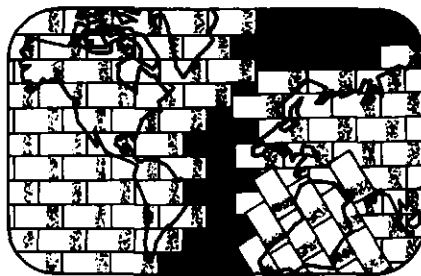


Presidential Address

Presidential Address to the Geological Association of Canada, Edmonton, Alberta



Gold Reserves of the World

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Introduction

During the winter of 1966-67 I prepared a paper entitled "Have 6000 Years of Gold Mining Exhausted the World's Gold Reserves" for presentation at an AIME Gold and Money conference. The paper was subsequently published in the April, 1968 issue of the CIM Bulletin. At that time the price of gold was \$35 an ounce. Now it is about \$130, having risen to almost \$200 in late 1974. I consider it appropriate to present this updated version of the paper in light of the price rise and of gold production developments in the last nine years.

History

From a particularly informative book on ancient gold mining by C. H. V. Sutherland I have estimated that less than one billion ounces were mined in the 5,500 years before 1500 A.D. when Columbus discovered America. Records indicate that some 2.8 billion ounces have been mined in the 484 years since then, making an approximate overall total in excess of three billion ounces.

From 4,000 B.C. when gold is first known to have been mined in any quantity, Egypt was the principal gold-producing area until the Romans started mining the Spanish deposits prior to the beginning of the Christian era. Spain continued to be the predominant producer during the first centuries A.D.

During the Dark Ages from the 5th to the 13th century, the Byzantines mined gold from long-standing Balkan sources in south-eastern Europe and Asia Minor, also from the Urals in central Asia and from eastern Africa. European

production reached its zenith in the 14th and 15th centuries but even so was modest, Hungary being the main producer with only 100,000 ounces annually. Important production during those two centuries also came from French and Portuguese colonies in West Africa.

The discovery of the Americas heralded the exploitation of rich gold deposits in Mexico and South America which during the 16th century produced more than 10 million ounces. Total world production in each of the 16th and 17th centuries was 20 to 30 million ounces.

Following its colonization by Portugal, Brazil by the middle of the 18th century was producing as much gold as all of the Spanish colonies in the Americas combined. Brazil's total output during that century is estimated at 25 million ounces, within an estimated total world production of 50 to 75 million ounces in that century.

Russian production of 300,000 ounces a year for a short period in the middle of the 19th century was the greatest in the world.

Then gold was discovered in California in 1849 and the United States became the leading gold producer in the world, a position it maintained for 50 years because of later discoveries in the western States, notably the Comstock Lode in 1859, the Homestake mine in 1876, and the discovery at Cripple Creek in 1891.

During the 1850s and 60s gold was discovered in Australia - in New South Wales, Queensland and Victoria, and in New Zealand. The important Kalgoorlie field in Western Australia was found in 1892, and by the end of the last century Australian production was 3.3 million ounces annually.

The Klondike and Alaskan placer fields were discovered late in the 1890s.

The gold camps of Ontario and Quebec were discovered early in this century, and important new lode deposits in Nevada in the late 50s.

But what has turned out to be the most momentous gold find of all time was the discovery in 1886 of gold-bearing conglomerate on a farm in the Witwatersrand region of South Africa. Everything concerning gold that had gone before or has happened since pales before the extraordinarily extensive and productive deposits that have subsequently been developed in the Rand. At its current rate of some 23

million ounces a year, the Rand is producing about 75 per cent of the western world's output and is producing annually as much as the entire world's estimated production in each of the 16th and 17th centuries. The Rand is producing annually almost one per cent of all the three billion ounces produced since gold mining began 6,000 years ago. And with a total production of one billion ounces since its discovery 90 years ago the Rand has already produced one-third of the world's all-time production.

Present Reserves

In my original paper this section was based on the \$35 per ounce price prevailing at the time. In a following section I predicted what the gold reserves of the world would be, given an increased price for gold. Now that a very substantial price increase has occurred it is interesting to check on the accuracy of my predictions.

