The Giant Gold Diggers: California's Land-Going Fleet of Dredges

By Noel W. Kirshenbaum

Gold dredging, originally developed in New Zealand, commenced in California around 1898. Dredging of river and alluvial placers has recovered a sizable portion of California's total gold production: dredging produced a total of about \$3 billion in gold at its current price. At one time, approximately seventy gold dredges were operating in the state, each a mobile production unit with a self-contained recovery plant. While modern mining machinery impresses many with its size and ability to operate under rugged conditions, many decades ago dredges and their components were already of massive size. Gold dredging equipment and enterprises from California figured importantly in operations in the remotest parts of the world. Even development of efficient, modern heap-leaching operations has not succeeded in producing gold at as low an operating cost as dredging. However, this once-prominent industry has almost ceased in California, with but one large bucket-line dredge still operating.

A floating gold dredge is a remarkable machine: it is an enormous, self-contained, mobile production unit combining both mining functions and metallurgical recovery. Even at the outset, dredges were already tremendously productive, recovering gold at low cost from placer deposits. A very small crew conducted a dredge's entire mining and metallurgical operations.

Types of Dredges and Their Operation

The floating bucket-line dredge has been by far the largest producer of gold by dredging. This type of dredge has a chain of buckets which scoops up gold-bearing material from a river bed or alluvium, thereby creating and excavating the pond on which the dredge floats. This excavated ore is conveyed to the processing plant aboard the dredge. Figure 1 depicts a bucket-line dredge with its continuous chain of open buckets. The bucket assembly is illustrated in Figures 2 and 3. A typical dredge of this type has additional important components: 1) the ladder, which supports the bucket-line; 2) the gantry, which raises or lowers the ladder; 3) spud(s), which are heavy pilings used as anchors or pivots; 4) conveyors to handle the ore and waste material; 5) the wash plant, wherein gold is recovered by gravity methods and amalgamation; and 6) the stacker, over which waste or tailings are discharged to the side or behind the direction of the dredge's movement.

Besides having mining capabilities, a dredge can move itself, and its on-board facilities can recover the precious metals in the mined ore. Mooring and manipulation of a huge bucket-line dredge are matters of no small concern. The spuds and/or cables are used for both functions. Cables, passing through sheaves at the corners of the dredge, are attached to anchors (if on a wide river) or to "dead-men" on the shore. A spud can be used as a pivot, and by winching the cables, spuds are used to "walk" the entire dredge in one direction or another. Gear is provided to raise or lower the spuds. The wash plant recovers the free gold in the fine gravel after cobbles or larger particles of rock are removed by trommels (rotating screens which segregate coarse and fine material).

Besides bucket-line dredges, there are other types of dredges: Drag-line dredges have produced significant quantities of gold, but they are not floating units. Confining our attention to floating types, such

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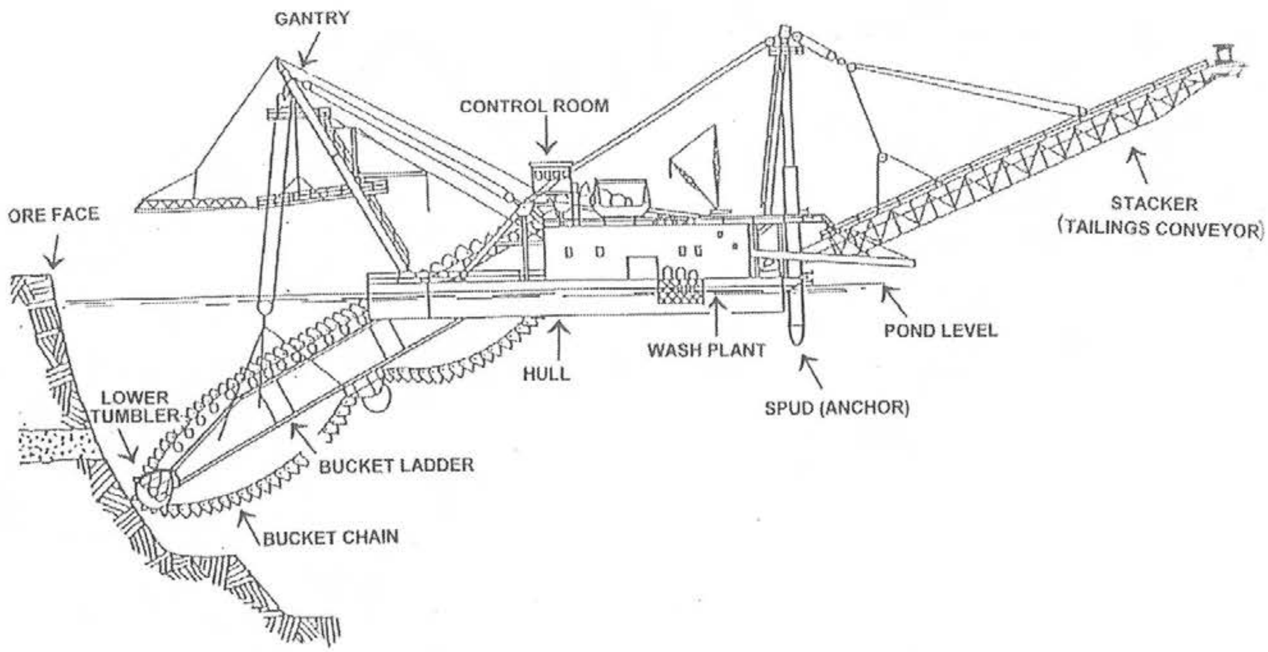


Figure 1 Schematic diagram of floating bucket-line dredge. From files of N. W. Kirshenbaum.

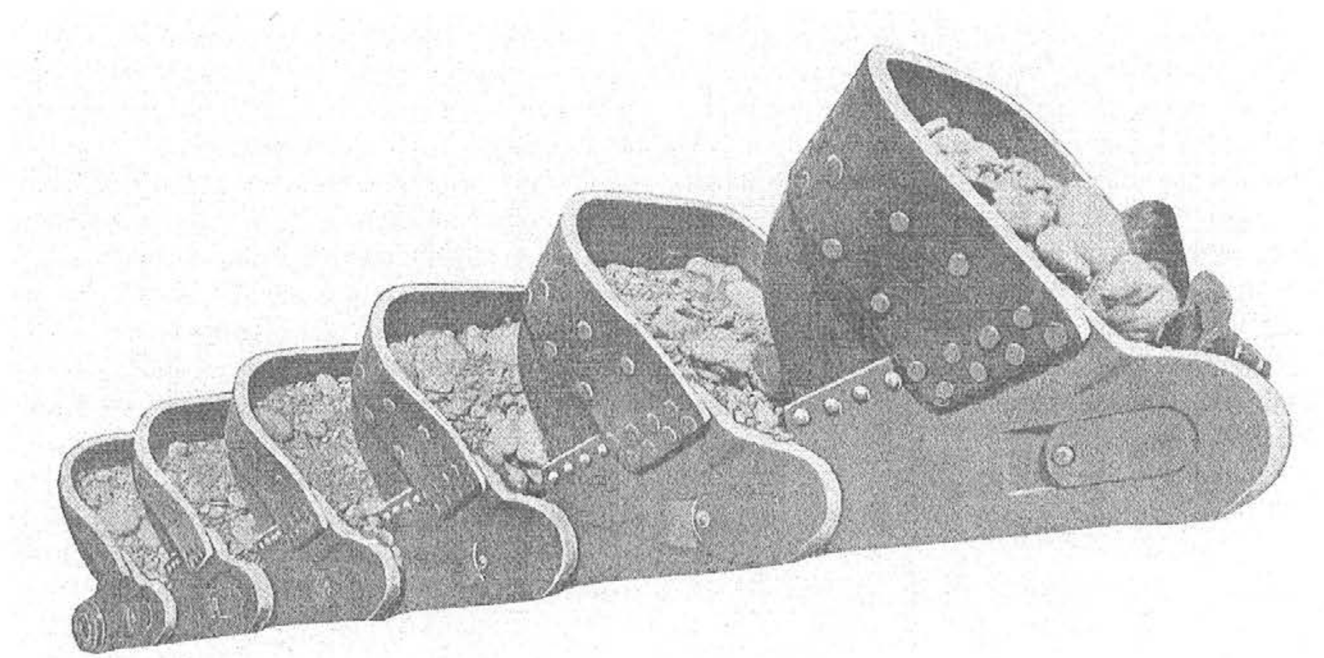


Figure 2 Bucyrus five cubic foot dredge buckets, containing ore. From *Placer Dredge Machinery*, Bucyrus Company, South Milwaukee, Wisconsin. (ca. 1900 - 05)

