

WHAT PRICE GOLD?

Part IV. The Unique Economics of Gold*

By Pierre R. Hines**

"Nature herself makes it clear that the production of gold is laborious, the guarding of it difficult, the zest for it great, and its use balanced between pleasure and pain."

Diodorus Siculus, First Century B. C.

THE MINING OF GOLD

Gold comes from three principal sources: gold placers; gold ore in lodes in rock formations where gold is the important value; and gold in base-metal ores in which gold is a by-product.

1963 Gold Production, U.S.A.^{1/}

	<u>Troy oz.</u>	<u>Percentage</u>
Placers	184,563	12.7
Dry and siliceous gold ores (lode)	748,200	51.4
Copper ores)	438,543	30.2
Other base-metal ores) by-product	82,704	5.7
<hr/>		
Total	1,454,010	100.00

^{1/} Source, U.S. Bureau of Mines figures.

The above table gives the relative percentages of the three sources of gold in the United States in 1963. This review is concerned primarily with the gold from placers and lodes, because the production of gold from the base-metal ores is dependent upon the prices of the base metals and not on the price of gold. The three sources have to be separated in discussion to avoid confusion about the economic principles governing gold production. The history of gold mining and how gold

* Part I, "Proposed plans for the improvement of the international monetary system," and Part II, "The official policy of the U.S. Treasury upon international monetary systems," were published in the September, 1965 ORE BIN, with Part III, "The relief given to foreign gold mines by their governments," in the December, 1965 issue.

** Mining Engineer, Portland, Oregon.

deposits occur in nature are essential to the understanding of the economics of gold. This review can sketch only briefly an outline of these two subjects.

Gold Placers

Occurrence

Most gold placers are formed by the erosion of a surface which has outcrops of gold ore. Weathering decomposes the rock, runoff water carries the disintegrated rock down the ravines and gullies to the creeks, and down the creeks to the rivers. In the process the rock is ground to sand and gravel.

Gold, which is resistant to chemical attack, occurs commonly as the native metal and only rarely as a telluride. Weathering frees the metallic gold from the associated rock. Its specific gravity is many times greater than that of the associated minerals; therefore, it sinks in running water and lags behind while the greater part of the sand and gravel is swept on. Thus the gold is concentrated and a placer deposit is formed.

History of production

Ancient placers: Placer gold is pure enough without metallurgical treatment to be worked and formed into ornaments, jewelry, and other objects. The sands and gravels in which placer gold is found are easy to dig and handle. It is not surprising, then, that the earliest cultures knew and used gold. Nor was the metal difficult to recognize. Its yellow, bright, and glistening grains and nuggets on a background of black sand at the point of a high-grade sand bar would be hard to overlook.

Time has wiped out all surface traces of some of the ancient placers, but others are still known and to this day may yield small amounts of gold. Although the source of gold used by some of the ancient cultures remains a mystery, the size of their reported stores and treasures contributes to the evidence of the antiquity of the gold-mining art.

The earliest known gold mining was in Egypt. Golden objects have been found there dating from the fifth millenium and the beginning of the fourth millenium B.C., proving that gold has been mined for 6,000 years (Sutherland, 1959, p. 27 and 33). Authorities agree (Rickard, T.A., 1932, p. 209-214) that the first gold was recovered from placer deposits. It was mined in Egypt almost continuously from the start of the fourth millenium B.C. to the beginning of the Christian era, or for approximately 4,000 years.

The sources of Egyptian gold are known, except for the region of Punt, whose location is disputed. The principal source was a belt of gold-bearing granitic rock 500 miles long extending southward from the Gulf of Suez and lying between the Nile River and the Red Sea, also farther south to the Sudan, Eritrea, and Ethiopia (Emmons, 1937, p. 384-390; Sutherland, 1959, Chap. II; Rickard, 1932, Chap. IV). Both placers and deposits in rock formations occur in this area. The Nile itself, in the stretch between the first and fifth cataracts, had rich gold placer deposits (Sutherland, 1959, p. 26-27).

The island of Thasos, and Macedonia and Thrace on the mainland opposite, were early sources of gold. Whether the Cretans, about 2000 B.C., or the Phoenicians, about 1200 to 1400 B.C., were the first to mine gold there, or whether they got

it through trade, is not certain. The mines were old and well known when Philip of Macedonia reopened them about 350 B.C. Herodotus describes accurately their location on the mainland, but time has removed all traces of them (Dominian, 1911, p. 576; Rickard, 1932, p. 358). Phrygia and Lydia (Turkey) became the most important gold-mining districts in the first millenium B.C. (Dominian, 1911; Sutherland, 1959, p. 65). The river Pactolus was famous for the placer gold recovered from its bed. Dominian (1911) places it as the tributary of the Gediz (Hermus, rising on the northern slope of Mt. Timolus). Sardis is on the Gediz about 45 miles from the Aegean. The wealth of Croesus and of Midas, the King of Phrygia, as well as the treasures of Troy, all came from this rich gold-bearing region.

The southeastern end of the Black Sea was an ancient source of gold. The seaport of Poti is in the Land of the Colchis, where Jason is believed to have stolen the golden fleece (Rickard, 1945, Chap. III). The river Phasis, which empties into the sea at Poti, was rich in alluvial gold. Pontus to the southwest of Colchis furnished Mithridates VI (120-63 B.C.) the gold with which he carried on his war with Rome (88 to 63 B.C.). Still later, Justinian, Byzantine emperor from 527 to 565 A.D., obtained gold from the Tchoruksu River, which flows into the Black Sea at Batumi. Tchoruk means "golden," and only recently was its name changed to Coruh Suku. The Dzanzul copper mines on a tributary of the Tchoruksu had ancient workings whose implements and utensils were pronounced to be Phoenician by the British Museum.

Many gold districts about which little is known are referred to in ancient records. Archaeological exploration in some cases has found sufficient gold in various forms to verify their existence. Some of them are Bokhara and the valley of the Oxus River (Sutherland, 1959, p. 70; Emmons, 1937, p. 347); Arabia; Ophir of the Bible; County Wicklow in Ireland; Wales; the headwaters of the Po River in northern Italy; and the rivers of the Ganges and the Indus (Sutherland, 1959, p. 90).

Probably the Cretans and the Phoenicians obtained gold from southern Spain by trading, and later on--when the Cartaginians founded Cadiz--they mined gold there. The headwaters of the Guadalquivir and the gold-bearing gravels of the Sierra Nevada were mined first. Spain's mineral wealth was one of the causes of the Punic Wars. After the second Punic War (218-201 B.C.), Rome drew large amounts of gold from southern Spain, but the really great amounts came from the Asturias in northwestern Spain after it was conquered by Augustus in 30 B.C. (Sutherland, 1959, p. 93-96; Emmons, 1937, p. 326-327). The remains can still be seen of the vast workings of the alluvial terraces on both slopes of the Cantabrian Mountains. The belt mined was about 80 miles long and was equal in production to that of any previous mining district. Rome drew gold from many old sources and some new; about the latter little is known. It not only mined gold but also obtained it by taxes, levies, tribute, and plunder.

Gold mining was disrupted by the fall of the Western Roman Empire (476 A.D.) and, later, the Eastern Roman Empire. It languished for more than 200 years. The Arabs invaded Spain in 711 and by the end of the summer had conquered half of it and within seven years they had taken over the entire country (Stephenson, rev. 1962, p. 129). They worked the Spanish gold mines vigorously. Later, in the eighth century, they extended their rule a thousand miles south of Marrakech to Timbuktu in West Africa. Timbuktu became a gold-collecting center for Nigeria and the Gold Coast (Sutherland, 1959, p. 115-116). Most of the Arabs' gold came from placer deposits. Their gold coin circulated throughout the Mediterranean.

Later discoveries: During the Dark Ages gold was washed irregularly in the Tiber, Po, Garonne, Rhine, and Rhone Rivers. Trade and mining revived in the 9th

century, and in the 13th to 15th centuries expanded rapidly. New discoveries of gold were made in Germany, Bohemia, Silesia, and Hungary. Late in the 16th century Germans washed out 100,000 pounds sterling of gold from the rivers in Scotland. The Middle Ages ended with the 15th century. The discovery of the New World opened a new and great source of gold.

The first gold which the Spaniards took out of Mexico and Spanish America came from the accumulated hoards of the natives and was in the form of ornaments and utensils. Mexico did not have any large placer gold deposits, but Colombia, Peru, Bolivia, Venezuela, and the Guianas did. At least half of all of the gold produced from these last five areas came from the river placers of Colombia, which still yield 300,000 ounces yearly. The gold that Spain received from the New World doubled or trebled the gold stocks of Europe and made a radical change in its finances, economics, and the course of its history. In the 18th century Brazil supplied Portugal with large amounts from placer mining.

Russia was the largest producer from 1820 to 1848 and the gold came mostly from placers. The Lena River gold field in Siberia ranks as one of the great gold placers in the world. It probably produced \$400,000,000 from 1846 to 1926. The Urals and Siberia have many other large gold placers (Emmons, 1937, p. 328-348). Since 1917 the U.S.S.R. has given out very little information on its industry, but its gold sales and exports in recent years show it is active.

Gold was not found in the United States until 1800 and then only in small deposits in the Southern Appalachians. The output from this region has never been large, although placer mining has continued to this day.

