

**ECONOMIC GEOLOGY
RESEARCH UNIT**

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WORLD GOLD RESOURCES
A REVIEW BASED ON HISTORICAL PRODUCTION
AND NEW DISCOVERIES

J. R. F. HANDLEY

— • INFORMATION CIRCULAR No. 217

UNIVERSITY OF THE WITWATERSRAND

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by J R F Handley

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EXECUTIVE SUMMARY

Gold is a medium of currency, a store of wealth and a hedge against economic or political disaster. Since time immemorial an estimated 110 518 tonnes of gold have been produced.

Africa has been the largest producer with a record of 50 520 tonnes followed by the Americas with 26 531 tonnes, Europe with 21 106 tonnes, Australasia with 7 871 tonnes and Asia with 4 490 tonnes.

The six countries with the highest recorded production are South Africa (42 085 tonnes), Greater Russia (15 921 tonnes), U.S.A. (10 875 tonnes), Canada (7 209 tonnes), Australia (6 471 tonnes) and Brazil (2 240 tonnes). No other countries have exceeded 2 000 tonnes.

Revival of gold exploration and mining since 1980 has seen a 6.1% annual increase in production for the period 1980 to 1988.

New discoveries and expansion of known deposits have resulted in an estimate of reserves for South Africa (39 862 tonnes), U.S.A. (4 435 tonnes), Canada (4 195 tonnes), Australia (3 669 tonnes), Papua New Guinea (2 600 tonnes) and Brazil (1 400 tonnes). No details of Russian reserves are available. These have been set at 5 000 tonnes.

At present production rates most countries will deplete existing reserves within 20 years, except South Africa (57 years), U.S.A. (22 years) and Canada (33 years).

The total gold content of known reserves is set at 65 061 tonnes. This is roughly 10 grammes of gold for every man, woman and child on earth today.

A shortage of gold supplies is likely as demand for jewellery alone has increased at 8.75% per annum for the period 1980 to 1988.

The first contraction in gold supplies is likely to come before the turn of the century when Australian production is expected to fall rapidly.

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The search for the yellow metal is no new thing.
The search for gold is the very history of the world.
ADÉLE LEZARD

ABSTRACT

Man's desire for gold commenced in pre-historic times and remains undiminished in today's modern civilization. Earliest gold mining is recorded from the Middle East and North Africa, in 3150 BC, with the search for gold extending outwards as civilization developed. Each wave of advancement brought the discovery of new goldfields and these were exploited. Successively large gold production shifted from Egypt to Nubia, Europe, Asia, West Africa, Colombia-Ecuador, Brazil, U.S.A., Australia, South Africa, Russia, Canada and Oceania.

Precise production figures from each area are unknown, as records often do not exist, or are incomplete. Even official records, since 1493, are not without error and usually underestimate production. The best estimate that can be made today is that total production of gold, from time immemorial to 1988, is 110 518 tonnes.

Looking to the future, gold production will be largely from those areas which have already been major producers. Changes in the price of gold, relative to production costs, since 1970 has seen exploration, development and production revived or expanded in almost all areas which were previously producers. Only a few new discoveries have been made. As a rule of thumb, it appears as though most areas will in the future produce only about 60% of historical production.

Present and future generations will have to look to a decreasing availability of gold for each individual, as the amount available will reduce to an average of only a few grams per person as population increases. This could be sufficient only to provide an engagement and wedding ring. The price and production of gold should be assured well into the future.

INTRODUCTION

Man's desire for gold was aroused in pre-historic times and remains undiminished in today's modern civilization. Gold has always been an indication of riches and provided a store of wealth for man and his governments. As a medium of currency it provided the most stable period of development and monetary control the world has known and today still provides a haven when crises arise in paper currencies.

Gold is not equally distributed over the Earth, but economically viable concentrations of the metal are scattered over all of the continents. Africa has been most generously endowed, followed by the Americas, Australia, Europe and Asia.

The history of gold goes back to at least 3150 BC when Menes recorded the value of gold as 2.5 times that of silver. This ratio was a result of the relative abundance of gold to silver as the former is present in all alluvial deposits, the earliest form of mining, while the latter has its greatest association with base-metals. As silver became more available, the price ratio of gold to silver increased in favour of gold, until today, where it hovers around 50:1.

Mining of gold is closely related to the economic parameters of the day. This has applied throughout history, although, at times, the use of slaves and prisoners saw some inordinately low grades of gold being worked with such labour. Many analysts have viewed slave-labour as cheap, whereas, in fact, it involved a major capital investment for the purchase of the slaves and on-going costs for their maintenance. For example, during the early days of mining in Minas Gerais, Brazil, a slave in his prime cost as much as 20 ounces of gold. This was in effect capital invested which had to be recouped before a profit was shown. The life of a slave was only about seven years in service, so that at 20 ounces or 622 grams of gold in value, he needed to produce at least 0.25 grams per day, just to balance his purchase price.

The economics of gold mining rests on the price of gold relative to the cost of extraction. There is a steady and constant demand for gold and the tendency throughout time has been to allow that average grade ores can be worked at the ruling price. This applies today and the bulk of the gold being produced is profitable, while a small percentage of gold is produced by mines working at a loss, and working in the hope that a price adjustment will make them profitable.

HISTORY

The first gold acquired by man was probably during the Stone Age when, after a flood, a bright-yellow nugget was left lying on the soil as the waters receded. Stone Age man was fascinated by its colour and its weight and carried it home. He may have tried to chip it and fashion it into an arrow head or a hammer, but he soon found that it was too soft. However, it was malleable and, by beating it with a rounded stone tool on a stone anvil, he produced the first sheet-gold. This he used to wrap around the handle of a flint knife.

Gold was initially most abundant in Egypt, where alluvial deposits along the Nile were the main source. The Pharaohs had already learnt to use gold, and bracelets, rings and ornaments made from gold-plate were produced. In 3150 BC silver was entering Egypt from the east and Menes decreed that the relative value of gold to silver was 2.5:1. This is the first known writing which referred to gold. Today the gold-silver price ratio hovers around 50:1.

The search for the metal soon extended southwards from Egypt into Nubia, and records of journeys taking several years suggest that seafarers sought gold down the east coast of Africa.

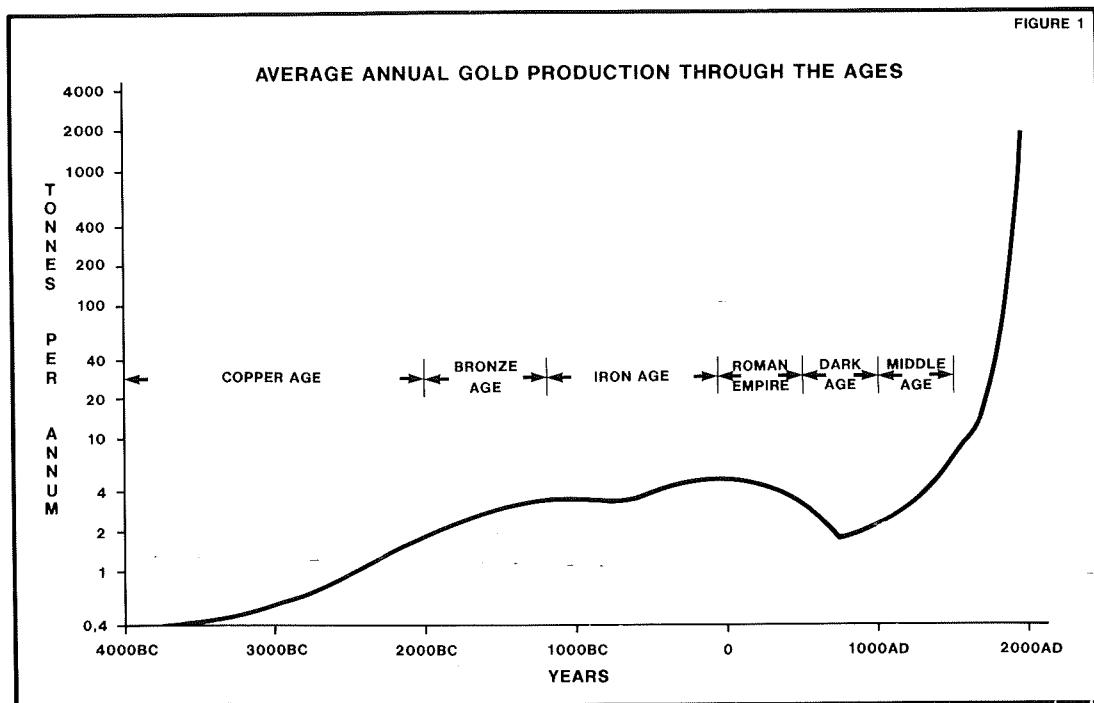
The entire Middle East, from the eastern Mediterranean to the Black and Caspian seas and southwards to the Persian Gulf, was an area of extremely sophisticated gold-working for 2000-3000 years prior to the Christian era. The Cretans were goldsmiths of a high order, executing repousse work, while the Sumerians had developed granulation techniques. Crete has very little gold of its own and it is believed that much of the gold was obtained by trade.