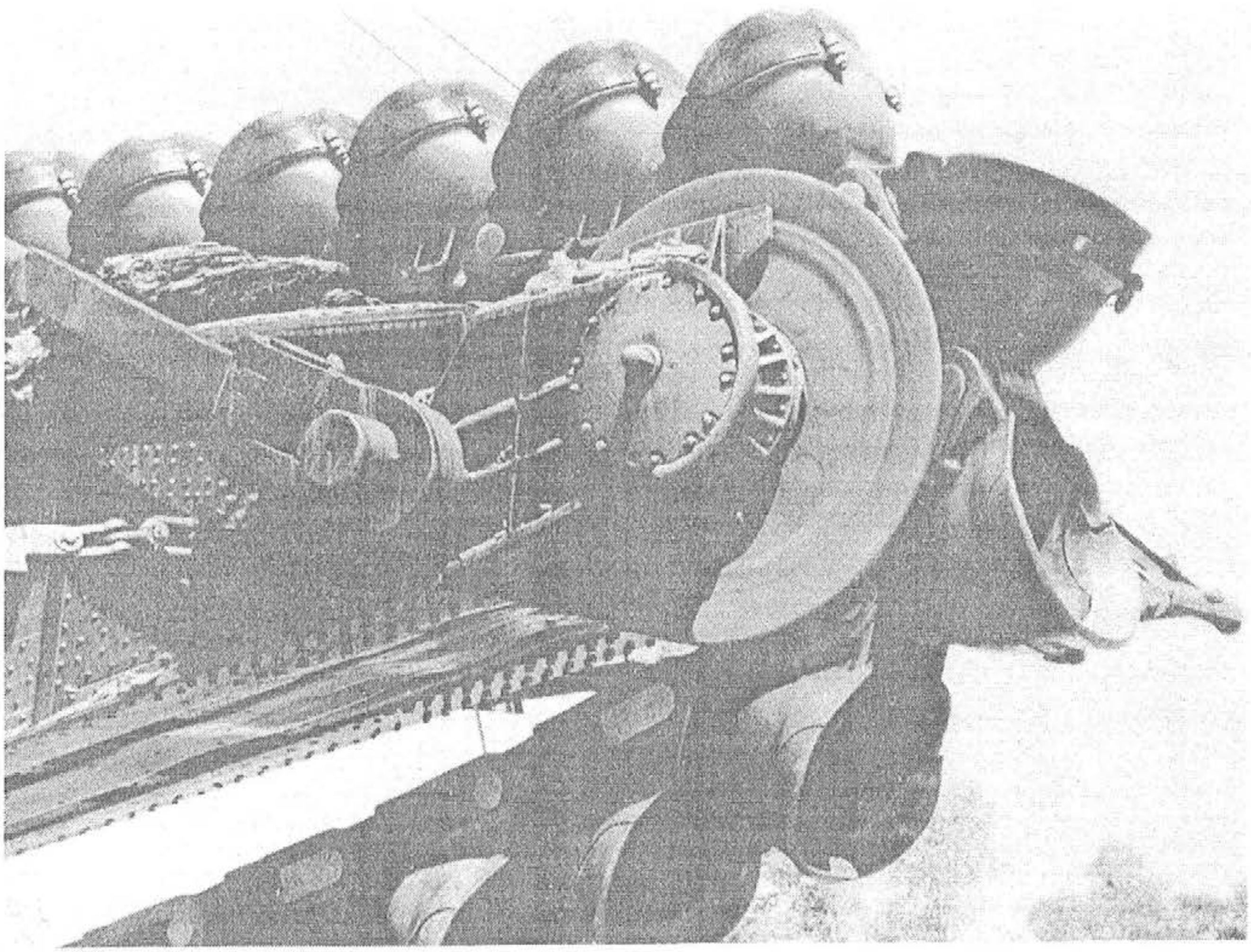


Figure 3 Lower end of digging ladder with 18 cubic foot buckets. Showing lower tumbler arrangement, buckets with bolted -on lips, and part of ladder suspension. From *Yuba Placer Mining Dredges*, Yuba Manufacturing Co., San Francisco, 1952.

dredges have included: 1) spoon dredges, a primitive unit that had a long pole attached to a dipper;[1] 2) suction dredges, that use the suction created by centrifugal pumps to recover loose material from the pond or river bottom; and 3) clamshell bucket and shovel dredges, both using a swinging crane on the floating unit.

There were several ingenious contraptions involving floating equipment, but they became obsolete quickly. These less known and less used units included:

1) *the pneumatic caisson*, which required the construction of a water-tight shaft similar to that used in building piers of bridges. A diver, at the bottom of the caisson, directed a stream of gravel from the river bed into a rock pump, which pumped the material to a floating vessel above. The Huron Submarine Mining and Construction Company had such an operation in the Sacramento River above Redding, California.[2] This concept could be successful where rich patches were known to exist, but it was a failure where the material was largely barren;

2) *the submarine dredge*, conforming with principles of the diving bell, was built but never used;[3]

3) *the vacuum dredge* (Bazin dredge and steam vacuum dredge). The Bazin dredge employed the pressure differential between the river bottom and the inside of the dredge's hull; water and auriferous sands were forced up a suction pipe projecting down from the hull to the river bed. A centrifugal pump received this material and, with added im-

pulse, delivered it to the washing apparatus. One disadvantage of this unit was that a considerable depth of water was required to produce sufficient vacuum (pressure differential) for efficient work. This defect led to the steam vacuum dredge, in which a boiler was connected to a closed chamber having a suction pipe extending down to the river bed. Steam was let into the chamber, expelling the air inside. A jet of water was then sprayed in, condensing the steam and creating a vacuum. Water, sand, and gravel (and maybe a little gold) were sucked in through the pipe to the chamber. The contents could then be discharged into a sluice. Again, however, the vacuum achieved was insufficient to provide the power and capacity required for efficient dredging.[4]

Development of Gold Dredging

The earliest attempt at gold dredging in the United States came in the 1850s when a sternwheeler river vessel was converted to a mining boat to mine gravels in the Yuba River, about nine miles east of Marysville, California.[5] This effort was, however, unsuccessful, and the development of the California dredging industry had to await events in far off New Zealand. (New Zealand, incidentally, can also take credit for having the world's first cyanide plant for the recovery of gold.) There, in the 1860s, a spoon dredge was developed for gold recovery, which used a hand-winch and rope to raise the dipper slowly and laboriously. That profitable returns could be had with this crude equipment is testimony to the richness of the deposits. During the 1870s, current-wheel dredges were used in New Zealand rivers; the flow of the river turned paddle wheels which drove a line of buckets. These "current wheelers" could only work in a running stream, as still water furnishes no power. In the 1880s, steam engines and boilers were installed in New Zealand dredges in place of undershot current wheels.