The discovery of gold in 1848 in California was the start of the modern Golden Age in mining. It opened a gold field on the western slopes of the Sierra Nevada that extended from the Feather and Yuba Rivers on the north roughly to the Stanislaus on the south in a belt about 100 miles long and 60 miles wide. From 1849 to 1852, the gold came almost entirely from placer mining and it amounted to about 3,200,000 ounces (Rickard, 1932, p. 766). "Mineral Resources of the United States" gives a total of at least \$1,175,000,000 (\$20.00 an ounce) for the placer gold taken from this field since 1848 (A.I.M.E. Lindgren Vol., 1933, p. 427). The first mining was done by manual labor with no better tools or gold-saving devices than the Romans had in northern Spain. Whether the placers on the west slope of the Sierra Nevada in California yielded more gold than some of the ancient gold fields is a conjecture, but that this was one of the most important discoveries is a certainty.

The discovery of gold in Australia in 1851 was the direct result of the 1849 California gold rush. E. H. Hargraves, when he heard the news, sailed from Sidney and arrived in San Francisco in October, 1849. While he was working on the Stanislaus and Yuba Rivers, he was struck by the similarity of the geology and rocks to a region in New South Wales which he knew. He returned to Sidney early in 1851, went to Bathurst and then to Ophir Creek, which flows into the Macquarie River. There, on February 12, 1851, he discovered gold. He then prospected the Macquarie for about 70 miles of its length and was successful in finding gold along the entire distance. He asked for a bonus and the Colonial Secretary gave him 500 pounds Australian; later the Legislative Council of New South Wales voted him 10,000 pounds Australian, and Victoria 3,200 pounds. A committee in the City of Melbourne offered a reward of 200 pounds Australian to the discoverer of gold located within 200 miles of the city. Gold was found at Buninyong in September, 1851; this was the beginning of the famous gold fields of Ballarat and Bendigo in Victoria.

During the decade from 1848 to 1858, the combined gold production of

California and Australia is estimated to have been \$1,200,000,000, while the world's gold stock at that time was \$1,500,000,000. This enormous gain in stocks gave great concern to the economists and bankers of that day (Rickard, 1945, Chap. VIII).

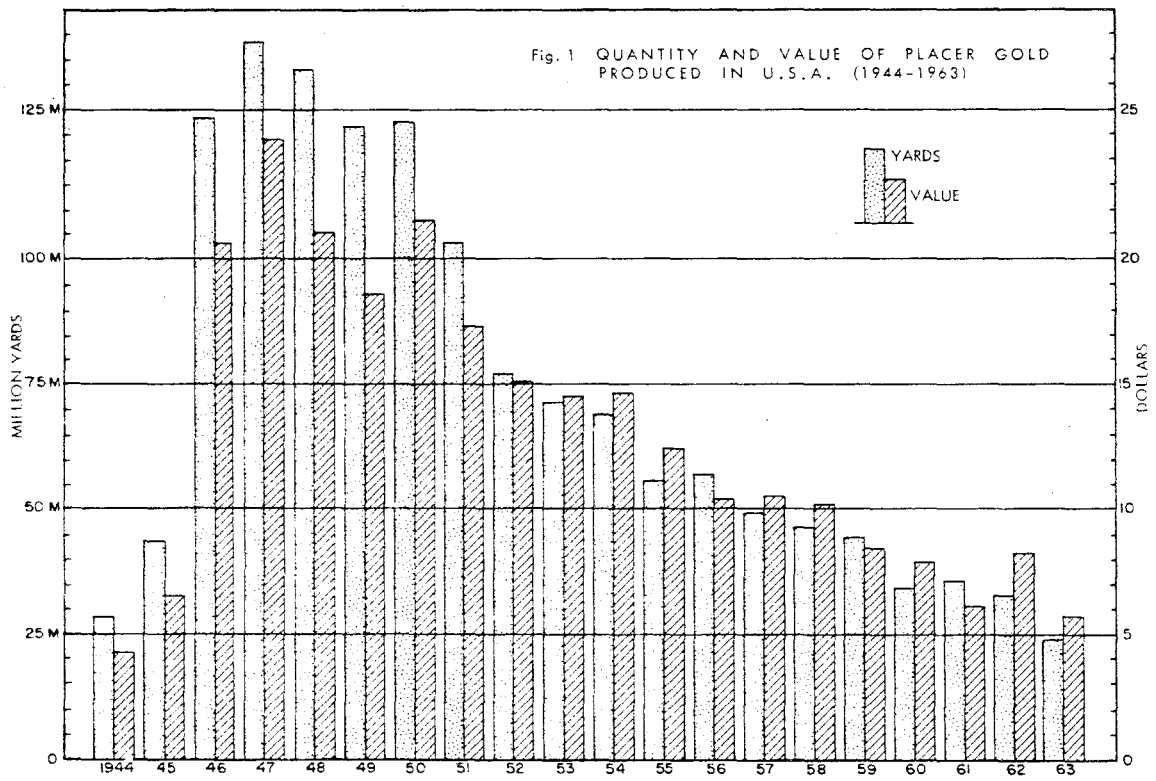
The consequences of the California gold discovery were far reaching. The search for other gold fields was vigorous. Prospectors scratched every stream bed, creek, and gully testing for gold, and when their gold pans showed a color they followed it to the source. The search was not only in the western United States but in British Columbia and New Zealand, and continued to include any region in which it was practical to mine. Some of the famous fields found in the West were California Gulch at Leadville, Central City, and Clear Creek, all in Colorado; Alder Creek at Virginia City, Montana; the placers of northwestern California and southwestern Oregon; and many smaller ones. The prospectors found not only gold placers but many ore deposits of other metals which became famous mining camps.

Hydraulicking and dredging: When the rich gold gravels were exhausted in 1865 in California, hydraulicking of the high banks and benches started. Hydraulic mining uses high-pressure water jets to wash down the sand, gravel, and dirt and to convey them over the sluice boxes, where the gold is collected, and on to the waste dumps. When practical, it is the cheapest method of removing and transporting dirt, clay, sand, and gravel. Hydraulicking in the Sierra Nevada was so extensive that by 1893 the debris was choking the Sacramento and San Joaquin Valleys and threatening navigation. The Caminetti Act of 1893 prohibited dumping the placer tailings and debris into the tributaries of the two rivers and required they be stored behind dams. As a result, hydraulicking in the Sierra Nevada rivers practically ceased (Peele, 1941, sec. 10, p. 552).

The gold dredge was brought from New Zealand to California in 1896. The chain-bucket or bucket-ladder dredge was developed from it in 1901 and a new cycle of placer mining commenced. A gold dredge is a combination of a bucket excavator and elevator, a gold-saving plant, and a stacker which piles up the tailing behind, all mounted on a barge floating on a river or an artificial pond. It made profitable the digging of large yardages of sand and gravel whose gold content was too low to work by previous methods, and it could dig down to 100 to 120 feet below the water line. Dredging was the cheapest method of working gold placers, next to hydraulicking, since it performed the whole operation from mining to recovering the gold and stacking the tailing. California gold dredging costs in 1912 to 1916 ran from 3.37 cents to 6.28 cents per yard. This opened a new field of placer mining and gave it new life (Peele, 1941, sec. 10, p. 577-589). Finding of gold placers in the Klondike in 1896 to 1898 was followed by more discoveries at Nome, Fairbanks, the Yukon, and other places. When the rich gravels were worked out, dredges were installed and Alaska and the Yukon became a famous gold-dredge field.

The last great placer discovery was in New Guinea in 1932. Eventually, as drilling proved more and more ground, eight great gold dredges were flown in by airplane (Rickard, 1945, Chap. XV). The Japanese captured the gold field in World War II and did considerable damage to the machinery. Dredging was resumed after the war; at present, only some limited hydraulic ground is being sluiced.

Effects of price fixing: The U.S. Congress passed the Gold Reserve Act on January 30, 1934, authorizing the President to reduce the weight of gold in the dollar to not less than 50 percent nor more than 60 percent. The next day President Roosevelt fixed the weight of gold in the dollar to correspond, raising the price of gold from \$20.67 to \$35.00 an ounce. The object of this Act was to raise the price of commodities, but incidentally it stimulated gold mining. So placer mining flourished



again until 1942, when War Production Board Order L-208 closed all gold mines in the United States. Order L-208 was rescinded July 1, 1945 and gold dredging resumed. Whereas the cost of labor and supplies had gone up during the war, the principal cost of gold dredging is in the big investment in dredges and land. This investment had been made before World War II and already had been partially amortized. The cost of power had risen slightly. Gold dredging continued until rising costs became prohibitive or no profitable dredging ground could be found.

Figure 1 shows the total value and the number of yards mined annually from 1944 to 1963 for all placer mines in the United States. As bucket-line dredging accounts for seven-eighths of all placer gold mined now, figure 2 was constructed to show the number of yards and the total value produced annually by gold dredging alone, and also the average yield per yard. Both figures show the gradual decline in placer mining in the United States. Figure 2 shows how the average yield per yard has increased to meet the rising costs of dredging. Placer mines supplied only 12.7 percent of the total gold production in this country in 1963. If gold dredging continues to decline at its present rate, it will come to an end in the United States in another 10 years.

