

A Retrospective Analysis of Commercial Exploration Strategies for Uranium in the Karoo Basin, South Africa

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ABSTRACT

Tabular sandstone uranium deposits were discovered in continental sediments of the South African Karoo in 1969. Subsequent airborne radiometric surveying located several hundred occurrences of which the majority are located in the south west of the basin near Beaufort West.

Very few exploration techniques were useful in defining targets; the most effective were geological mapping and radiometric surveys. More than 20 companies, with both South African and North American funding, undertook extensive exploration. Those with expertise in similar deposits held the initial advantage.

Target evaluation was mainly the result of pattern percussion drilling. Companies with large corporate targets were prepared to undertake extensive drilling along large (up to 40 by 3 km) mineralized sandstone channel complexes, whereas those companies willing to invest less tended to drill shallower and less expensive targets. Wide spaced drilling could rapidly delineate mineralized trends, highlight areas for infilling and establish regional controls on mineralization.

Four deposits underwent test mining but the drop in uranium price following the Three Mile Island accident has precluded exploitation as they are all of relatively low grade. The largest was probably viable in 1981 and the establishment of a mill would have enabled development of average size deposits of around 1 million tonnes. A cursory financial analysis suggests that return on these smaller deposits is quite sensitive to exploration costs but more sensitive to mill costs.

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INTRODUCTION

Uranium exploration expenditure, like that for base metals shows distinct cyclicity. In contrast to base metals this cyclicity has been governed by political events and accidents rather than economic cycles; the first boom from 1956 - 1964 reflecting demand for nuclear weapons and the second from 1973 - 1982 resulting from potential demand for nuclear power stations. The South African experience during the last boom cycle reflected the by-product nature of uranium production: uranium is produced largely from the auriferous Witwatersrand conglomerates and to a much smaller degree (3%) from copper mining at Palabora. Exploration expenditure was high in the Witwatersrand but mineral rights are in general tightly held by the major gold mining companies and lead times to new production are long. The obvious alternative was to explore for virgin districts of other deposit types: unconformity vein, granite hosted vein, alaskite, calcrete or sandstone hosted deposits.

This study details the exploration history within the main area of continental sediments in Southern Africa: the Late Paleozoic to Mesozoic Karoo basin (Fig 1). It attempts to quantify the technical success of the exploration and the reasons for this. We also attempt to relate financial attractiveness to changing price forecasts. Inevitably this account is subjective as much of the data is company confidential. However it is likely to be more reliable than for most exploration districts because the deposits are at present not economic to mine and many of the exploration groups have ceased trading.

GEOLOGICAL BACKGROUND

Prior to the discovery of uranium the geology of the Karoo Supergroup (or System as it was then known) was relatively well known in the Transvaal and Orange Free State Provinces, as it is host to southern Africa's major coal deposits. The southern part of the supergroup in the Cape Province was less well understood although it had been subject to detailed investigation for hydrocarbons by the state oil company SOEKOR and was the source of a well described fossil reptile population.

In South Africa the sequence is up to 1000m thick (Anderson and Van Biljon, 1979) and was divided into units, reflecting general lithostratigraphy that were also considered roughly chronological (Carboniferous to Jurassic). The sequence begins with an episode of glacial deposition (Dwyka Group) followed by marine deposits in the south (Ecca Group) passing upwards into continental deposits (Beaufort Group) followed by further continental sediments with coal (Molteno, Elliot, Clarens Formations) and terminated by volcanism (Drakensberg Volcanics). In addition, sediments north of approximately 32.5 degrees south are intruded by dykes and sills of the Karoo dolerite swarm, which are believed to be coeval with the volcanics. In the extreme south of the Karoo Basin the sediments were folded during the Cape Orogeny but this folding gradually diminishes within 300 km north of the present Cape Mountains.

Very little of the southern outcrop area had been mapped in any detail as it consists of alternating mudrocks and sandstone and is geographically remote. Apart from major escarpments at the approximate southern limit of dolerites and around the volcanic outcrop the Karoo is generally arid with little soil cover, flat and used for sheep ranching.

INITIAL DISCOVERY

The effective discovery was made by geologists of Union Carbide Corporation in 1969 (Danchin 1989). They recognized the similarity between the Karoo and the uraniferous sediments of the Colorado Plateau, where the company had extensive interests in the

UraVan Belt. Radiometric anomalies were already known from Karoo rocks in Zimbabwe and Madagascar. Initially, a geologist with experience in Colorado (Jim Dalrymple) made a carborne survey of the western Karoo and after considerable persistence encountered a distinct anomaly within lower Beaufort sediments on the farm Paardefontein (Fig 2), 25 km west of the Karoo town of Beaufort West. Although the anomaly itself is of no economic significance it did indicate that the area was uraniferous and, as expected, that the mineralization was hosted in sandstones and low in thorium. Thirty kilometres to the west a more significant anomaly was located on the farm Rietkuil. Based on this encouragement and an airborne survey Union Carbide took up options to prospect over a substantial area. Although they attempted to keep their involvement in the Karoo as secret as possible, by using an operating subsidiary of Ruig-hoek Chrome Mines and assuming the guise of prospecting for clay, the news leaked out. However Union Carbide were able to conduct extensive airborne radiometric surveys and locate a large number of surface shows. They quickly drilled a number of these including the high grade and extensive outcrop on the farm Rietkuil.

Some accounts (Ford et al, 1981; Le Roux and Toens 1986) credit SOEKOR (the state oil company) with the initial discovery. Although SOEKOR had cut radiometric anomalies in their oil tests in 1967 these results were not widely distributed and they were not significant in respect of the eventual commercial discovery. They were, however, instrumental in demonstrating to government the potential wide distribution of the mineralization.

By 1973 Union Carbide had drilled a number of prospects in the Beaufort West area, particularly concentrating at Rietkuil. In middle of that year they exercised their option to buy the farm for R277 000, bringing their activities to the notice of a wider public through the medium of the South Africa 'Farmers Weekly'. To encourage exploration the discovery of uranium in the Karoo was announced by the Minister of Mines in Parliament. Outside political events also conspired to change the attractiveness of uranium exploration in 1973 when the oil price doubled in the aftermath of the Arab-Israeli Yom Kippur war. Upward price movement in the spot uranium market began in 1974 and continued until the end of 1978 (Fig. 3). Forecasts of uranium demand made in 1974-5 suggested a serious supply shortfall as increasing numbers of reactors were planned to reduce dependency on imported oil (Fig 4).

Company	Parent	Approx. involvement	U Production (1977)
Union Carbide	U.S.	1969-1983	1035
Southern Sphere	Utah (US)	1972- 198?	1400
Essex Minerals	U.S.Steel (US)	1973-1977	500
Anglo- American	S.African	1974- 198?	980
Rand Mines	S.African	1972-1982?	420
Industrial Development Corporation	S.African	1973?- 1978?	None
J.C.I	S. African	1977- 1983?	500
Rio Tinto South Africa	RTZ (UK)	1975?- 1982?	400 (Namibia)

Company	Parent	Involvement	Company U Production
Esso Minerals	Exxon (US)	1974- 1983?	1220
Newmont	US	1974?- 1982?	?
Mining Corporation	SA	1978? - 198?	None
Phelps Dodge	US	1973- 1976	840

This combination of events attracted a number of companies, said to be twenty by Cole and Labuschagne (1985), to the Karoo over the next six years. Exploration spending (Fig. 5) rose rapidly until a peak was reached in 1979 prior to the Three Mile Island accident and the subsequent decline in the spot price and uranium demand forecasts. Major players in exploration and a summary of their known involvements are shown above.

AREA SELECTION

When companies began their search they were faced with a large area of outcrop (around 600 000 Sq. Km.) with few guide lines for target selection. In contrast to areas such as Wyoming there is no obvious source area enriched in uranium. Although the N.W. Cape was known to be enriched in uranium, and was the target of exploration in the early 1970s for calcrete and leucogranite targets, it was not the provenance of most of the Beaufort Group sediments. Work by Theron (1973) and Ryan (1967) had demonstrated that sediments in the southern Karoo were derived from highland areas to the south of the Cape Fold Belt, which had subsequently been moved by continental drift.

The scanty information on the stratigraphy proved of little help except to suggest that the Beaufort Group was largely fluvial in origin and that thick sandstones are present in the eastern Cape. Most companies opted to take land around Beaufort West coupled with investigation of some areas in other parts of the basin. Exceptions were Rio Tinto South Africa, which concentrated on the southern Orange Free State and two companies (Gencor and Lonrho South Africa) which targeted uranium associated with Ecca coals in the Springbok Flats of the Northern Transvaal.

One of the few innovative guides was the use by at least one company (Esso Minerals) the distribution of two sheep diseases, enzootic icterus and geeldikkop. These were considered by Brown and de Wet (1962) to be the result of sub-chemical selenosis and prompted immediate comparison with the reported selenium rich areas in the Western U.S. associated with uranium deposits. Large areas of the southern Karoo are affected by these diseases which are particularly prevalent in the Fraserburg and northern part of Beaufort West districts. This was taken by Esso geologists as an additional pointer to favourability of the Beaufort West area. Subsequent work by Bath (1979) has shown that enzootic icterus is more probably a result of copper poisoning and it is known that geeldikkop is caused by overgrazing of land containing the plant *Tribulus terrestris* (Kellerman and Coetzer 1984).