Bucket-line gold dredges were first designed and placed in service in New Zealand in 1882. By 1898, when gold dredging first started in California, New Zealand had thirty-six bucket-line dredges of six cubic-foot capacity. Soon thereafter, dredges were exported from New Zealand to Australia and Siberia. Dredging peaked in New Zealand about 1902, with almost 300 dredges in operation, being erected, or being moved.[6] This intense dredge activity in New Zealand has been attributed to the predominance of gold placers in the rivers or on nearby banks. By contrast, in California, most auriferous gravels were adjacent to or even away from existing streams, so extensive "dry-land" operations continued for a long time, using water brought in by flume or ditch to float the dredge and compensate for any seepage.

The first successful gold dredge to operate in the United States is usually said to have been in Montana, on Grasshopper Creek, near Bannock, Beaverhead County. This Bucyrus bucket-line unit started in 1895 and, after two rebuildings, achieved good results. Nevada and Georgia might also make claim to being first. An 1894 photo shows a clamshell dredge being operated at Dayton, Nevada, by the Carson River Placer Mining and Dredge Company. Moreover, a report for 1894 cites a Bucyrus "dredge-boat" operating on the Chestatee River in Georgia for the Chestatee Placer Company.[8] The following year, 1895, the number of dredge boats on the Chestatee River near Dahlonega had increased from one to three.[9] Some of these were scoop or dipper dredges.

Evolution of Gold Dredging in California

In 1897, a New Zealander, R. H. Postlethwaite, brought a bucket-line dredge design to San Francisco's Risdon Iron Works, which secured U.S. manufacturing rights. The first California dredge of this type had a sixty-seven foot ladder carrying thirty-seven buckets, each 3.5 cubic feet.[10] Placed into service in 1897 on the Yuba River near Smartsville, the dredge, 100-feet long and twenty-three feet wide, was wrecked by the river's turbulent waters. Postlethwaite learned from the experience, for he then advocated dredging on land rather than in the river. This required an excavation, with the dredge being assembled in the dry hole. By means of a flume or ditch, river water flowed to the excavation to float the dredge and overcome seepage.

The man most responsible for development of

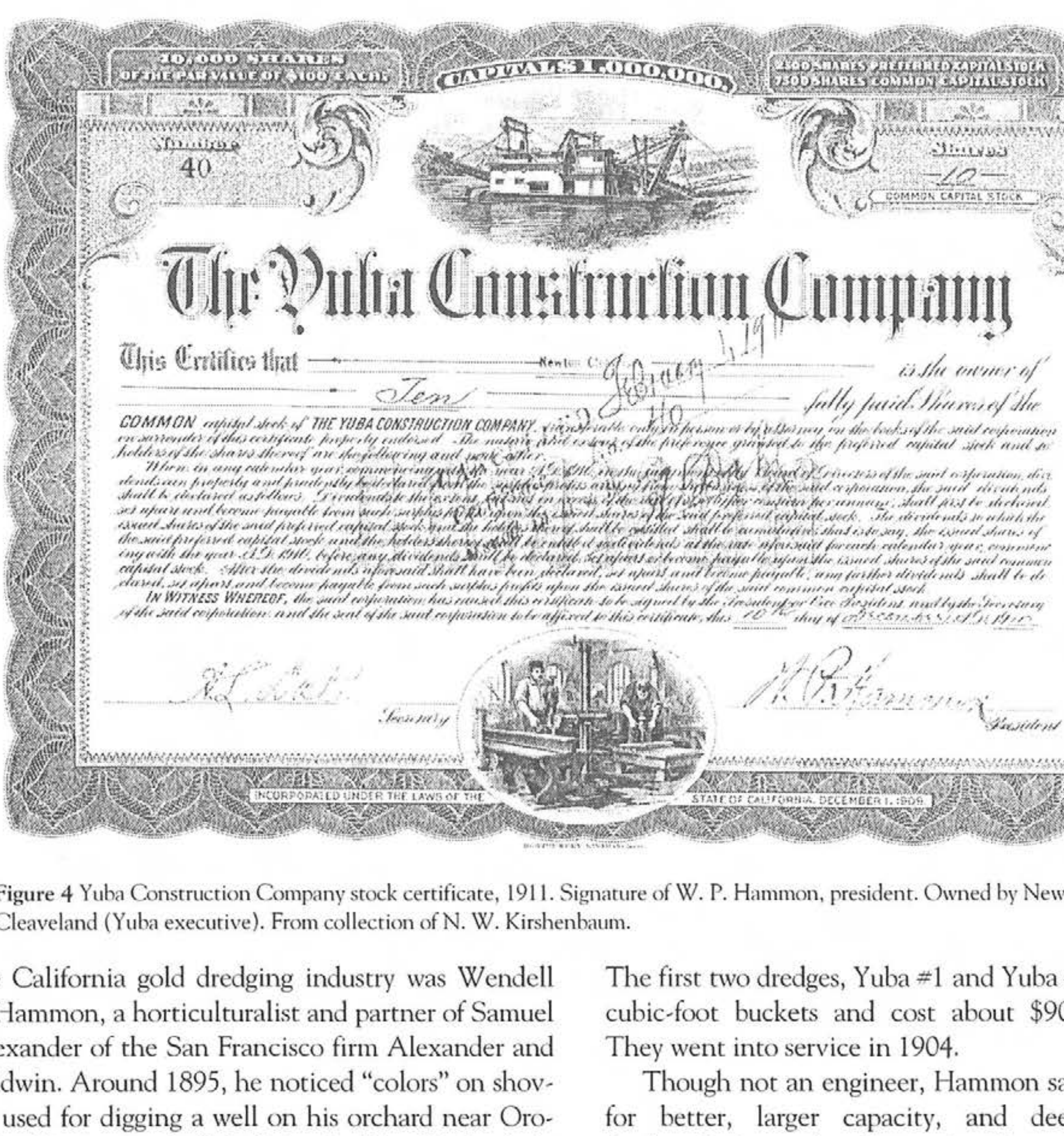


Figure 4 Yuba Construction Company stock certificate, 1911. Signature of W. P. Hammon, president. Owned by Newton Cleaveland (Yuba executive). From collection of N. W. Kirshenbaum.

the California gold dredging industry was Wendell P. Hammon, a horticulturalist and partner of Samuel Alexander of the San Francisco firm Alexander and Baldwin. Around 1895, he noticed "colors" on shovels used for digging a well on his orchard near Oroville. Having read of dredging in New Zealand, in due course he awarded Risdon Iron Works a contract to build a four-cubic-foot steam-powered dredge for operation near Oroville. This bucket-line unit, the first successful dredge in California, started operation in 1898, although many months of adjustments were required.

The Feather River area at Oroville, underlain by lava, required only relatively shallow dredging, to a depth of about forty feet. In comparison, Yuba River gravels extended down at least to sixty-five feet, making them more difficult to dredge. Hammon acquired property on the Yuba, and with some effort was able to find financing from Boston capitalists. The first two dredges, Yuba #1 and Yuba #2, had six-cubic-foot buckets and cost about $90,000 each. They went into service in 1904.