Production of gold spread from the Middle East into Europe and Asia during the Iron Age and the Roman Empire. Leaders in production during these times were Spain, and the area around the Carpathians and Russia, followed later by China and Africa. A major disruption took place during the Dark Age when production throughout Europe fell and recovered only slowly through the Middle Age.

Exploration of world trade routes by sea and land opened up new sources of gold. The Spanish gold from the Americas, much of it plunder, and subsequent mining, with Colombia as the largest contributor, created the first new, major source of gold. The discovery of gold in Brazil saw that country become the world's major contributor in the 18th century, and this was followed by the even larger discoveries in the USA and Australia. However, the biggest increase was still to come, with the discovery of the Witwatersrand deposits in South Africa in 1886. This production, to which must be added the contribution of Canada, saw total world gold production rising very rapidly.

Figure 1 illustrates the progression in average annual gold production in tonnes from the earliest recorded production to the present day. Apart from slight reverses during the Iron and Dark Ages, the trend has been steadily upwards. The periods over which the averages were taken have become progressively shorter as records are more frequent in the modern era. However, the increases are still dramatic when it is considered that, during the 18th century the average was 21.54 tonnes per annum, the 19th century 123 tonnes, from 1901 to 1940: 696 tonnes, from 1941 to 1970: 1186 tonnes and from 1971 to 1988: 1309 tonnes. Seeing the exponential growth of production in the period from 1700 to the present, one wonders whether similar growth levels are sustainable over a protracted time-period, such as the next hundred years.

Very recent developments are the emergence of the Pacific Islands as a major source, while economic conditions have seen a resumption of mining in all the old traditional areas.



Anomalously, the improved-profit conditions have had a negative effect on South African production. This brought into profitability very large tonnages of marginal ore, allowing average yields in the South African mines to fall steadily as shown in Table 1.

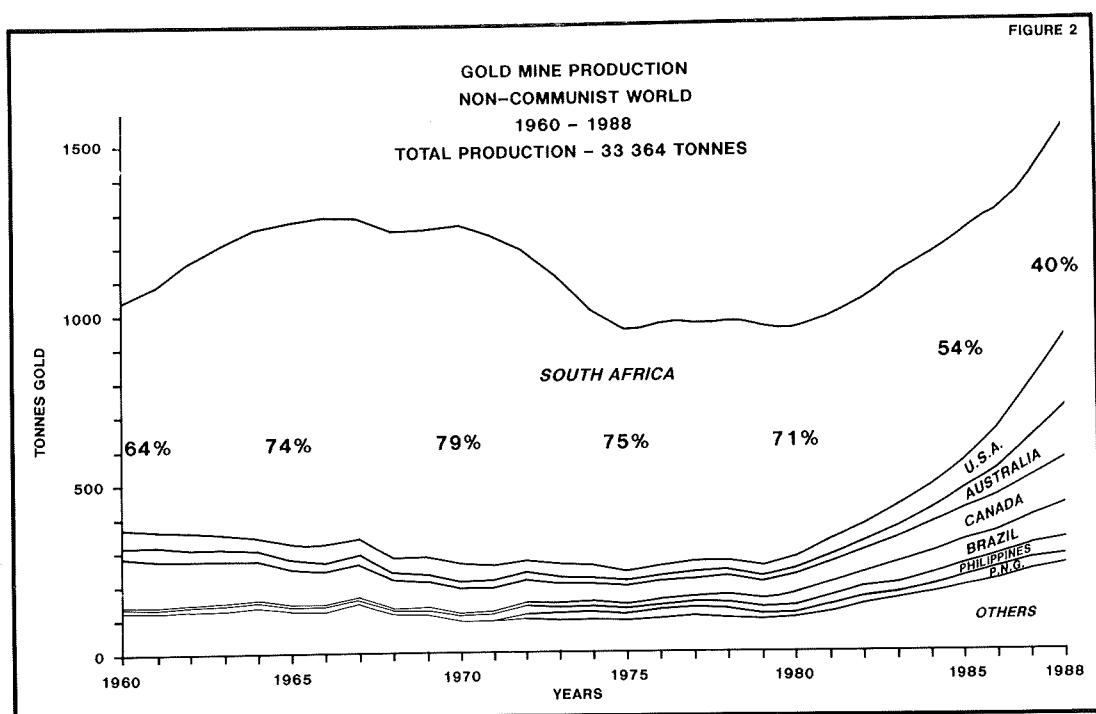
YEAR	TONNES TREATED THOUSANDS	FINE GOLD KILOGRAMS	AVERAGE GOLD CONTENT g/l
1970	79 965	1 000 417	12.51
1975	75 126	713 447	9.49
1980	93 263	672 875	7.21
1988	119 450	617 984*	5.17
*provisional			

Increases in tonnage treated have partly compensated for the fall in grade, but the general trend over the past nineteen years has been a fall in the kilograms of gold produced.

This is well illustrated in Figure 2 which shows annual Non-Communist gold production for the period 1960 to 1988. The South African production is indicated as a percentage of Free World production and, over the period, this has risen from 64% in 1960 to 79% in 1970, and then fallen to only 40% in 1988.

The dramatic increase in production from other major producers in the period 1980 to 1988 is also clearly visible and is part of the reason for the fall in the percentage contribution by South Africa.

Quiring (1948) in his "Geschichte des Goldes" has compiled the most comprehensive study of early gold production. His work was studied and summarised by Rene Sedillot in "Historie de l'Or" and by Goode (1972). The production statistics for the various countries according to them, are included in Table 2, while modern production has been added from several sources including Maclare (1908), Emmons (1937), American Bureau of Metal Statistics, Schmitz (1979) and Consolidated Gold Fields reports (1982-1989) to arrive at production up to 1988.



It must be appreciated that the totals shown for each country are subject to many uncertainties and unknowns. The best illustration might be the estimates for Egypt and Zimbabwe. Egypt is credited with 1 732 tonnes and Zimbabwe with 1 750 tonnes. In the first case, it is doubted whether the evidence of old workings in Egypt is sufficient for such massive production, even if large alluvial workings along the Nile have been destroyed by floods. As far as Zimbabwe is concerned, very extensive old workings were discovered when colonists entered the region in the 1890's. Estimates of the gold recovered from these workings have ranged between a low of 93 tonnes (3 million ounces) and a high of 550 tonnes from an estimated 90 million tonnes mined. The latter figure appears far too high and the former too low. It is possible that some Zimbabwean gold might have been reported in that of Egypt, as might gold from Nubia and Ethiopia and the Middle East.

There is documentation or archaeological evidence that Phoenicians, Persians, Indians, Chinese and Portuguese traded with the east coast of Africa. Archaeologists have only scratched the surface of the early history of the country.

The famed sources of gold of "Ophir" or "Havilah" might have lain somewhere in Africa and might have contributed to gold reported elsewhere, but, a solution of their true location may remain a mystery forever.

The first comprehensive records of gold production were started in 1493, but communications were obviously wanting, and it is impossible to rely on all the statistics. For example, in Brazil the "quinto" was a tax placed on gold produced in the "province" by the King of Portugal. Control of this tax was through various toll-gates erected along major lines of communication, but avoidance was not difficult. As a result the estimate of production for Brazil is made after adding an allowance for a certain amount of contraband gold. Contraband dealing applies to practically every country as man's desire to own gold frequently exceeds his honesty.

Table 2 is given as a best estimate of the source of past gold production worldwide. This is based largely on Quiring's data which have been updated, wherever possible, to the end of 1988.

Now what does this grand total of over 110 000 tonnes of gold really mean? We know that, at the end of 1988, total gold holdings in the hands of reserve banks was 29 382 tonnes, that the International Monetary Fund held 3 217 tonnes and the European Community 2 923 tonnes and that the bank of International Settlements held 205 tonnes, to give a grand total of 36 727 tonnes. After this the mined gold is spread across the world in vast quantities of jewellery, coins, dental fillings, objects d'art, claddings and in electronic or electrical equipment. Unknown amounts lie beneath the sea in ship and plane wrecks and a great deal of gold is buried with its owner, whether he be an ancient king or an ordinary man. Owing to its extreme durability, gold is never really lost, but many tonnes are at the moment lost to circulation. The man in the street probably has available to him less than an ounce per individual, taking past mined and future production into consideration.