TARGET SELECTION

The more conventional and most successful regional exploration technique for companies with all but the smallest budgets was airborne radiometric surveying. Fixed wing surveys were instrumental in detecting the better exposed occurrences, in all but the most rugged terrains, and define uranium provinces. However, individual deposits were

not always detected as result of poor exposure, wide flight line spacing and too small a crystal size. Commercial practice varied widely from the large crystal survey of the entire basin funded by the Department of Mines to small crystal surveys using light aircraft and a geologist observers. Typically costs were R1-3 /line km. Apart from very occasional paleo-placers, within Karoo and Cape age sediments, it was generally sufficient to examine the total count and uranium channels.

Helicopter surveys were used in the rugged Nuweveldberge and Drakensberg escarpments areas. Again survey practice was variable with some companies favouring informal surveys with geologists and a hand held scintillometer to more formal large crystal surveys. Informal flying has the advantage of flexibility as it is possible to land and immediately field check anomalies, trace prospective sandstones and is also possible to repeat a traverse in the frequent event of air turbulence.

Carborne surveys which were responsible for the initial survey were of restricted application because of the limited area of influence around roads and the location of the roads on the softer and less prospective mudstones and siltstones.

Ground radiometric surveys (Fig 6) were the favoured method of prospecting usually accomplished by technicians and labourers walking along grids and prospective lithologies. It was of course mandatory for geologists to carry a scintillometer.

Airborne surveying was coupled with regional geological evaluation using relatively cheap, government flown, black and white air photography. For example, in the Beaufort West area it was apparent from these surveys that most uranium occurrences (Fig. 7) were associated with a sandstone package, at and approximately above the stratigraphic level of the Poortjie sandstone of Rossouw and de Villiers (1953). Consequently most land was taken at this level. Outside the south western Karoo stratigraphic control was less obvious and land was largely optioned on the basis of the quality of surface uranium occurrences. Although the Lower Beaufort Group within a 100 km radius of Beaufort West contains several hundred uranium occurrences, other shows are known from the area between Victoria West and Richmond, south of Graaff Reinet, the southern Orange Free State and from the Molteno and Elliot Formations (previously Stormberg Series) in the Ficksburg and Qwa Qwa areas.

Obtaining land in the southern Karoo was relatively easy and inexpensive. Virtually all surface and mineral rights are owned by the same entity, usually the farmer. In addition, the agricultural value of the land is low, in 1973 around R15/ha, and individual holdings are large, usually in excess of 5000 ha. Option payments were around 30c /ha in 1973 but gradually increased to around R1/ha in 1979. Most farmers in the Karoo were grateful for extra income, at a time when overgrazing forced a reduction in their sheep numbers, and the possibility of buying a larger and better farm, if the option were exercised, was an attractive proposition.

Outcrops of mineralised sediments take three main forms:

- 1) calcareous, black weathering rocks known as koffiekliip (coffee rock)
- 2) bleached, limonitic, non calcareous sandstone and
- 3) reptile bones.

In some cases secondary uranium copper and arsenic minerals are developed. Only the first two types are of economic interest and detailed examination showed that the uranium occurs as discrete pods controlled by primary sedimentary structures within a much thicker and broader sandstone unit. For example, the main Rietkuil pod is around 150 x 100m with thickness of about 1m. Differences between the first two types merely reflect the calcite concentration of the mineralized sandstone. The problem for the exploration geologist was to decide how reliable an indication the outcrop grade and

geometry are of sub-surface grade and size. It was at this stage that considerable differences can be seen in company exploration policies. Some companies were interested in small shallow open pit targets (0.5-1 million kg U_3O_8) above the water table, lying at around 20-30m below surface, while other companies preferred to explore for large targets which would dip below the water table and require underground mining. Geologists with experience of Colorado Plateau geology were at a distinct advantage as they were able to predict the association of uranium mineralisation with thicker sandstones, in particular those thicker than around 14m. Particularly favourable locations are in areas of sandstone channelling or vertical stacking of sands. They were also familiar with the distribution of pods along mineralized trends within fluvial channels in contrast to Witwatersrand trained geologists who were more used to payshoots within tabular conglomerates.

Companies, such as Southern Sphere and U.S. Steel which entered the Karoo in 1973, were able to option farms with relative ease near the Union Carbide discovery but later competitors faced more severe competition. Rand Mines, chose, in contrast, to explore in the area to the west and south of this and optioned a block on the southern edge of the basin, where the sediments have suffered considerable folding. Although they generated a considerable number of targets, their tonnage potential at shallow depths was limited. As well as sandstone uranium deposits they drilled radioactive carbonatite at Salpeterkop, near Sutherland. This body contains substantial tonnages of niobium rich material but is unfortunately not amenable to beneficiation.

Esso Minerals entered the Karoo in 1974 and immediately optioned farms in the Beaufort West area. As most of the well exposed prospective acreage was taken by competitors, they were forced into areas of poorer exposure bounding a major salt river, which although prospective did not contain major airborne anomalies. In fact most encouragement came when a geologist (Chris Cameron) found a radioactive rockery in a farmer's garden whilst demonstrating the use of a scintillometer. This led to a airborne survey which located the source of the rockery as a low sandstone ridge and subsequently the discovery of the Ryst Kuil deposit. Elsewhere in the Karoo, Esso Minerals used more conventional techniques, particularly in the area near Sutherland.

Anglo - American and J.C.I. were relatively late entrants into Karoo uranium exploration. Whereas Anglo- American initially concentrated on the Richmond and Victoria West areas, J.C.I. selected the Sutherland and Laingsburg districts based on a regional stratigraphic survey (Wadley and Hoffman, 1986). Gradually moving west Anglo - American located a number of more significant occurrences, with limited strike extension, between Beaufort West and Sutherland, which were subsequently drilled in partnership with ENUSA (Spanish state uranium corporation). In the same area and to the north of Laingsburg J.C.I. drilled two targets; one within the Poortjie Package and another (DR-3), previously drilled by Rand Mines, about 1000m lower in the section.

TARGET EVALUATION

Although a wide variety of techniques were tried in the search for subsurface mineralization, very few were effective. The most useful tools were detailed surface mapping coupled with surface radiometrics and downhole logging of all available boreholes drilled for farm water supplies. Radon emanometry and alpha cup measurements were used but the impermeability of the mudstones enclosing the mineralized sandstones coupled with the tightness of the host sandstones proved impenetrable barriers to radon which could only escape along fractures. Ground water uranium measurements in farm boreholes are potentially useful, but are extremely difficult to interpret due to the need to correct uranium values for background increases caused by the age of groundwater and evaporation. Also, most farm boreholes are shallow and do not tap the major aquifer.

fers that are also host to uranium. Of the non- radiometric geophysical methods, only Induced Polarization is of any use from the surface. Response is dependent on the association of uranium with sulphides, particularly pyrite, and although this method was effective in detecting exceptionally thick sandstones at shallow depths, it was not robust enough to use on a regional basis.

Most subsurface exploration simply devolved to pattern drilling down dip from mineralized outcrops. Once it was established that most deposits were in equilibrium below the water table, drilling was almost entirely of the percussion variety. Occasional core holes were drilled for geological control but gross lithologies as well as grade were established by down hole logging. Above the water table wagon drilling was used.

At this stage corporate policies on size and depth become important. Major choices are whether drilling should concentrate on delineating pods or on defining a larger trend. Open file data (Fig. 8) contrast drilling patterns of some of the major companies that undertook exploration. J.C.I revealed (Wadley and Hoffman, 1986) that their exploration spacing was 200 by 200m which was gradually decreased in areas of encouragement to 25 by 12.5m.

Information on drilling is necessarily incomplete and some companies such as Rand Mines and Phelps Dodge drilled little. Down dip drilling of high quality surface mineralization optioned by these companies proved significant deposits at DR3 and Kareepoort respectively.

An example of drilling along a mineralized trend is shown in Fig 9. Both exploration and development drilling are shown for the Ryst Kuil area, only exploration drilling for the Kat Doorn Kuil area and initial wide spaced for the trend connecting the two. The initial sub- surface discovery was made where mineralization is preserved by down faulting along strike from the surface occurrence at Discovery ridge. The pod at Kat Doorn Kuil was found by drilling along the trend and the more structurally complex southern area as a result of drilling down dip from a small mineralized outcrop. The size of the pods can be seen from the distribution of drilling at Ryst Kuil.

Drilling at 25m or closer centres is necessary to define individual ore pods as the distribution is controlled by primary sedimentary structures of this scale. However delineation of trends can be accomplished by much wider spaced holes, once it is recognized that the higher grade pods are surrounded by a wide (500m - 1 km) halo of lower grade (0.002 to 0.04 m%U₃O₈) material. For example along the large Ryst Kuil trend it is possible to define the sand body and zones of interest using spacing as large as 800 by 400m holes. Although this would not indicate all the mineralized pods, it would have an excellent chance of intersecting at least some higher grade material. Use of the tables of Singer and Wickman (1969) shows that there is a 61% probability of one drillhole hitting a 200 by 25m pod with 800 by 400 grid at 45 degrees angle to the pod, and a 70% probability with more than one hole.