Much of Egypt's production came from placer deposits which were undoubtedly all found and worked by slave labour down to a very low grade. *The lode deposits were in short, shallow, small tonnage vein-shoots in Precambrian schists and pre-Carboniferous intrusives. Many unsuccessful attempts have been made to revive Egyptian gold mining. In Spain, as in Egypt, placer deposits were the most prevalent sources and slave labour made the exploitation of low grade vein deposits in Paleozoic granites profitable. My prediction that Egypt and Spain, as well as the former producing areas in southeastern Europe, would not derive much advantage from an increased price for gold appears correct; in the last five years there has been no production from Egypt, and Europe's annual production has risen merely from 200,000 to 500,000 ounces.*

Most of the lode gold deposits in the Cordillera of North and South America have been found in Mesozoic or younger rocks, commonly volcanics, intruded by granites and porphyritic rocks of Cretaceous or Tertiary age. The principal deposits have been characterized by their richness and shallowness, a notable exception being the Mother Lode of California. Being shallow, most of the deposits have been found and exhausted to a very large extent. Lode deposits of that type in all of the North and South American Cordillera

produced less than 500,000 ounces in 1974. As I did in 1967, I still predict that, with the odd exception such as the present activity in the Guanajuato area of Mexico, the typical Cordilleran locales will not be reactivated. Another exception of some promise in the Cordilleran regions are the hydrothermal Carlin-type occurrences of Tertiary age which, because of the submicroscopic nature of their gold, have defied detection by old-time prospecting methods. In addition, the United States Geological Survey has found large volumes of quartzose conglomerate of Mesozoic and Tertiary age in Idaho and Wyoming containing 0.01 ounce of gold per ton; the U.S. Bureau of Mines is trying to develop both mining and metallurgical techniques which would make such low grade deposits economic.

Placer deposits derived from the lodes have probably yielded more gold than the Cordilleran lode deposits. However, placer production has declined in all regions except Columbia and continues at a very low ebb today, although some renewal of dredging operations at Nome, Alaska is underway. Modern exploration techniques may find additional placer deposits, particularly in Bolivia and Columbia, but it is doubtful that all such deposits will exceed five million ounces.

The Cordilleran regions contribute significant quantities of by-product gold, mainly from porphyry copper deposits. *In 1969, such production approached 850,000 ounces, over 30 per cent of it coming from the Bingham mine in Utah. Taking the build-up of porphyry copper production capacity in the western States, Chile and Peru into account, it is likely that the Cordilleran regions will produce in the order of one million ounces of by-product gold annually for many years to come.*

The Homestake mine in South Dakota has produced approximately 30 million ounces of gold from 100 million tons of ore. The ore occurs in folded and altered Precambrian sedimentary rocks. In 1968 Homestake reported new deep ore bodies, and at the end of last year ore reserves were 15.3 million tons grading 0.264 ounces per ton.

Canada's Precambrian Shield has produced approximately 155 million ounces of gold, about 80 per cent of

Canada's total. Most has come from quartz veins in volcanic rocks intruded by granites and porphyritic rocks. Some has been by-product from base-metal deposits in volcanic rocks. In spite of the present price of gold Canadian gold mining is in a sad state of decline because of no large new ore discoveries, labour shortages, rapidly diminishing reserves, and steadily increasing costs. Although one or two small mines have been brought into production in the past several years, and one or two others are planned, they by no means make up for the great number of formerly big producers which have closed down or are closing down. In 1967 I predicted that the Cadillac-Malartic region in northwestern Quebec, which has large tonnages grading 0.1 ounces of gold per ton, would benefit from a substantial price increase. *Unfortunately, although the region is having a resurgence of gold exploration, that low grade is simply not sufficient, even at the present price of gold, to offset the great capital and operating cost increases that have occurred in the last five years. It is likely that Canada's annual production, which fell below two million ounces in 1973, will soon be less than 1.5 million ounces. Assuming a \$130 per ounce price, Canada's total lode reserves probably do not exceed 10 million ounces.*

Other than South Africa, the other parts of the western world to which I have not referred altogether produced about four million ounces in 1974; of that total Ghana and Papua New Guinea each produced 700,000 ounces (the latter as by-product from the Bougainville porphyry copper mine), the Philippines and Rhodesia each 600,000 ounces, Australia 500,000 ounces and Brazil 400,000 ounces. Total production from such countries will likely continue to be 4 million ounces annually for years to come; in Brazil, the Anglo-American company has acquired the famous Morro Velho mine, and is carrying-out drilling and exploratory adit work on the Proterozoic gold-bearing conglomerate Jacobina property, the Homestake company has entered Australia's famed Kalgoorlie field, Ghana has deposits with proven depth extension, and a new gold mine with reserves in excess of four million ounces has started in the Dominican Republic.