CURRENT PRODUCTION AND RESERVES

Production, reserves and exploration results in the Free World are well documented. However, there is a tendency to withhold some exploration data for security reasons. This applies particularly to South Africa where a large gold mine is a substantial prize and release of drilling results often is made only when a new mine is proved.

A further problem in summatting existing reserves is that the published figures are often for different classes of reserve. On mines, the current proved reserves are usually given. In prospecting a total resource or geological ore-reserve is often quoted. These latter might never be mined as the deposit is still in the pre-feasibility stage. The statistics which follow must be accepted with some caution and should be interpreted taking the restraints listed below into consideration.

Finally, one must appreciate that an estimation of this type is a moving target, as ore is constantly being depleted and new additions are being made. At the present time, exploration is ahead of mining, so that reserves are being increased at a rate faster than depletion is taking place. The estimates must be considered to be a minimum figure for most countries.

TABLE 2

ESTIMATES OF TOTAL PRODUCTION BY COUNTRY TO END 1988

	TONNES GOLD	REGIONAL TOTAL TONNES GOLD
AFRICA		
Egypt	1 752	
Nubia	1 828	
Ethiopia	613	
West Africa	1 650	
East Africa	154	
Zimbabwe	1 750	
South Africa	42 085	
Others	688	50 520
EUROPE		
Iberia	1 894	
France	600	
Great Britain	95	
Italy	230	
Carpathians	939	
Russia	15 921	
Others	1 427	21 106
ASIA		
India	1 520	
Greater China	910	
Japan	303	
Arabia	156	
Asia Minor	172	
Others	1 429	4 490
AMERICAS		
Colombia	1 989	
Ecuador	74	
Peru	381	
Bolivia	425	
Chile	489	
Brazil	2 240	
Mexico	1 795	
USA	10 875	
Canada	7 209	
Dominican Rep.	106	
Nicaragua	36	
Others	912	26 531
AUSTRALASIA		
Australia	6 471	
New Zealand	950	
Papua N G Area	300	
GRAND TOTAL		110 518

The following constraints apply to the reserve estimates:

Mines - An effort has been made to arrive at a total reserve by extrapolation of value-trends and by considering drilling results over the entire property or by using expected life with current production-rates.

Projects - The entire resource as disclosed by the operators has been used; where there is no disclosure an estimate has been made based on adjacent properties.

Completeness - Numerous journals have been consulted and all published data located have been included.

Averages - These are calculated for actual mining operations, as well as for dump-reclamation and alluvials, which have completely different economic constraints. These averages, where given, are based on many properties and, hence, are not expected to vary greatly if a few properties have been omitted for any country by oversight.

Economics - The reserves are based on todays parameters, and no consideration has been taken of possible future changes in the gold-price/production-cost ratio.

Exceptions - Many countries have still not reacted fully to the upturn in exploration, particularly countries such as China, Iran, Nicaragua etc; for such areas available gold has been taken as ten times current annual production.

Communist Block - No reliable data are available and the figures quoted must be considered calculated guesses.

Table 3 is an estimate of the quantity of gold available in ore currently known for the various countries mentioned. For ease of comparison, the countries are listed in the same order as in Table 2.

The large tonnage of gold available in South Africa results from mining fringe areas in all the goldfields as well as extensions and a completely-new goldfield which appears to be emerging in the Potchefstroom area. Of course, the quantity mined is sensitive to the gold-price and increases in working-costs. Practically all these mines are in the deep-to-very-deep category, and containing costs is not an easy matter. Nevertheless, the South African gold mines have very elastic ore-reserves which can expand rapidly on an increase in gold-price. This was a feature throughout the 1970's and is likely to be repeated. The elasticity stems from two major causes, namely, the development-reticulation is capital-intensive, but, when it is in place, it usually accesses vast tonnages of ore and marginal ore. Only a slight advantage, such as an increase in the gold price, can have a dramatic effect on total ore available. This is discussed more fully in the section on South Africa.

In the case of the USA, the estimated available gold is considered to be conservative. Exploration in that country is exposing new ore in some very large bodies almost daily. The Carlin trend appears to be a very major gold source under present-day working conditions, but exploration is still not sufficiently advanced for an estimate of the total resource to be made.

TABLE 3		
ESTIMATES OF TOTAL AVAILABLE GOLD IN RESERVE		
	TONNES GOLD	REGIONAL TOTAL TONNES GOLD
AFRICA		
Egypt	50	
Nubia	50	
Ethiopia	35	
West Africa	290	
East Africa	35	
Zimbabwe	180	
South Africa	39 862	
Others	150	40 652
EUROPE		
Iberia	100	
France	50	
Great Britain	25	
Italy	25	
Carpathians	50	
Russia	5 000	
Others	100	5 350
ASIA		
India	100	
Greater China	400	
Japan	150	
Arabia	75	
Asia Minor	100	
Others	150	975
AMERICAS		
Colombia	500	
Ecuador	25	
Peru	100	
Bolivia	100	
Chile	440	
Brazil	1 400	
Mexico	100	
USA	4 435	
Canada	4 195	
Dominican Rep.	80	
Nicaragua	20	
Others	200	11 595
AUSTRALASIA		
Australia	3 669	
New Zealand	70	
Papua N G Area	2 600	
Others	150	6 489
GRAND TOTAL		65 061

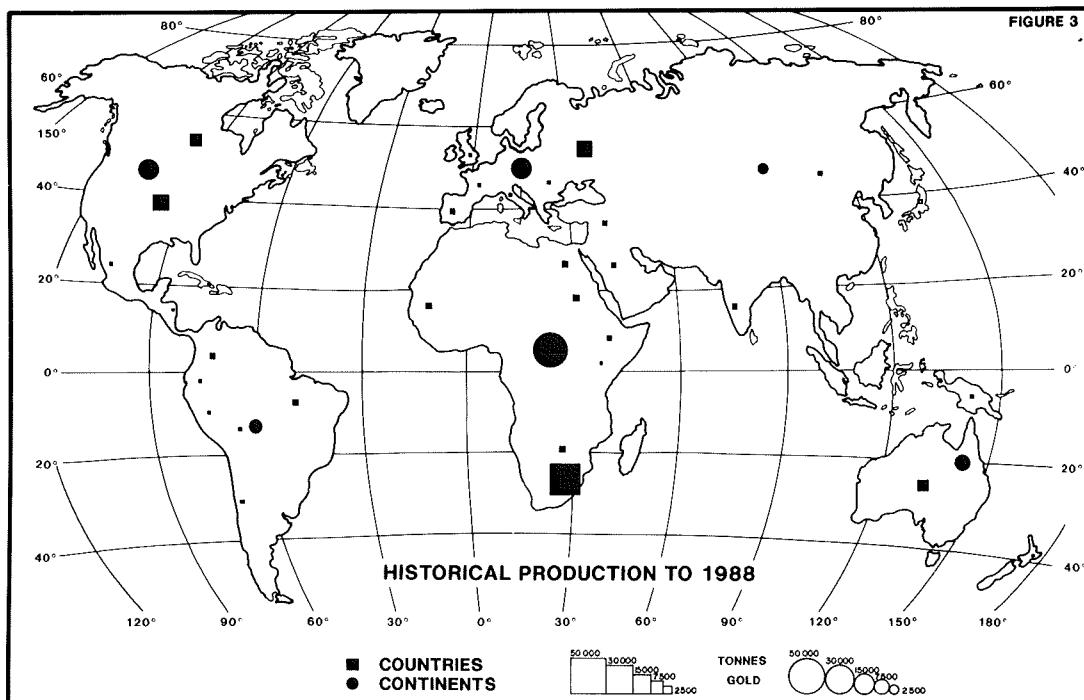
Papua New Guinea is another country in which expectations far exceed past production. This comment also applies to many other Pacific islands, and this area is expected to become a major source of gold in the future.