Definition of the sand bodies is important as mineralization occurs at the edge and within sandstone stacks. On a regional scale, wide spaced drilling has been used to define the distribution of areas of major mineralization. For example, along the Ryst Kuil trend (Fig. 9) they are located at changes in direction of the major sand body. These regional interpretations greatly refined surface prospecting and led to the recognition of prospects further along trends. In some areas mineralized sandstones are stacked and definition of trends in upper sands highlighted areas within underlying units. As drilling progressed the potential of different parts of the stratigraphy became apparent; complex variable sinuosity sandstones, such as Ryst Kuil, contained the most continuous mineralized pods whereas pods within the braided system in upper sandstones near Suther-

land were higher grade but less continuous. An exception to this generalisation is the DR-3 prospect of J.C.I which is stratigraphically lower and may represent a marginal marine environment. Grades in the northern part of the Basin tended to be lower. The only significant potential by-product is molybdenum and is generally closely associated with the uranium. Molybdenum grades are up to 0.2% Mo but the average tenor in deposits such as Ryst Kuil is 0.05% (Cole and Wipplinger 1989)

TECHNICAL SUCCESSES

Although the uranium price slump has made exploitation unattractive since 1981, four deposits in the main Karoo Basin were subject to feasibility studies; DR-3 (J.C.I.), Mooifontein (R.T.Z.S.A.), Reitkuil (Union Carbide) and Ryst Kuil (Esso Minerals). Reserve figures for prospects are confidential but they are estimated to range in size from 1 million to 10 million tonnes, with Ryst Kuil probably the largest deposit. Published estimates of reserves recoverable at costs of less than \$80/kg are 17700 tonnes. A further 29700 tonnes are recoverable at prices of between \$80 and \$130 per kilogram. The overall grade distribution as published by the South African Atomic Energy Corporation is shown in Fig. 10; median values are 0.8 kg/t.

The coal deposits in the Springbok Flats have also been evaluated in detail. Reserves are indicated as 23800t at similar grades to the southern Karoo.

In general it seems that companies with exposure to the Colorado Plateau were prepared to drill deeper and consequently discovered larger deposits, although this involves significantly higher expenditure both during exploration and during any mining operations. The following table summarises the known success of the companies mentioned in Table 1.

Company	Result
Union Carbide	Feasibility study Rietkuil plus several other average sized deposits
Southern Sphere	Several average sized deposits
Essex Minerals	Withdrew after finding small deposit
Anglo- American	Small deposits
Rand Mines	Niobium deposit
Industrial Development Corporation	? little drilling
J.C.I	Feasibility study at DR-3
Rio Tinto South Africa	Feasibility at Mooifontein, Edenburg
Esso Minerals	Feasibility at Ryst Kuil plus other average to medium sized deposits
Newmont	?
Phelps Dodge	Little drilling

COSTS

We have not had access to full costings but are able to make estimates. If drill costs are taken as 40% of the total costs and percussion drilling was around R10 /m, then a 3000 hole programme to delineate a major trend would have cost R 7.5 million in 1979. A smaller 60 000m project, such as DR-3 would be R1.5 million. From Fig. 5 it can be seen that overall figures published by the South African A.E.C. are compatible with these estimates. Total expenditure from 1975- 1983 was around R43 million. These figures do not include development drilling or trial mining, which would add significantly to them.

VARIATION IN ATTRACTIVENESS WITH TIME

As this was a virgin area most explorers started with only a comparative idea of potential financial returns. It soon became clear that the average grade and thickness were of the order of 0.1% U₃O₈ and 1m. The size of deposits shows considerably more variation, as indicated above. Based on a comparison with practice in the U.S., it seems that only the largest deposits (> 3 million tonnes) would support a small mill with a 700 t/day capacity. Most deposits contain of the order of 0.5- 1 million kg of uranium and would therefore have to truck ore to a central mill.

Ryst Kuil was the subject of a full scale feasibility study from which Ford et al (1982) provide a summary of the potential returns using both acid and alkaline leaches to recover uranium and molybdenum (Fig 11). Their analysis suggests that milling costs may exceed mining costs (around R12/t). We have made some calculations for an average sized deposit, based on their analysis, and costs for uranium production collated by Bechtel Inc. (1978) for the Western U.S. Our base case is a 1 million tonne deposit, 30 miles from a mill, found as a result of a R10 million exploration programme and producing at a uranium price of \$80 /kg. This model gives a positive rate of return of 10.5%. As our cost estimates are probably inaccurate, it is more interesting to examine the sensitivity of the return to changes in uranium price, exploration cost and distance to the mill and the results are shown in Fig. 12. Uranium price is by far the most important factor but exploration cost can be significant and a doubling of the budget to R10 million would make the project much less viable. The average sized deposits are therefore viable in times of high uranium price.

CONCLUSIONS

Exploration in the Karoo was a technical success although the drop in the price precludes exploitation in the near future. Once mineralization was discovered, different exploration approaches developed. Some companies were keen to find shallow small deposits at lower exploration costs whereas others were prepared to invest large sums for a potentially higher return. Companies with experience in this type of exploration were at a distinct advantage. A cursory economic evaluation demonstrates the sensitivity of these small deposits to excessive exploration spending.

Key exploration techniques were surface geological mapping, radiometric surveys and extensive drilling.

ACKNOWLEDGEMENTS

Former colleagues in Esso Minerals Africa, Southern Sphere Mining and Development and the Geological Survey contributed to our understanding of this area and we thank them for this.