The gold picture in China continues to be a mystery. China has granites of Precambrian, Carboniferous and Jurassic age and gold is associated with all of them. There are also placer deposits particularly in northwestern Mongolia in an extension of the Altai field in Russia. China's total production since the 16th century has been estimated at 12 million ounces. United States authorities have estimated an annual production of 50,000 ounces in the 70s. Considering the size of the country and its varied geology, China could have considerable potential reserves.

That leaves the two principal gold producing countries in the world, Russia and South Africa. As previously stated, South Africa is producing about 75 per cent of the western world's gold output. That is a strong indicator of where the bulk of the western world's reserves are. The Witwatersrand region includes seven mining areas which occur along a 250 mile arc with the Evander area at the northeast end and the Orange Free State area at the southwest end. In between from east to west are the East, Central, and West Rand areas and the Klerksdorp area. (Fig. 1). The East, Central, and West Rand areas were developed shortly after the initial discovery in 1886. The Klerksdorp area was worked in a small way early in this century but was not recognized as a major area until the mid-thirties. The Far West Rand area was discovered in 1939, the Orange Free State area in the late forties, and the Evander area in the fifties.

All of the ore in the region is contained in quartz-pebble conglomerate reefs occurring in the lower section of the Upper Witwatersrand System of Precambrian age. There are eight principal conglomerate zones or reef groups, all of which contain gold, but the most important are Main, Bird, and Kimberley Groups and their correlatives. Some of the mines have been developed to more than two miles in depth.

In 1966, with the price of gold at \$35 per ounce, 23 strong mines in the Rand produced 24 million ounces, and some 30 other waning mines, which had contributed the bulk of the region's fabulous past production, produced seven million ounces for an overall total production of 31 million ounces. There were also five new mines being brought into production at that time, with a

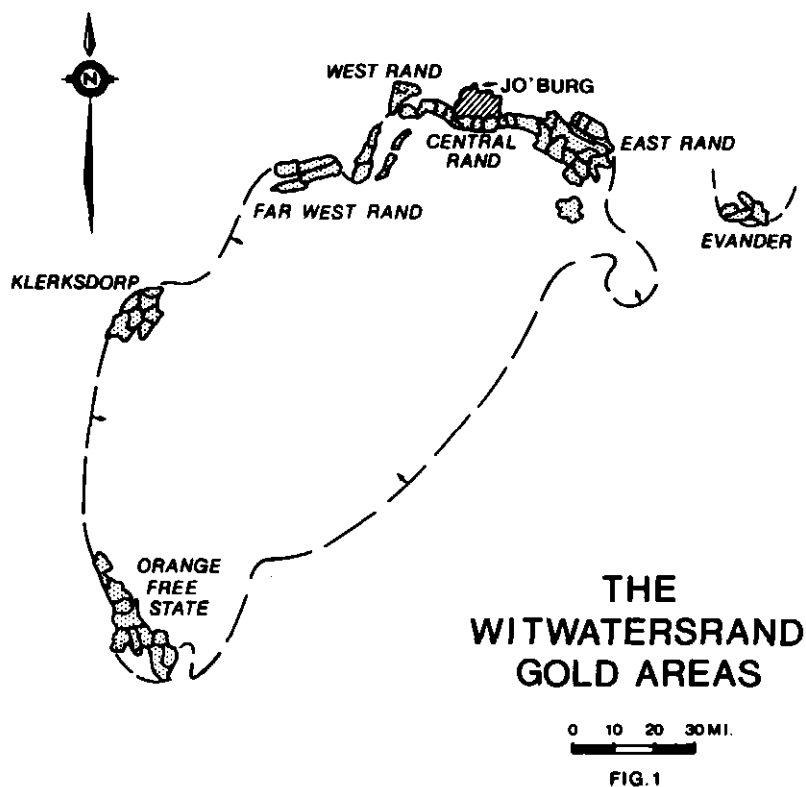


Figure 1
The Witwatersrand Gold Areas

combined capacity of 4.75 million ounces annually. On the basis of \$35 gold those total 28 strong mines had a total annual productive capacity of 29 million ounces from 60 million tons at an average grade of approximately 0.5 ounce per ton; none of the mines had an estimated life less than 10 years, 20 of them had estimated lives in excess of 20 years, and three had estimated lives in excess of 30 years; in total they had an estimated minimum total reserve of 500 million ounces contained in one billion tons of ore. The significant rise in the price of gold has permitted those 24 mines (four of the 28 have been merged with other mines) to bring back into their reserves and mine extensive low-grade tonnages which had previously been deleted. As a result, last year their combined total production yielded 20.2 million ounces at a reduced overall average grade of approximately 0.3 ounce per ton; 16 other mines (including the new Randfontein Cooke Section mine in the West Rand which commenced in 1973) produced 2.5 million ounces from 17 million tons of ore with an average grade of 0.16 ounces per ton.

