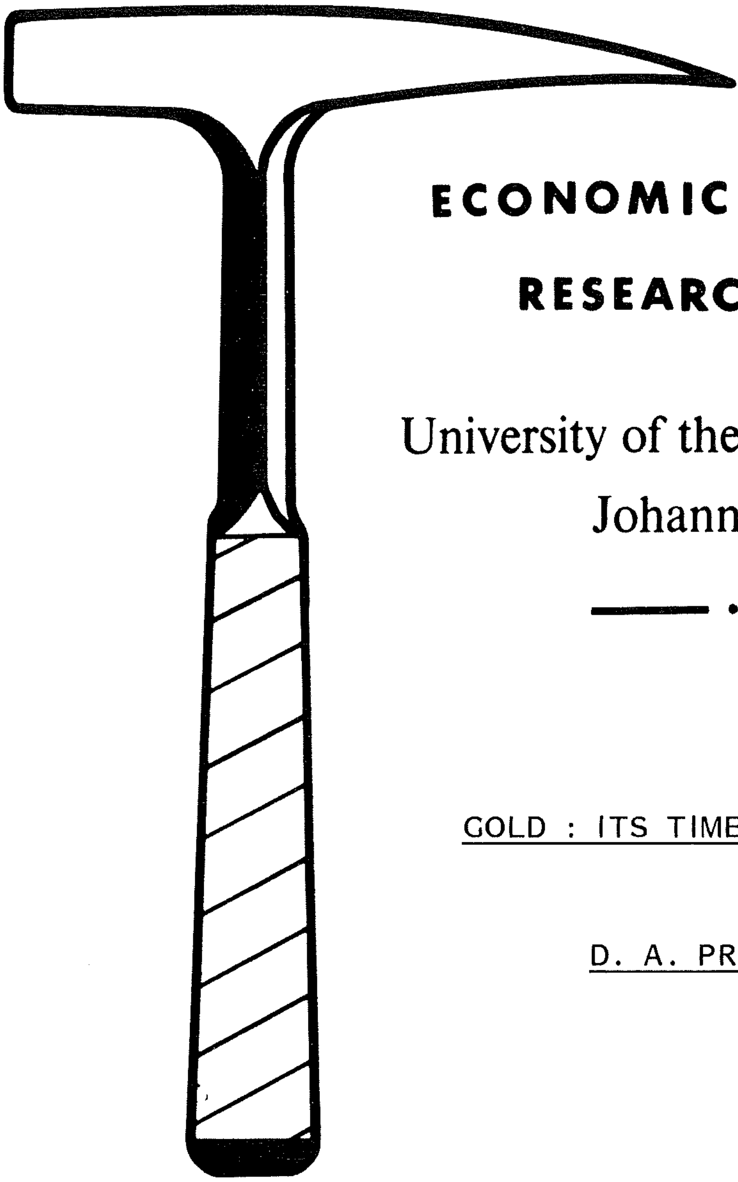

ECONOMIC GEOLOGY RESEARCH UNIT

University of the Witwatersrand
Johannesburg

GOLD : ITS TIME AND ITS PLACE

D. A. PRETORIUS

INFORMATION CIRCULAR No. 207

UNIVERSITY OF THE WITWATERSRAND
JOHANNESBURG

GOLD : ITS TIME AND ITS PLACE

by

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The centenary of the discovery of the Witwatersrand goldfields was marked by the holding of an international conference on gold — Gold 100 -- organized by the South African Institute of Mining and Metallurgy. The conference was held in Johannesburg, between September 15 and 18, 1986. The opening day was devoted to the delivery of plenary addresses by invited speakers, in which broad reviews were presented of virtually all aspects of the exploitation, recovery, and marketing of gold, with particular emphasis on gold mining in the Witwatersrand Basin. Two volumes of technical papers appeared soon after the holding of the conference, but the volume of plenary presentations, under the editorship of the Chamber of Mines of South Africa, still remains to appear. Publication has been delayed repeatedly, and no date for the issuing of this volume has been determined yet. Consequently, it was decided to make available, without waiting further for the publication of the volume as a whole, one of the plenary papers — "Gold : Its Time and Its Place" — as an Information Circular. The fact that the address was delivered on 15 September, 1986, should be borne in mind in the realization that the information presented is somewhat dated.

GOLD : ITS TIME AND ITS PLACE

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GOLD : ITS TIME AND ITS PLACE

It is written that there is a time and a place for everything in this world, and, whether it be a barbarous relic or a thing of joy and beauty forever, gold, indeed, has its time and its place in the evolution of the Earth. There have been good times and bad times for gold, not from the point-of-view of its market-price, but with respect to the geological eras during which the metal was enriched or impoverished in the rocks accessible to Man in the 6000 years of his recorded history. At times, conditions have been extraordinarily favourable for significant gold mineralization, while, during other periods, almost no gold of any consequence has been introduced into the Earth's crust. Also, there are good places and bad places, regions where great goldfields have been discovered, and continue to be found, and others where prospectors have come across nothing but disappointment and despair.

The Geography of Gold

In 1984, gold was mined in 65 different countries throughout the world, and a total recovery of 1447,544 metric tons (46,540 million ounces) was entered in official records. In Figure 1, the ten most important

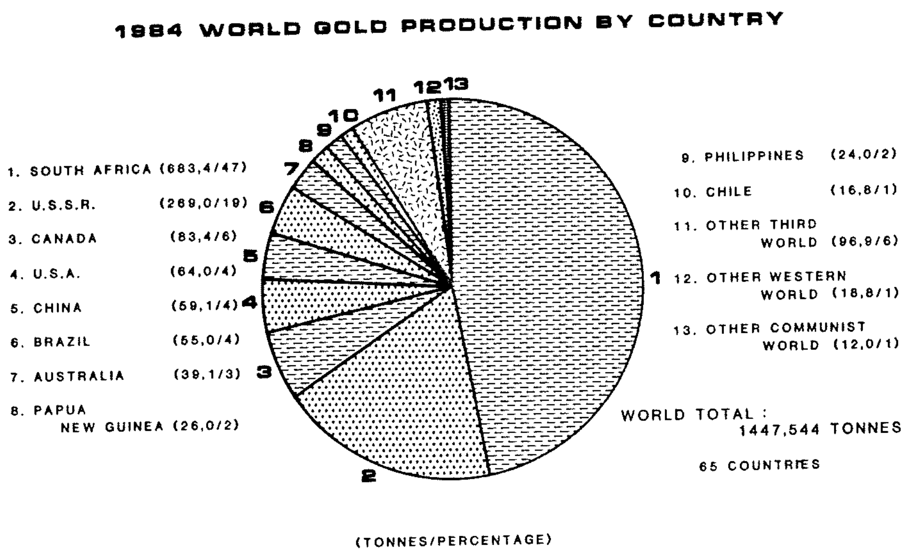

Figure 1 : *World gold production for the year 1984, according to individual countries and politico-economic regions. Output in metric tons and percentage contribution to total world production are shown.*

producing countries are indicated, together with the combined output of the remaining countries in the Western World, the Communist World, and the Third World. As it had for so many preceding years, South Africa dominated the scene, being responsible, in 1984, for 683,4 tonnes, equivalent to 47 per cent of the world's production. In second place was the U.S.S.R., contributing 19 per cent. Between them, South Africa and Russia mined two-thirds of all gold won. As an approximation, it can be concluded that 66 per cent of the gold came from the Western World, 24 per cent from the Communist World, and 10 per cent from the Third World.