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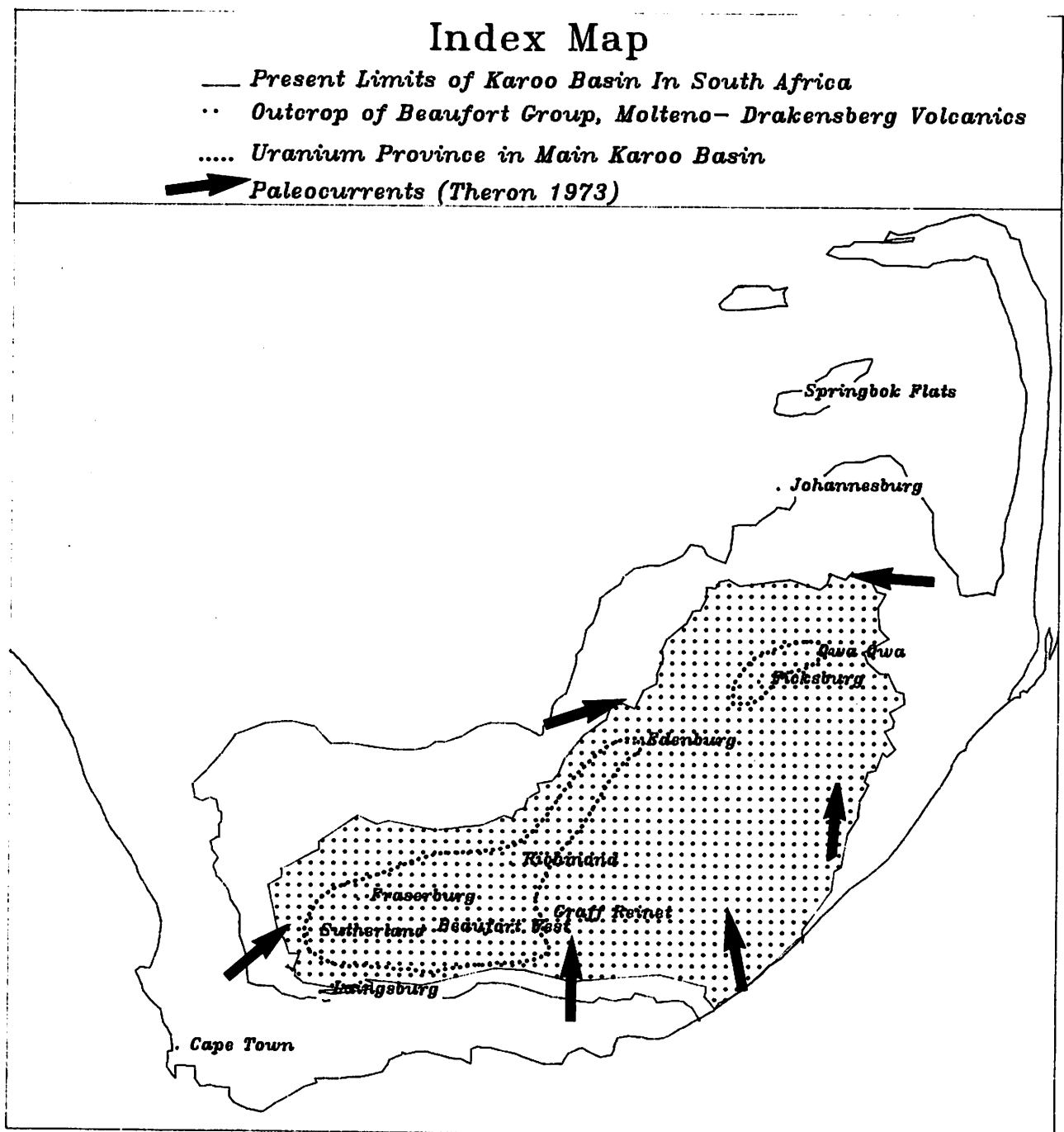
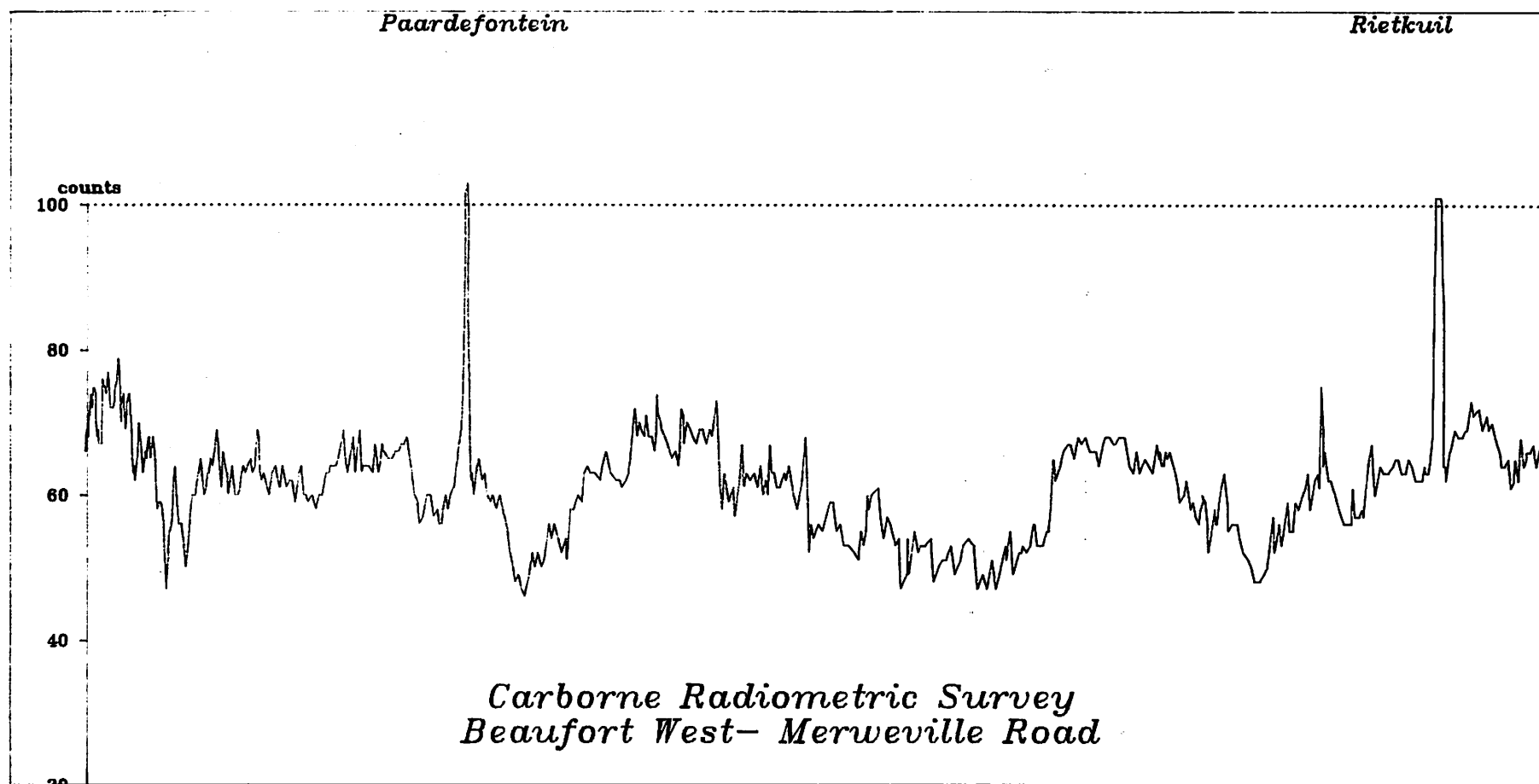


Figure 1

II

Moon and Whateley

Figure 2 A similar survey was responsible for the initial discovery. The distance from Paardefontein to Rietkuil is approximately 30 km.



Spot U Price Nuxco \$ per lb.

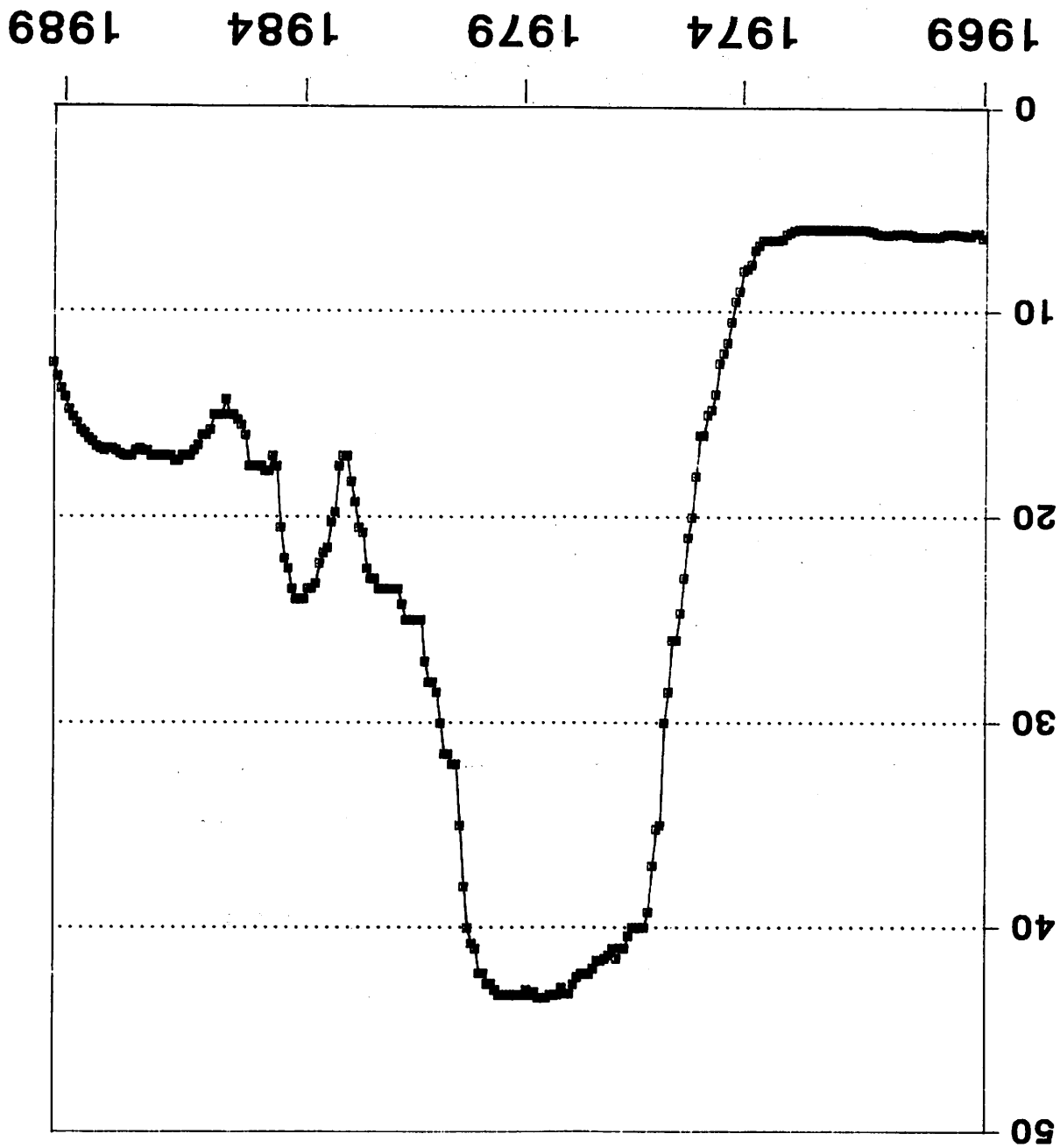
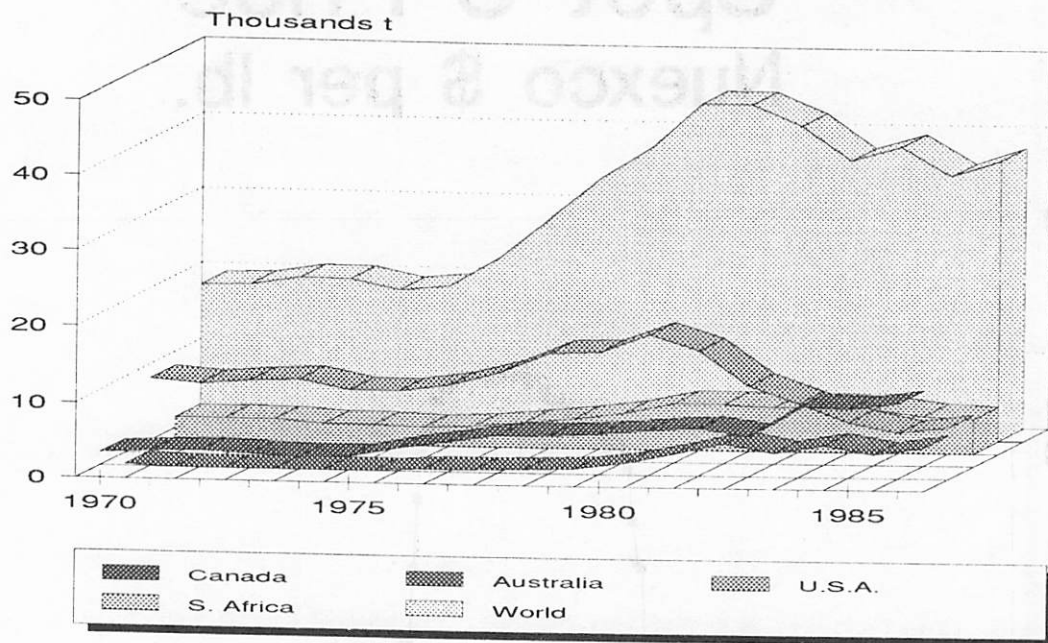
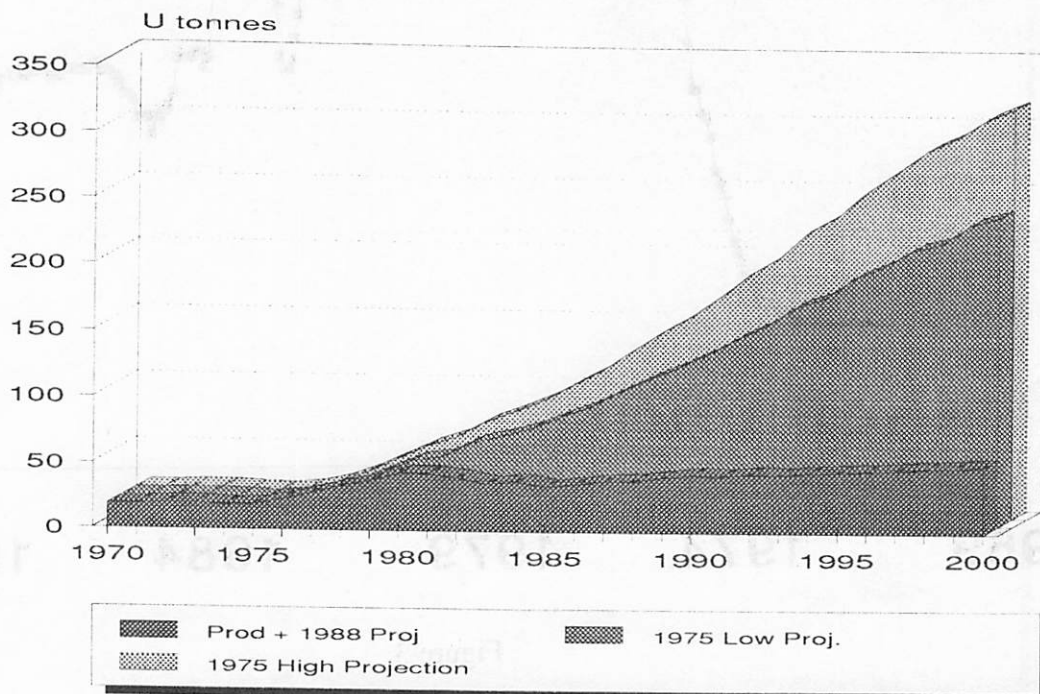