Though not an engineer, Hammon saw the need for better, larger capacity, and deeper-digging dredges. Insistent that the engineering and design be done in California and under his supervision, he formed his own engineering and manufacturing concern, the Yuba Construction Company. This later became the Yuba Manufacturing Division of Yuba Industries Incorporated (see Figure 4). He started in 1908 by buying the Western Engineering Company of San Francisco, a firm that had represented the Bucyrus Company. On the Yuba River, Hammon founded the firm Yuba Consolidated Gold Fields, probably the largest, most efficient, and most profitable placer dredge operation in the world. With his early experience at Oroville, Hammon made shrewd property acquisitions and became directly associated

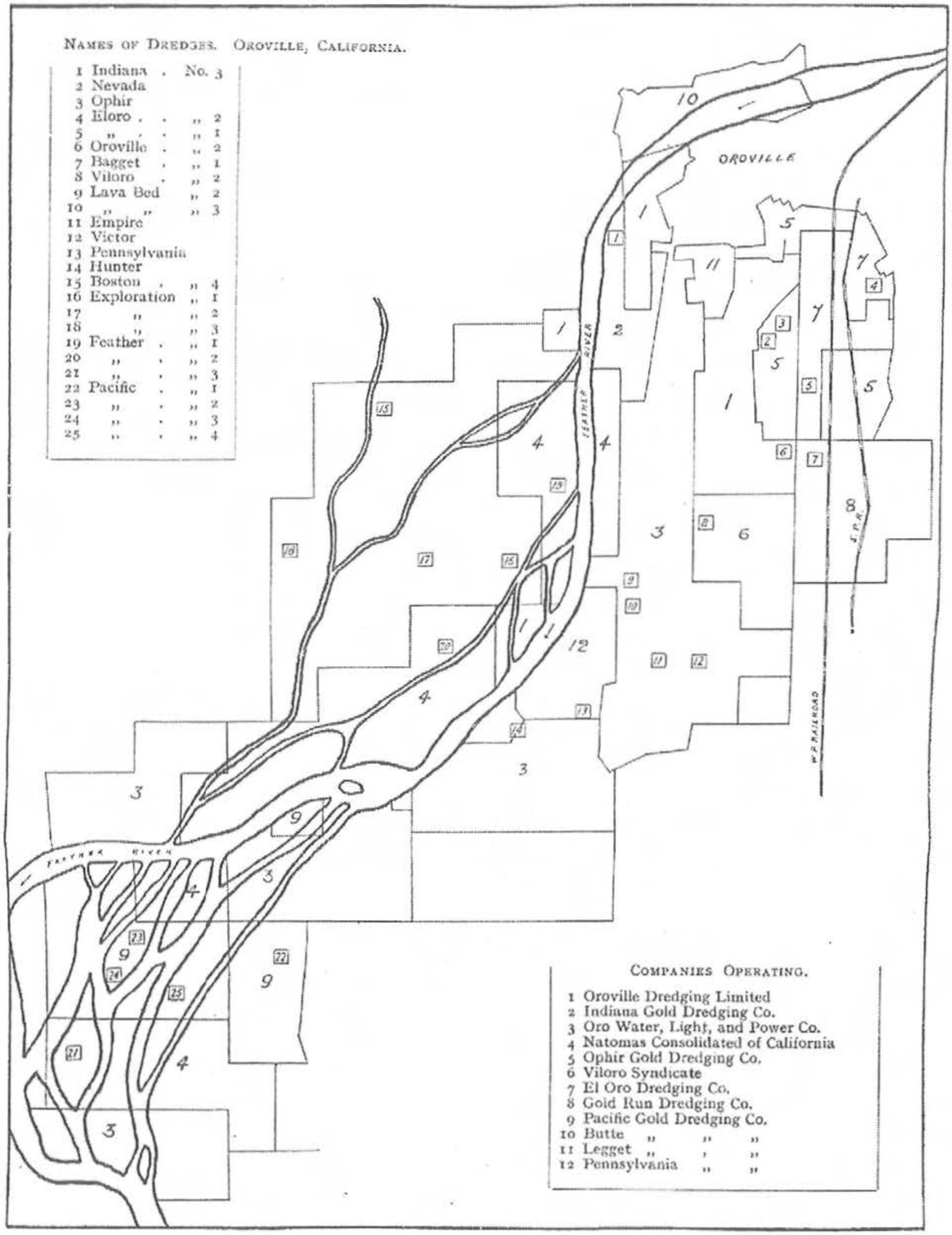


Figure 5 Dredges and dredge companies operating in Oroville District. From T. C. Earl, *Gold Dredging*, 1913.

with two other major dredging firms: Oroville Dredging Limited, financed by British capital, and Natomas Consolidated, financed by San Francisco capital.

Hammon had tremendous energies and diverse interests; he started as a farm operator and went into dredging, then into engineering and manufacturing, buying a foundry in 1913 to cast and produce heavy dredge components. He pursued gold dredging in Alaska, tin dredging in Portugal, railway and power construction in California, oil in southern California, and copper in Arizona. In 1927, Yuba acquired land on the American River near Folsom and installed four dredges; this became the Capital Dredging Company. In 1930, Yuba also acquired a small dredging company operating on the Merced River.

The early 1900s brought rapid expansion to California gold dredging. A 1910 tabulation reported thirty-one companies with a total of sixty-eight gold dredges in the state: Butte County had twenty-nine operating dredges; Yuba County had fourteen, plus two under construction; Sacramento County had ten; and gold dredges have also operated in Calaveras, Siskiyou, El Dorado, Merced, Placer, Shasta, Stanislaus, Trinity, and Amador counties.[11] In terms of total California gold production, the Hammonton (Yuba County) and Folsom (Sacramento County) dredge districts ranked with the lode mine production of the Grass Valley and Jackson-Plymouth districts of California. Third in dredge production was the Oroville District which ranked seventh overall, and the Snelling District, Merced County, was fourth in dredge production but much lower on the list of state gold districts.[12]

Until Hammon's operations began in the Yuba goldfield, the Feather and American rivers were