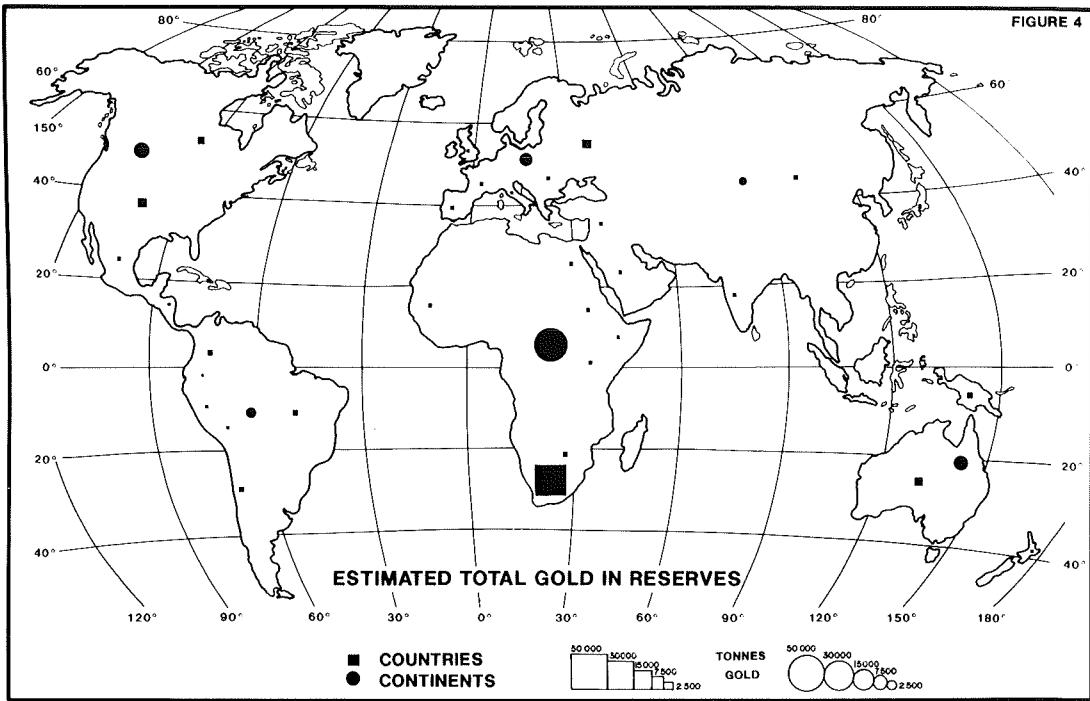
China and Russia both present problems in that very little is known of current developments. In the case of China, the past production might be grossly underestimated, as historical records in China have been less adequately researched than in many other countries.

Apart from these few exceptions, it would appear that, in most countries, future production will be only a fraction of past production at present economic conditions. This means that the steady increase in gold consumption will outstrip supply in the medium term. Should this happen, the gold price will probably rise appreciably in order to encourage an increase in supply. This will impact on exploration once again and lead to the exploitation of leaner ores.

WORLD DISTRIBUTION OF GOLD

As an adjunct to Tables 2 and 3, the world maps in Figures 3 and 4 give an indication of the distribution of past gold production and the estimate made of current available gold reserves. The dominance of Africa, North America and Australia is immediately evident. The emergence of Papua New Guinea can be seen on Figure 4.





FROM THE PRESENT INTO THE FUTURE

In the Free World, four countries are providing the backbone of gold production and these same countries are carrying out exploration in the lesser developed nations. There is little doubt that, in gold exploitation, expertise is a major factor and the ability of the operator to "produce the goods" is most important. The Anglo-Saxons appear to have risen to this challenge, and, since 1800, the major contribution to world gold production has been from efforts directed by these nations. One wonders what the overall result would have been had the Anglo-Saxon nations had free rein into the Comecon countries. China is now starting to welcome them, but a major learning curve will have to be surmounted before production really takes off.

Regarding future production from the Soviet Union, Mongolia and China, Timothy Green (1988) comments: "The test in all three countries will be how effectively it can be developed. Observers of Soviet mining argue that one of the reasons why gold output has stagnated at around 300-330 tonnes for a number of years has been the sheer inefficiency of both precious metal and base metal mining." This is all very well, but, until Western geologists, mining engineers and evaluators get free rein to look at the prospects, any forecast must remain highly speculative. After all, no degree of expertise can put the gold into the ground. Natural abundance is a necessity for success. On the basis that historical production is a guide to future production, it would seem that the prospects for the Comecon countries are not overly bright.

Taking these factors into consideration, one might view future gold production as being heavily dependent on the "big four", namely, South Africa, the USA, Canada and Australia. At present cost constraints, the future source of gold production appears to be based on the reserves of these countries:

TABLE 4

ESTIMATE OF "BIG FOUR" GOLD RESERVES

	TONNES ORE MILLIONS	GOLD CONTENT TONNES	AVERAGE CONTENT g/t
SOUTH AFRICA MINES NEW FIELDS	3 088 1 870	23 077 16 804	7.47 9.86
U.S.A.	2 511	4 435	1.77
CANADA	2 032	4 195	2.06
AUSTRALIA	1 962	3 669	1.87

This table emphasizes the vast superiority of the South African deposits which are not only top of the list in tonnage of gold available, but also in grade. In contrast these mines are deep, require high capital investment, have long lead-times between initiation of development and production, and have the highest demands in technology. The other mines are all at, or close to, surface; the ore in most cases can be worked by open-cast methods and leadtimes are short. The difference of the grades takes account of the two highly different exploitation scenarios.

In terms of the future gold price, the South African mines can survive, provided that the South African government continues its profligate policies and allows the Rand to continue to depreciate. Any major strengthening of the Rand, accompanied by cost controls in South Africa, could bring pressure on other producers which are operating from much lower gold contents, hence profit bases. This leaves the future gold production scenario wide open and beyond the control of the geologists, mining engineers and technologists who devote their efforts to producing gold in sufficient quantity and at competitive costs to satisfy world demand.

In order to obtain a better view of the major players in future gold production, the individual countries are now considered separately. This review includes the "big four" from the Free World. A brief review of three other major participants, namely Russia and the Comecon countries, Brazil, and the Pacific Basin have been included, as these are believed to be the other major players in future gold production.

AUSTRALIA

Australian gold production has played a significant part in world supplies since the discovery of gold in Victoria in 1851. Two major peaks have occurred in the production history, the first in the mid-1850's, during the major exploitation of alluvial gold in Victoria, and the second in the early 1900's, following the discovery of the West Australian Archaean goldfields. During this latter period, the United States was only marginally ahead of Australia as the world's major gold producer.

The bulk of Australia's gold has been won from greenstone belts in the Archaean of Western Australia. This is closely followed by gold from Palaeozoic rocks in Victoria, Queensland and New South Wales, while Lower Palaeozoic rocks have made small contributions from the northwestern part of the continent.

Re-working of gold derived from Palaeozoic deposits during the Tertiary led to the formation of some alluvial and eluvial deposits and the famous "deep leads".

According to available records total Australian production to the end of 1988 was 6 471.3 tonnes.

During the 1980's, Australian gold production has shown remarkable increases, and the 1988 production of 152 tonnes represented a new, all-time, annual high. Since 1980, production has increased from 17 tonnes to 152 tonnes, at an average annual increase of 31.5%, the highest percentage increase attained amongst the major producers. (Production for the 12 months to June 1989 was 177.5 tonnes).

The massive increase has been attained by a return to all the old, known mining-areas where modern extraction techniques and opencast-mining methods have allowed low-grade deposits to be worked. Capital costs have generally been low, and profitability has been high, while at the same time, no federal taxes and only minor taxes in some states, are levied on gold production.

The tax position is likely to change in 1991, but as gold has become a major contributor in Australia's balance of payments, it is unlikely that mines will be forced to close, and some relief may be considered for marginal operations. Afterall, 152 tonnes of gold is worth US\$ 759 million at US\$ 360 per ounce, and no government will give this up lightly. Additional to the above considerations, is the fact that a large number of Australian mines are shallow, low-grade, opencast operations with limited ore reserves. Many of them would be likely to close, in any case, in the early 1990's, as ore is depleted. There is thus all the more reason for the Australian government to try to get the most gold out of a depleting asset.

Not all the current mines are in old mining areas, and some notable new discoveries, such as Big Bell, Kidston and Boddington, will be making contributions into the next century. The by-product gold from the large Olympic Dam copper-uranium mine will be significant for half a century while the gold associated with the Que-Hellyer deposits will also make a long term contribution.

A summation of ore reserves and resources of known deposits in Australia suggest that, on current knowledge, at least 3 669 tonnes of gold could be recovered in the future. Of this total, 1404 tonnes are likely to be by-product gold and gold in tailings, leaving some 2 265 tonnes to be recovered from existing gold mines. At current production rates this gives the Australian mining industry a life of at least 20 years. It is likely that the life will be somewhat longer, as the current production rate of 150 tonnes per annum is probably not sustainable beyond the next 5 years.

The average grade of Australian gold reserves is very low, as a high proportion is opencast ore and a great deal is by-product gold. It is estimated that the average grade for the entire resource is only 1.87g/t while the gold mine fraction of this has an average grade of 3.09g/t. These low grades make the industry susceptible to gold price, cost and taxation changes.

BRAZIL

Brazil became the world's major gold producer in and around 1735, when exploration of the land led to the discovery of major alluvial deposits in many parts of the country. These derived mainly from Archaean greenstone belts, although some Proterozoic conglomerates, which carry low concentrations of gold, made a contribution.

