URANIUM IN THE GROUNDWATER OF THE KALAHARI REGIONS SOUTH OF THE MOLOPO RIVER

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ABSTRACT

During the past eight years more than 2 000 groundwater samples have been collected from boreholes in the Kalahari south of the Molopo River. The areas investigated are bounded by the edge of the sandcover in the south and are situated between 20° and 25° E longitude.

The results were interpreted against geological, geohydrological and hydrogeochemical maps compiled for the areas investigated. In the area north of Vryburg (Piet Plessis Block) uranium anomalies in the groundwater were located in basement granite. In the western area between the Korannaberg (22°15'E) and the South West Africa/Namibia border (20°E) (Gordonia block) uranium anomalies in the groundwater were found to occur in basement granite, Dwyka Formation and the Kalahari Group. Radiometric borehole logging of a limited number of boreholes confirmed the presence of uranium anomalies within these rock types.

Occurrences of uranium were discovered at Tsongnapan in the Dwyka Formation in the form of phosphatic argillaceous nodules in which uranium is associated with apatite. On the farm Rus-en-Vrede near Vanzylsrus, uraniferous diatomaceous earth was discovered at the junction of the Madala palaeodrainage and the Kuruman River.

Although no new uranium deposits have been found as a result of this study, several new occurrences of uranium were indicated. A study of the distribution of uranium provinces and its time-bound characteristics suggest that the Kalahari Desert, both in South Africa and Botswana, still holds potential for uranium deposits. With the present recession in the uranium industry no further investigations are envisaged, but, should the market improve, some of the anomalies located may warrant further attention.

INTRODUCTION

Discoveries of uranium deposits in the arid parts of Western Australia during the early seventies sparked off an interest in similar regions in South Africa. Government airborne radiometric surveys in the Kenhardt area successfully pinpointed several uraniferous calcrete occurrences (Treasure, 1977). Similar radiometric surveys flown over the sand covered areas of the north-western Cape, however, failed to reveal any anomalies (Day, 1976a, 1976b).

To augment these surveys and to stimulate uranium exploration of the vast sand covered area, NUCOR embarked on a groundwater survey of the

Gordonia Block. A multidisciplinary approach was adopted and the study entailed an evaluation of the distribution of uranium in the groundwater against all the relevant geological, geophysical and hydrological data in order to

(i) establish potential uranium source and host rocks, and
(ii) evaluate the uranium potential of the area.

As a result of this survey, occurrences of uranium in the Dwyka Formation and younger deposits were found and reported on by Levin (1978, 1980, 1981). The area of investigation was extended from 22° E longitude eastwards to the Korannaberg. The uranium distribution in the groundwater was studied with the aid of natural isotopes and radiometric borehole logging (Levin, et al., 1983).

Extensive data on the geology, hydrology and hydrogeochemistry of the sand covered areas east of the Korannaberg were published by Smit (1977). In a joint venture, NUCOR and a French company investigated the uranium in the groundwater of areas selected on the basis of Smit's work.

LOCATION AND PHYSIOGRAPHY

The area investigated covers some 70 000 km^2 within the sand covered Gordonia, Postmasburg, Kuruman and Vryburg Districts of the northern Cape (Fig. 1). The topography varies from a monotonous undulating