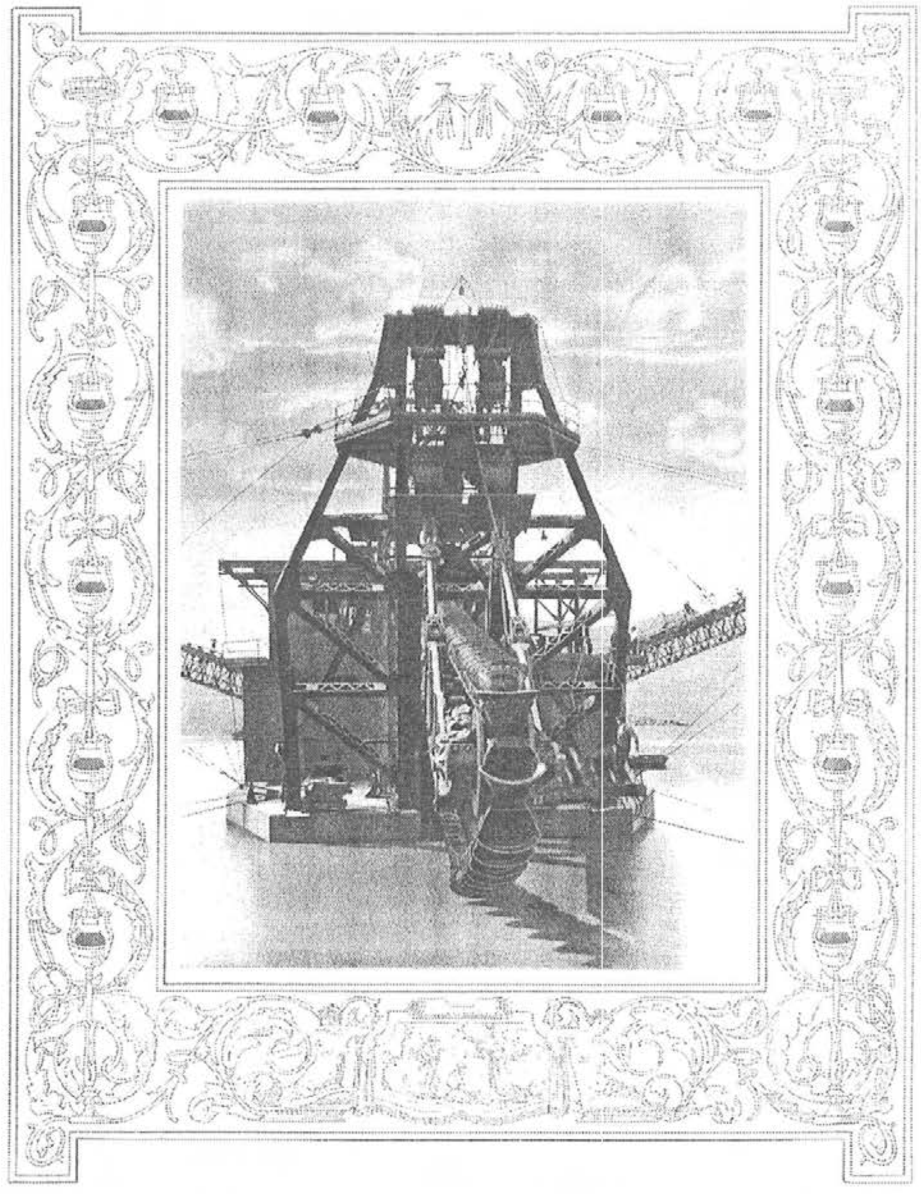


Figure 6 Frontispiece from S. P. Johnson, *Gold Dredges*, 1927. (Only the frontispiece and title have this ornate decoration on top and bottom of the page; all other pages merely have the bucket chains.)

California's main dredging areas. By 1908, thirty-five dredges and twelve dredging companies were active in the Oroville (Feather River) field alone.[13] A map of the Oroville Dredging District from a 1913 publication shows the location of twenty-five dredges and the land holdings of the twelve operating companies (see Figure 5).[14] A 1910 map of that same district details even greater intensity of dredging on land immediately adjacent to the city of Oroville: besides showing twenty-four active dredges, the map depicts location of twenty-three dismantled or abandoned dredges.[15]

The sight of these huge moving machines and the squealing and grinding noises of steel scraping against rock makes a visit to even a single working dredge a memorable sensory experience. Imagine the cacophony of twenty-four dredges at Oroville, county seat of Butte County! When dredging ceased in the Oroville field in 1952, its total gold production was estimated at 1,964,000 ounces.[16]

Yuba Consolidated Gold Fields ranked first in U.S. gold production from 1910 to 1915 and second from 1916 to 1927.[17] Over the sixty-five year period ending in 1968, Yuba dredged about 1.1 billion cubic yards at a field-operating cost of 6.3¢ per cubic yard, and a gross return of 12.75¢ per cubic yard.[18] In 1959, gold recoveries were 16.56¢ per cubic yard.[19] Estimated total dredge production from the Hammonton District was 4.8 million ounces, worth $1.3 billion at a gold price of $275 per ounce. Over its lifetime, the Yuba goldfield has been mined by twenty-two dredges, one of which still operates.

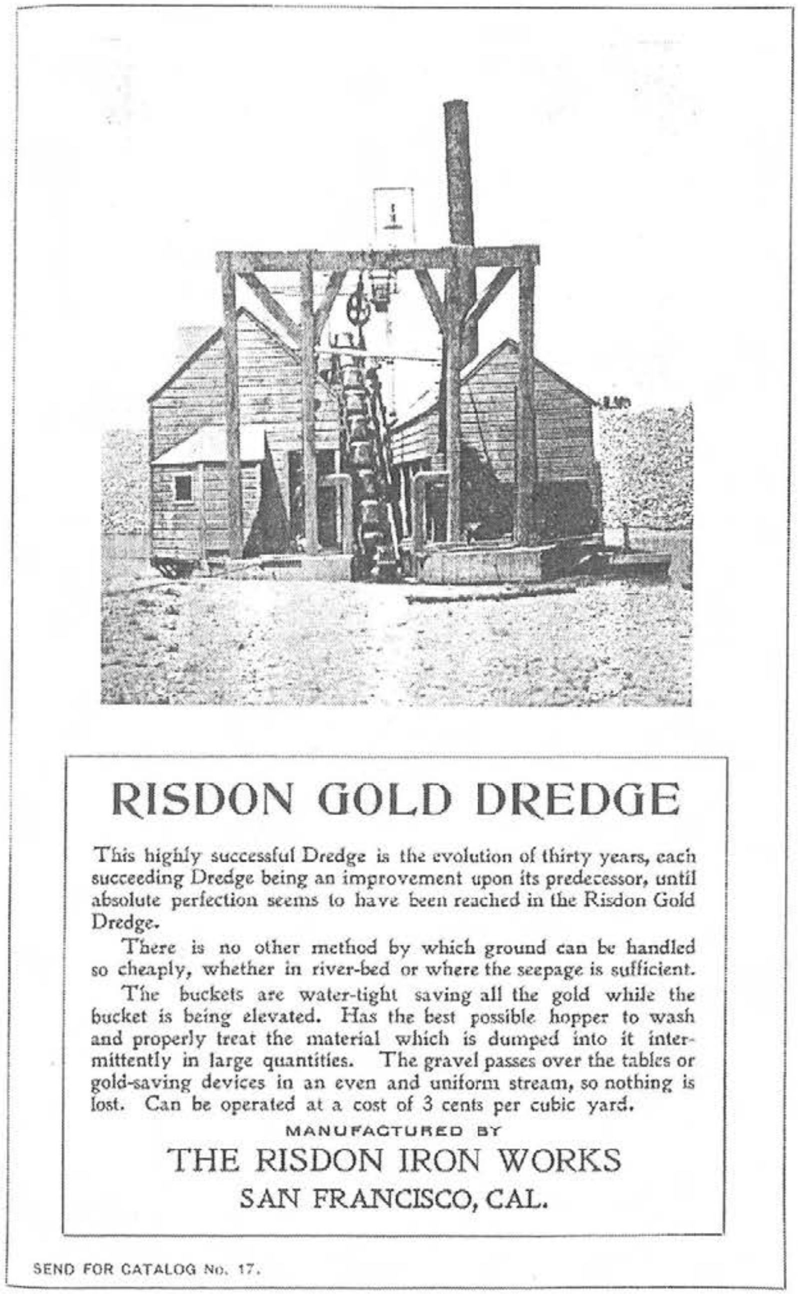


Figure 7 Advertisement for Risdon Iron Works' gold dredges. From *California Mines and Minerals, 1899*.

The Yuba organization was unique, the company being a dredge manufacturer as well as operator. Its operations were a testing ground for dredging and dredge manufacture. Dredges were moved from service in California to Guatemala, Surinam, Malaysia, Brazil, and Korea. Besides units which originally operated in California, Yuba Manufacturing built dredges for Alaska, Colorado, Idaho, Montana, Oregon, Bolivia, China, Colombia, Malaysia, New Guinea, the Philippines, and Russia.[20]

The pride the Yuba organization had in its activities is evident in a promotional book, *Gold Dredges*, printed in 1927 by the most distinguished San Francisco printer of the period, John Henry Nash.[21] Its subtitle, *The Part Played by the Yuba Manufacturing Company in the Great Romance of Dredging for Placer Gold, Platinum and Tin*, is indicative of its effusive writing style. The book is illustrated with photographs by Gabriel Moulin, another eminent San Franciscan. Each page has a beribboned border of a chain of dredge buckets printed in green (see Figure 6), and the book is hardbound in sheepskin and board.