Alluvial mining led to the discovery of the source-rocks, and, during the period from 1820 to 1900, numerous underground mines were in production. The famed Morro Velho Mine commenced production in 1835, once was the deepest mine in the world, and has produced nearly 300 tonnes of gold to the end of 1988. The mine still has considerable potential and there is the prospect of replacing ore mined for many years to come.

Estimating past production for Brazil is fraught with difficulties, and many writers in the past have ended by applying a factor for gold that was never declared. Records are based on shipments of gold to Portugal, this being the King's portion of the total production, the "quinto". In addition, records exist from many of the toll-gates at which the quinto could be paid. However, the Brazilian constitution allows citizens to mine freely, provided that it is done by rudimentary means, with the result that many "garimpeiros" fossick around with pans in streams. In exceptional cases, such as Serra Pelada and the Alta Floresta operations, to mention only two, tens of thousands of workers descend on a new discovery and work for their own account. Small groups are often formed under a leader who provides food and tools, but, in essence, much gold is produced by individuals.

The number of "garimpeiros" who are active in Brazil is not known, but is probably between 200 000 and 300 000. Cumulatively, the quantity of gold is significant even if each person produces only a few grams per annum by intermittent work. The magnitude of this production is reflected in the annual Brazilian statistics, where the gold produced by operating mines represents only about 20% of the annual total of 100 tonnes.

It is estimated that Brazil has produced a total of 2 240 tonnes of gold to the end of 1988. Current production is running at approximately 100 tonnes per annum.

Exploration has been active in Brazil since the economic miracle of the 1970's, but it was only from about 1976 that serious attention was paid to gold. Numerous old properties were re-examined and reserves established. Special mention might be made of Cuiaba, Sao Bento and Crixas, while some significant new discoveries were made such as Araci and Serra Pelada. It is estimated that current resources in mines have a total gold content of approximately 600 tonnes of gold. Alluvial resources are impossible to estimate, but, by working current and possible new discoveries, it is considered that some 800 tonnes might be won from this source during the next ten years.

Periodically some extravagant claims of the richness of Brazil in gold have been made, with a total resource of 30 000 tonnes. There is nothing new to support these claims, and the current estimated resource of 1 400 tonnes might prove to be generous. However, Brazil is one of the largest countries in the world, has a high proportion of prospective gold-terrane and has some Witwatersrand-type deposits currently being worked. If an extension or a new basin for such rocks is found, the potential in Brazil could be enhanced.

CANADA

Canadian gold production has not shown the massive fluctuations of many other countries. First recorded production was in 1886, and this expanded rapidly to 41.9 tonnes of gold per annum in 1900, with the discovery of the Klondike field and faded to 21.9 tonnes in 1905 as the output from Klondike subsided. Thereafter, Canadian production rose steadily until Canada surpassed Australia as a producer in 1921, with production at 28.7 tonnes, and the United States in 1931, when production had reached 84 tonnes per annum. Maximum production was recorded in 1941 at 166.8 tonnes and output was above 100 tonnes per annum until 1966.

From 1931 until 1986 Canada was a fairly steady producer and was second to South Africa in Free World production. Canadian production again passed 100 tonnes per annum in 1986, and 128.5 tonnes was recorded during 1988. The increase in production in recent years has not been as dramatic as that of Australia and the USA. However, the large number of gold deposits, the solid base being provided from by-product production, growing production from the Hemlo field and revived production in old established goldfields, will see Canadian production at a high level for many years.

It is estimated that total gold production for Canada to the end of 1988 was 7 209 tonnes.

Canada enjoys a very wide range in age, type and spread of gold deposits, and hardly a province of Canada has failed to make a contribution. In age, the deposits extend from the Archaean to young placer gravels. In addition, Canada has a substantial proportion of by-product gold, which is one of the reasons for its fairly steady production over the years. The discovery and developments in the Hemlo field are of a high calibre, and full production here will bolster Canadian output for many years. Active treatment of old mine-dumps and tailings is also being undertaken.

The Canadian mining industry has a long record of successful exploration and exploitation, with a high level of expertise. The infrastructure in many areas allows for the rapid development and exploitation of relatively small ore bodies, which collectively help to contribute to the overall production. Canadians are also explorationists of a high order, and risk-capital for mining ventures is not hard to raise. As a result, several thousand properties are being examined by over a thousand companies composed of highly expert seniors and a large number of very active juniors at the present time.

An estimate of available reserves has been made as follows:

	TOTAL RESERVES MILLION TONNES	CONTAINED GOLD - TONNES	GRADE g/t
All ore-bodies	2 032	4 195	2.06
Alluvials and base-metal deposits	1 592	660	0.42
Gold mine reserves	440	3 535	8.03

This resource is well balanced, and the bulk will be mined. As a result, Canadian production is seen to be well set for at least 25 years into the future, and, with exploration still very active in many promising areas, one can predict that much of the ore mined will be replaced by extensions and new discoveries.

RUSSIA AND THE COMECON COUNTRIES

No statistics of Russian production have been made available since 1929, so that the estimates of total, past production and current annual production, are based on flimsy evidence. Most estimates use Russian sales of gold as a guide, but these vary considerably, depending on the demands of balancing foreign payments, and also the need to finance special imports from time to time. This method gives a long-term indication of Russian sales, but Russia is also an astute trader in the market and frequently appears as a buyer. The estimate also does not take into consideration internal consumption, which must be considerable, for electronics, dentistry, jewellery and arts. There is also a flow of gold between Russia and other Comecon countries, the net effects of which are impossible to determine.

A final question is how much gold has Russia retained in its reserves. These are currently placed at between 2 000 and 3 000 tonnes, but this is an estimate based on minimum facts.

With all these unknowns, it is difficult to estimate total production to date. Emmons, in 1937, estimated total production from Russia and Siberia to 1934 as 3 221 tonnes, and his figure for 1935 production was 194 tonnes. Sales have certainly indicated some increase in Russian production during the period from 1935 to the present, as sales for the period 1980-1988 summate to 1 954 tonnes or an average of 244 tonnes per annum. However, there is absolutely no clue as to how much gold has been retained in reserves. In order to arrive at an approximate estimate, the following summation is presented:

	TONNES GOLD	TONNES PER ANNUM
Production to 1934	3 221	-
1935-1988 (on sales)	10 200	189
Reserves - say 2 500 tonnes	2 500	46
TOTAL PRODUCED	15 921	-

All sources are in agreement that Russian production is second in the world to South Africa, but there are wide divergences between estimates made by the CIA, US Bureau of Mines and dealers in Europe. Timothy Green (1988) concludes that Russian production was about 325 tonnes in 1986, and expansion to 400 tonnes was possible by 1990, but he saw little chance of further expansion beyond this level. Russia is thus firmly in the number two position, but with USA production rising from 30.5 tonnes in 1980 to 205.3 tonnes in 1988, there is a chance that the mid-1990's might see the USA challenging for the second position.

Forecasting gold resources for future mining is equally difficult. An estimate of a gross 5 000 tonnes of gold in all reserves was made in compiling Table 2, but this must be viewed with a great deal of caution.

SOUTH AFRICA

The discovery of gold on the Witwatersrand in 1886 moved South Africa into the position of the world's major producer by 1898. This was lost soon afterwards, with cessation of mining during the Anglo-Boer war, but by 1905 the top position was again attained. This has now been held for 84 years and is likely to hold well into the 21st century.

Apart from Witwatersrand gold, production is also recorded in South Africa from Archaean and Proterozoic deposits, recent alluvials and as by-product gold from base metal and platinum mines. Non-Witwatersrand gold constitutes only about 2% of total production to date.

PRODUCTION TO DATE

Total production of gold up to 31 December 1988 is estimated to be 42 085 tonnes. Production has been separated according to some of the major goldfields, and this automatically introduces a modicum of classification, in that the Archaean and Proterozoic deposits report separately from those of the Witwatersrand. However, in early years, considerable production was made from mines on the Witwatersrand which were not members of the Chamber of Mines. This gold has been grouped with "Other" production and, accordingly, introduces a bias in favour of the "others".