There are several reasons for the decline in placer mining. Profitable placer ground has become hard to find. Long ago, wherever a pack could be carried, a canoe paddled, or a horse or mule could travel, and today wherever a "jeep" can climb or an airplane can land, the prospector has already been. Placer gold always leaves a golden trail. A single gold "color" in a gold pan was sufficient for an old prospector to start in to trace it to its source. This method of prospecting has not been improved on in recent years, nor need it be. What is now left is usually a false lure for the inexperienced.

The price of gold has remained fixed at \$35.00 an ounce since 1934, and in the meantime all placer mining costs have gone up and up and up. At the same time, as more yardage has been mined the yield per yard of the gravel left has become poorer. Now the two curves have crossed each other. Then, too, the government regulations covering gold mining, especially placer mining in the Western States and some foreign lands, are so restrictive that these regulations alone are sufficient to make placer mining unprofitable.

The only thing remaining to do to save placer mining is to raise the price of gold. How much there is to save is a question, and those who could best answer it are gone. Placer mining is an ancient industry which has seen its best days if the gold price stays at \$35.00 an ounce. New placers have come with the exploration of virgin regions but few unexplored areas now remain.

Gold Lodes

Occurrence

Gold lodes do not occur in the few simple forms which gold placers do. They appear in rocks of every age from the Precambrian to Quaternary. Lode gold deposits follow various geological structures, such as fault zones, anticlines, synclines, stringers, fissures, shattered zones, strata, dikes, and contacts between an igneous rock and some other rock. Ore deposits are classified according to the physical-chemical conditions under which they were formed. Lindgren's classification is the one in general use (A.I.M.E., 1933, Ore deposits of the Western States, p. 20-21).

The deposition of the gold is rarely uniform but varies from rich to lean. The form of deposition may be in bands, in a series of lenses separated or connected, in irregular shapes like splashes of ink on blotting paper, or at vein intersections. Visible gold is not common in an average ore, and it is necessary to sample frequently, assay, and plot the gold assays on an accurate mine map to guide its mining.

The geologic knowledge of gold deposits is extensive, and there is published information on all of the above variations. Among the better known books is W. H. Emmons' "Gold Deposits of the World." Not only Emmons' but several other volumes on the economic geology of ore deposits must be studied earnestly to appreciate the fact that geology is the "door" to finding and producing gold. The key or the lock-combination to the "door" is always hard to find and is never duplicated.

Lode gold deposits are difficult to discover. They do not always crop out, and if they do only a small area may be exposed or it may be hard to distinguish from the surrounding rock. Also, the outcrop may be covered by overburden, muskeg, or a body of water. Placers, a good sign of lode gold in the vicinity, are not always formed or may have been swept away in a previous geological period, thus giving no indications of a hidden gold deposit. The history of gold mining is full of the element of luck, the fortuitous circumstances which led to the discovery of most of our famous gold-mining districts. The rarity of these important finds is reflected in the gold-production records which show up as pulsations or surges when great new gold-mining districts are opened.

History of production

Early lode mines: Mining of gold from hard-rock formations is an ancient art, but the exact date when it began is not known, nor is it known whether the first lode ore mined was turquoise, copper, or gold. The Egyptians were the first recorded miners, and Diodorus at the end of the second century B.C. described their methods (Sutherland, 1959, p. 29; Rickard, 1932, p. 209-214). The rock was broken by heating with a wood fire and then cooling with cold water, which caused it to crack. The cracked rock was pried out with a gad or moil and hammer; the broken rock was carried out in baskets or skins by boys; the rock was broken down to pea size, then ground to fine sand in granite mortars. The ground material was washed on inclined tables and the golden particles caught on the rough surface were removed by sponges. It was all laborious hand work, particularly the grinding in a mortar. The total man-days required to extract gold from a ton of rock would be 20 to 30 times that needed to extract gold from a yard of placer gravel. The man-days needed to produce an ounce of gold would depend upon the richness of the rock and the placer gravel. It could easily take 10 man-days to yield an ounce of gold from a placer, while to produce an ounce of gold from ore with 10 man-days' labor would require an ore running two to three ounces per ton, which is a very high-grade ore. Because of the very nature of the two sources of gold, placers would be mined long before deposits in rock formations were.

The simplicity of the methods for extracting gold from rock formations did not require any great technical advance or knowledge, so the Egyptians probably mined lode gold for several thousand years before Diodorus' account in 200 B.C. What proportion of the Egyptians' gold came from lode deposits will never be known. The remains of their gold mining can still be seen in the desert between the Red Sea and the Nile River. It is estimated that at one place a million tons of ore were mined; at another three to four miles of tunnels are still standing. The important fact is that

the total of gold from all sources was enormous. It appears that gold was more desired then than now. An autocratic government with plenty of slave labor not only mined gold for 4,000 years but also sent expeditions by sea to Africa and Arabia looking for it. Archaeologists have found records of the gold received annually by some of the Pharaohs; also the gold in their treasuries, their gifts of gold to other monarchs, and the gold which went into their tombs. More than that, the temples had large amounts of gold, and later rings and small bars of gold were used in commerce. Until 1200 to 1400 B.C. Egypt was the main source of gold in the ancient world.

The silver mines of Greece are famous because the revenue from them built the fleet which defeated the Persians in the naval battle at Salamis in 480 B.C. The Greeks' gold came mostly from placers; the only well-known gold mines in rock formations were in the Rhodope Mountains in Thrace and Macedonia (Dominian, 1911, p. 569-589).

The mines in Spain worked by the Romans were lead, lead-silver, copper, and mercury. Spain's gold placers were notable, but the gold veins were seldom rich enough to mine.

The history of gold mining is unknown from the fall of the Western Roman Empire to Medieval times. During this period gold was scarce in western Europe. Gold mining revived in the 13th and 14th centuries when mining of lode gold commenced to displace placer mining. Gold mines were opened in a belt from Germany, through Czechoslovakia, Silesia, Austria, Hungary, and Rumania (Transylvania). Mining was still done by heating the rock with fire and cooling it with water, although other advances were made. Ground water prevented the ancient miners from going deep. During the Middle Ages, water power was used to drive crude pumps for raising the mine water to the surface, and where the elevation permitted it small drainage tunnels were driven. The hard work of grinding the ore was done by wooden gravity stamps with iron shoes, and driven by water wheels. Gold became plentiful again in western Europe.

At the beginning of the 16th century, the gold of the Americas began to arrive in Europe. The Spaniards mined silver ore in Mexico and South America, but they mined very little gold ore from rock formations. They contributed to the arts of mining and metallurgy by using horses and mules for hoisting ore and turning arrastras; by designing the arrastra itself for grinding and amalgamating silver and gold ores; and by instituting the patio process, which was the basis for the Washoe process that recovered gold and silver from the ores of the famous Comstock Lode in Nevada. Mexico has been the leading producer of silver for 400 years. El Oro near Mexico City was the only important gold-mining district, and it is now exhausted.

United States: The use of steam power and the better quality of iron available at the end of the 18th century benefited all mining. The Comstock Lode was discovered in 1859. It was the premier gold-silver mining district of the United States, the gold being about 40 percent of the value expressed in dollars. But it was also more than the premier gold-silver producer, because it was the turning point at which gold production from deposits in rock formations commenced to grow rapidly, eventually to become the principal source of gold. The Comstock Lode was a great fissure, $2\frac{1}{2}$ miles long and in places several hundred feet wide. It was mined down to 3,000 feet, but the great bonanzas were all above the 2,000-foot level. The mining problems were so many and difficult that if it had not been a bonanza it would have been abandoned. Mining the huge ore bodies exposed large areas of weak roof which had to be supported while the ore was removed; the problem was solved by the invention

of the square-set method of timbering. The quantities of hot water and the heat made it almost impossible to mine at times. Then the recovery of the gold and silver had to be solved, and the Washoe process or pan-amalgamation process was contrived. Many modern methods of drilling, blasting, hoisting, pumping, and ventilating were introduced. The conversion of the wooden stamp mill to cast iron and wrought iron was an important advance. Steam power and better cast iron and wrought iron made many of the mining and milling methods possible.

It would be difficult to say which deserved the greater credit for giving the incentive to the search for gold and silver, the Gold Rush of '49 to California or the discovery of the Comstock Lode. Many placer miners left California and went to the Comstock, later returning to California about 1864. They took back with them the knowledge of hard-rock mining and ore recovery which they had gained on the Comstock. This was the beginning of the mining of gold deposits in rock formations in California, particularly on the Mother Lode and in Grass Valley and Nevada City. Other gold fields found in the United States were notably: the Homestake mines in the Black Hills of South Dakota, 1874; Alaska Treadwell and Juneau district, Alaska, 1882; Cripple Creek, Colo., 1891; Tonopah, Nev., 1900; and Goldfield, Nev., 1902.

The above districts produced roughly 30 percent of the gold mined from lodes (dry and siliceous ores) in the United States; the balance of the lode gold came from smaller mining districts or from single mines such as Oatman, Ariz., Bodie, Calif., and Camp Bird, Telluride, and Gilpin County, Colo. The Carlin mine near Reno, Nev., began producing in May of 1965 and is the first important new gold mine discovered in the last 35 years. The geological occurrence of the gold in the famous mining districts and mines of the United States has been varied and diverse. According to their geological character, their productive life has been from 20 to 90 years. Their depth has been from a few hundred feet to more than 4,500 feet. Koschman and Bergendahl (1961) have given a good review of their future ore reserves.