If the mega-regions of the world are considered, then Africa leads with 49 per cent. Eurasia follows in second place, with 24 per cent, the Americas in third position, with 19 per cent, and the Australo-Pacific region in fourth place, with 8 per cent (Figure 2). Within the broad mega-regions,

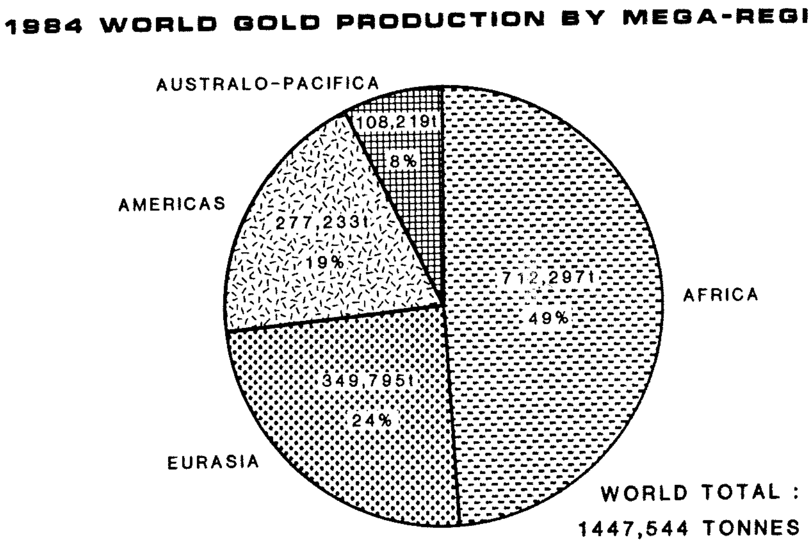

Figure 2 : World gold production for the year 1984, according to geographical mega-regions.

particular geographical entities stand out clearly as the favoured loci of anomalously-large accumulations of gold. In Africa, the metal is won essentially from the southeastern segment of the continent, with relatively minor amounts coming from North, West, Central, and East Africa and the southwestern portion of Southern Africa (Figure 3). In Eurasia, Siberia dominates the scene. In the Americas, the Cordillera, running from Alaska to the Andes, and the eastern sectors of Canada and Brazil are where the great discoveries of gold have been made. In Australo-Pacifica, the major goldfields are to be found in the volcanic belt stretching from Japan to New Zealand and in the western and eastern extremities of Australia (Figure 4). In the remainders of the mega-regions, the great bonanzas have eluded the seekers after fortunes.

The Sources of Gold

In order to understand the nature of gold mineralization, it is important to categorise the different sources of gold. In a broad context, there are three major sources : placer-gold; lode-gold; and gold as a by-product from the mining of other metals (Figure 5).

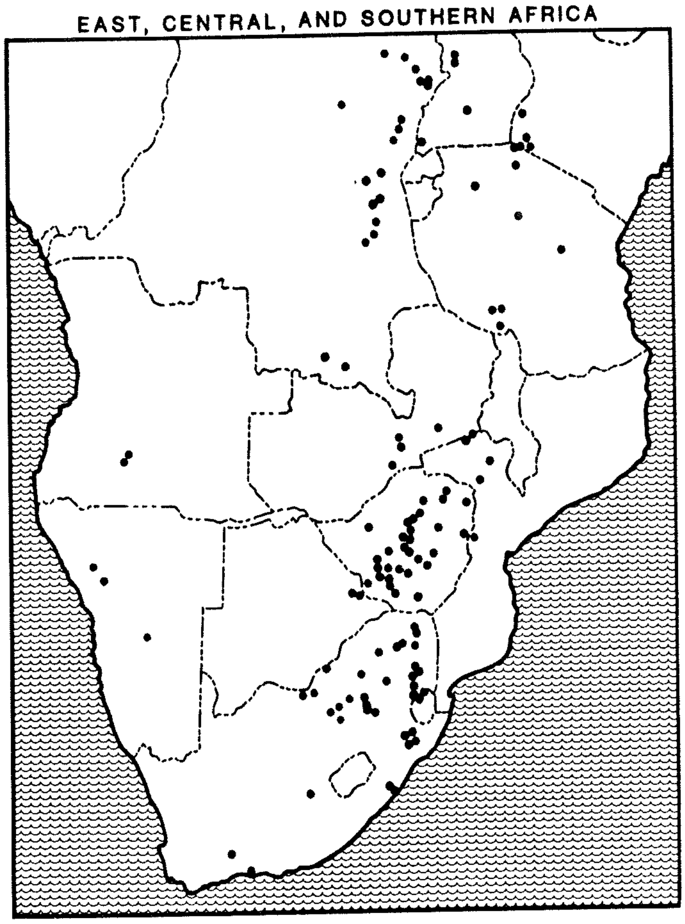

Figure 3 : *Distribution-pattern of the gold-bearing areas of East, Central, and Southern Africa, showing the major concentration of gold mineralization in the southeastern segment of the sub-continent and the marked paucity of auriferous areas in the western half of the sub-continent.*

In a finer sub-division, placer-gold can be seen as alluvial or eluvial, with, by far, the greater percentage being concentrated in the gravels of present-day rivers. With respect to lode-gold, quartz veins, often with spectacular visible gold, were the first targets of hard-rock gold-mining. Replacements, disseminations, and exhalatives constitute the most important sources of gold discovered within the last thirty years. Whether in the western Pacific region or the western United States, these replacements, disseminations, and exhalatives, which are essentially related to volcanic activity, now are the most sought-after types of mineralization in the new wave of gold exploration. The fifth category of lode-deposits is represented by conglomerates, ancient placer deposits, which, because of the contribution from the Witwatersrand goldfields, are the most impressive providers of the metal. The mining of copper is the most fruitful source of by-product gold.