TABLE 7

GOLDFIELD	TONNES MILLED MILLION	GOLD RECOVERED KILOGRAMS	AVERAGE CONTENT g/t
CENTRAL RAND	922.306	7 658 880	8.30
EAST RAND	1 175.725	9 839 224	8.37
WEST RAND	365.061	1 950 811	5.34
KLERKSDORP	438.909	4 614 711	10.51
WEST WITS LINE	616.846	7 301 314	11.84
WELKOM OFS	773.524	7 696 555	9.95
EVANDER	150.235	1 163 870	7.75
SUB-TOTAL	4 442.606	40 225 365	9.05
OTHER	232.165	1 846 178	7.95
TOTAL	4 674.771	42 085 368	9.00

CURRENT PRODUCTION

During 1988, South Africa produced 621 tonnes of gold. Mines which are members of the Chamber of Mines accounted for a total of 581 610.4 kg, from a total of 112 673 000 tonnes milled at an average grade of 5.13 grams gold per tonne. In addition some 10 155.1 kg of gold were recovered by Chamber members in the retreatment of slimes dams. The balance of approximately 29 tonnes was made up by production from other Witwatersrand mines or reclamation of old sands and slimes dumps (16 tonnes), Archaean gold mines (8 tonnes) and by-product gold (5 tonnes).

The average grade recovered by the major mines continues to fall. This is due to two main factors. Firstly, the ability of the mines to treat lower grade ores due to ever increasing prices for gold received in Rand terms and, secondly, the effects of mechanization which permits the mining of thicker, lower-grade reefs. This continued fall in grade is having a long-term negative effect as the quantity of ore that can be raised and milled is restricted by the design-capacity of the shafts and extraction plants. The increase in production of 14 tonnes in 1988 relative to 1987, was a result of the commissioning of new, small mines and shafts and a slight rise in the yield of some marginal mines which were forced to mine slightly higher grades.

The industry as a whole remains very strong. The total ore reserve (blocked by underground development) declared during 1988 for all mines was 271 million tonnes with a combined gold content of 2 519 605 kg to give an average grade of 9.3 grams per tonne. Part of this reserve is tied up in shaft- and drive-pillars, but a very high proportion should be mined before the mines close down. The average grade of 9.3 g/t is healthy. Furthermore, a calculation based on drilling results or extrapolation into undeveloped areas within existing mining leases and claims suggests that the industry, as a whole, has a geological ore reserve of 3 029 million tonnes with a total gold content of 22 398 520 kg at an average grade of 7.39 g/t. This compares favourably, in the light of current Rand gold prices, with the historical yield of 9.05 g/t recorded for the entire Witwatersrand industry until the end of 1988.

THE FUTURE OF THE EXISTING SOUTH AFRICAN GOLD MINES

From the previous section, it is quite apparent that vast quantities of gold remain to be mined within existing mining-leases and claims. This quantity is put at 22 400 tonnes of gold, but it must be remembered that, throughout the ages, the tendency has been to adjust man-made currencies and laws to allow satisfaction of the gold wanted by man. Any increase in the price of gold immediately brings into the category of ore many millions of tonnes of what was previously marginal ore. As an example, the ore-reserves of several South African mines are quoted at varying gold-prices. This shows very clearly two features, namely, the sensitivity of the particular mine to gold-price variations and also the varying quantities of gold in the ore at different prices. The figures for Freegold, the largest South African mine, have been extracted from the 1988 Annual Report of that company:

TABLE 8			
GOLD PRICE RAND/kg	ESTIMATE OF ORE RESERVE '000t	ESTIMATE OF AVERAGE GRADE	GOLD CONTENT (TONNES)
R29 000	43 134	10.47	451.6
R32 000	48 417	9.84	476.4
R35 000	53 099	9.60	509.8

It is quite apparent how the available tons and gold-content increase and average grade decreases as the gold price rises. The Rand gold price is largely independent of the Dollar gold price and is a reflection of the internal and external economy of South Africa, relative to that of its major trading partners. The price received by the mines has continued to rise, in Rand terms, in South Africa in recent years, as higher internal inflation has caused the Rand to fall in value relative to other currencies. This feature also applies to the production of other countries, such as Australia and Brazil (for much the same reasons), but USA companies are faced with a fixed Dollar gold price.

In the case of Freegold, mentioned above, the available tonnage increased by 9,7% and the contained gold by 7,0% on a price increase of 9,4% (R32 000 to R35 000). On this basis, a similar adjustment industry-wide could impact on the content of the geological ore-reserve which would increase from 22 400 tonnes of gold to roughly 24 000 tonnes of gold.

It might be argued that no ore-body is indefinitely elastic in this manner, but in the case of the Witwatersrand reefs, the elasticity is, in fact, very large. Ore-reserves are usually based on one or two reefs. Higher prices bring conglomerates, not previously considered, into the regions of payability. If this happens, the tonnage increase can be large and the gold content increase significant. Thus, the case quoted is very conservative, and the future availability of ore, given improved gold prices relative to costs, could be very large.

Figure 5 shows cumulative-frequency distribution curves for a normal-grade reef which could support a gold mine and a second curve for a reef which could not be economically worked on its own. The second reef would become payable in a high gold price scenario, and its contents, whether it reported as 30% or 70% payable, would become available for mining at a marginal additional cost.

It is this availability of ore which contributes to the longevity of many Witwatersrand mines. In the waning stages of the life of a mine, capital expenditure tends to fall, and this impacts on working costs. As a result, other conglomerates, not previously mined, can be explored and evaluated and often contribute to the end-life of the mine. A case in point might be the follow-up exploitation of the Kimberley Reef, Footwall Reefs, Black Reef, UK5 Reef and UK3 Reef in the East Rand goldfield after the main money-spinner, the Main Reef Leader, had been almost fully exploited. Not one of these reefs had sufficient grade and tonnage to allow a major new mining venture to be supported by them, and they have been mined only because of the infrastructure provided during the exploitation of the Main Reef Leader.

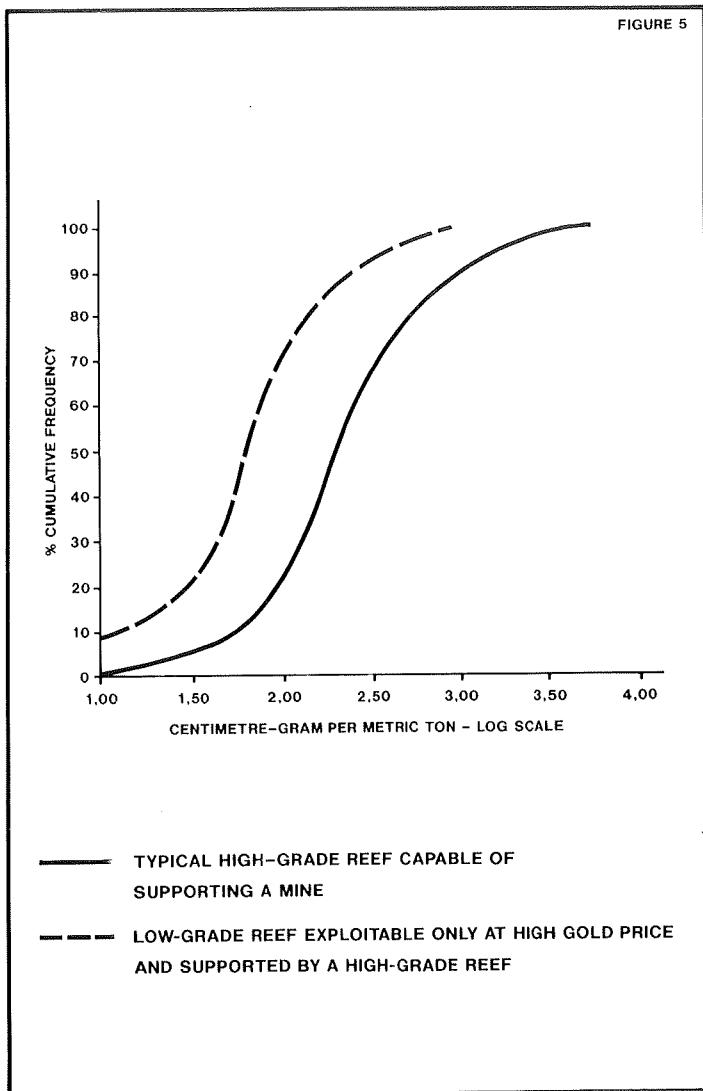
DUMP RETREATMENT

During the 102 years of production on the Witwatersrand billions of tonnes of sands, slimes and waste-rocks have accumulated at surface. These enjoy very-low marginal costs when exploited, and their gold content of less than a gram per tonne can be profitably extracted. Several companies are already operating in this field and, as mines approach closure, the exploitation of material at surface becomes a major consideration in the break-up value of the company.

At the present time, surface rock-dumps are being exploited as part of mill-feed for many companies, such as Western Deep Levels, Vaal Reefs, Randfontein, Hartebeestfontein and others. The gold won is a part of normal operations and need not receive special consideration here.