Risdon Iron Works of San Francisco was another important California dredge manufacturer, building sixty-four gold dredges between 1897 and 1911.[22] Figure 7 is an 1899 advertisement for Risdon;[23] presumably the "evolution of thirty years" refers to New Zealand experience which, as mentioned earlier, was provided to Risdon by R. H. Postlethwaite, only a year or two earlier. In 1911, Risdon was absorbed into the adjacent Union Iron Works, then owned by Bethlehem Steel. Bethlehem continued dredge manufacture, building twenty gold dredges between 1911 and 1929.

Significance of Dredging in California Gold Production

Not long after Marshall's 1848 discovery, gold production peaked in California. The state produced nearly four million ounces in 1852, virtually all from placer deposits.[24] Neither lode nor hydraulic mining had yet become significant, and the first successful dredge was almost a half century away. Gold production quickly dropped, although until the 1880s hydraulic mining helped maintain California output. Although dredging in California started in the nineteenth century, its greatest contribution to production came in the late 1930s and lasted until 1942—a result of the 1934 gold price increase and the commissioning of large, new dredges. Total U.S. dredge production peaked at 904,149 ounces in 1940, with the industry concentrated in California.[25] From its commercial inception in 1895 to the end of 1948, U.S. bucket-line dredge production of gold totaled almost 21 million ounces, of which more than 12.5 million ounces were produced in California. Gold dredging ceased during World War II, but following the 1945 lifting of War Production Board Order L-208 prohibiting gold mining in the United States during the war, many dredges resumed activity. In 1947 and 1948, thirty-five bucket-line dredges were operating in California, but the number rapidly diminished because of inflationary conditions amid the fixed price of gold.[26]

Challenges Encountered by California Dredge Operators and Manufacturers

Environmental Concerns

In the 1880s severe regulation of hydraulic mining started in California, a result of damage caused by mining debris to rivers and lands downstream from the hydraulicking operations. In 1884, Judge Sawyer's landmark decision in the Ninth Federal Circuit Court in San Francisco prohibited the discharge of hydraulic mine tailings into tributaries of the Sacramento and San Joaquin rivers.[27] Legislation was proposed at various times to prevent accumulation of debris from dredging as well, and to prohibit the dredging of land usable for agriculture.[28] Only about 2,500 acres of arable land was claimed to be suitable also for dredging; nevertheless, because dredging debris is so visible, it is environmentally suspect even though, if contained, it is not necessarily polluting to river systems. For example, the current U.S. Geological Survey topographic map of the Brown's Valley, California quadrangle, clearly shows the landscape sculpted by the dredging operations at Hammonton; contour interval in the dredged area of this map is twenty-five feet. Figure 8 shows an aerial view of this area, with the operating dredge, as seen in the 1980s.

Transport of Dredge Components

In order to transport heavy, massive equipment from the several California dredge manufacturers to remote and distant sites, it was vital to sectionalize dredge components, especially in the days when mules were a principal mode of transportation. Even "small" dredges had heavy elements (see Figure 9). The following, extracted from a 1906 letter by

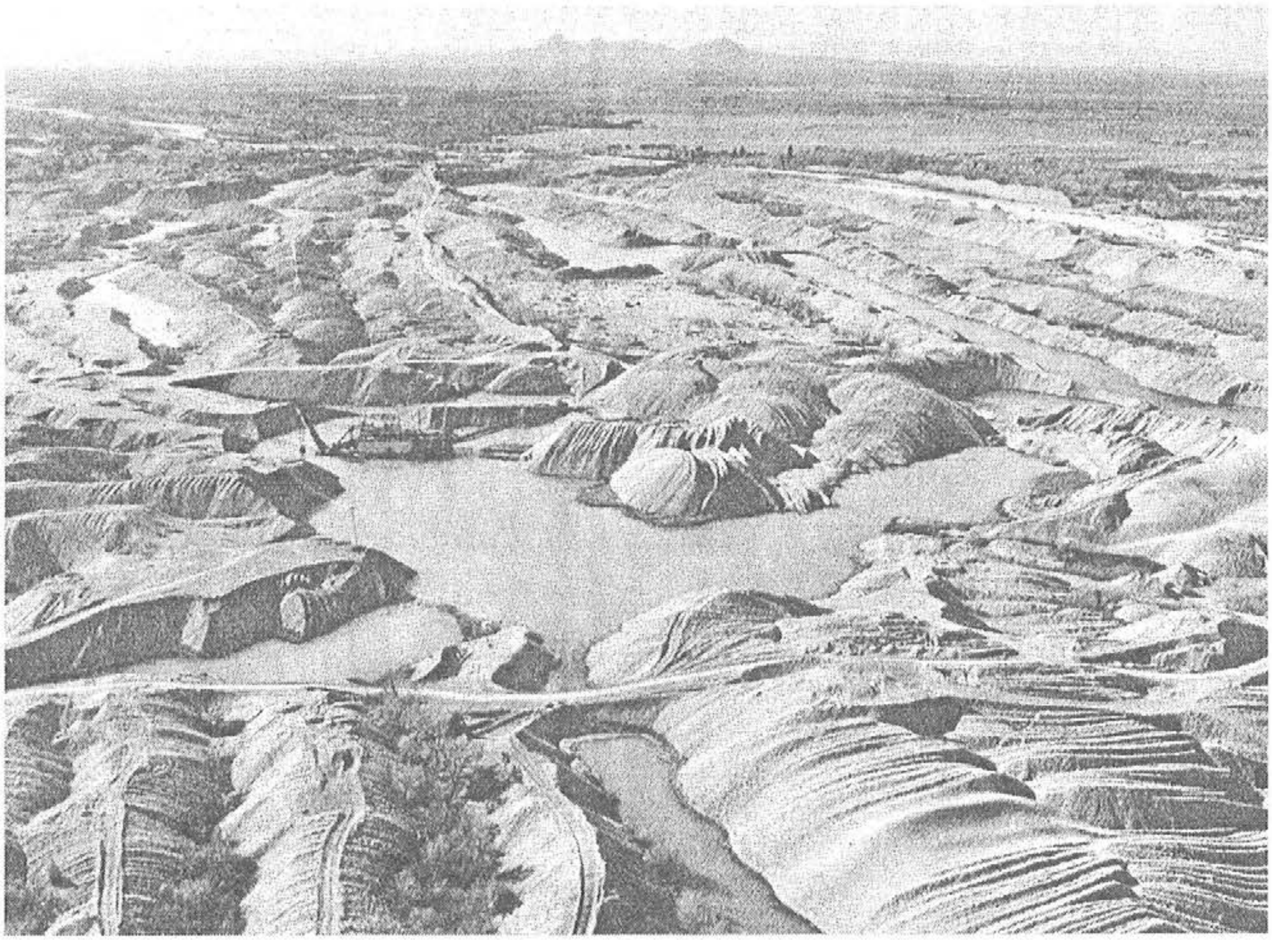
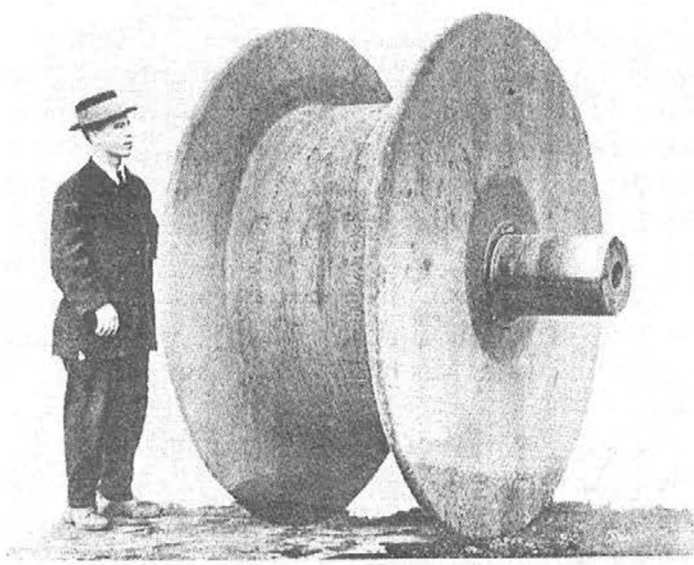


Figure 8 Portion of Yuba property with operating dredge. Yuba Natural Resources, Inc., San Diego. Annual report, 1986, cover.