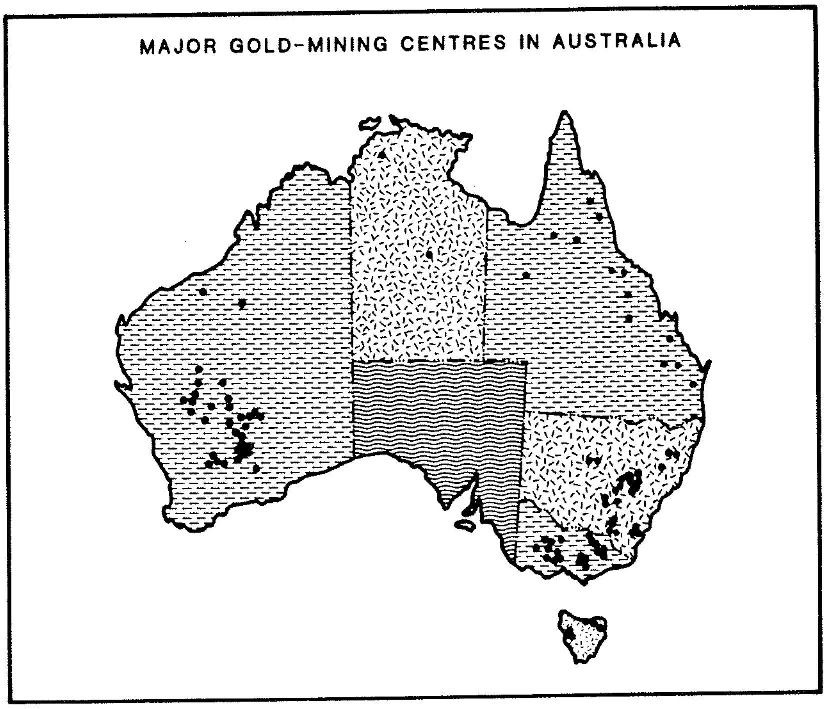

Figure 4 : *Distribution-pattern of the major gold-mining centres of Australia, showing the preferential concentration in the western and eastern margins of the continent and the relative absence of significant gold deposits in the central region.*

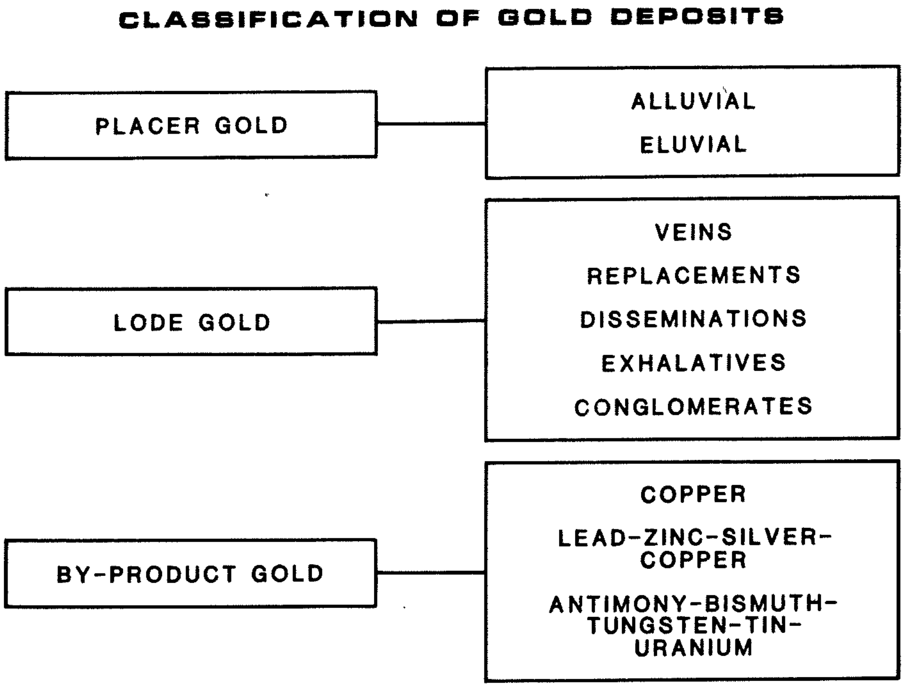

Figure 5 : *A simplified and generalized classification of the sources of the world's gold production.*

Generally speaking, the great copper-fields of the world, particularly those of the porphyry type, are also significant suppliers of by-product gold.

Two examples have been compiled of the various sources of gold in individual countries. Figure 6 indicates the derivation of the U.S.A.'s 1984 production, while Figure 7 reflects that of the 1984 production from Australia. An estimate also has been depicted in Figure 8 of the sources of all U.S.A. output since the first available records (1804) up to the present (1984).

1984 U.S.A. GOLD PRODUCTION BY SOURCE

SOURCE OF GOLD		%	TONNES
LODE GOLD	:	84	53,774
COPPER	:	9	6,077
PLACER GOLD	:	2	1,287
SILVER-GOLD	:	2	1,157
SILVER	:	1	0,802
LEAD-ZINC-COPPER	:	1	0,618
OLD TAILINGS	:	<1	0,320
			64,035

Figure 6 : The sources of gold production in the U.S.A. for the year 1984.

1984 AUSTRALIAN GOLD PRODUCTION BY SOURCE

SOURCE OF GOLD		%	TONNES
LODE GOLD	:	92	35,829
LEAD-COPPER	:	3	1,142
LEAD-ZINC	:	3	1,081
COPPER	:	2	0,840
BISMUTH	:	< 1	0,189
PLACER GOLD	:	-	-
			39,081

Figure 7 : The sources of gold production in Australia for the year 1984.

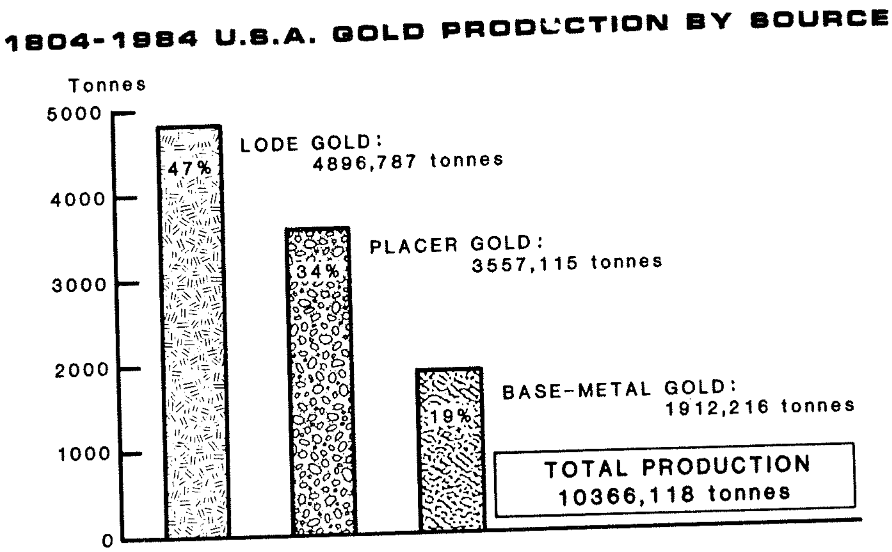

Figure 8 : *The sources of total gold production in the U.S.A. for the 180-year period between 1804 and 1984.*