The working of sand- and slimes-dumps is, however, a new industry and often separate from any underground mining operation. Major operators, such as ERGO and East Daggafontein, are making a significant contribution to gold (and uranium and pyrite) production. It is estimated that these, and other similar operations, have total reserves of 1 124 million tonnes from which a recovery of 0,22 g/t will result in gold production of some 252 tonnes. It should be remembered that, to date, over 4 600 million tonnes have been milled in South Africa, and as the mining industry winds down, most of the slimes derived from this will ultimately be retreated, and this could yield, in total, about 1 000 tonnes of gold.

FIGURE 5



ARCHAEOAN AND PROTEROZOIC GOLD

The first discoveries of gold in South Africa were made in Archaean rocks. Since that time, approximately 1.5% of total production, or roughly 500 tonnes of gold, have been derived from this source.

Several small companies have recently embarked on the exploration and exploitation of Archaean deposits and they are likely to remain a small force in future South African production. However, current estimates place future production at a further 426 tonnes of gold, which means that these deposits will retain their ranking in future production.

BY-PRODUCT GOLD

The platinum, copper and antimony mines make a contribution to gold production. It is estimated that the total production from this source is currently approximately 5 tonnes per annum. Most of these mines have long lives and production may be expanded, so that a steady contribution might be expected in the future.

NEW DEVELOPMENT IN EXISTING GOLDFIELDS AND NEW GOLDFIELDS

The last goldfield discovered in South Africa was the Evander goldfield in 1952. This followed the discovery of both the Welkom (OFS) goldfield and the West Wits Line immediately prior to World War II, and the expansion of the Klerksdorp goldfield during the same period. The development of these four major expansions in the post-war period demanded a major investment and strained available capital and manpower resources. As a result, exploration tended to wane and exploration companies, which numbered about 80 in 1948, fell to zero, as they were absorbed into the major mining houses or were liquidated.

During the period 1965 to the present, there has been an upsurge in exploration. This commenced, first, with the examination of the fringes of the known goldfields and, later, from about 1978, expanded into new areas which have the potential to host new goldfields.

The fringe-areas were not without success, and, over the past 20 years new mines such as East Driefontein, Elandsrand, Deelkraal, Unisel, Beisa, Beatrix, Joel and Oryx have entered the lists. During the same period many existing mines had their leases increased in size. Numerous prospective areas are approaching the evaluation stage and South Deep, Western Ultra Deep, Moab, Lucas Block, Doorn Rivier, Vermeulens Kraal Noord, Kalkoenkrans, Loraine North, Area 1 West, Area 1 East, Poplar, Rolspruit and Twistedraal might become mines or parts of existing mines during the next decade. (For locations see Figure 6.)

As the fringes of the goldfields became better understood, exploration moved further afield and the introduction of more advanced geological and geophysical techniques saw break-throughs in previous problem areas. Several discoveries have been made and new goldfields might emerge. Most advanced is the Potchefstroom Gap, a fifty kilometre break, between the western end of the West Wits Line and the Klerksdorp goldfields. Here, significant gold values have been found and the likelihood of a new goldfield is very real. Less well known are exploration activities in the South Rand Goldfield, the Koster, Ventersdorp, Barkley West, Bultfontein, Verkeerdevlei, Reitz, Bethlehem, Kroonstad, Lindley and Heilbron districts and the Vredefort Dome. Many of these areas will return to the peaceful agricultural or pastoral activities after exploration ceases, but indications suggest that a new goldfield, based on Witwatersrand rocks, might emerge in more than one area, and, if it does, it is likely to be big from previous experience.

It is still too early to make projections in many of these areas, but some work is sufficiently advanced for intelligent guesses to be made. These guesses are given in Table 9.

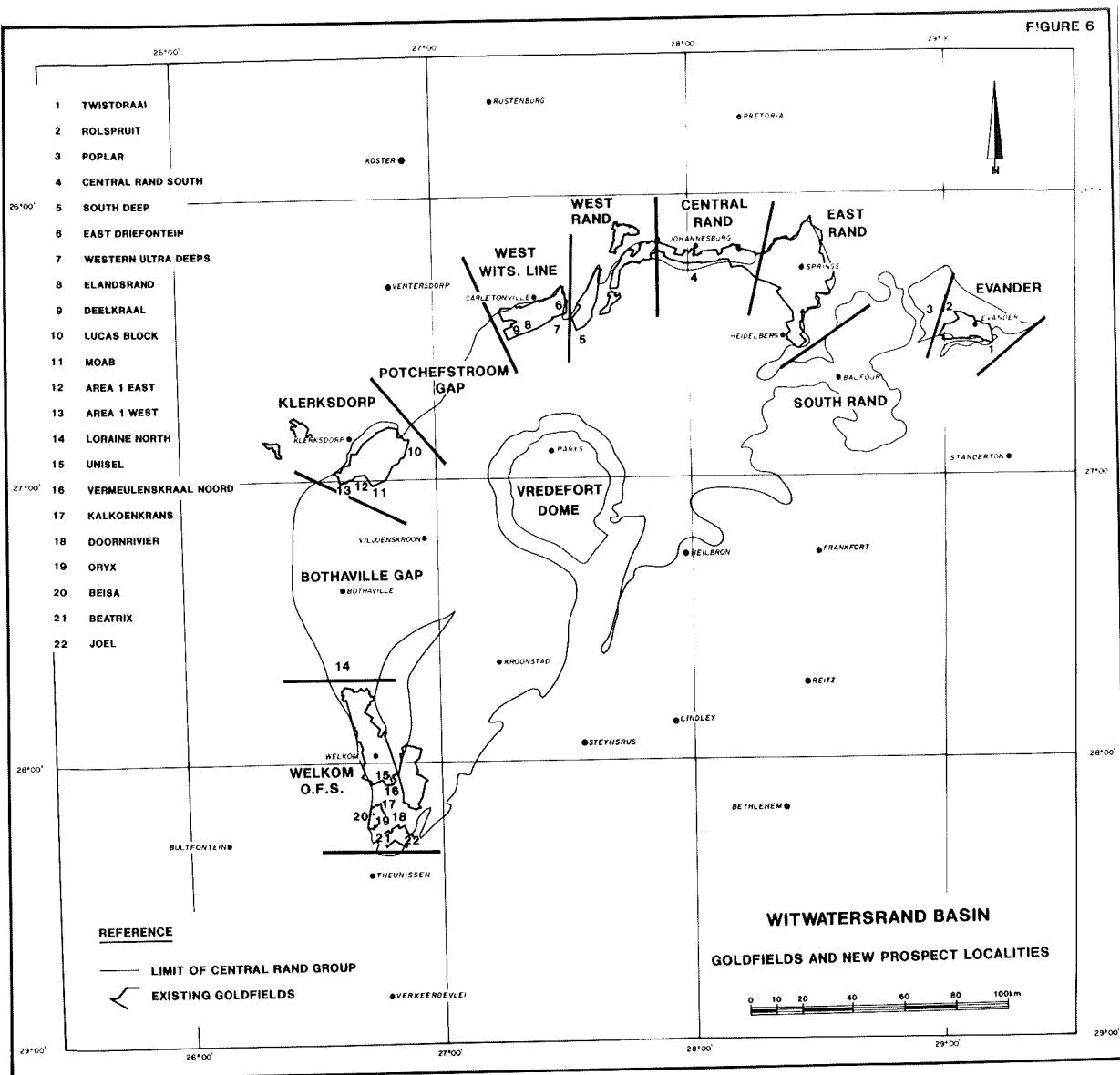
The spread of exploration is fairly well established, and new ventures give an idea of the vastness of the resources of the Witwatersrand Basin. Also significant is the large time-span between initiation of work and an established mine. Some of the exploration listed has already been intermittently underway for more than 20 years, and many of these targets will not be brought to account before the end of the century. Two things are immediately apparent:

- much more gold remains to be found in the Witwatersrand
- active mining is likely to continue well into the next century

TABLE 9

AREA	ESTIMATED TONNES - MILLIONS	GRADE g/t	GOLD CONTENT TONNES
O F S South	350	8	2 800
Lorraine North	125	8	1 000
Potchefstroom	800	10	8 000
South Deep	330	7.5	2 475
Western Ultra Deep	100	11	1 100
Central Rand South	50	12	600
Evander Goldfield	85	6	510
South Rand Goldfield	30	10	300
TOTALS/AVERAGE	1 870	8.98	16 785

FIGURE 6



FUTURE PRODUCTION

Based on current cost/gold price relationships, it is estimated that future South African production is likely to be derived from the following sources:

TABLE 10	GEOLOGICAL RESERVES AND CONTENT		
	TONNES ORE MILLIONS	GOLD CONTENT TONNES	AVERAGE CONTENT g/t
MINE LEASES	3 029	22 399	7.39
DUMPS & SLIMES	(1 124)	252	(0.22)
ARCHAEOAN	59	426	7.26
BY-PRODUCT	N/A	(500)	N/A
NEW GOLDFIELDS	1 870	16 785	8.98
TOTALS/AVERAGE	4 958	39 862	8.04

The large tonnages and reasonable grades still available suggest strongly that South Africa will remain the major world gold producer for at least another 40 years. It will continue, beyond this time-span, to be a force if current exploration discloses hitherto unknown goldfields. The life might also be extended if further advances in technology allow mining to be carried to depths beyond 4000 metres below surface.