Three more new mines are being brought into production in the Rand, the Deelkraal and Elandsrand in the Far West Rand with, respectively, reserves of 45 million tons of 0.53 ounces per ton and 66 million tons of 0.59 ounces per ton (ultimately at 870,000 and 960,000 ounces annually), and the Unisel mine in the Orange Free State with reserves of 15 million tons of 0.64 ounces per ton - 600,000 ounces annually. A great deal of exploration work is being carried out in the Rand, and although it appears unlikely that any more new areas will be discovered, the reserves of existing mines will undoubtedly be expanded further and other new mines may be developed in the known areas. Just last month it was reported that the South African Lands mine is going to spend \$8.6 million to prove a new mine in the southern half of its property in the East Rand.

The Rand has produced approximately 260 million ounces in the nine years since I estimated that it had a minimal reserve of 500 million ounces at the \$35 price. I consider that that production has been or will be replaced by the large additional profitable

reserves which have resulted and will result from the substantial increase in the price of gold. I therefore estimate that the reserves in the Rand, based on a \$130 per ounce price, are still in the order of 500 million ounces.

Since the beginning of this year several spokesmen have stated that South African production this year will level off at last year's rate of some 22.7 million ounces - admittedly the result of continually rising costs coupled with the present static price range forcing mines to stop appreciably lowering their mill-head grades as they have been able to do during the past six years. Those statements have largely been supported by the first quarter production data; total production was merely two per cent lower than production in the last quarter of last year. Of some interest is the fact that of the 12 mines which produced in excess of 200,000 ounces each during the quarter, eight operated at slightly lower grades than the previous quarter. Assuming a \$130 price, I predict that South Africa's annual production will decline slightly during the next couple of years to 22 million ounces and that it will maintain that level to the end of the century; increasing costs should be offset by improved utilization of labour and improved mining techniques, permitting the present overall average mill-head grade of 0.3 ounce per ton to be maintained.

Now for the *pièce de resistance* - Russia. In my original paper I was able to write only the following about Russia's gold situation:

"Unfortunately, reliable data on Russia's gold industry are meagre. Placer deposits have historically been the main producers. They are thought to be contributing almost 50 per cent of current annual production, which is estimated at six million ounces by United States authorities and at 10 million ounces by British authorities, who consider that their information pipelines are better. The lode deposits are mainly quartz veins in a variety of Precambrian and Paleozoic rocks. There is little doubt that Russia's gold deposits are widespread and that its reserves are of very considerable magnitude, probably in the order of 200 to 300 million ounces."

Since 1967 several important sources of data have come to hand which have supported my earlier statements with

one exception - there is very little if any Russian gold production from Precambrian rocks.

In 1974 a book entitled "Ore Deposits of the USSR" was published which includes a chapter by M. B. Borodaevskaya on Russia's gold deposits. Russia's extensive alluvial placer gold deposits range in age from Mesozoic to Quaternary. The deposits are commonly buried, those in eastern and northeastern Russia under glacial deposits, those in the Urals under Cretaceous marine deposits or Cenozoic continental deposits. Although no economic Proterozoic conglomerate deposits have yet been found in Russia, gold is known to occur in Precambrian conglomerates in a number of regions. Russia's lode gold deposits occur principally in volcanic belts of early Paleozoic to Cenozoic age intruded by granitic rocks. The deeper deposits are generally of lower Paleozoic age, the shallower ones upper Paleozoic to Cenozoic in age.

Data which I now have on Russian gold production come mainly from reports by David Dowie, a consultant in London, England who, during the last decade, in collaboration with Michael Kaser, a leader in economics at the University of Oxford, has accumulated a great deal of information on Russian gold production. His data have been published in the Consolidated Gold Fields comprehensive annual gold reviews. The last review, dated June 1975 and entitled "Gold 1975", contains an appendix by Dowie entitled "Soviet Gold in 1974 - Including revision of gold production estimates for 1950 to 1975". His data, which he satisfactorily subjected to cross-checking, are quite startling. From 4.5 million ounces in 1950, Russia's gold production has been increasing steadily to an estimated 14.2 million ounces last year, more than 60 per cent from the Yakut region and eight per cent from the Lena region. Other important placer regions are Zabaikal, Amur, Primorsky and the Urals. The most important gold lode deposit regions, in decreasing order, are Yakut, Zabaikal, Zapsib, Uzbek, Armenia, Kazakh, the Urals, Altai, Severovostok and Yenisei. Slightly more than 10 per cent of Russia's gold production is by-product from copper mines, principally those in the Urals. (Fig. 2 shows the widespread distribution of Russia's many important gold producing regions.)

