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SOUTH AFRICAN URANIUM RESOURCES — 1997 ASSESSMENT METHODOLOGY AND RESULTS

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Abstract

The first commercial uranium production in South Africa started in 1953 to meet the demand for British/US nuclear weapons. This early production reached its peak in 1959 and began to decline with the reduced demand. The world oil crisis in the 1970s sparked a second resurgence of increased uranium production that peaked in 1980 to over 6,000 tonnes. Poor market condition allied with increasing political isolation resulted in uranium production declining to less than a third of the levels achieved in the early 1980s. South Africa is well endowed with uranium resource. Its uranium resources in the RAR and EAR-I categories, extractable at costs of less than $80/kg U, as of 1 January 1997, are estimated to 284 400 tonnes U. Nearly two thirds of these resources are associated with the gold deposits in the Witwatersrand conglomerates. Most of the remaining resources occur in the Karoo sandstone and coal deposits.

1. INTRODUCTION

The Earth and Environmental Technology Division (EET) of the Atomic Energy Corporation of South Africa Ltd., (AEC) is responsible for the assessment of South Africa's uranium resources and production capability on an on-going basis. These assessments are carried out with the close cooperation of the mining companies, whose assistance is acknowledged and greatly appreciated. The results of this ongoing assessment are compiled to ensure confidentiality and reported to the International Atomic Energy Agency (IAEA) every two years for publication in *Uranium Resources, Production and Demand.*

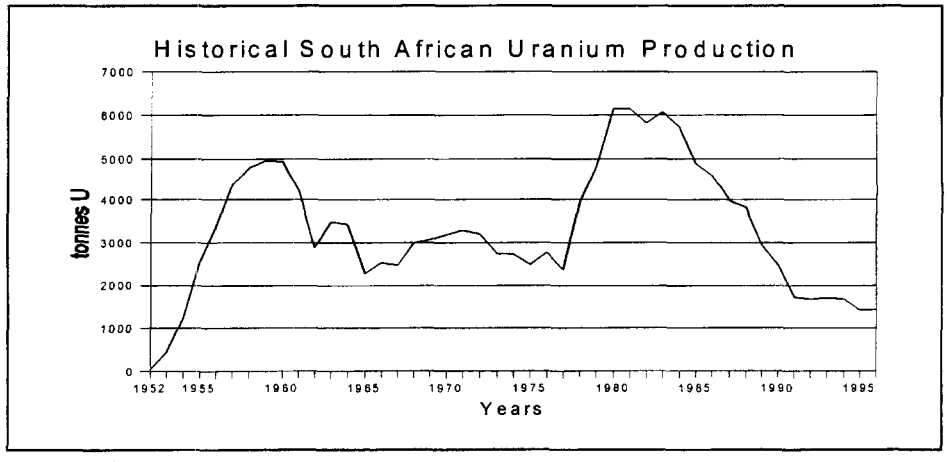

FIG. 1. Historical South African uranium production.

South Africa has been an important player in the international uranium market since its inception in the early 1950s. In the mid 1940s South Africa's potential for uranium production came under scrutiny for the first time when a joint British/US team visited the country to investigate the reported presence of uranium in the Witwatersrand gold mines. The presence of significant amounts of uranium was established and this was followed shortly in 1953 by

the establishment of the first commercial uranium plant in South Africa. Production expanded rapidly to accommodate the military needs of the Western World for their nuclear weapons programmes (Figure 1). By 1959 these needs began to decline as did South Africa's uranium production. The world oil crisis in the 1970s sparked a surge in the price of uranium and South Africa's mining industry was quick to react to the increased demand with production more than doubling in 5 years. The uranium price peaked in 1979, then fell dramatically over the next 3 years. This was reflected by a steady fall in South African uranium production from 1981. The 1980s were characterised by plant closures and declining production capability, which continued into the 1990s. Poor market conditions allied with increasing political isolation resulted in uranium production declining to about a third of the levels achieved in the early 1980s.

Since 1967 the AEC has been monitoring and assessing the country's uranium resources and production capability. In addition exploration activities and uranium production are also monitored. The AEC plays no active role in the commercial uranium industry in South Africa but from time to time has engaged in research activities aimed at better defining the controlling factors of uranium mineralisation in various environments. These activities have been carried out in conjunction with researchers at various academic institutions and the results released to the private sector.