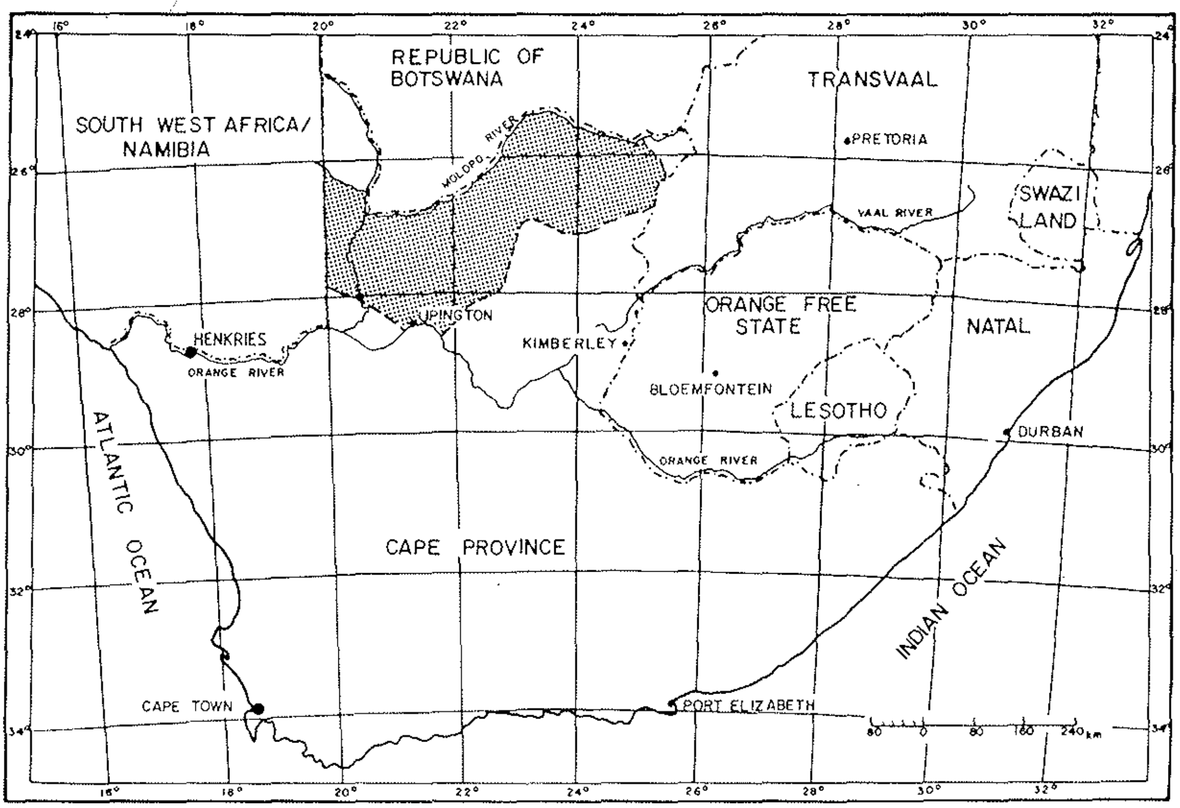

FIG. 1. LOCALITY OF THE STUDY AREA IN THE KALAHARI SOUTH OF THE MOLOPO RIVER

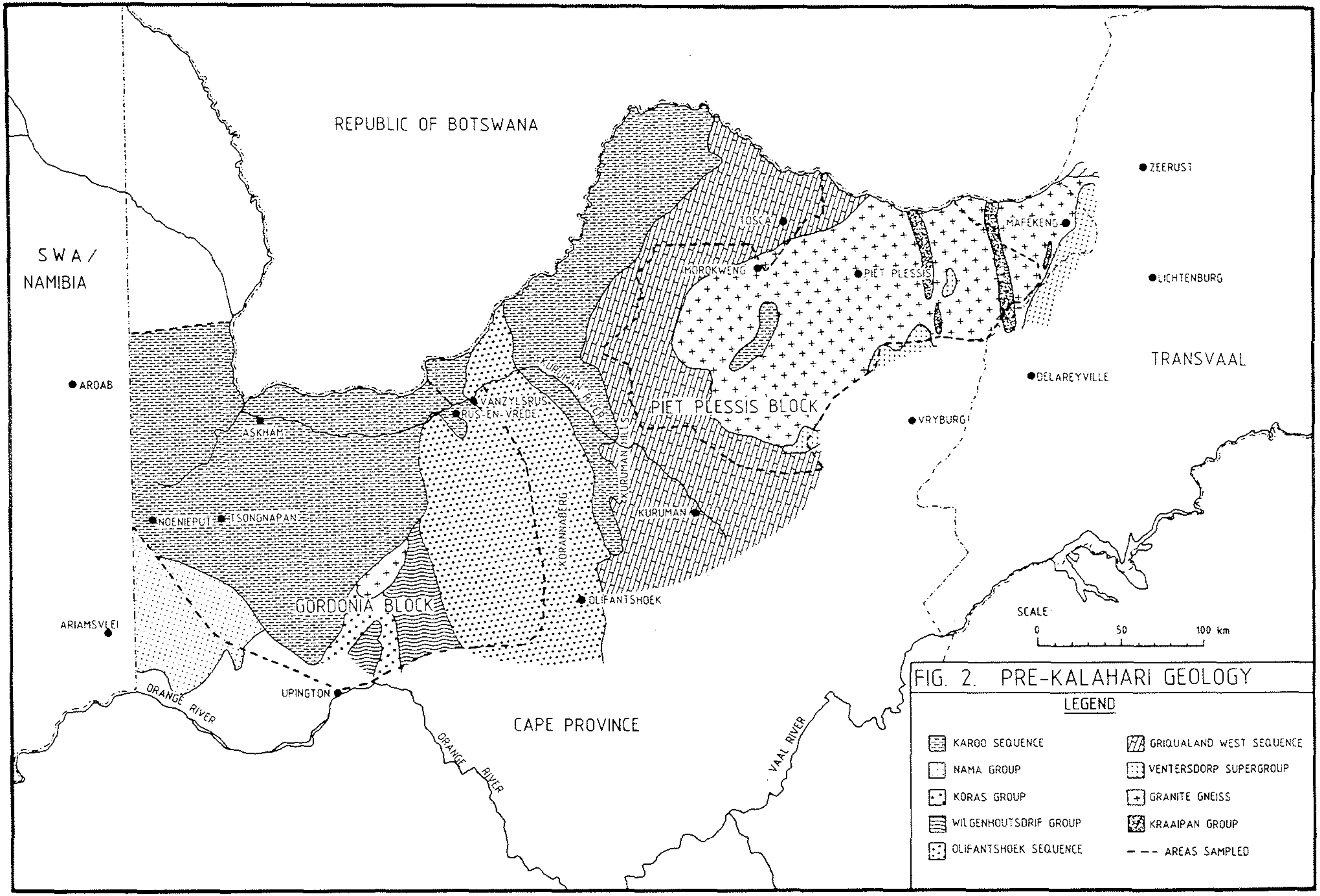

FIG. 2. PRE-KALAHARI GEOLOGY

landscape consisting of grass-covered red Kalahari sand dunes in the Gordonia Block to the flat savannah-type plains north of Vryburg and Kuruman (Piet Plessis Block). The only topographic features are the Kuruman Hills and the Korannaberg, both striking north-south (Fig. 2).

The climate is semi-arid with extremes in day and night temperatures, especially in Gordonia. Annual rainfall decreases from east to west from about 300 mm. at Vryburg to about 200 mm. in Gordonia. The greater part of the precipitation occurs as thunderstorms between February and April each year.

The area investigated includes the catchment areas of the Kuruman and Molopo Rivers. Both these rivers are ephemeral, draining to the west, to join in Gordonia.

GENERAL GEOLOGY

As about 80 % of the area is sand covered, earlier workers such as Rogers (1907) and Du Toit (1916) mapped the outcrops along the edge of the sand cover and the few exposures in drainages. A pre-Kalahari geology map (Fig. 2) was compiled from Smit (1977) and Levin (1980) using published material, borehole records and an interpretation of the aeromagnetic surveys.

Basement Granite

Outcrops of basement granite are restricted to a few exposures along drainages north of Vryburg, while outcrops are absent in Gordonia. In general the granite is medium grained, white, greyish to red and consists mainly of microcline, quartz and muscovite. In Gordonia, biotite-rich gneiss grades into granite.

The granite in the Piet Plessis Block has been dated at 1 800 Ma (Levin,1981) and is intrusive into the rocks of the Kraaipan Group.

Pre-Karoo Geology

The distribution of the rock types of the pre-Karoo formations east and west of the Korannaberg is reviewed by Smit (1977) and Levin (1980) respectively. The pre-Karoo geology occurring in the area is as follows:

Ventersdorp Supergroup - Volcanic rocks and quartzite of the Allenridge Formation are the oldest of the pre-Karoo rocks.

Griqualand West Sequence - The oldest formation in the sequence is the Vryburg Siltstone Formation consisting mainly of siltstone which is followed by the dolomite and chert of the Campbell Group and jaspilite and banded ironstone of the Griquatown Group. The Gamagara Shale Formation follows the Griquatown Group and consists mainly of shale with interbedded quartzite. The Makganyene Diamictite Formation precedes the lavas and banded ironstone of the Cox Group.