Examination of the world's total 1984 gold production, in terms of this broad classification of gold mineralization, shows that 88 per cent came from primary gold deposits and 12 per cent was drawn from by-product sources, and that, of the primary sources, conglomerates dominated (Figure 9). Forty-

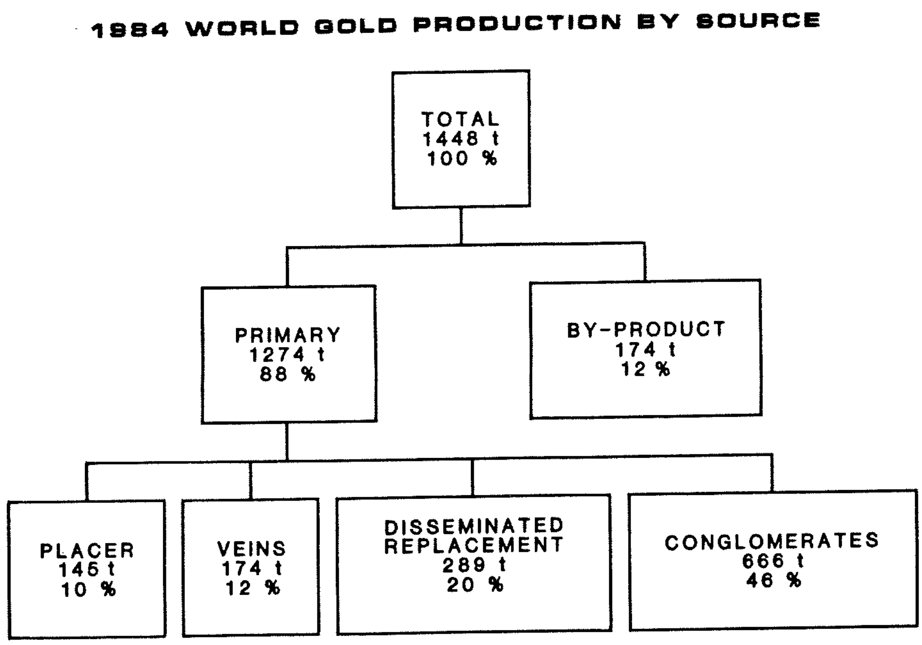

Figure 9 : *The sources of total world gold production for the year 1984.*

six per cent of total world output emanated from conglomerates, 20 per cent from disseminated , replacement-type deposits, only 12 per cent from veins, and an even lesser amount from placers, 10 per cent. Placer and vein sources which, last century, were the paramount suppliers of gold, today play only a minor role in bringing new gold onto the market.

The Time and Place of Gold Mineralization

The classification of the different sources of gold carries within it an implicit time-element, the contribution of geological time to the definition of good times and bad times for the formation of significant mineralization. The really important auriferous conglomerates are old; placer deposits are very young. The disseminated- and replacement-type ores are young, while gold-bearing quartz veions span the entire spectrum of geological age.

Analyzing the distribution of 1984 world gold mineralization by the age of the actual mineralization and the age of the host-rocks reveals that, from mineralization emplaced within the last 100 million years, virtually yesterday and today in respect to geological time, 18 per cent of 1984's production was extracted, 26 countries contributing (Figure 10). The middle-aged deposits, ranging from 100- to 2000-million-years old, contributed 22 per cent, from 26 countries. Sixty per cent of the total production came from deposits in 19 countries, ranging in age between 2000 and 3500 million years. As far as future production is concerned, young gold will become more and more important. Consequently, within the next few decades, it might be anticipated that the proportion of middle-aged gold will decrease, and that the youngest deposits and the oldest deposits, between them, probably will contribute of the order of 80-85 per cent of the total world's gold production.

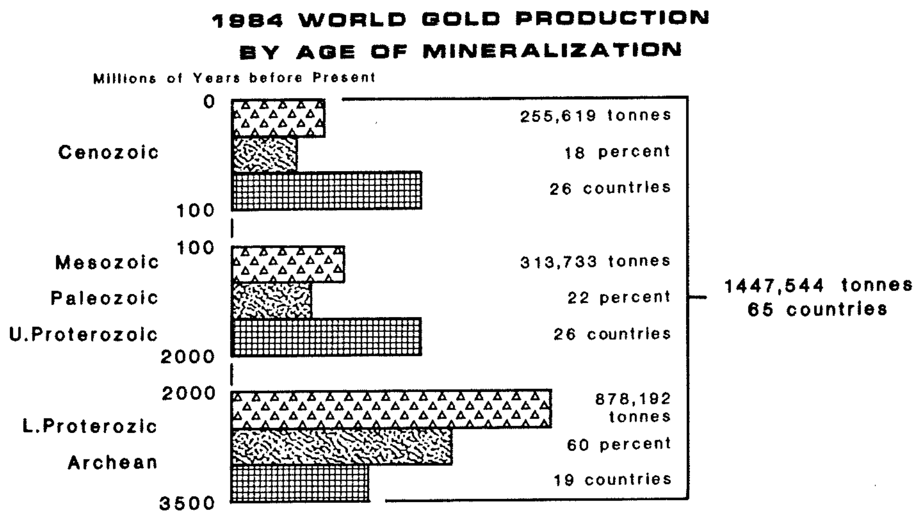

Figure 10 : *World gold production for the year 1984, according to the geological age of the mineralization. Output is shown in metric tons and as a percentage contribution to total world production. The number of countries is indicated in which gold deposits, according to three variable time-ranges, are mined.*

When the element of time is introduced into geological environments, it carries with it implications of space. Since there is a rational pattern in the evolution of the Earth, time and space are intimately related. This is well demonstrated by the distribution of very young deposits. They are preferentially concentrated in what is known as the "ring of fire" around the Pacific Ocean, starting in New Zealand, going up through the Solomon Islands to Papua New Guinea, through the Phillipines into Japan and the extreme eastern portion of the Soviet Union, through Alaska, Yukon, and British Columbia into California and Nevada, and then down through Central America into the Andes along the western margin of South America. There is a conspicuous absence of these young deposits in any of the interior portions of the major continents; they are always on the margins of the continents, particularly those margins which rim the Pacific. There are no indications of these young deposits around Africa, or Europe, or the eastern portions of North and South America. It is significant that, in addition to the young gold mineralization, the "ring of fire" is also a most favourable region of porphyry copper mineralization. Consequently, there is not only a substantial development of primary gold, but also important contributions of gold as a by-product. An impressive example is the Bougainville copper deposit which, as far as gold is concerned, ranks as about the thirteenth largest gold producer in the world.

The "ring of fire" is an expression of the mechanism of plate tectonics, the process of evolution of the Earth by which earlier, cohesive, supercontinents were fragmented, to yield the distribution pattern of continents and oceans, that decorates the Earth's surface today. Within the last 200 million years, the various plates, broad segments containing continents, continental shelves, and parts of the ocean floors, have tended to move away from each other or, in other instances, towards each other. Zones of collision or subduction house the regions of young gold mineralization, circumscribing the Pacific Ocean. Significantly, the edges of the continents where spreading, or moving apart, is taking place do not favour the development of this young mineralization.