Australia: The rich placers of Ballarat and Bendigo in Australia led to the source of their gold, which was the great gold reefs of the same names. It was not until 1882 that the Mount Morgan mine in Queensland became a great gold producer. Western Australia is a vast arid waste and prospecting was held back by natural hazards. It was not until 1891 that a real gold find was made at Coolgardie and it did not last (Rickard, 1945, p. 204). Kalgoorlie nearby turned out to be one of the great gold deposits, famous for its "Golden Horseshoe," so named after the shape of the outcrop of its vein or lode system. Kalgoorlie produced 529,000 oz. in 1963, and is now the principal gold-mining district in Australia (Mining Engineering, October 1964). Australia has held fourth place in world gold production for a number of years.

South Africa: Seventy percent of the world's gold production now comes from a mining district called the Witwatersrand in South Africa. Its name has been shortened to the Rand, or the Rand gold fields. The field is in the shape of an arc about 300 miles in length. Fifty-nine working mines are scattered in bunches along it at the present time. No other gold field is similar or compares in size, extent, depth, or past and present gold production. It produced 29.3 million ounces of gold in 1964 and has produced to date a total of approximately 675 million ounces worth 23 billion dollars. A knowledge of its history, the manner in which the gold occurs, its mining, and its economics is essential to every student of gold and money. This review can give only a brief outline sufficient to bring out a few of its elements and controlling principles.

The Rand is a grand geological structure, a basin of sedimentary beds 25,000

feet thick consisting of quartzites, slates, and conglomerates, known as the Witwatersrand Group. The basin is roughly 160 miles long and 70 miles wide, of which only the rims have been prospected. About 300 miles of the rim has been explored, and only about 40 percent of it has gold-bearing areas. The beds dip steeply 50° to 80° at the surface, and as they go down flatten out to 30° to 40°. The gold occurs in the conglomerates which are called bankets by Rand miners. A conglomerate is a gravel containing rounded and water-worn fragments consolidated into rock. The gold-bearing conglomerates are locally known as reefs or leaders or reef leaders. They have been mined to 11,000 feet vertical depth, and plans have been made to go down to 13,000 feet. The gold follows channels in the conglomerate. The conglomerate may extend laterally for miles and down to depths beyond practical mining limits, but the gold is not so uniformly distributed. The gold-bearing areas are large and so are the barren areas. The thickness of the pay ore varies from 30 to 8 inches; 13,000,000 ounces a year comes from an 8-inch streak.

The persistency of the gold-bearing reefs and leaders has been the foundation for the continuous and increasing production for the 80 years since the 1886 discovery. Careful geological surveys have guided the drilling for and the location of the extensions of the known gold-bearing reefs. A shale carrying sufficient magnetite so it can be traced by magnetic instruments lies above the gold-bearing group; it has been successfully traced to the Far West Rand group, which accounts for 21 percent of the gold production now and has further promise.

The average yield of gold per ton of ore in 1913 was 6 dwt. (\$6.00); in 1937, 4.4 dwt. (\$7.70) after the gold price was raised to \$35.00 an ounce; in 1953, 3.89 dwt. (\$6.81). As prices of materials and labor went up, the yield in 1958 per ton of ore became 5.23 dwt. (\$9.15); and recently 7.12 dwt. (\$12.50) (Kriz, 1965). Fixing the price of gold at \$35.00 first increased production and, secondly, made lower grade ores profitable. Then, as costs increased with high prices for supplies and higher wages, richer ore had to be mined to make a profit, leaving behind unmined lower grade ore. The extension since 1950 of the old Rand into the Orange Free State brought into production a new group of seven mines whose rich ores yield 9.8 dwt. (17.15) and account for 35.8 percent of the present total production. The greatly increased production has come from the new rich mines, while the old Rand has been dying from exhaustion of high-grade ore. Although notable advances in mining practices have been made, they have not been sufficient to keep up with inflation. Based on present conditions, the gold production is expected to decline gradually within the next three or four years. The new mines have a life expectancy of 20 years or more, but their production is not sufficient to maintain the present rate.

It is hard even for a mining engineer to grasp the size of the Rand, which mines 80,000,000 tons of ore in one year to produce 29,000,000 ounces of gold worth one billion dollars. The gold is only 1.25 parts in 100,000 by weight in the ore. Gold mining on the Rand employs roughly 450,000 miners, of whom 11 percent are Europeans and the balance natives. The City of Johannesburg, located in the center of the old Rand, started from nothing and grew with the gold-mining industry until it has a population of 1,100,000 people today. For more information on the Rand see: Emmons, 1937, p. 421-437; World Mining, 1965, p. 22-26; Robertson, 1965; Mining Engineering, 1962, p. 41-48; Kriz, 1965.

Canada: Canada did not become an important gold producer from lode mines until about 1924. The increase in the price of gold in 1934 brought on an increase in the production rate, so that by 1938 Canada took second place in free-world gold production exclusive of the U.S.S.R. Canadian production continued to rise, and

in 1941 reached a peak of 5,345,000 ounces. Thereafter it decreased slowly and in the last two or three years has been about 4,000,000 ounces. During the past 10 years, 83 percent of the Canadian gold has come from dry and siliceous ores, 15 percent as a by-product of base-metal ores, and 2 percent from placer mining. The total gold production has been 136,000,000 ounces valued at \$6,500,000,000Can.

Porcupine was the first of the great Canadian gold-mining districts. It was discovered in 1909 in Ontario. It has three great mines whose production is now declining - the Hollinger, Dome, and McIntyre-Porcupine. Since 1910 Porcupine has produced more than a billion and a half dollars in gold. The Hollinger on and off for many years has been the premier gold mine in North America. Kirkland Lake was the second great gold-mining district in Ontario, located 60 miles east of Porcupine. Discovered in 1912, it had three large mines, Lake Shore, Wright-Hargreaves, and Teck-Hughes. Kirkland Lake has produced 50,000,000 ounces of gold valued at \$750,000,000Can.

The Lake Shore and the Hollinger competed for first place in gold production in North America over the years. Then they were surpassed by the Kerr-Addison in the Larder Lake district 20 miles east of Kirkland Lake. As early as 1906, gold was found at Larder Lake and started a rush which dwindled to nothing in 1910. The mines were reorganized and refinanced many times, but it was not until 30 years later, in 1936, that a series of events occurred which could happen only in mining. A large body of ore of profitable grade was found which had been narrowly missed previously, and Kerr-Addison suddenly boomed on the big stock exchange at Toronto. Kirkland Lake has produced today more than 750 million dollars. Its production is dropping gradually, as depth, rock bursts, and ever-increasing costs eat up the profits.