D'Arcy Weatherbe, describes a problem with which Risdon Iron Works and others had to contend.[29] Weatherbe referred to the task of transporting Risdon dredge components from a point near Accra on the Gold Coast (Ghana) to a site some sixty miles inland: "The native method, of carrying the load on the head, was to be used, and, as a good porter will only take about 200 lb. in this manner, it will be readily understood that the parts had necessarily to be light. Of course, many pieces could be slung between several natives. It is related that a case is on record of a gigantic native from the Sahara carrying 400 lb. in this manner." The ladders, trommels, and buckets were sectionalized, and the riveting was done at the dredge site. Engine cylinders, weighing about 1,000 pounds each, were the heaviest single pieces. Circular parts were cased in wood and rolled along a newly



A ROUND MANGANESE LOWER TUMBLER

Figure 9 Manganese Steel Lower Tumbler of Dredge. From *Yuba Dredges*, ca.1916.

built road. However, as the road surface was graveled, the native carriers avoided the road and "took to the old trail, preferring it because the gravel hurt their bare feet."

History was made in the early 1930s when Placer Development Limited of Canada air-freighted dredge components to its remote Bulolo dredge site in the interior of Papua New Guinea. Yuba equipment from California was shipped in sections by sea to Lae, New Guinea. Special planes were designed by the Junkers factory in Germany to fly the components to the mine site. After World War I, Germany was prohibited from building military planes, but it had developed the best type of commercial aircraft. Equipped with American Hornet engines, the planes had a pay-load capacity of 7,000 pounds which was the critical load, as the dredge's upper tumbler-shaft weighed just that much.[30] To recognize this achievement, Charles Arthur Banks, Managing Director of Bulolo Gold Dredging Limited, was awarded the Mining and Metallurgical Society of America's Gold Medal in 1938 for "The Application of Aërial Transportation to the Development of Remote Mining Operations."[31]

Technological Improvements and the End of an Era

In time, dredges were built with larger buckets and with longer ladders and bucket-lines (see Figure 10). The largest Yuba dredge was #20, built in 1939, equipped (as were some others) with a line of 132, 18-cubic-foot buckets.[32] Annual capacity was 4.3 million cubic yards of gravel. Its hull was 251-feet long, 80-feet wide, and 12-feet deep. Digging depth was 120 feet below water level, and the dredge was able to build a bank or tailings pile 50-feet high—a total of more than 170 feet from top of the bank to bottom of the excavation. Along with Yuba #17 and #19, #20 was equipped with hydraulic monitors to wash the high banks into the dredge pond. The trommel screens were nine feet in diameter and from 30- to 50-feet long. These large dredges had a total crew complement of twenty-two to twenty-five men for round-the-clock operation.

Besides Yuba, many other dredging companies operated in California. Natomas was one of the longest in existence; it started dredging at Oroville about 1908 and by 1916 had a fleet of eleven dredges operating in the Folsom field's American River placers in Sacramento County. At one time, Natomas

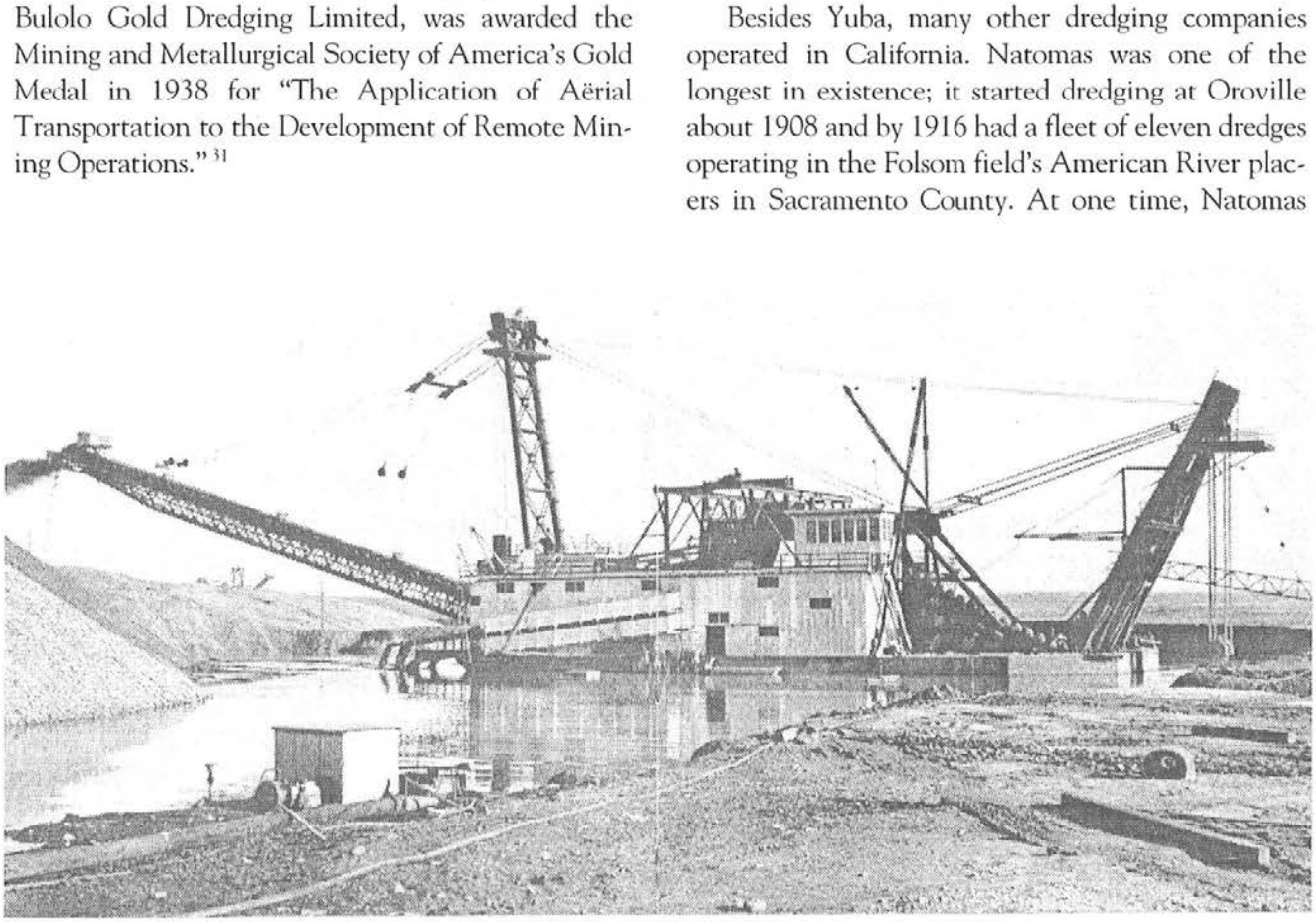


Figure 10 Capital Dredging Co., Dredge #4. Built by Yuba, 1937. Equipped with 18 cubic foot buckets which dug to 82 feet below water level. From *Yuba Placer Mining Dredges*, 1952.

was the largest owner of dredging land in California. The company had extensive shops in Natoma, nearby the town of Folsom. By 1960, the Folsom field had but a single active dredge. In 1962, Natomas ceased its California dredging operations, leaving Yuba as the state's last survivor. In 1959, Natomas's average yield from dredging was 10.19¢ per cubic yard while the cost was 9.56¢ per cubic yard.[33] In total, Natomas dredged about one billion yards of gravel.