Figure 3

Uranium Production



Uranium Projections

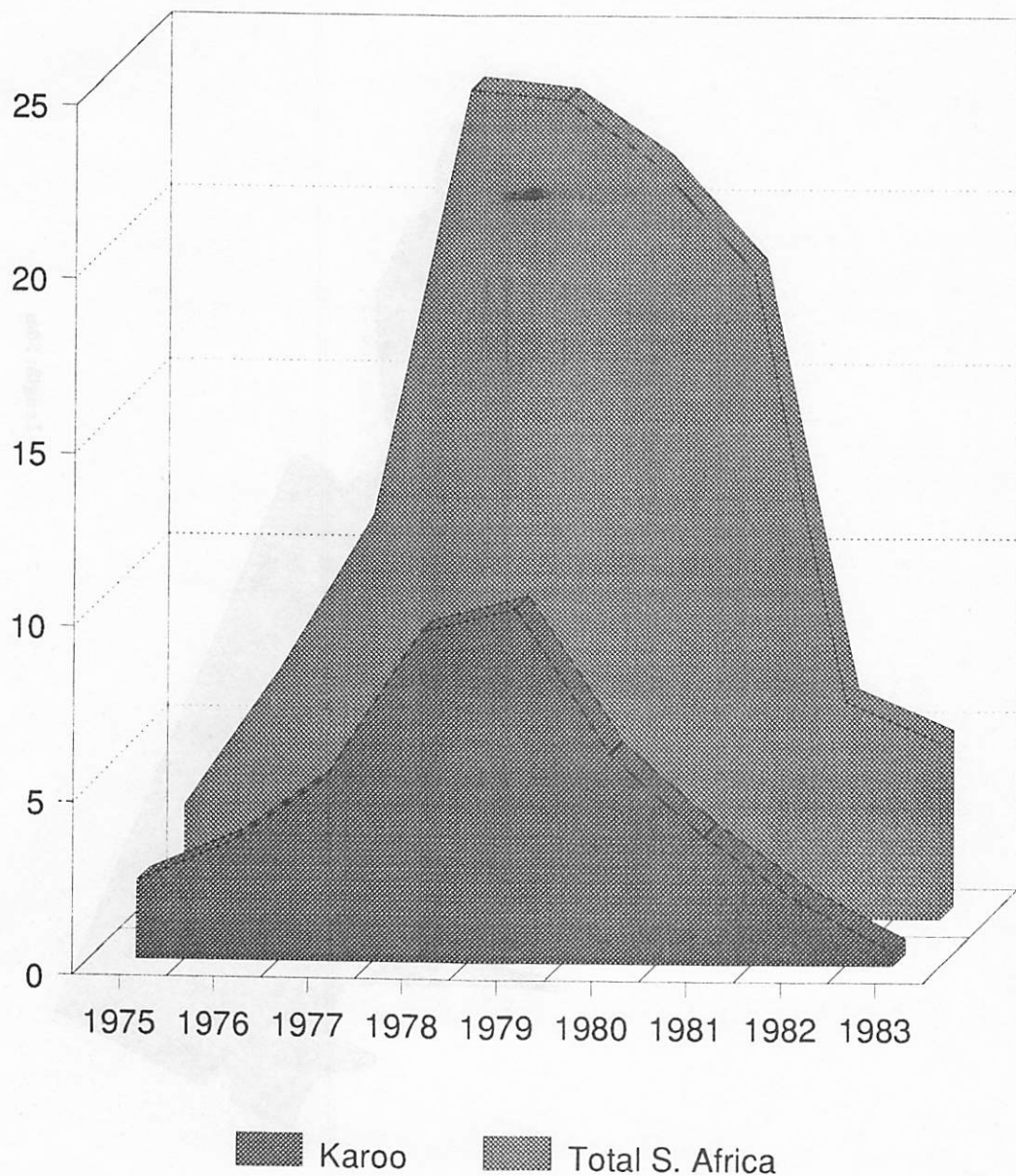


Source: OECD/NEA

Figure 4 Distribution of Uranium Production and Historical Production against 1975 projections for demand

Exploration Expenditure

Million Rand



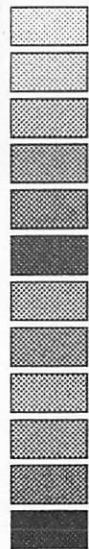
Source: NEA/OECD/SAAEC

Figure 5. Spending on Uranium Exploration in South Africa

Rietkuil Anomaly C

Moon and Whateley

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ABOVE	3850.0
	3500.0 - 3850.0
	3150.0 - 3500.0
	2800.0 - 3150.0
	2450.0 - 2800.0
	2100.0 - 2450.0
	1750.0 - 2100.0
	1400.0 - 1750.0
	1050.0 - 1400.0
	700.0 - 1050.0
	350.0 - 700.0
BELOW	350.0