The old and middle-aged gold is restricted essentially to the interiors and edges of continents well away from the rim of the Pacific. In that Africa has no contact with the Pacific, it is devoid of young gold deposits. There is no semblance of the type of either copper or gold mineralization which characterizes the Andean chain of South America and the Cordilleras of North America.

A revealing region in which to study the distribution in space, as a measure of the distribution in time, of gold mineralization is the Indo-Australian plate. In Australia, the major concentration of gold occurs in the west, as exemplified by Kalgoorlie, and in the east, in Victoria, New South Wales, and Queensland (Figure 4). All the deposits in the western part of Australia are located in rocks older than 2 000 million years. The central part of Australia does not host large volumes of important gold mineralization, and its rocks are of middle age, falling between 500 and 2 000 millions years old, a time generally unfavourable, in many respects, to the emplacement of gold. In the east, most of the gold mineralization is of an age of 200-400 million years. There is a definite younging from west to east, of the age of the rocks of Australia and an associated variation in the time-space relations of good and bad environments for gold mineralization. To complete the study of the whole of the Australian plate, to the old deposits of Western Australia and the younger deposits of eastern Australia must be added the very young mineralization of Papua New Guinea, the Solomon Islands, and New Zealand, situated on the edge of the plate.

The 1984 production of gold from the Indo-Australian Plate was drawn almost equally from old gold and very young gold. Figure 11 shows that 40 per

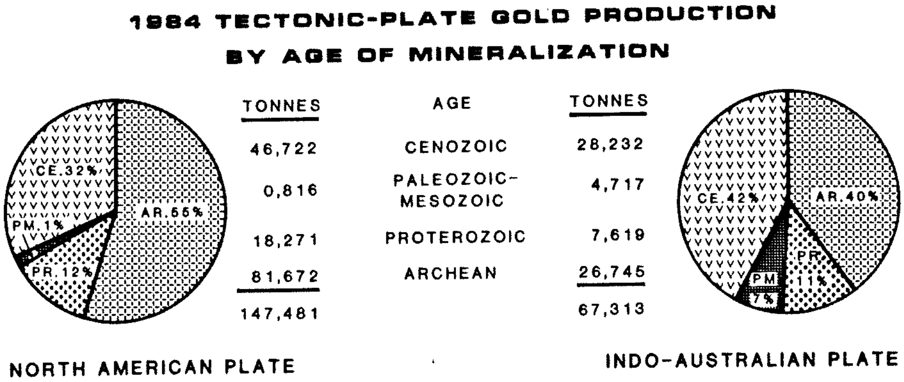

Figure 11 : *Gold production, for the year 1984, from the North American Plate and the Indo-Australian Plate, according to geological eons. Output is shown in metric tons for each eon and as a percentage contribution of each eon to the total production from each plate.*

cent had its source in the Archean rocks of Western Australia, 18 per cent in the Proterozoic and Phanerozoic formations of central and eastern Australia, and 42 per cent in the very young rocks of the Pacific "ring of fire". A similar story is apparent on the North American Plate, the old regions contributing 55 per cent of the gold, the middle-aged deposits only 13 per cent, and the very young mineralization 32 per cent. Clearly, as far as preferential regions for gold mineralization are concerned, it is the youngest, contained within the "ring of fire" around the Pacific Ocean, and the oldest, located within the ancient stable nuclei of the continents, which are the most attractive. The middle years of the Earth's evolution represent a period of distinctly lower favourability for the development of important gold deposits.

An attempt has been made to expand the analysis of gold production from one year, 1984, to the full recorded history of man, stretching over almost 6000 years from 4000 BC to the end of 1984. Obviously, such an estimate can be regarded only as an approximation compiled within very wide limits of accuracy and heavily loaded with uncertainties. Possibly, a total of 107 000 metric tons of gold has been mined by man in the last 6000 years (Figure 12). In the initial period of 5400 years, possibly about 19 per cent of the world's gold was produced, which came almost exclusively from placer deposits, at the rate of about 4 tonnes per year. The beginning of the 15th century marked the Spanish entry into South America and the mining of a substantial proportion of gold from the young mineralization of the Andes. Over the next 500 years, possibly 10 per cent of the world's gold was won, at a rate of 23 tonnes per year. The year 1886 saw the discovery of the Witwatersrand, and, in the past 100 years, there has been a dramatic change in the supply of gold to world markets. Seventy per cent of total world output has been mined in the past century, at an average rate of 757 tonnes per year.

TOTAL WORLD GOLD PRODUCTION
4 000 B.C.-1 984 A.D.

PERIOD	TONNES	%	YEARS	T/YR
4 000 B.C.-1 400 A.D.	20 000	19	5 400	4
1 400-1 886	11 300	10	500	23
1 887-1 984	75 700	71	100	757
4 000 B.C.-1 984 A.D.	107 000	100	6 000	18

Figure 12 : *Approximate estimate of total world gold production over 6000 years of history, from about 4000 B.C. to 1984 A.D. Spain's access to the gold resources of South America dates from 1400 A.D. The discovery of payable Witwatersrand conglomerates was made in March, 1886.*

Putting the estimated 107 000 metric tons of production into the context of geological time, instead of historical time, and going back 4000 million years, two pronounced peaks of gold emplacement in the Earth's crust can be seen (Figure 13). The first peak, between 2500 and 3500 million years

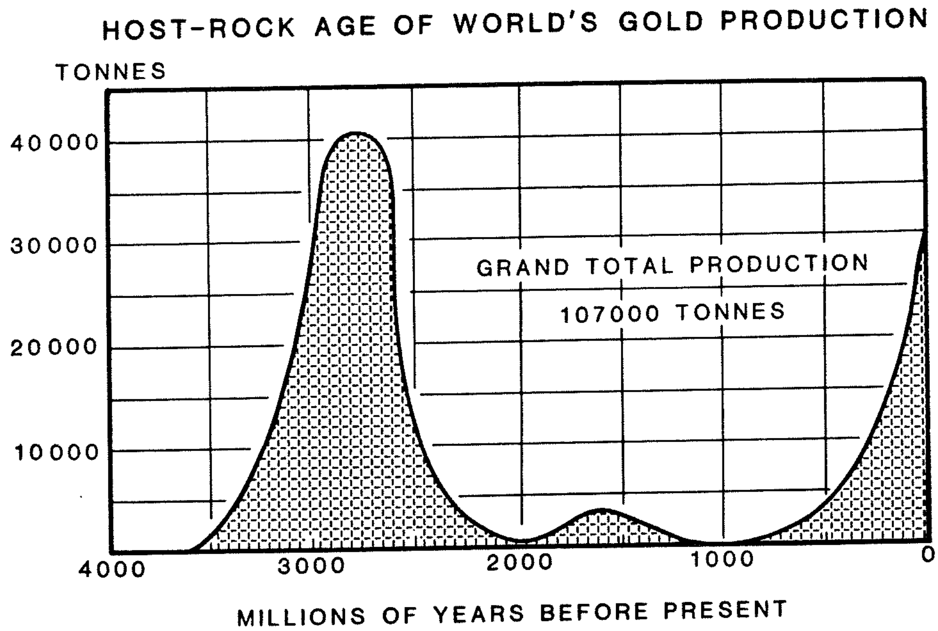

Figure 13 : *The distribution of gold mineralization through geological time, as indicated by the age of host-rocks to the various types of deposits. The optimum times for the introduction of significant concentrations of gold into the Earth's crust coincide with the earlier and later eons of crustal evolution, with the eons between being relatively unfavourable.*