2. GEOLOGY OF SOUTH AFRICA'S URANIUM OCCURRENCES

Uranium in South Africa is hosted in a variety of geological environments, of which only four are of real significance currently. These will be touched on only briefly as they have been reported on extensively elsewhere. Of major importance are the gold deposits of the Witwatersrand quartz pebble conglomerates which have significant uranium as a by-product. The mineralisation is hosted in reefs composed of coarse detrital sediments ranging from conglomerates to coarse sandstones. They are found in seven major goldfields extending around the northeastern to southwestern rim of the Witwatersrand Basin and account for the majority of South Africa's uranium production. Grades are low, generally lower than 0.05% U_3O_8, but the ubiquitously associated economic gold mineralisation make them economically viable. Almost all of the gold mines have uranium resources but these are often too low grade to warrant extracting the uranium. These resources are mined in conjunction with the gold but the uranium is not extracted and is dumped onto the tailings dams. These tailings dams can constitute significant low cost, easily accessible uranium resources if care is taken not to dilute these uraniferous slimes. Another factor to consider is the use of cemented slimes as backfill in mined out areas of the mine which effectively sterilises this potential resource.

The sandstone and coal hosted deposits of the Karoo Supergroup are the only other important uranium resource base in South Africa. They contain about one quarter of the total uranium resources in the country. The sandstone hosted deposits are generally small and erratic in nature, occurring in palaeochannel sandstones, with grades of up to 2% U_3O_8, but with average grades of about 0.1% U_3O_8. Molybdenum occurs as an accessory element which could be extracted as a by-product. The AEC recently completed an intensive stratigraphic and palaeontological study of these deposits which indicated that there exists a considerable potential for the discovery of further deposits. The coal hosted deposits are more extensive and continuous, but generally have lower grades, averaging about 0.05% U_3O_8.

South Africa has a number of intrusive alkaline complexes of various ages, two of which are known to contain uranium mineralisation. The Pilanesburg complex in the Northwest Province hosts a variety of exotic elements including uranium but low grades have resulted in little interest being shown in it. The Phalaborwa Igneous Complex in the Northern Province has major copper, phosphate and vermiculite mines. The copper mineralisation is hosted by carbonatite and has very low grade uranium associated with it in the form of uranothorianite. It is only the large scale of the operations which allow the uranium to be extracted economically. This is the only uranium producer in South Africa outside the Witwatersrand Basin.

Monazite in heavy mineral sands along the east and west coasts of South Africa contains low concentrations of uranium. The sands are being exploited for their ilmenite, rutile, zircon and monazite contents but the uranium is not being extracted. Other environments which host uranium mineralisation are younger surficial sediments in northwestern Cape, granitic gneisses in Namaqualand and marine phosphate nodules off the southwestern coast of South Africa. None of these will be of any economic interest in the foreseeable future.

3. EXPLORATION

No exploration for uranium as a primary target has taken place in South Africa for over a decade. All work in the Karoo Basin ceased in the early 1980s and in the Witwatersrand Basin gold has always been the primary target for exploration activities. The almost universal relationship between gold and uranium mineralisation in the Witwatersrand Basin has resulted in additional uranium resources being discovered during gold exploration. In the late 1980s gold exploration in the Witwatersrand Basin was at a high tempo, but a stagnant gold market since then has resulted in a severe curtailment of exploration programmes with little drilling taking place. This situation is unlikely to change without a substantial improvement in the gold market. Similarly a marked improvement in the uranium market appears necessary to stimulate interest in uranium exploration outside the Witwatersrand Basin, because of the low grades and small size of the potential targets.

4. URANIUM RESOURCES

South Africa is well endowed with uranium resources and has been ranked in the top five nations in this regard for many years. A major proportion of these resources occur as a by-product of gold mineralisation and South Africa is in the unique position of being the only major uranium producing nation which produces all its uranium as a by-product to the exploitation of other mineral commodities. The size of a large part of the resource inventory is thus dependent on factors external to the uranium market, but it has the fortunate effect of allowing South Africa to tailor its output to the prevailing market conditions, but. The by-product nature of the uranium mineralisation also imposes certain constraints on how the resource inventory is estimated.