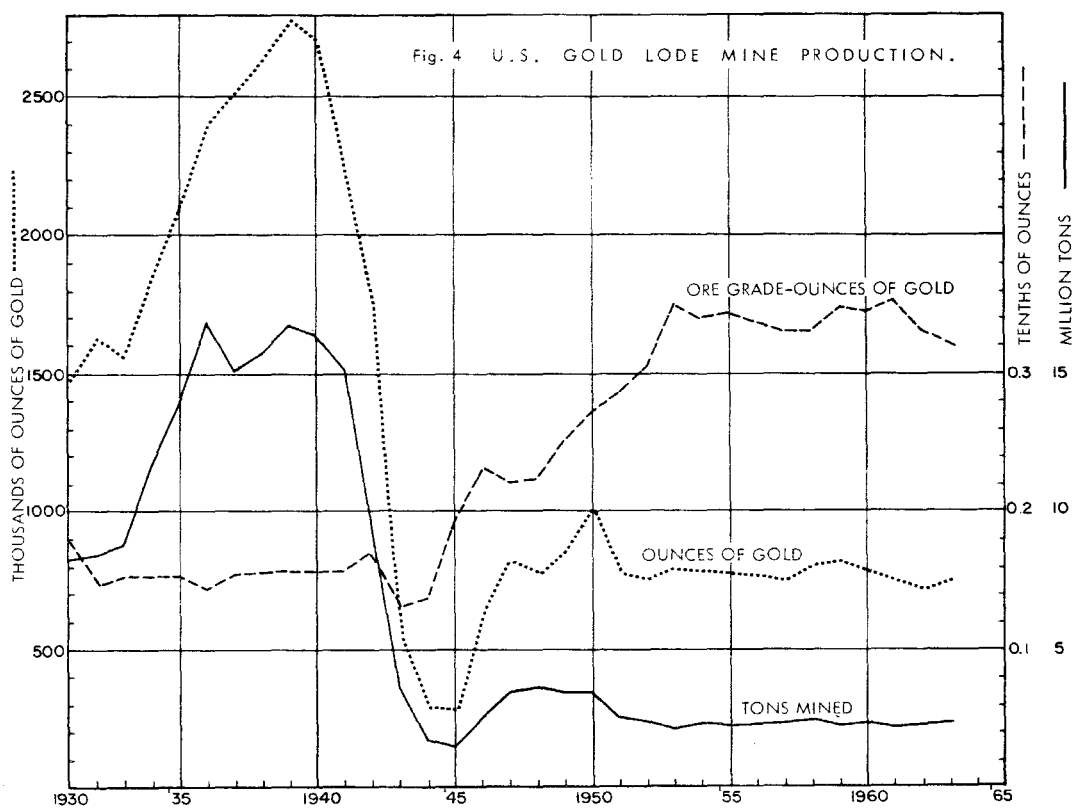
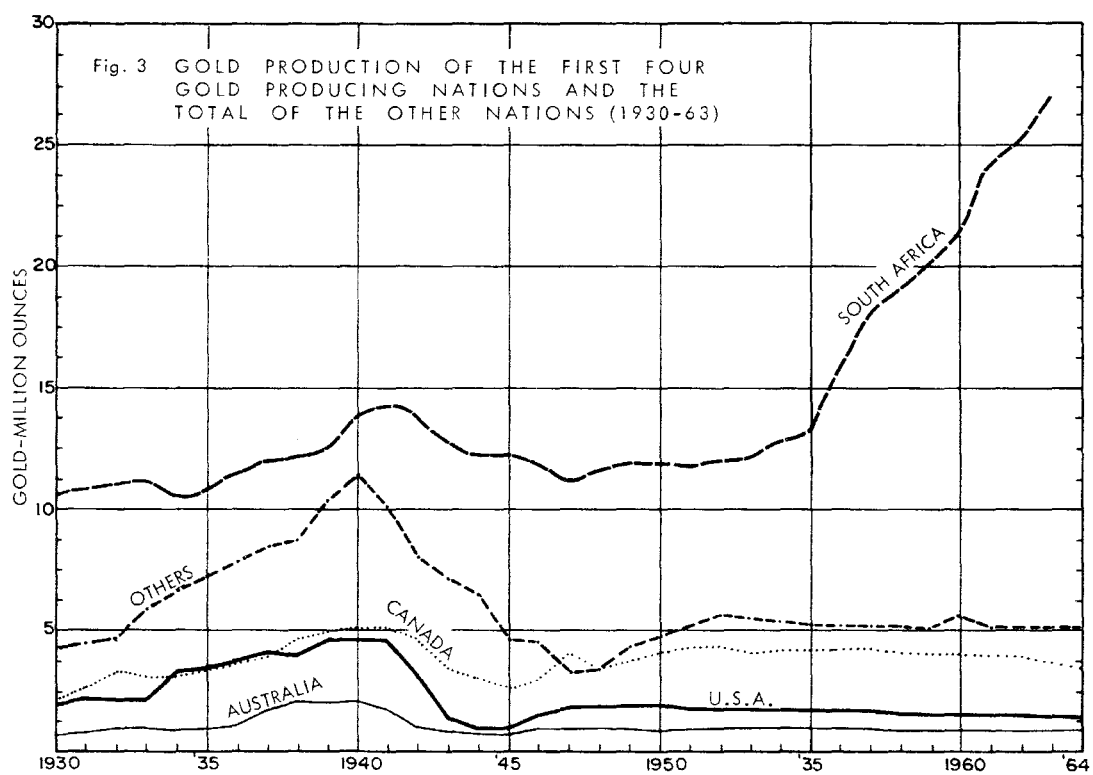
Canada has a large number of gold-mining districts which produce 52 percent of the gold from auriferous quartz mines. They are Cadillac-Malartic and Bourlamaque-Louvicourt districts, Que.; Port Arthur, Ont., and Red Lake, Patricia district, Ont.; Bralorne-Pioneer and Caribou Gold, B.C.; and the Yellowknife district, N.W.T. From 1952 through 1962 these mines produced a yearly average of 3,760,000 ounces, which is 70 percent of the 1941 peak year.

The rocks in most of Quebec, Ontario, and Newfoundland, and in parts of Manitoba, Saskatchewan, and the Northwest Territories, all of which comprise more than half of the land area of Canada, are of Precambrian age - some of the oldest rocks known. They have been intruded by granitic and porphyritic rocks, with which most of the gold deposits are associated. Ontario produces two-thirds of the output from auriferous quartz gold mines, and Quebec one-sixth. Gold is abundant in this vast area of Ontario and Quebec, but it occurs as networks of veins or in shear zones, many of which do not show on the surface. They cannot be traced as the conglomerates are traced on the Rand. The geology of the Ontario-Quebec area is important but too complex to be described in detail here. The Canadian Shield is a treasure house of metals - gold, iron ore, nickel, copper, lead, and zinc.

A great batholith occurs along the coast of British Columbia. A batholith is a large, irregular, deep-seated igneous mass which may broaden as it goes downward. Several productive gold mines have been found on both the eastern and western sides of this batholith. The geology here is different from that of Ontario and Quebec.

Canada still has a potential for future gold production - one of the few regions that does. For more information on Canadian gold mines see: Hoffman, 1946; Canada, Dept. of Mines and Technical Surveys, 1964; Verity, 1962, p. 256-272; Beard, 1964; Ross, 1965; Emmons, 1937, p. 38-106; and Wansbrough, 1965.

World production: Figure 3 shows what is happening to the individual



gold-producing countries. The first four countries in order of gold production and the others in one lump sum have been plotted separately. The only increased production is in South Africa; Canada, the United States, and Australia show a gradual decline; the others are barely holding to the same annual production. The increase by South Africa comes from new, high-grade mines and from mining ores which contain uranium as a by-product. The decline in other countries is due to the fixed price of gold.

Processing methods

Gold ore at or near the surface of the ground is usually oxidized. The oxidized zone may extend downward for only a few feet but can extend for hundreds of feet. The gold itself is not oxidized, but the sulfides with which it is associated are. The oxidizing action frees the very fine gold particles which were locked up in the sulfides. The oxidized ores are called free-milling ores, which means the greater part of the gold may be recovered by amalgamation with mercury, an old, simple, and cheap process. The gold recovery may be from 70 to 85 percent. When the unoxidized sulfide zone is reached, the ore becomes refractory, the gold recovery falling off rapidly so that only 10 to 30 percent may be recovered by amalgamation. Often a further recovery of the gold-bearing sulfides can be made by various concentrating devices and machines; for example, blankets, corduroy, vanners, and flotation. The concentrate has to be shipped to a smelter or treated by another process, which means high freight and treatment cost, and lower recovery.

Mac Arthur and the Forests patented the cyanide process in 1887 and 1888. They discovered that a weak solution of potassium cyanide would dissolve gold and that the gold could be precipitated from the solution by finely divided zinc. The ore to be treated was reduced to a suitable size and leached in a tank with a weak cyanide solution to dissolve the gold; the solution was drained from the ore, then clarified and passed through a series of boxes filled with zinc shavings, where the gold was precipitated while the barren solution overflowed and was returned.

The final product of the cyanide process is gold bullion. Bullion worth \$100,000 and 900 fine weighs only 218 pounds, so a large amount of gold can be transported easily by any means, such as mule back, airplane, automobile, or railway. The mill supplies - lime, cyanide, steel for grinding, zinc, etc. - weigh only about 10 to 12 pounds per ton of ore milled. Power is not a serious problem. Summing up, the cyanide process is well fitted for the requirements of ore treatment in remote regions of rough country and poor transportation. It is the process most generally used for dry and siliceous ores where gold is the principal value; it has increased gold recovery and made profitable mines which otherwise could not have operated. The cyanide process is one of the valuable advances made in gold production, and so far no better process has been discovered to supplant it (Dorr, 1936).

By-Product Gold

By-product gold comes from copper and from lead-zinc ores, with most from the copper ores. Its production depends upon the price of those metals rather than on the price of gold. Less than 10 percent of total world production is by-product gold. More than half of gold production during the last six years has gone into industrial uses, the arts, and hoarding. Less than half went into the world's gold stocks.

Therefore, even if gold were abolished as a monetary unit and the principal gold mines shut down, by-product gold would still be in demand. Thirty-six percent of the United States' gold production comes from by-product gold. It would supply only nine percent of this country's consumption. Since by-product gold is produced regardless of the economic principles which govern the gold production of placer and lode mines, it complicates and masks the true situation if the three are considered jointly. For this reason they are taken up separately.

Rising Costs of Production

Figure 4 shows graphically what is happening to the mines producing gold from dry and siliceous ores in the United States. Gold-mine production has dropped to 26.7 percent of the peak in 1939; the number of tons mined to a fifth; the grade of the ore has almost doubled. With a pegged price for gold, the only way a gold-lode mine can meet inflation and rising costs is to mine selectively higher and higher grade ore. If it can't, it must close.