There is every indication that Russia's gold reserves are immense and that its gold production is going to continue to rise markedly. In July, 1967 the Intelligence Digest, a British publication, carried an illuminating report on Russian gold development. After a quote from a member of the Soviet Academy of Sciences that the gold reserves and the gold deposits of the Soviet Union were to become one of the main supports of the Socialist world system in its struggle against world capitalism and that every effort was going to be made to increase gold production considerably, the article then reported an announcement in Russia that geologists had discovered extensive new deposits in Armenia, Georgia, Uzbek, the Urals, Yenisei, Lena, Amur and Severovostok. In his report last year Dowie stated that large 1975 production increases were planned for the prolific Severovostok placer area which is contributing 25 per cent of Russia's total production, that a new Amur railway under construction would open up many large deposits for which two new dredges would begin operating in 1975 and the construction of several more started, and that a new gold town of 30,000 inhabitants was planned in Armenia.

Considering all of the preceeding data, and assuming a \$130 per ounce price, I estimate that Russia's gold reserves, like South Africa's are in the order of 500 million ounces. I predict that Russia's annual production will continue to rise markedly, that it will surpass South Africa's in some 20 years' time, and will attain a level of 25 million ounces by the end of the century (Fig. 3).

To summarize the world picture at a \$130 per ounce price, I estimate that western world production other than South African will gradually fall from its present annual level of 8.2 million ounces to 6.3 million ounces early in the '90s through to the end of the century because of declining lode production in Canada and the United States. Total western world annual production will therefore fall gradually from slightly more than 30 million ounces this year to 28 million ounces early in the '90s through to the end of the century. On the other hand, I predict that because of Russia's increasing production, total world annual production will rise continually from its present level of slightly more than 45 million ounces to

52 million ounces early in the '90s and to 53.5 million ounces by the end of the century, being in those years greater than ever before (Fig. 3).

MS received May 18, 1976.

Figure 3
Gold Productions Forecasts based on \$130 per ounce price

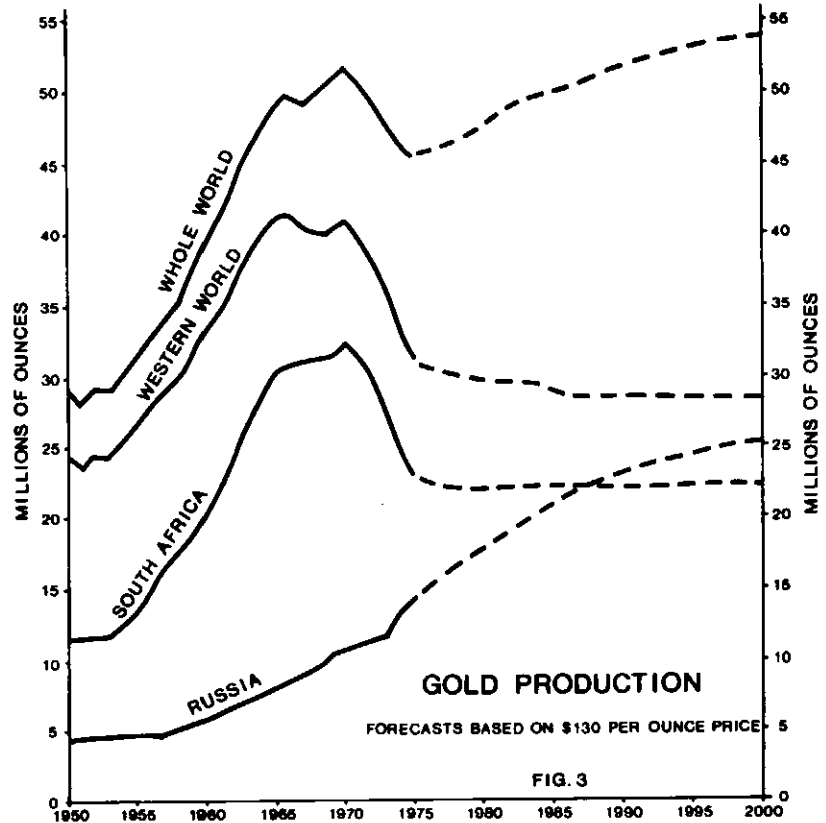


Figure 2
Gold Producing Regions in Russia