4.1. Assessment procedure

The definitions and terminology used for South Africa's uranium resource assessment are those as used for the IAEA publication, *Uranium Resources, Production and Demand.* Interested readers are referred to the latest edition for further information.

The resource estimation procedure is carried out on a property-by-property and a reef-by-reef basis and consists of five stages (Figure 2).

Budgetary and staff constraints prevent the AEC from gathering raw data and conducting resource evaluation estimates itself. All companies operating in South Africa furnish full particulars of their exploration activities with regard to uranium and provide the AEC with estimates of their uranium resources, both for active mining operations and prospects, under conditions of strict confidentiality. The reporting of resource estimates is done on standardised forms to ensure uniformity of the data and discussions. These resource assessments are conducted on the basis of a US dollar/rand exchange rate set as the 1st January of the year of assessment. In the case of the Witwatersrand gold deposits a gold price is also specified as this has a direct bearing on the size of the associated uranium resources.

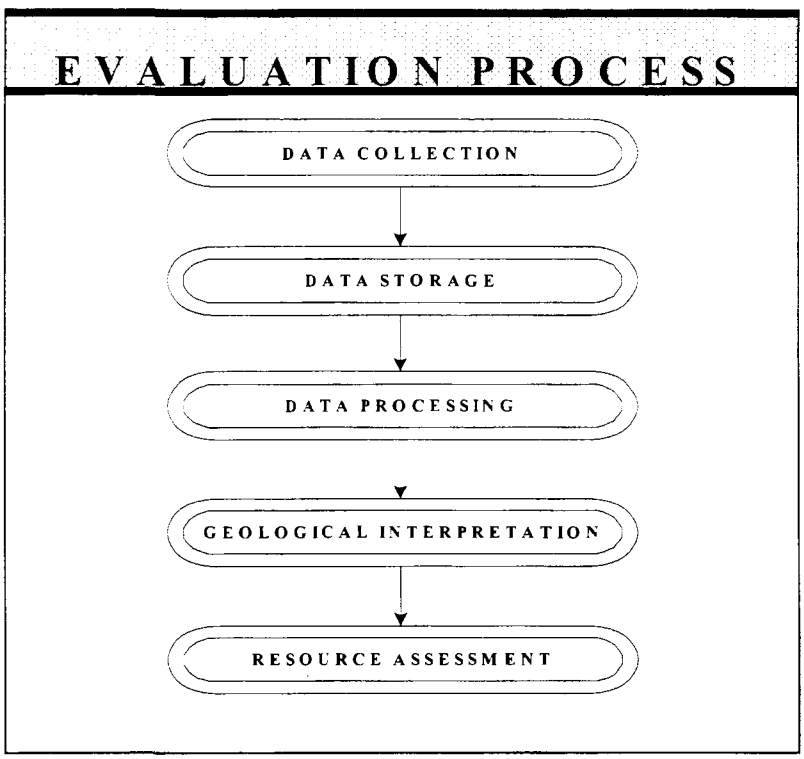

FIG. 2. Uranium resource evaluation process.

The data received from the mining and exploration companies are stored in a computerised database to facilitate data manipulation. The database is structured to allow the selective extraction and manipulation of specific information as required in the estimation process.

The resource estimates supplied by the companies are assessed in terms of the known geological setting of the resource as revealed from the exploration reporting and discussion with the personnel involved. The estimates are also compared with the previous estimates of the resource, and in the case of active mines, with past production records. Discrepancies and anomalies are referred back to the relevant company for discussion with the evaluation personnel and possible revision. When the resources returns have been finalised, the estimates are compiled to yield a national uranium resource inventory which can be used to project production capabilities and allow planning of the country's energy strategies.

A number of factors need to be considered during the resource assessment process with respect to their cost categorisation, particularly where the uranium mineralisation occurs as a by-product.

4.2. Cost categorisation

Uranium resources in South Africa fall into three categories based on their relationship with associated mineralisation, if any. It may be the primary mineralisation, as is the case in the Karoo deposits; it may be a co-product, in the case of some of the Witwatersrand reefs; or most commonly, it occurs as a by-product. The method of determining the cost categorisation of the uranium resources is different in each case.