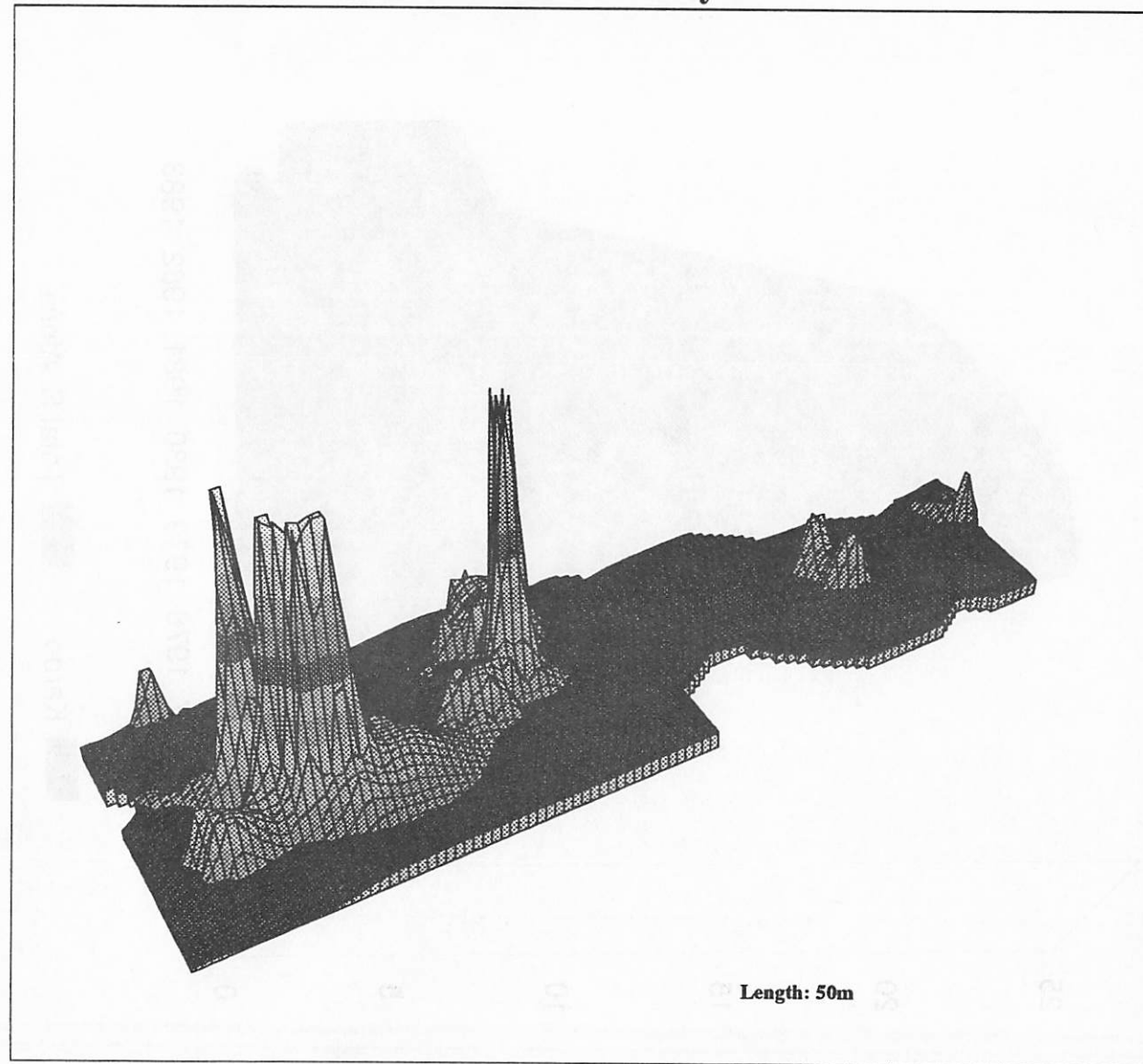


Figure 6 Pseudo 3 D plot of radiometric grade of the Rietkuil C anomaly. Note the variation over the order of metres.

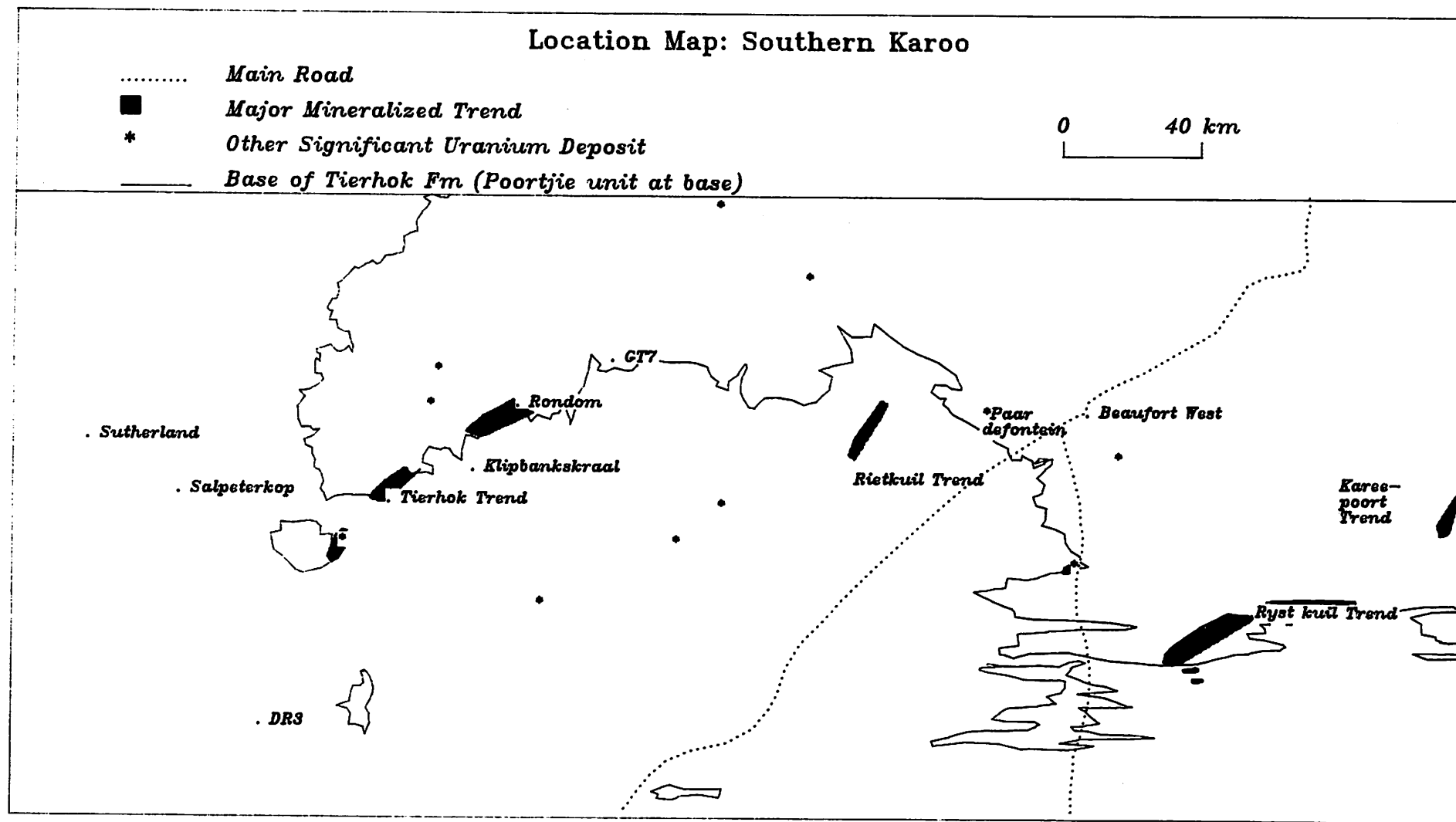


Figure 7

Figure 8 Mooifontein is near Edenburg; the River deposit in Qwa Qwa. Sources: Le Roux 1982a,b; Brynard et al 1982, Brynard and Le Roux 1982