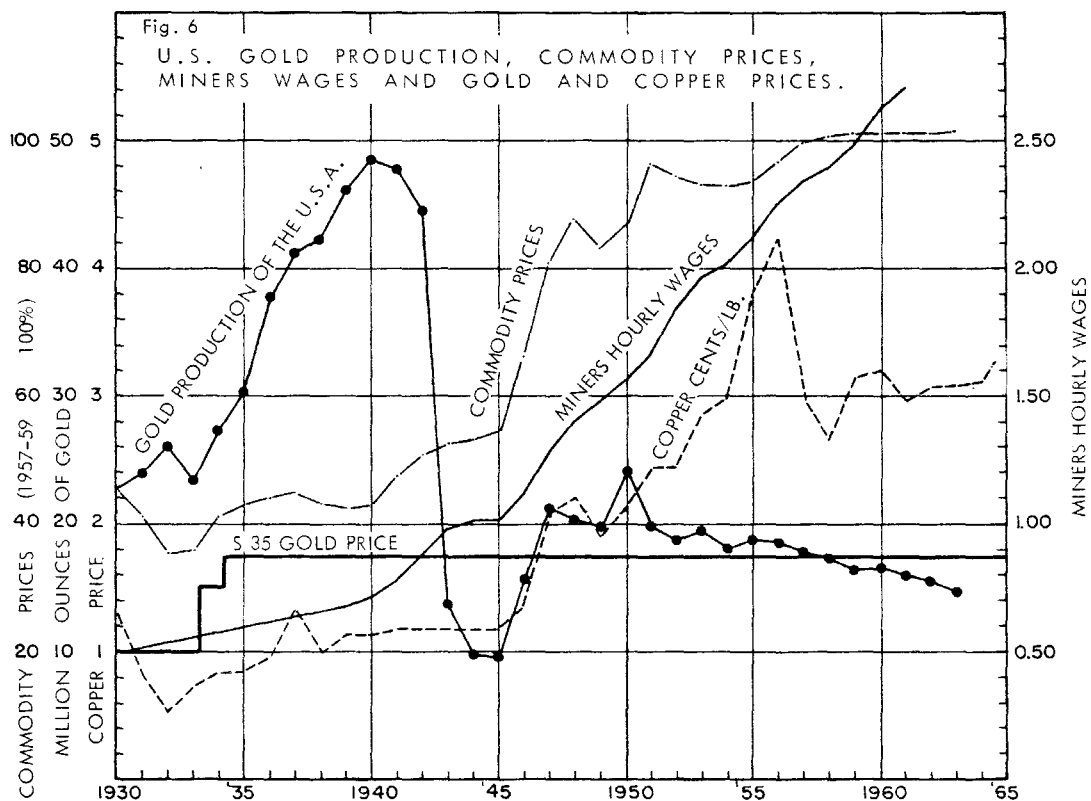
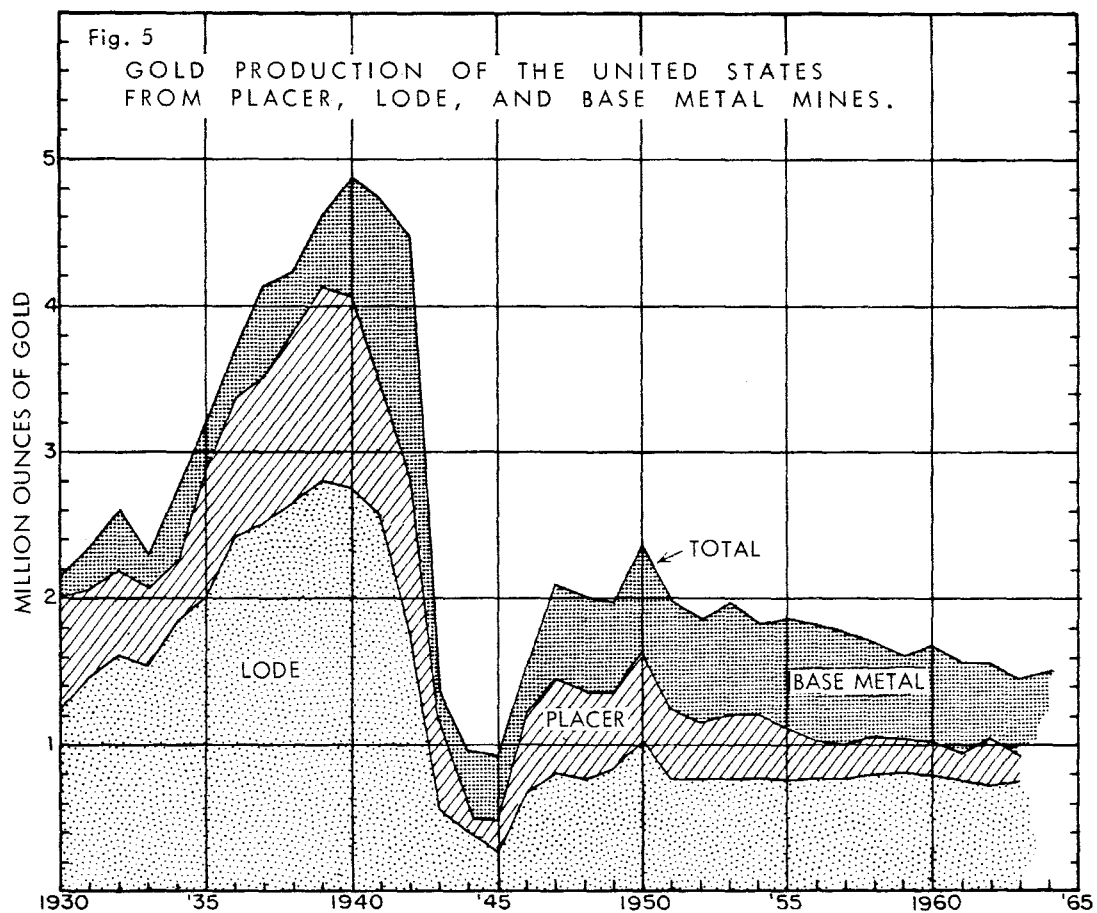
Since the reopening of the gold mines in 1945, the Homestake Mining Co. has produced three-quarters of the lode-mine gold in the last decade, and consequently figure 4 reflects its operations in this period more clearly than those of the few other mines now operating. Koschmann and Bergendahl (1961) in their forecast upon gold production under favorable conditions show distinctly how many gold mines have been shut down since the end of World War II and how the Homestake production dominates the statistics. Not only have many mines stopped mining, but some famous districts are dormant.

Figure 5 shows the relative changes in the United States' gold production from 1930 to 1963 for the three sources - lode, placer, and base metal. It illustrates what has been said previously about the marked decline of gold from placer mining and from dry and siliceous ores.

Figure 6 tells how the price of gold first stimulated gold production after it was raised from \$20.67 an ounce to \$35.00 in 1934, and then how it depressed gold production later while its price remained nailed down by law for 30 years. The plot also depicts how, in the meanwhile, wages rose 500 percent and commodity prices 265 percent.

The price of copper is also plotted on figure 5. It rose from 5+ cents per pound in 1932 to 31 cents in 1964. Gold and copper are not strictly comparable, because about 85 percent of the copper ore mined in the United States is by the open-pit method. The copper mines have made sufficient advances in open-pit mining to hold their mining costs per ton down to about the same level for the past decade, while high-cost gold mining underground has not been able to make any great reductions in labor costs. Why can't gold mining shift from under ground to open pits? This is a fair question. They do when the geology of a gold deposit lends itself to open-pit mining, but auriferous quartz mines which can be so mined are rare and valued highly. The new (1965) Carlin mine in Nevada is such an open-pit mine. The initial capital expenditure was \$10,000,000 in preparation for mining and milling 2,000 tons daily. While a low operating cost will be achieved, the first cost of machinery, equipment, and preparations for mining is high, because of the increases in these items of two and a half to three times since World War II (Engineering and Mining Jour., 1965; Mining Engineering, 1965; Fortune, 1965).

A good example of how costs have risen in this country is shown in the table



<u>Homestake Mine Costs</u>				
	<u>1941*</u>	<u>1962*</u>	<u>1964**</u>	<u>1965***</u>
<u>Production</u>	1,499,988 tons	1,868,741 tons	2,032,955 tons	2,031,500 tons
Gold content	\$13.02/T	\$10.85/T	\$10.68/T	\$10.88/T
Payroll	\$ 4,500,000	\$ 10,000,000	\$ 11,331,000	\$ 11,345,298
Local taxes	337,739	806,000	867,000	939,306
Employee benefits	207,137	629,638	717,000	1,081,448
Supplies & equip.	1,230,668	4,023,000	5,194,000	5,500,000

* McLaughlin, 1963, p. 28.

** Kellar, Feb. 2, 1966

***Kellar, Feb. 7, 1966

"The outlook for the year 1966 is not encouraging. In the year immediately ahead we already foresee approximately \$130,000 per year increase in social security taxes (including medicare), a further increase in the cost of supplies and materiel of \$100,000 per annum, \$75,000 per annum reflecting the impact of a full year of the increased sales tax rate of 3% which became effective July 1, 1965, \$30,000 per annum in increased electric power costs and \$70,000 per annum increased cost in county taxes, to say nothing of possible future wage increases." (Harder, 1966)

of statistics above concerning the Homestake mine in South Dakota.

Tyler (1959) gives a thorough discussion of 1959 mining costs, explaining how they have risen since World War II. All mining costs everywhere have gone up since 1934. Of the 48 lode gold mines in Canada in 1964, 44 have received assistance under the Emergency Gold Mining Assistance Act (Canadian Minerals Year Book 1964, Gold, p. 1). Of the 59 mines operating on the Rand, 16 are losing money or are making an unsatisfactory profit. The South African Government is assisting Rand mines in several ways. The gold-mining industry is not the only American industry which has suffered from inflation. It is, however, the only American industry which is forced by law to sell its product to the U.S. Government at a price fixed in 1934 and which has received no subsidy or relief of any kind.