Where uranium is the primary product, the process is relatively straight forward. First a US dollar/rand exchange rate is determined as the uranium price is denominated in US dollars and working costs are calculated in rands. The tonnage and grade of the deposit estimated using one of many ore reserve estimation techniques depending upon the amount of information available and the characteristics of the mineralisation. These range from normal and lognormal mean, through various distance weighted and trend surface techniques through to kriging. The former are usually applied in prospect situations, but the trend in South Africa is, more and more to use kriging, especially on the mines where large data sets and access to low cost computing power are available. Mining and metallurgical process losses are estimated and the cost categorisation is determined from the working costs (including all forward costs) and the estimated recovery grade.

In the case where one or more other extractable minerals are present, but neither the uranium nor the other minerals are economic, the uranium would be a co-product. Here the grade and tonnage of the deposit are determined as before, but the cost categorisation of the uranium becomes a function of the revenue generated by the other minerals. This revenue is offset against the total estimated working costs and the residual shortfall is used to determine the cost category of the uranium.

Uranium becomes a by-product where the primary mineral being exploited is economically viable by itself. The grade and tonnage of the orebody is then constrained by the market conditions of the primary mineral and the working costs required to extract it. The extractable uranium is thus only that which falls within the boundaries of the primary mineral's orebody. The cost of extracting the uranium is then only the incremental cost of metallurgical treatment of the milled ore to extract the uranium, as the mining and milling costs are borne by the revenue generated by the primary mineral. This is the case with the majority of the Witwatersrand gold deposits and enables the profitable exploitation of otherwise uneconomic uranium resources. Hence the gold price as well as the exchange rate are of critical importance in determining the size and the cost categorisation of the uranium resources. The magnitude of South Africa's uranium resource base is thus also very dependent on the state of the gold mining industry. This is in a depressed state at present with threats of curtailment of operations at certain sections of some mines. It remains to be seen how the industry weathers these threats which it has survived in the past, but problems of low productivity and high working costs need to be addressed.

For the 1997 South African uranium resource assessment, the gold price was set at US$370/oz Au and the US$/rand exchange rate at US$1 = R4.70.

4.3. 1997 Assessment results

South Africa's uranium resources as at 1 January 1997 in the RAR and EAR-I categories, extractable at costs of less than $80/kg U are estimated to be 284 400 tonnes U. The Witwatersrand conglomerates and slimes account for 73% of the total or 207 900 tonnes U, with the Karoo sandstone and coal deposits making up most of the rest (Table I). Other than these two main depositories the other deposits only contribute just over 1% of the total resources.

There is little change in this estimate when compared with that made two years ago, with only a 9% increase in the RAR and EAR-I categories, extractable at costs of less than $80/kg U. This is to be expected because very little exploration has been carried out in the Witwatersrand Basin and none outside the Basin. However a more substantial increase in the resources could have been expected because the gold price in rand terms rose by 24%. This increase was almost completely offset by a 21% increase in estimated workings costs. Figure 3 shows the changes in cumulative resource estimates for the RAR and EAR-I categories exploitable at costs up to $130/kg U for the last five reporting periods.