ago, was followed by a relatively minor period of favourability, between 1200 and 1800 million years ago. The second peak started 500 million years ago and would appear to be still in the process of developing. It would seem that, within the last 100-200 million years, there might have been a regeneration of the geological factors, responsible for substantial gold emplacement, that prevailed in the early years of the evolution of the Earth's crust. The present time might be part of the early stages of the second grand cycle of gold mineralization.

The Witwatersrand Goldfields

The outstanding contributor to the old peak of intense mineralization has been the Witwatersrand Basin. Within ten years of its discovery in 1886, John Hayes Hammond, the eminent American mining engineer, proclaimed the Witwatersrand as the greatest of the world's goldfields. Every development since then has substantiated his opinion.

In almost 100 years of mining, it is estimated that 40 500 metric tons of gold have been recovered. Four-and-a-quarter billion tons of ore have been milled, with a recovery grade of 9,5 grammes per tonne for the 153 mines which have operated, at one stage or another, during the history of the Witwatersrand (Figure 14). In addition, from the year 1952 onwards, uranium has been added as a by-product. The Witwatersrand goldfields today are accepted by the majority of geologists, who work in them, as very old placer

WITWATERSRAND PRODUCTION : 1887-1985

GOLD WON :	40 518,008 tonnes
ORE MILLED :	4 255 million tonnes
AVERAGE GRADE :	9,52 g/tonne
NO. OF MINES :	153
PERIOD :	1887-1985

U-OXIDE WON :	136 669,349 tonnes
ORE MILLED :	628 million tonnes
AVERAGE GRADE :	0,217 kg/tonne
NO. OF MINES :	31
PERIOD :	1952-1985

Figure 14 : *The total production of gold, from the Witwatersrand Basin, between May, 1887, when the first output was declared from an outcrop mine, and the end of 1985. Also indicated is total amount of uranium oxide recovered between 1952, when production commenced, and the end of 1985.*

deposits, paleoplacers, of alluvial gold which accumulated, between 2750 and 3100 million years ago, in sands and gravels. When the ancient Witwatersrand placer deposit is compared to the young placers of the present day, it can be seen that the Witwatersrand has yielded about 1,2 billion ounces of gold, whereas the biggest of the modern placer deposits, in California and Siberia, have produced about 40 000 million ounces of gold. The amount of gold that has been recovered from the Witwatersrand is thirty times greater than the most important of the present-day placer deposits. Quite anomalous conditions must have existed in Witwatersrand times, which were most favourable for the accumulation and preservation of gold. Nowhere else in the world has a region been found that is similar to the Witwatersrand with respect to the amount of gold it contains or its potential for producing more gold. Up to the present, it would appear to be a unique feature which is exclusive to the very old, south-eastern segment of the African crust.

After 100 years of geological investigation, a great deal has been learned about the nature, geometry, sedimentary fill, and gold-uranium mineralization of the Witwatersrand Basin, but, also, knowledge of many aspects remains equivocal or incomplete. Between 2750 and 3100 million years ago, a large body of water, enclosed at times, which might well have been a lake or a shallow sea, occupied a region roughly oval in shape, extending in a north-easterly direction (Figure 15). The bulk of the material washing into the

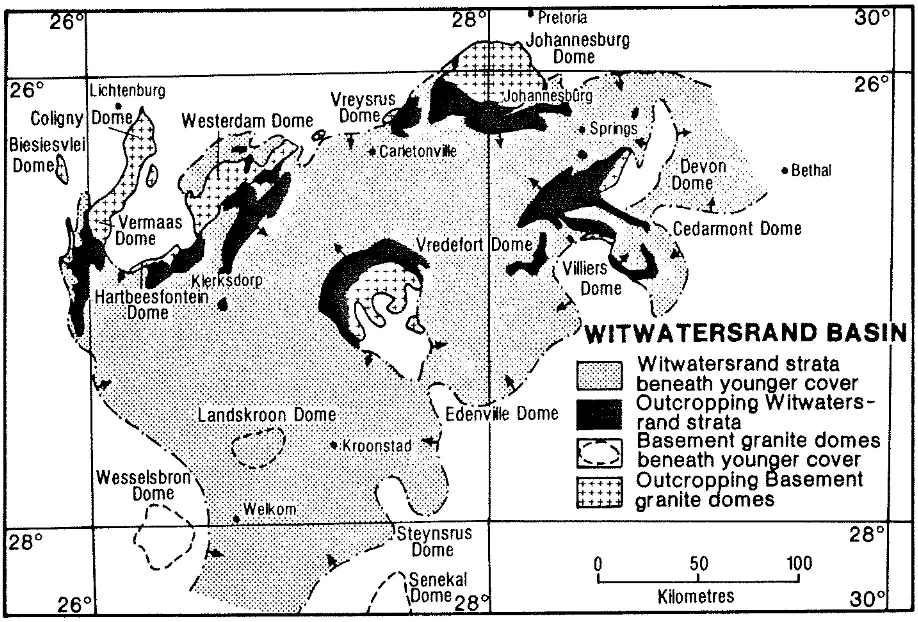

Figure 15 : *The extent and geometry of the Witwatersrand Basin, showing the small proportion of the depository's expanse which is represented by outcropping Witwatersrand strata and the location of structural domes which influenced the siting of the various goldfields.*

depository was contributed from the north, northwest, and west, so that, in the northern Cape Province, the western and central Transvaal, and the western Orange Free State, there appears to have been a terrane very much enriched in gold. The erosion-products of this region were transported by rivers, flowing south-eastwards and eastwards, and were ultimately deposited in the form of large-scale braid-deltas where the rivers discharged into the lake or shallow-sea waters. There is a marked tendency for the significant gold deposits to occur on the western, northwestern, and northern sides of the basin, whereas the southeastern portion of the basin, to date, has not been proved to host any goldfields of consequence. At least six rivers have been indicated as flowing into the northwestern side of the depository, and, at the mouths of each of these, a major goldfield developed. Between the Carletonville and East Rand goldfields, the braid-deltas tended to overlap and coalesce, to give the impression of a continuous tract of gold-bearing conglomerate and other rock-types over a distance of almost 150 kilometres. East and west of this tract, there are gaps between the known goldfields, in which the possibility cannot be discounted that additional braid-deltas remain to be discovered (Figure 16).