ECONOMICS OF GOLD

The Scarcity of Gold

Gold has been sought and mined for more than 6,000 years, not just by individuals but by kings, governments, conquerors, adventurers, and corporations. All five continents and many of the world's islands have been searched and mined. The airplane, helicopter, four-wheel-drive automobile, and the shallow-draft motorboat have opened the wilderness and made it easy of access. Scarcely any virgin land or unexplored areas where gold might be found remain, except the sea floor which is receiving increasing attention. Gold never was plentiful in the past nor is it plentiful today. New mines will be found, but their ability to maintain the present rate of annual production is doubtful; an increase in production is not foreseeable at a

price of \$35.00 an ounce. The scarcity of gold is a continuing fact which the monetary authorities refuse to recognize. In spite of predictions to the contrary, the world has never suffered from a surplus of gold, even when the discovery of great bonanzas doubled the gold stocks.

Important Factors in Gold Production

Geology of the deposit

Geology bears much the same relationship to gold mining that climate does to agriculture. It is the most important principle in the evaluation of a gold mine or a gold-mining district. Geology determines the ease or difficulty of finding and following the ore; the size and persistence of the ore bodies; the grade and distribution of the gold in the ore; the method of mining and metallurgical treatment; and the ultimate value of the deposit or district. When the great variation in all of these elements is considered, only an experienced mining engineer or a mining geologist can determine what their total effect is upon the economics of a given mine or district.

It is particularly the geology which distinguished the South African Rand from other gold-mining districts and at the same time geology is responsible for making it the greatest gold-mining district ever found.

Recovery process

The gold dredge is an important element in gold production, because it makes profitable the mining of large, low-grade river bars and benches which otherwise would not be mined.

The cyanide process is the principal metallurgical process used for recovery of gold from dry and siliceous ores, because it recovers more gold at less cost than the older methods.

New discoveries

Gold is not linked to supply and demand the way most metals are. The supply is limited and the demand unlimited. Gold production rises and falls in a series of irregular waves, depending upon the discovery of new deposits. This is a matter of historical record. If the production of the important individual gold-mining districts in the United States is plotted separately, these waves take shape and explain the ups and downs of the overall production. These waves are of variable magnitudes and are a function of the geology of the mining district and of the ore occurrence (Hines, 1959). The policy of gold miners is to get out the gold from a new discovery as rapidly as is consistent with maximum profit, and this policy governs production.

Effect of Price Changes

When the price of gold was raised from \$20.67 an ounce to \$35.00 in 1934, the production of gold was stimulated. The primary purpose of the raise, however, was to increase the prices of agricultural products and thus benefit the whole domestic economy, not just the gold-mining industry. After all, in the United States the

price of gold had not changed for a hundred years, and under the gold standard it was not necessary.

Following World War II, as inflation raised the price of commodities and wages went up, the price of gold remained fixed. The result was that the cost of mining a ton of ore or producing an ounce of gold kept climbing and profits kept going down. The fixed price of gold then depressed gold mining everywhere except on the South African Rand, where new, high-grade mines were found and some old mines were able to market uranium as a by-product of gold mining.

If the U.S. Treasury had been as zealous in stabilizing the purchasing power of gold as it has been in maintaining the price of \$35.00 an ounce, the price would not be the factor it now is in suppressing the production of gold. Raising the price would open mines now shut down; conserve ore by saving gold in ore too low-grade to mine at present prices, ore which will be lost on account of the tremendous cost of reopening an abandoned mine; start new projects now unprofitable; and encourage the search for new deposits.

Recently, several economists have argued that if the National Treasuries and the Central Banks refused to support gold, which they now do by buying and selling it freely at \$35.00 an ounce, the value would collapse, because the number of purchasers and the amount of the funds are not sufficient to buy all of the gold now used for monetary purposes. It may be true that the price would fall, but the value would not for mankind has always valued gold.

If the price of gold dropped ever so little, the gold mines would have to shut down. The base-metal mines could not supply the demand for gold for industrial and artistic purposes. When the price had gone down far enough, speculators would enter the market. It is, indeed, probable that a syndicate would take over and control the price as is done in the marketing of diamonds. Many individuals in the United States who have not been able to buy and own gold for 30 years would do so. In time, gold would increase in price to a point where it could be produced profitably, and then the value of paper money would fall.

The high prices for shares in gold mines disproves the idea that the price of gold can be set by a few monetary authorities. Applying the economics of commodities to the economics of gold is always a mistake. The economics of gold is particular and not general. Man has an inborn appreciation of gold which is beyond abstract ideas.

Future Supply of Gold

The supply of gold for the future depends upon the discovery of new mines, the future price, and the decisions of the international monetary authorities. The Administration at Washington has ordered a survey made of the gold mines in this country to determine what the effect upon production would be if the price of gold were raised to several different levels. This is badly needed information.

The only forecast which can be made with any confidence now is that, if the price remains at \$35.00 an ounce, production from deposits now being mined and whose principal value is gold will continue to decrease and eventually will stop. It is doubtful that new discoveries will do anything but postpone the day when gold mines cease to produce.

Three trustworthy forecasts based on present knowledge are: "How about gold?" (Koschmann and Bergendahl, 1961): "Gold output of Witwatersrand will fall fast after

peaking about 1968" (World Mining, 1965, p. 22-27); and "Review of gold production (McLaughlin, 1960, p. 9-13).

Official Ignorance

The word "ignorance" as defined in the dictionary means "the condition of not being informed." It is strictly in this sense that the word "ignorance" is applied here to the U.S. Treasury's position on gold. Let us now re-examine the Treasury's official position.

In 1962, Robert Roosa, then Under-Secretary for Monetary Affairs, testified before the Committee on Interior and Insular Affairs of the U.S. Senate as follows:

Mr. Roosa: "Gold is special, because it is the monetary metal and it is different. In our view, in the United States it is not a commodity, and, therefore, is not subject to any of the same criteria, the same approaches that may be relevant for Congressional action with respect to other metals or other kinds of commodities, cotton for instance."

Senator Anderson: "You do believe that \$35.00 an ounce adequately represents the cost of production of gold? "

Mr. Roosa: "Yes, sir."

Senator Anderson: "Do you have statistics which permit you to say that? "

Mr. Roosa: "The evidence is basically that of the capability of the principal producing mines elsewhere to produce gold at that price. Now I would add this further point--that so long as gold is a worldwide monetary metal, what is important to us is that gold is produced, becomes available, as it does, increases as I say, in output in 10 years of nearly 50 percent, plus gold coming from other sources and into the known streams; this is in addition to mining, reprocessing, reclaiming and so on of gold; there has been an increase of about 75 percent in total annual availabilities of gold over the last 10 years.

"So the final criterion is whether the price is producing a supply, and it is, and it turns out in economic life all the time that particular areas find that that is not the thing they can do best, and they do something else.

"I am afraid, with respect to gold mining, that may be the case in this country."

Senator Gruening continues the questioning.

Senator Gruening: "It is correct, is it not, that it was raised in 1934 from \$20.70 an ounce to \$35.00 and has remained there ever since? "

Mr. Roosa: "Yes."

Senator Gruening: "And it is fixed there by Government action? "

Mr. Roosa: "Yes."

Senator Gruening: "And the miners are not allowed to sell it for any more?"

Mr. Roosa: "Yes."

Senator Gruening: "Is there any other industry that is subject to that kind of limitation?"

Mr. Roosa: "No, sir, this is because gold is gold."

It is worth while to analyze Mr. Roosa's evidence in detail. His opening statement is correct, but he does not stick to it. His belief that \$35.00 an ounce for gold is adequate is not sustained by the gold-production costs in the United States, Canada, Australia, and for the old mines on the Rand. His opinion that the price of \$35.00 an ounce is adequate to supply the world's gold requirements is questionable on two grounds. First, is the present supply of gold really sufficient? Certainly, no wider area of disagreement in monetary matters could be found than how much gold is needed for world trade. Second, will the supply take care of the future? Those in the gold-mining industry competent to judge do not think so. To Mr. Roosa's closing remark that "Gold is gold" should be added "And the U.S. Treasury is the U.S. Treasury."

What Price Gold?

Gold has a dual nature, one as a metal and the other as a monetary unit--its price is fixed, the demand infinite, the supply scant. Consequently, the economics of gold is unique. Ignorance of these simple facts of gold production has done great harm to the future supply of the world's gold and particularly to the gold-mining industry.

Future supply is just as important for gold as for any other commodity. It takes years to find a promising gold occurrence, more years to explore it, several years to develop it and to work out the metallurgical treatment. The total time required to bring a gold mine into production today may run from 6 to 10 or more years and there is no guarantee that it will be profitable even then.

It also takes considerable time and involves much risk to reopen an old mine.

Metal miners work the richest ores first, and as these become exhausted the miners are forced to turn successively to lower and lower grade ores. A grade of ore is eventually reached below which mining is no longer profitable and mining stops. Mining will not resume until lower costs of production are achieved, or improved methods of mining and metallurgy with higher recovery are found, or the price is increased.

If the monetary authorities cannot look farther ahead than their immediate requirements for a money in which citizens and countries will have confidence, the people will have to pay eventually for this lack of foresight.