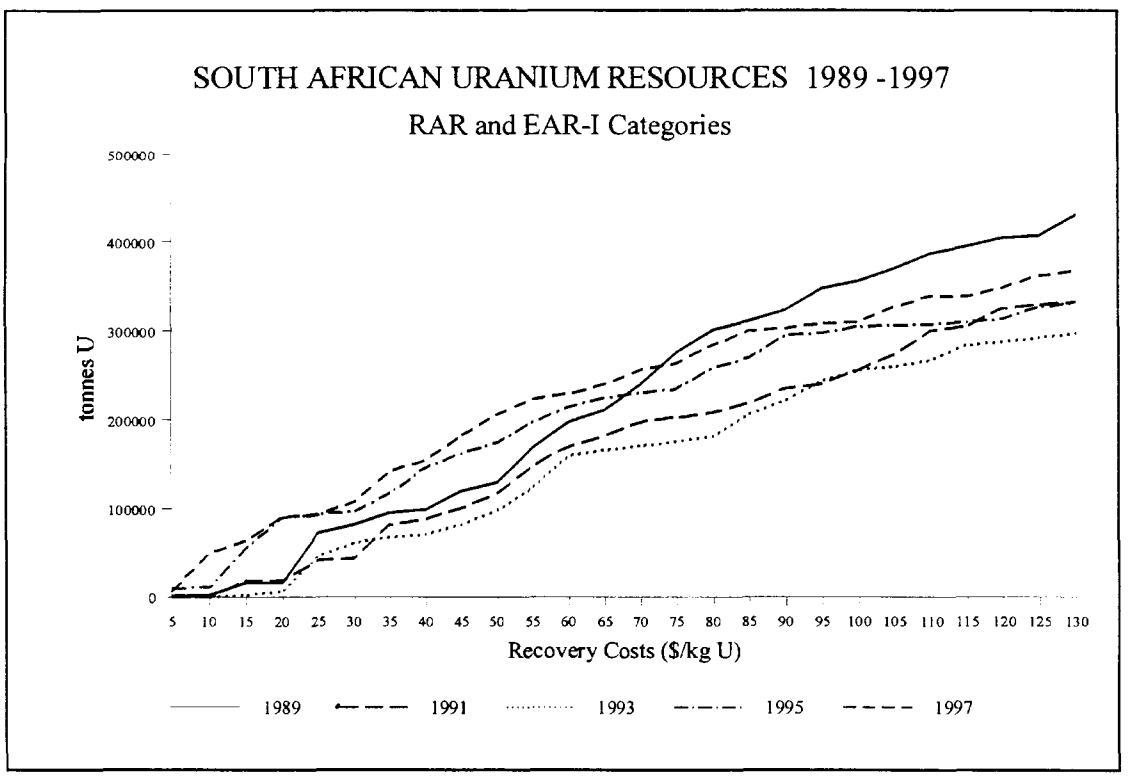

FIG. 3. South African cumulative uranium resources.

These fluctuations are a function of changes in the gold price, exchange rate and working costs as little or no exploration took place during this time. South Africa's physical uranium resource base has remained relatively static for the last decade but individual deposits have been moved from one cost category to another depending on the factors mentioned above. This situation is likely to persist in the future until the gold and/or uranium markets improve, which would stimulate exploration resulting in the addition of new resources to the national inventory.

TABLE I. SOUTH AFRICAN URANIUM RESOURCES AS AT 1 JANUARY 1997

Deposit Type	RAR			EAR-I			Total RAR+ EAR-I <$80	Total RAR+ EAR-I <$130
	<$40	<$80	<$130	<$40	<$80	<$130		
Witwatersrand Conglomerates	93300	47900	24300	41700	11200	1900	194100	220300
Witwatersrand Tailings	4000	9800	16400				13800	30200
Karoo Sandstone	1500	19700	2100	2700	4200	800	28100	31000
Karoo Coal	11700	27600	8600		5100	1700	44400	54700
Surficial		700				400	700	1100
Alkaline Complex		2100			1200		3300	3300
Total 1997	110500	107800	51400	44400	21700	4800	284400	340600
Total 1995	107500	97200	53900	39400	16400	19400	260500	333800
Difference %	+2.79	+10.9	-4.64	+12.69	+32.32	-75.26	+9.17	+2.04

5. CONCLUSIONS

The South African uranium industry has been in a parlous state for the last decade, as evidenced by declining plant closures and declining production. Exploration for uranium has virtually ceased for several years, except for serendipitous discoveries resulting from gold exploration. Current uranium market conditions make any resurgence of interest unlikely in the short term. It is only the by-product nature of the uranium mineralisation which has allowed the current producers to continue uranium production operations.

Intensive exploration in the Karoo during the 1970s and in the Witwatersrand Basin established a large uranium resource inventory which has only been marginally depleted by mining operations. The magnitude of the resources are dependent on the vagaries of the $/R exchange rate and the gold price, but in spite of continuing upward pressure of working costs they remain a significant proportion of the world's total. The South African mining industry's past performance indicates that, given improved market conditions, it would be capable of increasing production substantially in a short period of time to take advantage of an increase in demand.