Although some bucket-line gold dredges continued operating in Alaska and the Goodnews Bay platinum dredge operated there until the 1970s, Yuba's California dredges, the last in the "lower 48," temporarily ceased operating in October, 1968—just when the price of gold was allowed to increase above $35 per ounce. In 1979, ownership changes led to a new organization: a joint venture between a subsidiary of St. Joe Minerals Corporation and a new firm, Yuba Natural Resources. Dredging resumed on Yuba #21 in 1981, and this dredge remains in operation at Hammonton. Yuba #21 was originally built by Yuba Manufacturing Company for Natomas's operations in Sacramento County. This dredge twice underwent major modifications: first, when it was sold to Yuba Consolidated Goldfields and moved to Yuba County; later, in 1980-81, when it was moved to the deep Yuba reserves by the joint venture. Its ladder was extended to enable digging to 140 feet below water level — one of the deepest digging dredges in the world.[34]

Economic Comparison

Today, heap-leaching is used for extracting gold economically from ores so low in grade that the values cannot be seen even with a petrographic microscope. Such ores have typical cutoff grades of about ***0.02 ounce per ton***. At current gold prices of about $275 per ounce, the contained gold value is therefore ***about $5 per ton of mined ore***. By comparison, gold dredges for decades mined ore having values measured in **cents per cubic yard**.[35] After World War II, when operating costs had risen to 10 - 15¢ per cubic yard, the ore had to yield about 20¢ per cubic yard for a viable dredging operation. Simple calculation shows that (even at $35 per ounce) *dredging thus recovered gold profitably at ore grades below 0.005 ounce per ton!* Even at today's much higher gold price, this corresponds to only about $1.50 per cubic yard, (roughly $1 per ton, as a cubic yard of gravel weighs considerably more than a ton.) Compare these dredging economics with those of today for heap-leaching "low grade" ores!

Despite economies of scale provided by today's large digging equipment and haul trucks, the efficiency of dredges and their low labor requirement still give them the undisputed economic advantage just mentioned.[36] [37] Nevertheless, for environmental reasons, it is unlikely, at least in California, that we shall see a revival of gold dredging, regardless of the price of gold.

Notes

1. Charles Janin, *Gold Dredging in the United States* (Washington: U. S. Bureau of Mines, Bulletin 127, 1918), 5. Janin states that spoon dredges worked by hand had some success in New Zealand. California spoon dredges used steam power; the iron spoons weighed upward of a thousand pounds.
2. J. D. Doolittle, *Gold Dredging in California* (California State Mining Bureau, Bulletin 36, 1905), 99 -101.
3. C. C. Longridge, *Gold and Tin Dredging*, 3rd ed. (London, The Mining Journal, 1913?), 63.
4. *Ibid.*, 63-64.
5. For a global review of the history of gold dredging, see Clark C. Spence, The Golden Age of Dredging: The Development of an Industry and Its Environmental Impact, *Western Historical Quarterly* XI (October, 1980), 401 -414.
6. C. M. Romanowitz, "California's Gold Dredges," *Mineral Information Service*, California Division of Mines and Geology, 23 (August, 1970), 158.
7. J. Thompson and E.A. Dutra, *The Tule Breakers* (Stockton: University of the Pacific, 1983), Plate 5-19.
8. *The Mineral Industry, Its Statistics, Technology and Trade - 1894*, 3 (New York: Scientific Publishing Co., 1895) 632.
9. *Ibid.*, 1895, 4 (1896) 292.
10. *Ibid.*, 1898, 6 (1898) 358. An excellent contemporary dis-

cussion of river dredging for gold, by Walter Renton Ingalls, is on 354-359 this volume, a portion of his section "Progress in the Metallurgy of Gold and Silver", 336-366.

11. "Dredging Operations in California in 1910," *Mining and Scientific Press*, 102 (January 7, 1911), 49.
12. W. B. Clark, *Gold Districts of California* (California Division of Mines and Geology, Bulletin 193, 1970), 13.
13. *Ibid.*, 103.
14. T. C. Earl, *Gold Dredging* (London, E. & F. N. Spon, 1913), facing 166.
15. W. B. Winston, *Gold Dredging in California* (California State Mining Bureau, Bulletin 57, 1910), facing 110.
16. Clark, *Gold Districts of California*, 104.
17. *Shareholders' Report*, Yuba Goldfields, Inc. May 1, 1974.
18. Romanowitz, "California's Gold Dredges," 166.
19. Clark, *Gold Districts of California*, 62. Minor amounts of platinum were also recovered. Tailings reported to average about 6¢ gold per cubic yard.
20. *Yuba Placer Mining Dredges*. (San Francisco: Yuba Manufacturing Co., 1952).
21. S. P. Johnson, *Gold Dredges*. (Marysville and San Francisco: Yuba Manufacturing Co., 1927).
22. Thompson and Dutra, *The Tule Breakers*, 202.
23. *California Mines and Minerals* (San Francisco: California Miners' Association, 1899), i.
24. Clark, *Gold Districts of California*, 4.
25. *Minerals Yearbook*, 1948 (Washington, U.S. Bureau of Mines), 598.
26. *Ibid.*, 1421
27. Edwards Woodruff v. North Bloomfield Gravel Mining Company, et al. Cited as 9 Sawyer 441 or 18 F 753 (1884).
28. Janin, *Gold Dredging in the United States*, 198-9.
29. D. Weatherbe, *Dredging for Gold in California* (San Francisco: Mining and Scientific Press, 1907), 206-207.
30. T. A. Rickard, *The Romance of Mining* (Toronto: MacMillan, 1944), (New Guinea Gold, 403-432).
31. *Proceedings of the Mining and Metallurgical Society of America* 31 (1938) 40.
32. J. C. O'Brien, *California Journal of Mines and Geology* 48 (April, 1952). Mines and Mineral Resources of Yuba County, 150 - 151.
33. Clark, *Gold Districts of California*, 48.
34. *The Mining Record*, November 18, 1981. "Gold Dredge Rebuilt At Cost Of $10 Million". The original digging depth of this dredge was 107 feet. The dredge's 147 fourteen cubic foot buckets are designed to run at twenty-five buckets per minute, to process 4.5 million cubic yards annually, nearly 7 million tons.
35. In early days of California gold dredging, "Earth that yields three and a half cents a cubic yard will pay for cost of operation. Everything over that is profit, and the range of yield is from ten to fifteen cents." Gold at that time was $20.67 per ounce. Charles S. Aiken, "Farming for Gold," *Sunset* XXIII (December, 1909), 651-656.
36. Peter Rich, "Placer Evaluation: New Methods Make Alluvial Gold Worth Another Look," *Minerals Industry International*, November, 1996, 44-48.
37. Some statistics on a nine cubic foot dredge at Nome, Alaska: two night shifts employed four hands each—a winchman, two oilers and a deckhand. Day shift: seven hands which included the above plus the Dredgemaster and a shoreman. Total operating crew: about fifteen per day. For six month season, dredge mined and processed about 1.6 million cubic yards. Source: Mr. Ed Hunter, Victor, Colorado, 1999.