Under current economic conditions and with the present level of expertise, there seems little reason to doubt the ability of the South African mining industry to produce another 40 000 tonnes of gold.

However, a single large deterrent exists in the form of the fiscus and threats from labour and AIDS need to be considered.

The fiscus has become less and less willing to assist the initiation of new projects by allowing tax-shields from existing operations. The Poplar project has lain dormant for ten years and, recently, Freegold has failed to negotiate suitable tax arrangements in respect of expansions to the north and south of its leases. Several other large capital-intensive projects, deserving of a tax-break, are on the drawing boards and they need some assistance. The fiscus should take note of all the other taxes in the form of sales tax, personal income tax and business tax which will be generated by a large new development. Soft pedalling on mining and lease taxes could be amply rewarded in other ways. Failure to do so will mean that much of the gold resource might lie in the ground forever.

The industry has suffered from excessive demands by labour, which, with inflation, are pricing South African mines out of the market. These need to be addressed.

AIDS is widespread in Africa and has appeared on South African mines. This is a threat which, by the turn of the century, could be threatening mines throughout the world by restricting the availability of labour.

THE PACIFIC BASIN - PAPUA NEW GUINEA AND OTHERS

PNG is the joker in the pack. In recent years, some very large tonnages of ore in copper porphyries have been discovered. The gold content, often enhanced at surface by supergene enrichment, is considerable. The bodies are large and can be mined by opencast methods. In addition, epithermal gold deposits related to the "Pacific ring of fire" volcanism have led to the discovery of many other ore-bodies. In Japan, some very rich epithermal deposits have been found.

The entire arc from Japan, southwards through the Philippine Islands and then eastwards and southwards as far as New Zealand, is the scene of intensive prospecting and many targets are emerging. This new area is still in the stage of infancy and there is very little history of gold mining on which to base predictions. However, what has been found to date is very large and in only five deposits more than 2 000 tonnes of gold is probably recoverable. Declared reserves or geological tonnages for the Papua New Guinea area now gross 2600 tonnes of gold. This must be a minimum figure, as a large number of well advanced prospects are in the drilling stage, but firm announcements of reserves are still awaited.

Exploitation depends on many factors, and the Pacific Basin region has several negative factors. Capital costs are high, as the deposits are large and remote from infrastructure. Political risks are also high in many areas. Add to this the difficult topographic and climatic conditions and it all adds up to a large negative effect on feasibility studies. Contrarywise, in New Zealand, where most of the above factors do not exist, a very strong conservationist lobby is opposing mining ventures or, if mining is allowed, it will be subject to costly restraints.

All in all, the Pacific Basin is a large, new gold source and, while it may take some time to get the entire show on the road, by the turn of the century this area could be one of the majors. Papua New Guinea's production has grown from 14.3 to 32.6 tonnes per annum during the period 1980-1988, while other producers in the area have improved production from 1 tonne in 1980 to 6.2 tonnes in 1988.

UNITED STATES OF AMERICA

The history of gold mining in the USA was without special interest until the discovery of gold at Sutter's Mill on 24 January 1848. Within a year production soared and the USA became the world's major producer. Challenged periodically by Australia, the USA remained the premier producer until South Africa topped the list at the turn of the century.

Production from California attained 122.3 tonnes in 1852, after which it declined steadily, but remained considerable, with an estimated total production of about 3 400 tonnes produced to the present.

USA production followed that of California until the discovery of the Klondike goldfield, which extended into Alaska, so that around the turn of the century, production again exceeded 100 tonnes per annum. The impetus to gold production by America going off the gold standard in 1932 saw a major increase in USA production which remained above 100 tonnes per annum until 1942. The War Production Board's order resulted in the closure of many mines and production fell to 30 tpa almost immediately. It recovered slightly after the war to reach 74 tonnes in 1950, after which a general decline set in until the 1980's.

The discovery of the Carlin deposit in the 1960's was really a turning point, but the true impact was felt only when the price of gold started to rise during the 1970's, and many companies entered gold exploration. Part of the exploration was forced on the industry when base metal and ferrous metal prices entered a low phase during the oil crisis and gold alone was an interesting prospect.

The results since 1980 have been phenomenal with output rising from 30.5 tonnes in 1980 to 205.3 tonnes in 1988, an annual compounded rate of increase of 26.9%. During the same time, exploration has outlined a multiplicity of new deposits, and the Carlin trend in Nevada has emerged as one of the world's great repositories of gold.

Much of this new gold might never have been mined had it not been for new developments, principally the carbon-leach process, which enables low-grade/high-tonnage extraction of gold. Also, many of the new deposits are disseminations of gold in large bodies amenable to opencast mining, so that cheap, low capital investment is possible. Heap-leaching has become a new art, and ores with under one gram per tonne can be exploited.

Apart from low-grade disseminations of the Carlin-type, some exceedingly high-grade concentrations over considerable borehole widths have recently been drilled along the Carlin trend. This work is still underway and a large-tonnage, high-grade deposit seems certain. This will impact favourably on the ore reserve figures to be quoted.

In addition to hard-rock gold deposits, the USA has a fair resource of alluvial deposits which are receiving attention. Improved base-metal prices have also resulted in some of the copper mines being revived and becoming a by-product source of gold.

The USA gold resource is the most unpredictable of all those studied, except that any estimate made on available facts is sure to be low. From information collected up to the time of writing, it is estimated that the total USA resource is as follows:

TABLE 11			
	TONNES ORE MILLIONS	CONTAINED GOLD TONNES	AVERAGE GOLD CONTENT g/t
TOTAL RESOURCE	2 511	4 435	1.77
GOLD MINE ORE	2 173	4 280	1.97
ALLUVIAL/OTHER	339	155	0.46

There is very little doubt that the USA gold mining industry is set fair for further expansion. The base is already well established and indications from exploration suggest that far bigger things are in the pipeline. There is a good chance that the USA will overhaul Russia as the world's second producer within a few years.

SUMMARY AND CONCLUSIONS

It is quite apparent that the increase in gold price since 1970 has spurred exploration and production of gold. This is a new wave which is still in its ascendancy, and the peak, in terms of discoveries and production, has not been reached. World gold production, over several centuries, is progressing on an exponential curve, and new heights are indicated. However, resources are limited at current gold prices, and maintained production at present levels will see a reduction in available gold in the long term. In most countries a life of less than 20 years can be seen, but the main producers appear to have resources well in excess of this time-span. Nevertheless, the ability of the majors to continue to produce at the high levels of today might come under pressure beyond the year 2010, and shortages of gold might begin to be felt.

South Africa will be the dominant source of gold for many years, with 22 400 tonnes of gold estimated to be inside present mining leases at an average grade of 7.39 g/t. New goldfields and mines are estimated to contain 16 785 tonnes of gold in ores, with an average grade of 8.98 g/t. Together with base metal ores and by-product ores, South Africa is set to produce another 40 000 tonnes of gold. This could be produced at a slightly accelerated rate relative to present production which would still leave South Africa dominant in world gold until the year 2040.

Three other countries, the USA, Canada and Australia, have substantial reserves of 4 435 tonnes gold in ore averaging 1.77 g/t, 4 195 tonnes gold in ore averaging 2.06 g/t and 3 669 tonnes gold in ore averaging 1.87 g/t respectively. In all three countries production is rising rapidly as easily accessible ore, close to surface, is brought to account. The USA in 1988 produced 205.3 tonnes, Australia produced 152 tonnes and Canada 128.5 tonnes, which would suggest that production at these rates would see current identified reserves depleted in 22, 13 and 33 years respectively. Australia, in particular, will see production fall off rapidly in the next decade.

The estimate of total ore reserves suggests that some 65 000 tonnes of gold are available, against the approximately 110 000 tonnes already mined. Carat jewellery has been using increasing amounts of gold since 1980 when 945 tonnes of gold were used against 1844 tonnes in 1988, representing an annual compounded increase of 8.75%. During the same period mine production in the non-Communist world has increased from 959 tonnes to 1538 tonnes, or a compounded rate of 6.1%. It is apparent that a shortage of gold will emerge despite increased production.

With increasing world populations, each man, woman and child will have available to him or her much less than an ounce of gold, which represents only a few rings, so that in the long term it is believed man's demand for gold will increase, rather than decrease, and the price will adjust accordingly.

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