Olifantshoek Sequence - An unconformity separates the Olifantshoek Sequence from the underlying Cox Group. The Sequence comprises the Mapedi Shale Formation, the Lucknow Quartzite Formation, the Hartley Andesite Formation, the Volop Quartzite Group, and the Groblershoop Schist Formation.

Wilgenhoutsdrif Group - Comprises mainly schist and phyllite of the Zonderhuis Formation and schist and metavolcanic rocks of the Leerkrans Formation.

Koras Group - comprises alternating sedimentary, andesitic and quartz porphyry formations.

Nama Group - Only quartzite with intercalated purple micaceous shale of the Fish River Formation occurs in the area.

Karoo Sequence

Although the Dwyka Formation has a wide distribution under the sand cover (Smit, 1972) it outcrops mainly in the pans of western Gordonia and along the South West African border. In the east, Smit (1977) noted a single exposure in a brickworks quarry south-east of Kuruman. It is horizontally bedded and consists mainly of blue to grey mudstone, siltstone, shale and tillite. The distribution, thickness and suboutcrop of the Karoo Sequence in Gordonia were determined from borehole data (Levin, 1980). In this region it was subdivided into an upper sandstone and shale member, the equivalent of the Prince Albert Formation of the Ecca Group and the lower tillite and shale of the Dwyka Formation. In the Vanzylsrus area, the Dwyka Formation occurs in synclines or glacial valleys.

Kalahari Group

With the exception of the mountains and the few isolated outcrops, the entire region is covered by the Tertiary to Recent deposits of the Kalahari Group. About 75 % of the area is covered by aeolian sand which attains thicknesses of up to 30 m. in Gordonia. Underlying the sand is a sandstone layer which is both calcretised and silcretised. Red and yellow clay, which is locally calcareous, overlies basal gravels.

URANIUM DISTRIBUTION IN THE GROUNDWATER

Sampling of the groundwater for uranium was done in three phases;

(i) about 300 samples were taken in the western part of the Gordonia Block by NUCOR,
(ii) 200 samples in the eastern part of the Gordonia Block by NUCOR and
(iii) 1 700 samples in the Piet Plessis Block by a French company in a joint investigation with NUCOR.

Anomalous areas are shown in Figure 3 and are constituted by uranium values in excess of 25 ppb.