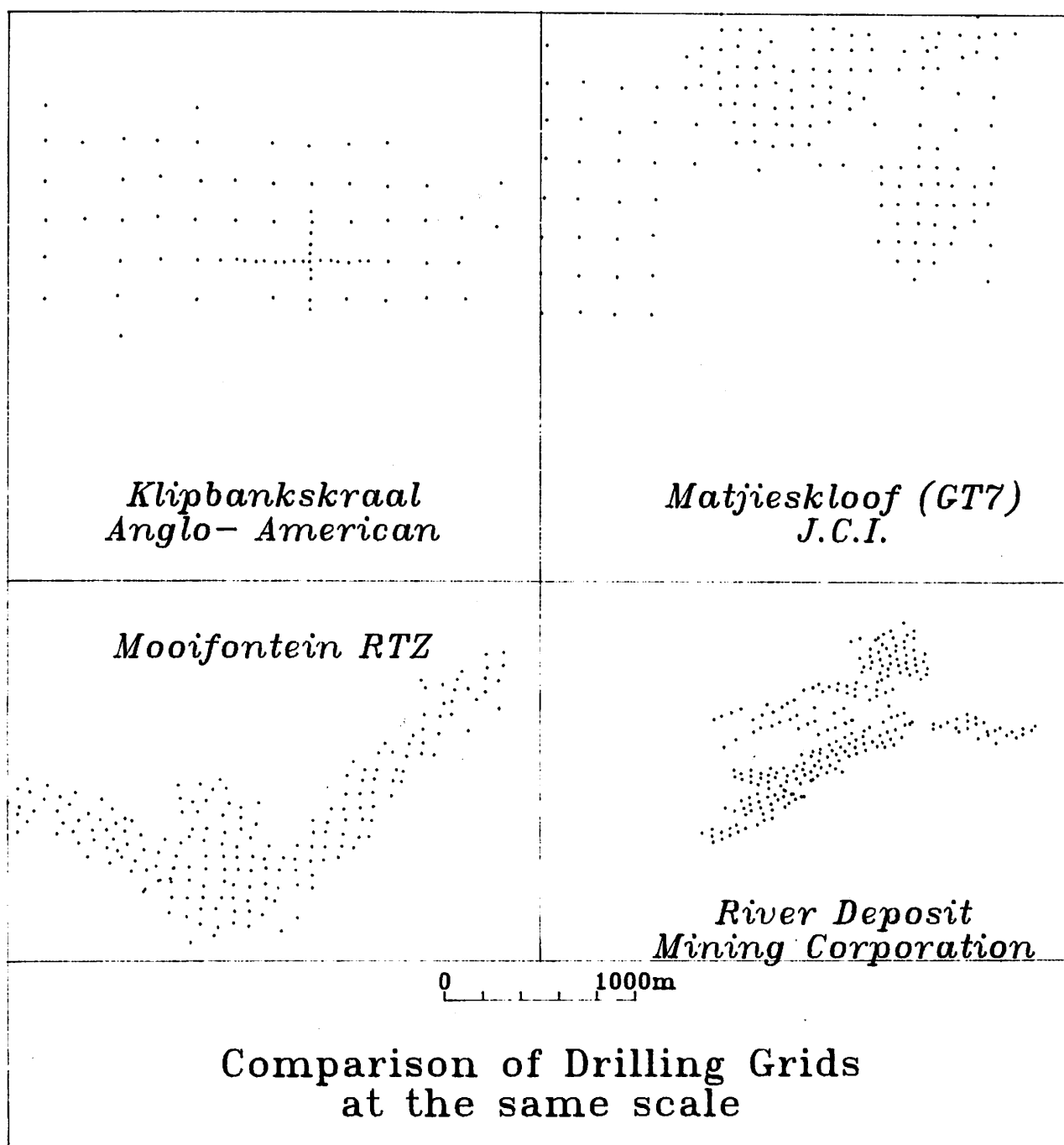
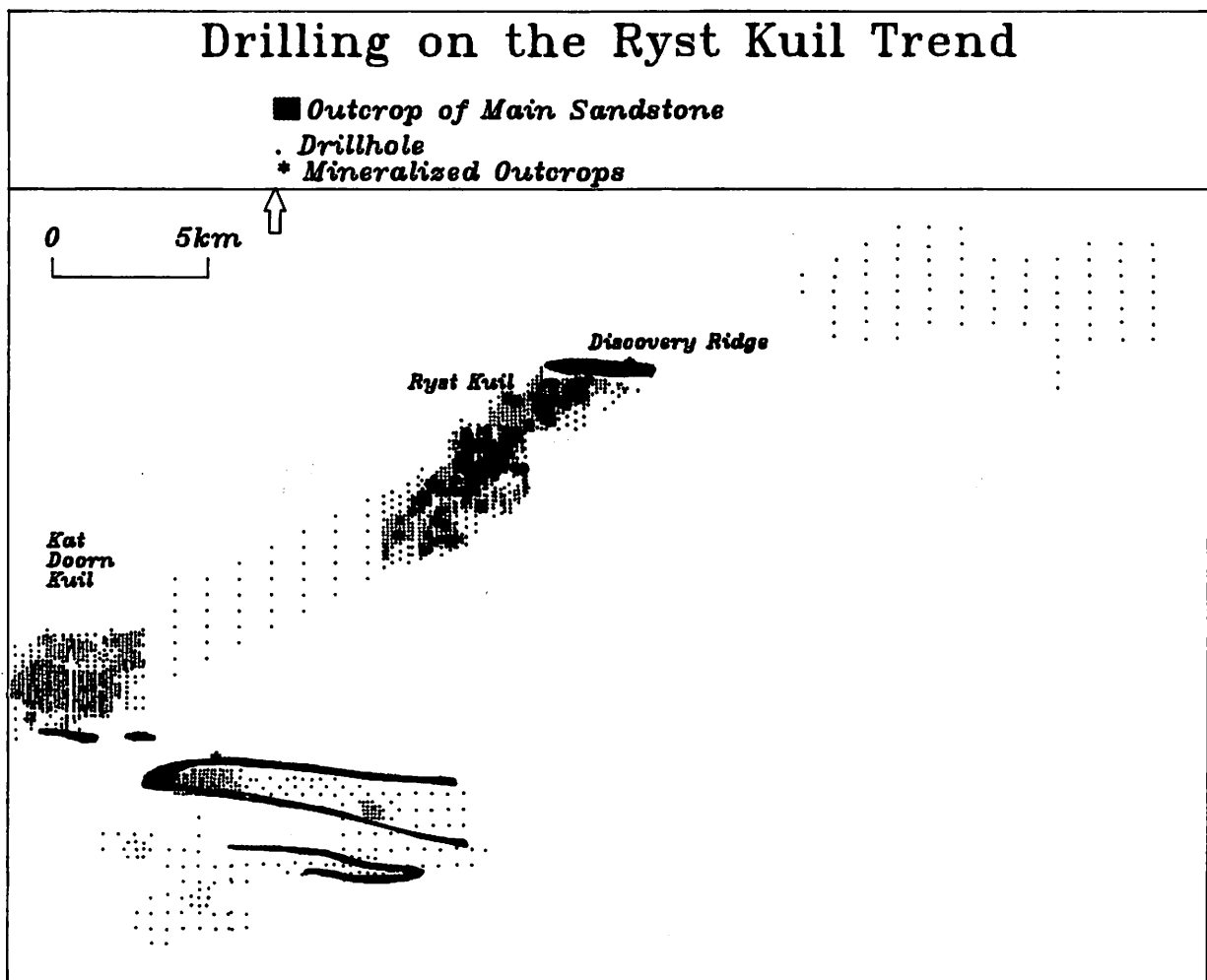