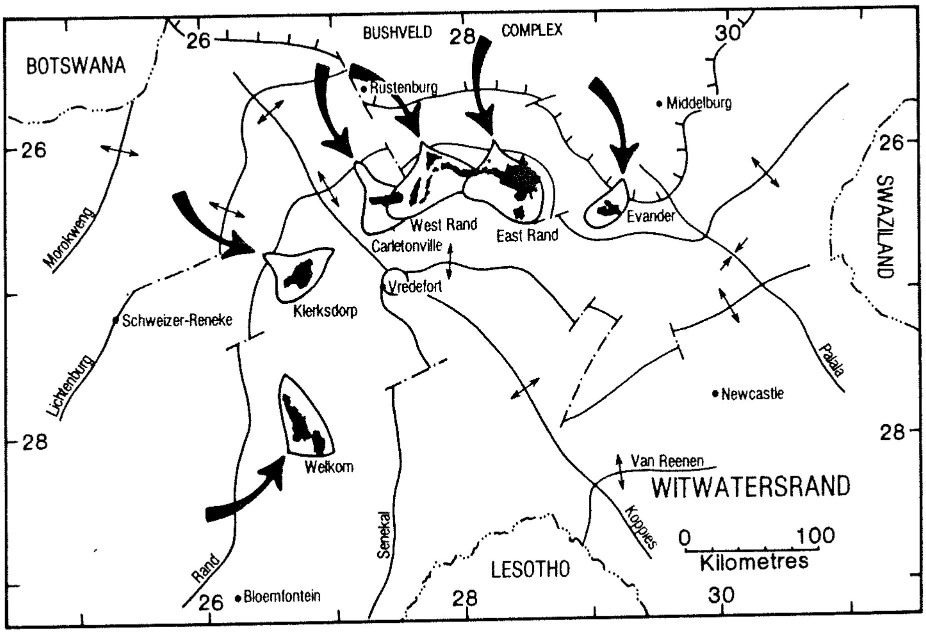

Figure 16 : *The location of the braid-deltas which host the individual goldfields of the Witwatersrand Basin. The general directions of flow of the fluvial systems, at the mouths of which the braid-deltas developed, is shown, as well as the traces of the more prominent synclines and anticlines which influence the geometry of the basin.*

The gold-bearing material is represented by fluvial-type accumulations of gravel, mainly quartz-pebble gravel, rounded pyrite grains, and sand, the latter two of which constitute the matrix of the classic banket or conglomerate. The gold is an integral part of the sand-fraction and not of the gravel and is so fine-grained and so sparsely distributed that it is very seldom visible.
On the margins and at the base of the braid-deltas, quiet-water conditions prevailed, which were very favourable for the growth of primitive algae. The intermatted and interwoven algal filaments acted as an effective trapping-agency for the ultra-fine particles of gold which washed beyond the sands and the gravels. Were it not for the presence of these algal mats, which were to become what is known as carbon seams, such gold would have been dispersed into the depository and lost. In some goldfields, at least 40 per cent of the total amount of gold present in the various mineralized horizons was entrapped in these algal mats.

The association of gold and algae is not unique to the ancient Witwatersrand goldfields. The Forty-Niners of California indulged in what they called 'moss-mining'. As the water-levels dropped towards the end of the rainy season, they would go down the streams and rivers, flowing off the Sierra Nevada, in flat-bottomed boats, scraping off from the banks and exposed rocks the accumulation of greenish algae, which they called moss. The algae was dried out and burned, and they recovered gold from the ash. Thus, "carbon seams" were being mined in 1850 in California.

At the interface between fluvial systems and lake- or sea-waters, there was a shore-line where wave-action helped concentrate the heavy minerals, including gold. From the mid-delta lakewards, beach-type gravels, as well as river-gravels, were laid down. Generally, at the apices of the braid-deltas, energy-conditions were too strong to permit the fine particles to settle, and these portions of the goldfields are usually impoverished in gold and uranium. The optimum mineralization of the conglomerates developed where the waters of the depository reacted with the waters of the rivers (Figure 17).

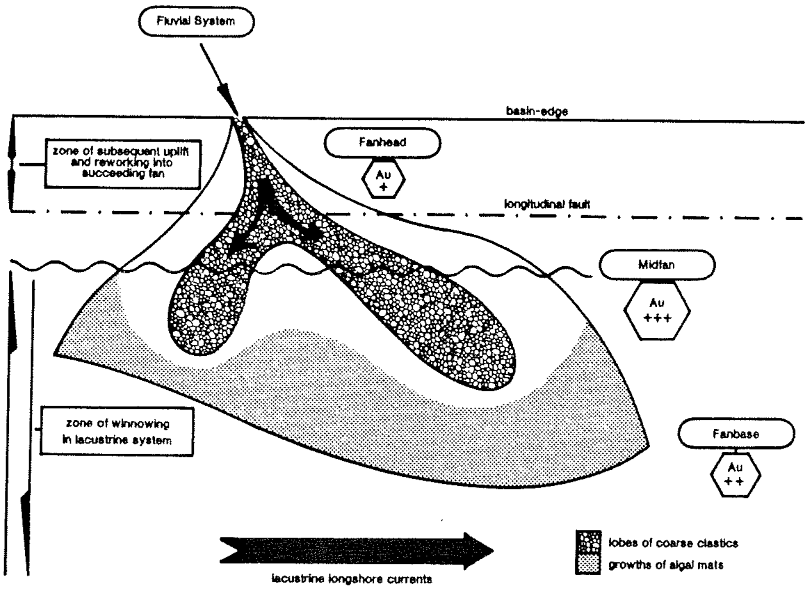

Figure 17 : *A conceptual model of a Witwatersrand braid-delta or fluvial fan which constitutes a basin-edge goldfield, showing the distribution-pattern of the different sedimentological facies which influence large-scale variations in the prospectivity of different segments of an individual goldfield.*

The Future of the Witwatersrand

At the celebration of the centenary of the discovery of the Witwatersrand goldfields, it is appropriate to review, as has been done, very briefly and very superficially, in the preceding paragraphs, what is known about this extraordinary depository of gold and uranium mineralization. A remarkable volume of information and understanding has been garnered of a remarkable ore-deposit, and a great deal can be said of the course which exploitation of the goldfields has taken. But, what of the future of the Witwatersrand mining industry?

