sluice is in sections, with drops between, the water and sand may be returned from the undercurrent tables to the main stream, and several undercurrents may be installed at convenient points along a sluice.

The screen or grizzly in the main sluice may present the most difficult problem in building a satisfactory undercurrent. The screen should divert all the undersize yet not take so much water that it causes plugging of the main sluice below the undercurrent. The proper size of opening can be determined only by experiment. A screened or barred opening, the full width of the main sluice and a few inches to a foot or more long, will usually draw off as much water as can be spared. New water may be added to either the undercurrent or main sluice if the screen opening does not take out the right quantity for successful operation. Usually minus 1/4- to 1/2-inch material is desired for the undercurrent, and either punched-plate screen or iron-bar grizzlies may be used to make the separation. Grizzlies should be made of tapered bars or screens punched with tapered holes with the largest openings downward, otherwise they will plug and render the undercurrent ineffective.

Because undercurrents need a wide, shallow stream, grades of 12 to 18 inches per 12 feet must be used, depending largely on the type of riffle. Cobblestone, block, transverse or longitudinal wooden strips, rails, screens, or fabrics may be used for riffles. Often several types of riffles are used on successive parts of one undercurrent. Undercurrents may be a few to 25 or 30 feet wide and 10 to 50 feet long.

Most of the gold recovered by undercurrents is so fine that it does not settle in the relatively swift, deep current of the main sluice, but part consists of gold that is freed from its matrix of clay by dropping through the grizzly and rolling over the undercurrent riffles. All coarse gold is saved in the first few boxes of the main sluice unless conditions are radically wrong. Unless the undercurrent is installed at the end of the sluice, or at least below where gold is recovered, not all the saving in the undercurrent should be credited to its installation. In the early days when hydraulicking was at its height undercurrents were much favored, sometimes 5,000 to 10,000 square feet of undercurrent being used along a single sluice line. The gold saved in them occasionally exceeded 10 percent of the total clean-up but more often was less than 5 percent. As this recovery usually was effected by 5 or 10 large tables and as considerable would have been saved by the main sluice without the undercurrents, the economy resulting from their use was perhaps doubtful. Bowie[39] presents details of the use of undercurrents in early Californian practice and indicates that their particular field lay in the treatment of cement gravels. Of the several undercurrents observed by the authors in use in 1932 it is doubtful, as shown before, if many were justifying their installation. Table 13 gives data on undercurrents in use at mines operating in 1932.

Operation of Sluice Boxes

Under favorable conditions a properly designed and constructed sluice box requires little attention other than periodic clean-ups and minor repairs which are made at the same time. Unfortunately, such a combination rarely occurs, and an appreciable part of the miner's operating expense is chargeable to work along the sluice lines.

39 Bowie, A. J., A Practical Treatise on Hydraulic Mining in California: Van Nostrand Co., New York, 3d ed., 1889, pp. 252-262.

The best results are obtained when a steady flow of water and gravel passes through the sluice. An excessive flow of clear water through the sluice will bare the riffles, causing some gold to be lost. On the other hand, a continued overload of gravel will plug the sluice at some point so that sluicing must be stopped for the time needed to clear the obstruction; this time lost may be appreciable. If plugging cannot be prevented by increasing the grade or the flow of water or reducing the feed, one or more sluice tenders must work along the sluice with forks or shovels to keep it open. This added cost may be serious at small mines. All effort should be directed toward getting the gravel into the box and letting the water do the rest.

Large boulders are another cause of expense and lost time. When the maximum size of boulder that the sluice will carry is known, all boulders larger than this should be prevented from entering the boxes. Relatively little work directed to this end will save hours of delay in clearing plugged sluices and unnecessary wear and tear on the boxes and riffles.

An exception is found in the operation of "booming." A necessary condition of this work is a heavy head of water which usually fills the sluice to the brim. Sometimes little or no work can be done in the pit while the water is on, and the entire crew may profitably patrol the sluice with long-handled shovels to guard against stoppages which might be disastrous because of the large flow of water and gravel. Before each "boom" all oversize boulders should be moved out of the course of the water.

Cleaning Up

Clean-up time should be kept to a minimum. This can be done by cleaning up as seldom as practicable and by using efficient methods. Large hydraulic mines, particularly if the water season is short, clean up only once a season except perhaps the upper one or two boxes. Dredges clean up every 10 days or 2 weeks, because large amounts of gold are recovered in relatively short sluices with attendant possible loss when the upper riffles become heavily charged. This necessary delay is used for routine repairs on the dredge. In ground-sluicing the clean-up period ranges from weeks to months, while in shoveling-in operations the sluice may be partially cleaned up daily. The danger of theft from the upper, richer boxes can be lessened by filling them with gravel at the end of each day's work.

The general principle is the same in all clean-up operations, but practice differs widely. Clear water is run through the sluice until the riffles are bare, the stream being reduced enough to prevent washing out the gold. Then the water is turned off or reduced to a very small flow, and the riffles of the first box are lifted, washed carefully into the box, and set aside. Any burlap or other fabric used under the riffles likewise is taken up, rinsed into the box, or placed in a tub of water where it can be thoroughly scrubbed. Then the contents of the sluice are shoveled to the head of the box and "streamed down" with a light flow of water. The light sand is washed away, and rocks and pebbles are forked out by hand. This operation is repeated until the concentrates are reduced to the desired degree of richness. Gold or amalgam may be scooped up, as it lags behind the lightest material at this stage, or all the black sand with the gold, mercury, and amalgam may be removed and set aside for further treatment. Successive boxes are treated similarly, until the sluice is bare. The last step is to work over the whole sluice with brushes and scrapers to recover gold and amalgam caught in cracks, nail holes, or corners. At the Wisconsin mine a small box was set up in the main sluice and the concentrate from the riffles shoveled into it to reduce the bulk. At the Round Mountain mine the concentrate from the lower section of the sluice was treated in a quartz mill.