Authorities may set the price of gold by law, but they cannot fix its production costs. Nature does this, which is undoubtedly why monetary authorities find it easier to print money than to encourage the finding and mining of gold.

References for Part IV

- A.I.M.E., 1933, Ore deposits of the Western States: A.I.M.E. Lindgren Volume, 1st ed.
- Beard, W. J., 1964, Gold: in The Canadian Minerals Year Book, Canada Dept. of Mines and Tech. Surveys.
- Canada Dept. of Mines and Tech. Surveys, 1964, Rept. of the Admin. of the Emergency Gold Mining Assistance Act, fiscal year ended March 31, 1964, Ottawa, Canada.
- Dominian, Leon, 1911, History and geology of ancient gold fields of Turkey: A.I.M.E. Trans., vol. 42, p. 569-589.
- Dorr, John V. N., 1936, Cyanidation and concentration of gold and silver ores: New York, McGraw-Hill Book Co., 1st ed.
- Emmons, W. H., 1937, Gold deposits of the world: New York, McGraw-Hill Book Co., 562 p.
- Engineering and Mining Jour., 1965, Newmont unveils open pit: Engineering and Mining Jour., vol. 166, no. 7, p. 76-79.
- Fortune, 1965, Newmont Mining fourth generation of gamblers: Fortune, October 1965, p. 132-137, 241-246.
- Harder, James O., 1966, Written communication from James O. Harder, Vice Pres. and Mgr., Black Hills Operations, Homestake Mining Co., Jan. 1, 1966.
- Hines, Pierre R., 1959, Highlights in the history of gold production in the United States: The ORE BIN, vol. 21, no. 4, April, 1959, p. 31-36.
- Hoffman, Arnold, 1946, Free gold, the story of Canadian mining: Associated Book Service, New York.
- Kellar, Kenneth C., 1966: Written communication from Kenneth C. Kellar, Homestake Mining Co. attorney, Feb. 2, 1966 and Feb. 7, 1966.
- Koschmann, A. H., and Bergendahl, M. H., 1961, How about gold?: Mining World, vol. 23, no. 1, p. 26-28.
- Kriz, M. A., 1965, Gold: Engineering and Mining Jour., 96th Annual Survey and Outlook, vol. 166, no. 2, p. 86-92.
- McLaughlin, Donald H., 1960, Review of gold production: in First Gold and Money Session, A.I.M.E. Pacific Northwest Metals and Minerals Conference, p. 9-13.
- _____, 1963, Second Gold and Money Session, A.I.M.E. Pacific Northwest Metals and Minerals Conference, p. 26-29.
- Mining Engineering, 1962, South Africa: Mining Engineering, vol. 14, no. 12, p. 41-43; Western Deep, a great new gold mine: Mining Engineering, vol. 14, no. 12, p. 44-48.
- _____, 1964, Kalgoorlie center of gold mining: Mining Engineering, October 1964, p. 107-108.
- Peele, Robert, 1941, Mining Engineers Handbook, 3rd ed., vol. 1, sec. 10, p. 552; p. 577.
- Rickard, T. A., 1932, Man and Metals: New York, McGraw-Hill Book Co., p. 209-214, 358, and 766.
- _____, 1945, The romance of mining: McMillan Co. of Canada, Ltd.
- Robertson, Angus, 1965, All that glitters: Barrons Weekly, March 8 and 15, 1965.
- Ross, A. C., 1965, Canadian gold: Barrons Weekly, May 3, 1965.
- Stephenson, Carl, 1962, Medieval History, Europe: New York, Harper and Row, 4th ed. rev. by Bruce Lyon.

- Sutherland, C. H., 1959, Gold: London, Thames & Hudson.
- Tyler, Paul M., 1959, Economics of the mineral industries: A.I.M.E. Seeley W. Mudd Series, Chap. 5.
- United States Senate 87th Congress, 1962, Hearings before the Sub-Committee on Minerals, Materials, and Fuels before the Committee on Interior and Insular Affairs, March 15 and June 8, 1962, p. 204-205.
- Verity, T. W., 1962, Gold: in The Canadian Minerals Year Book, Dept. of Mines and Tech. Surveys, Ottawa, Canada, p. 256-272.
- Wansbrough, V. C., October 1965, written communication.
- _____, Various reports in Canadian Metal Mining Assoc. publications.
- World Mining, 1965, Gold output of the Witwatersrand will fall fast after peaking about 1968: World Mining, June 1965, p. 22-26.

* * * * *

SPARTA SEISMOLOGICAL STATION OPERATION CHANGED

The U.S. Coast and Geodetic Survey took over the operation of the Blue Mountains Seismological Station near Sparta in Baker County January 1, according to the Environmental Science Services Administration of the U.S. Department of Commerce.

The station was operated the first three years by Texas Geotechnical Corp. under contract from the Air Force, serving both world-wide explosion detection and earthquake-reporting service.

It is considered one of the highest-gain or most sensitive stations in the world and under the new assignment will be the sensing unit for the new sea-wave warning system announced by the Department of Commerce.

Stations making up the system will be located at Adak, Sitka, and Palmer (Alaska) under the Coast and Geodetic Survey. Multiple seismic array systems are being constructed at the sites which will automatically record data from remotely located seismic instruments. Observers will be able to read very quickly required seismic data so that warnings can be issued much more rapidly and protection against seismic sea waves generated by local earthquakes will be provided for the first time.

A similar seismic array system will be installed at CGS's new Northwest Observatory at Newport, Wash., increasing the warning system for waves generated locally along the West Coast. Communications will be relayed to Honolulu Observatory, Pacific headquarters. Newport, located 60 miles north of Spokane, will also provide geomagnetic data and with a special sensing capability will be a valuable addition to the Pacific Seismic Sea Wave Warning System.

Baker station will automatically furnish data to Newport, needed in the release of wave-warning information to Honolulu Observatory. (The Record-Courier, Baker, Oregon, December 16, 1965.)

* * * * *

WELL RECORDS AVAILABLE

The Department released records of the Gulf Oil Corp. "Porter 1" oil test drilling from its confidential files on February 1, 1966. However, Gulf released this information to the public through the Salem Printing & Blueprint Co. shortly after abandonment in January 1964. The test hole was located 5 miles west of Halsey in the NE $\frac{1}{4}$ sec. 27, T. 13 S., R. 4 W., Linn County.

* * * * *

THUNDER EGGS ON EXHIBIT

A permanent collection of sawed and polished thunder eggs is on exhibit at the Department's museum in the State Office Building in Portland. Upon request, the eggs were graciously supplied by the various rock and mineral clubs in Oregon as examples of the new "State Rock." Included in the exhibit are a few cabochons cut from thunder eggs. Most of the stones are from the well-known Friday Ranch locality east of Madras in Jefferson County; a number are from the Ochoco region near Prineville in Crook County; several are from Opal Butte in southern Morrow County; and one is from a locality east of Burns in northern Harney County. One specimen, which came from an outcrop in the vicinity of Idleyld Park in Douglas County, represents the first reported thunder-egg locality west of the Cascades. The entire collection demonstrates not only that thunder eggs are objects of beauty and interest, but also that enthusiasm for collecting, cutting, and polishing these and other agate materials is shared by a great many rock and mineral clubs throughout the state.

An illustrated report telling how the thunder egg became the State Rock, where it is found in Oregon, and theories on its origin was published in the October 1965 issue of The ORE BIN.

* * * * *

OIL AND GAS REPORT REVISED

The Department has just issued "Oil and Gas Exploration in Oregon" as Miscellaneous Paper 6. This report, originally compiled in 1954 by R. E. Stewart, has been revised and brought up to date by V. C. Newton, Jr., Petroleum Engineer for the Department. The new edition contains a history of exploration in Oregon, a review of the geology of sedimentary basins, the development of Oregon's oil and gas laws, exploration statistics for both onshore and offshore drilling, tabulated data on each well including gas and water analyses, and a comprehensive bibliography. Included with the report is a map of Oregon showing the location of all the wells drilled. The 41-page book sells for \$1.50 and may be obtained from the Department of Geology and Mineral Industries, 1069 State Office Building, Portland.

* * * * *

ALDRICH MOUNTAIN QUADRANGLE PUBLISHED

The U.S. Geological Survey has recently issued "Geologic Map of the Aldrich Mountain Quadrangle, Grant County, Oregon," by T. P. Thayer and C. E. Brown. The map, designated as GQ-438, is accompanied by a short text on a separate sheet which describes the Tertiary geology of the area. Tertiary units include the Clarno Formation, Picture Gorge Basalt, Columbia River Group undivided, Mascall Formation, and Rattlesnake Formation. Pre-Tertiary rocks, shown on the map, include Paleozoic rocks of probable Permian age intruded by Late Permian or Early Triassic peridotite, gabbro, serpentine, and albite granite. Lying unconformably on the older rocks are Late Triassic and Late Cretaceous sedimentary formations.

The Aldrich Mountain quadrangle lies between Dayville and Mt. Vernon a few miles north of the Suplee-Izee pre-Tertiary inlier. A report on the geology of the Suplee-Izee area by W. R. Dickinson and L. W. Vigrass will be published by the Department this spring. GQ-438 may be obtained from the U.S. Geological Survey, Denver Federal Center, Denver, Colo. 80225, for \$1.00.

* * * * *