One of the foremost questions to be asked refers to the future life of the goldfields. For how many more years can it be anticipated that the Witwatersrand will remain a significant contributor to world gold production? Many projections have been attempted, employing various prices of gold, and all of these reflect the general trend depicted in Figure 18. Different

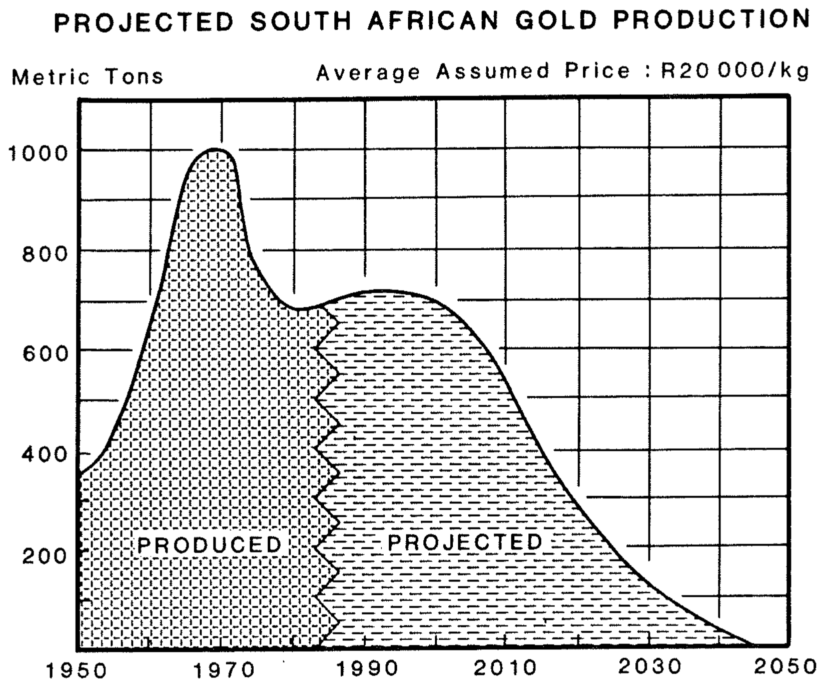

Figure 18 : *Projection from the year 1985 to the year 2045, showing the anticipated progressive decline in South Africa's total gold production over the 60-year period. The projection assumes that no further major goldfields will be found in the Witwatersrand Basin.*

projections move the dates and heights of the inflection points, but the downward direction of all the forecasts is a constant feature. Even if new mines in the development stage are considered, the concensus of forecasts rings the death-knell of the Witwatersrand by 2045, sixty years from the present.

The ultimate goal of exploration is to prove this prediction wrong. Encouragement can be taken in the fact that, in reviewing the overall history of the Witwatersrand, it can be seen that, three times previously, persuasive pronouncements have been made that mining in the Witwatersrand Basin was approaching its end. The first was as early as 1890, when all the outcrops had been located. It was stated that there was nothing more left to be found.

The introduction of diamond-drilling forced opinions to change. The period of pessimism, which marked the 1920's, started to be lifted in the early 1930's, when exploration was revolutionized by the advent of a new prospecting technique in the form of geophysics. The most recent cloud of gloom appeared by the end of the 1950's, when, after the discovery of the Evander Goldfield, continued exploration produced negative result after negative result. Frequent predictions were made that the end of new discoveries had been seen and that the complete Witwatersrand Basin had been delineated. The successful application of sedimentology brought back an air of optimism. On all three occasions, geologists and other prognosticators were proved to be wrong, and it would be cause for celebration if the forecasts illustrated in Figure 18 again were shown to be in error. But, exploration today is very much more complex and a considerably more expensive undertaking than it was on those previous occasions when the efforts of geologists lifted the grey skies over the Witwatersrand Basin.

It can be argued that, in the gaps between the established goldfields, there are still wide expanses of the Witwatersrand Basin in which it might be anticipated that further river-systems, other than the six presently known, could have flowed into the depository and could have formed braid-delta goldfields at their mouths. However, even if they are there, they might well be beyond the depth which can be reached by present-day drilling and, certainly, beyond the depth of economic mining. Of course, there could well be other areas, far removed from the gaps between goldfields, where geological conditions could have been especially conducive to the concentration of gold, at one time or another, during the closing chapters of the Witwatersrand story.

Exploration in the Witwatersrand Basin is, in all senses, a search in what, in old-time prospectors' parlance, would be called *aniah* (a-needle-in-a-haystack) country. The needles are very small and the haystacks are very large, as a consequence of which the pursuit of new goldfields, to stave off the projected decline from the year 2000 onwards, assumes high orders of effort, money, and risk. The magnitude of the undertaking is well illustrated in the case of prospecting for further mineralization in the Carletonville Goldfield, where the Carbon Leader constitutes a target of first-rank importance, but, often, of exceptional thinness. It is difficult enough looking for something only a few millimetres thick, even if it were blatantly exposed on surface, but the exploration geologist is confronted by the daunting fact that, generally, he has a thickness of up to 2 500 metres of rock-hard hay covering a needle that might be only 10 millimetres thick (Figure 19).

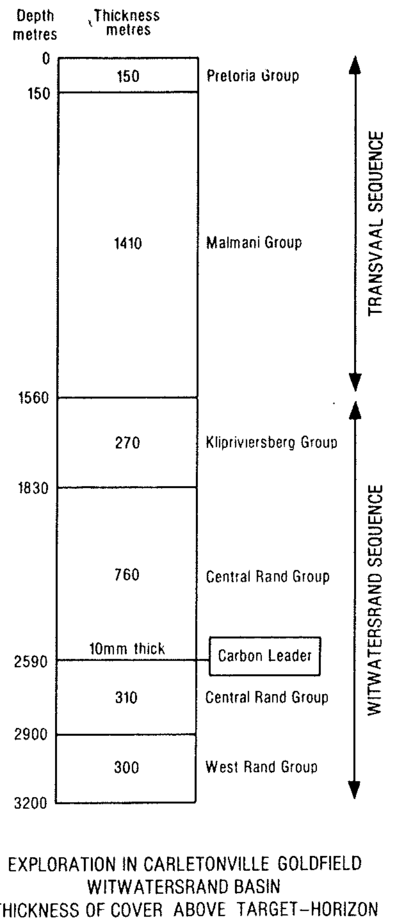

Figure 19 : *An example of the 'needle-in-a-haystack' scenario which prevails in current Witwatersrand exploration. A 'needle', 10 mm thick, lies buried beneath a bale of 'hay' almost 2600 metres high in the Carletonville Goldfield. The richly-mineralized Carbon Leader is a particularly-attractive target, even at depths of 3000 metres.*

Obviously, a formidable task, a colossal challenge, confronts the geologist. The Witwatersrand gold mining industry stands or falls on his success in finding significant tonnages of new high-grade ore at relatively shallow depths. At all times, he should remind himself of what Charles 'Doc' Lindeman, legendary prospector and poker-player of the Klondyke, said in 1897: "Prospecting is a gamble in which there always will be winners and losers. To win the game, a gambler must have money, skill, cunning, perseverance, and luck. But, above all, he must be a brave man".

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