Figure 9



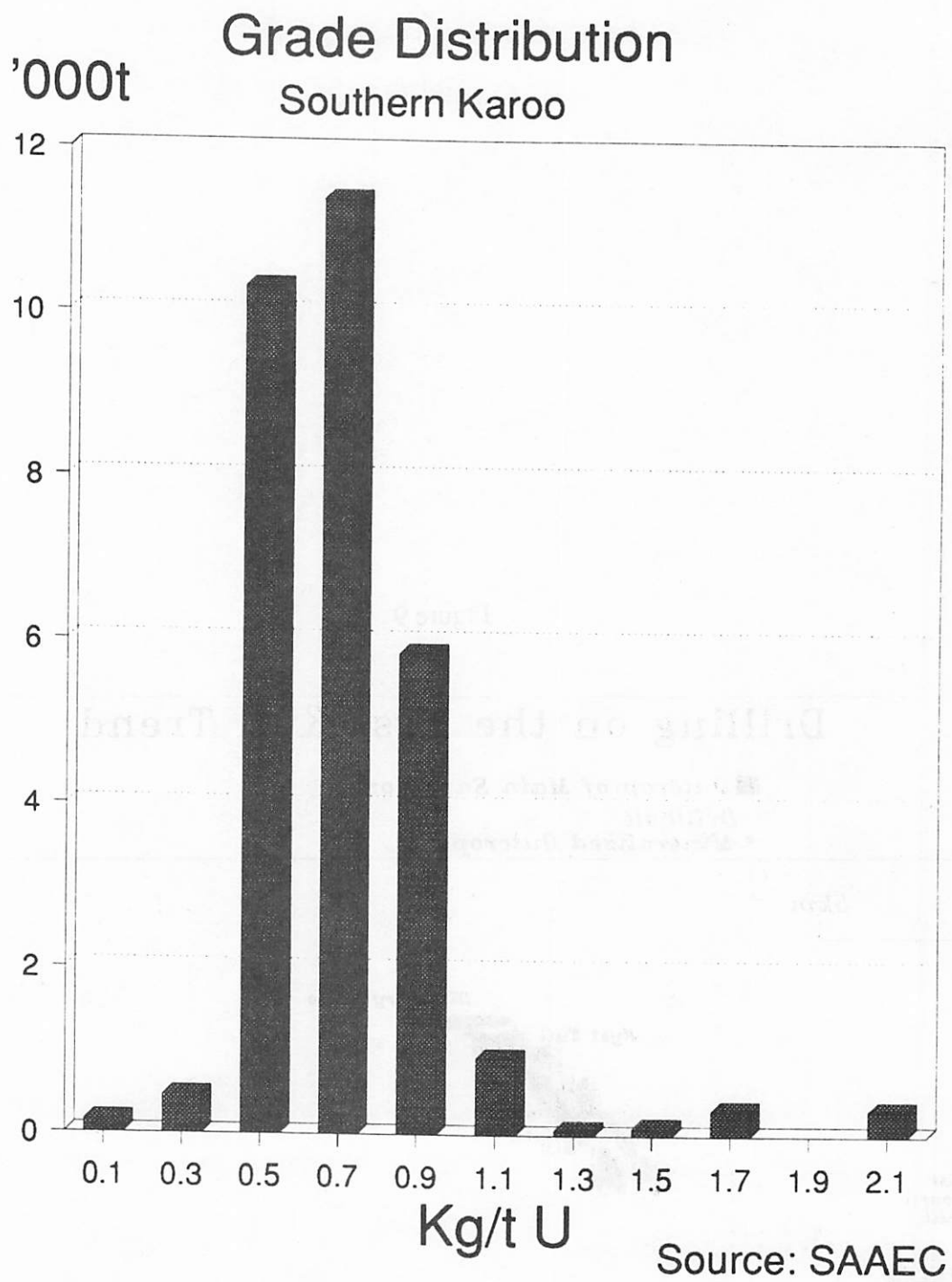


Figure 10 Grade Distribution for Karoo Deposits

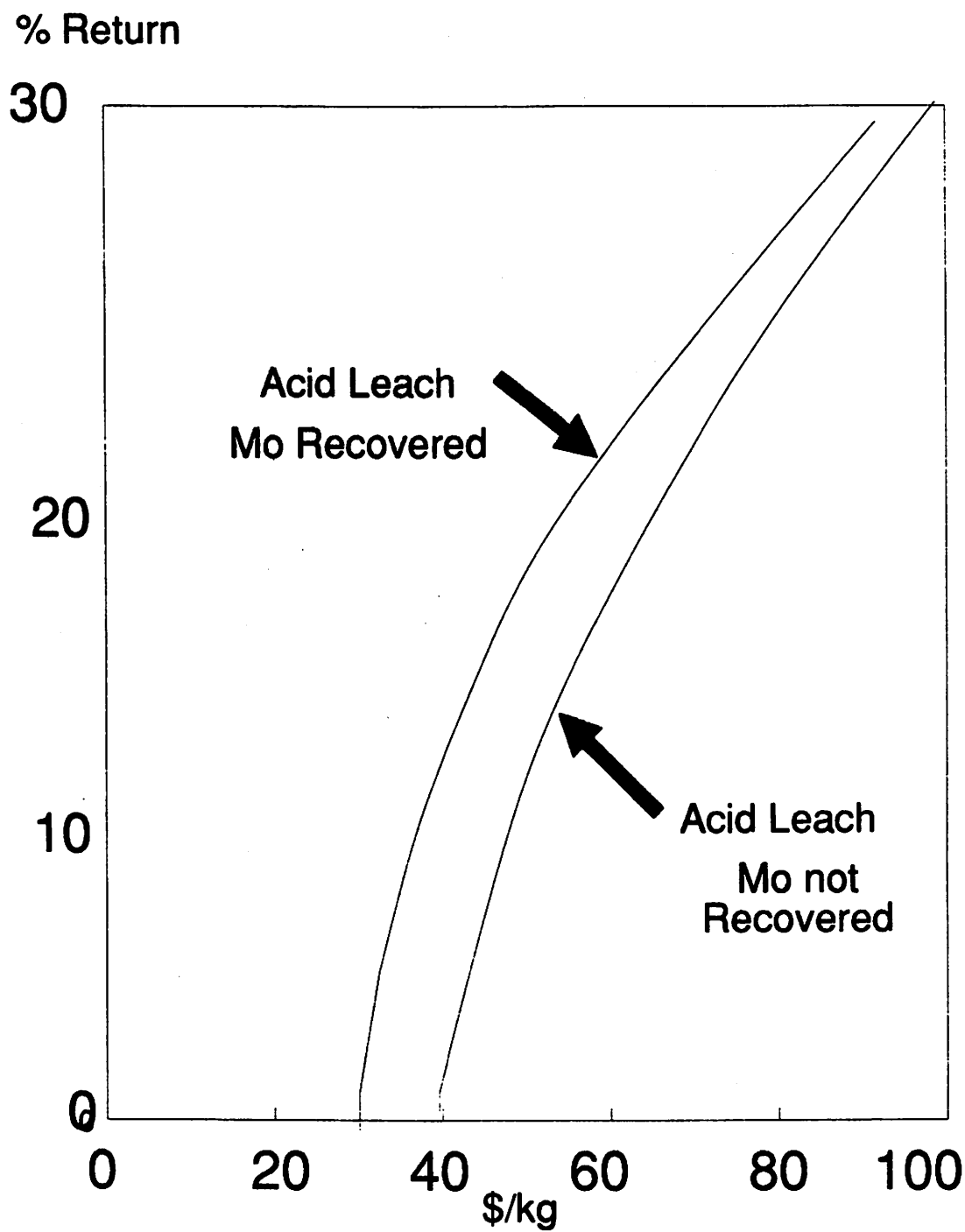


Figure 11 Return on Investment against Uranium Price: Rystkuil
(After Ford et al 1982)

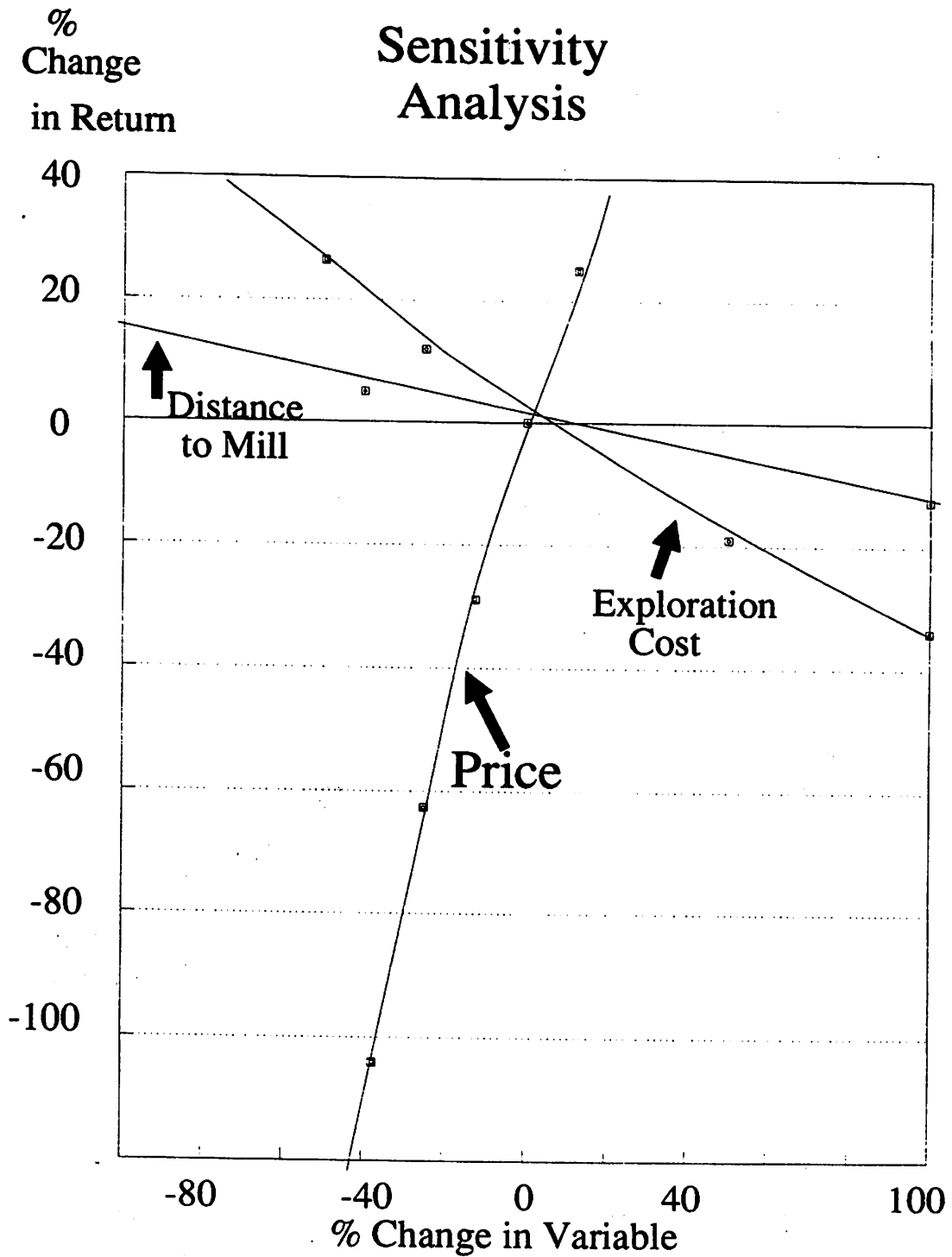


Figure 12 Sensitivity of Return on a 1 million tonne deposit
 Base Case: Price R80/kg, exploration cost R10 million and 30 miles to mill