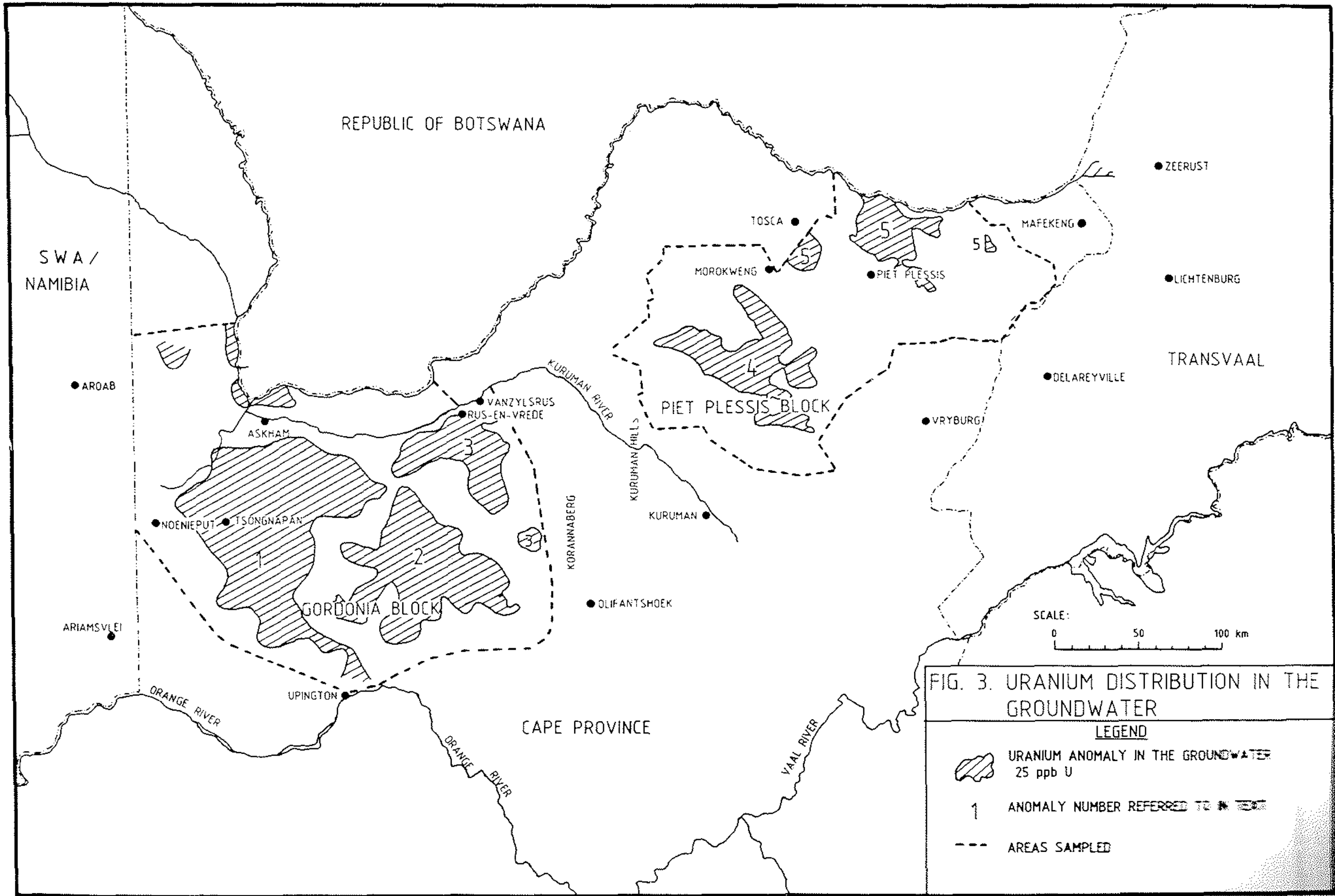

FIG. 3. URANIUM DISTRIBUTION IN THE GROUNDWATER

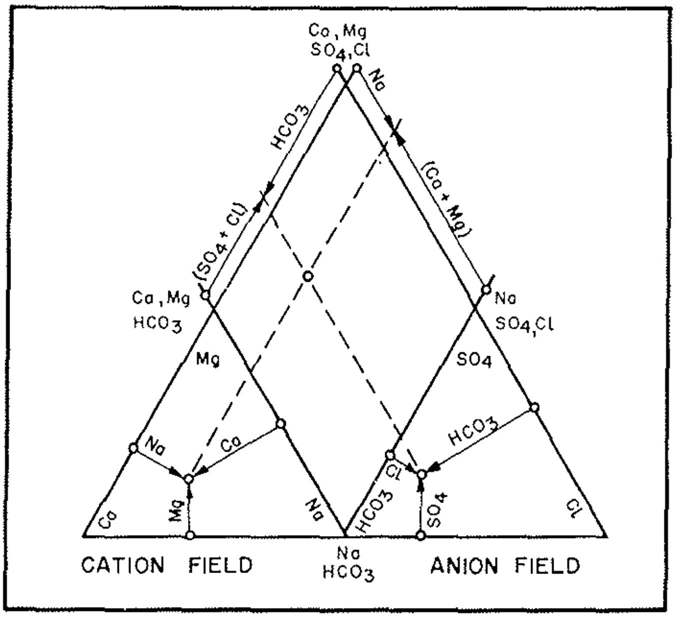

FIG. 4 PIPER DIAGRAM

In order to divide the areas sampled into groundwater regimes, all the analyses were plotted on the Piper diagram (Fig. 4). The method employs plots of relative percentages of cations and anions in the two triangles, with the reacting values being extrapolated to a single point in the intervening diamond-shaped field. In this way, the chemical character of each sample is obtained. Based on this method three regimes were recognised, corresponding to the distribution of the total dissolved solid (TDS) (Fig. 5):

Group I (Fig. 6) are waters originating from the recharge areas of the Kuruman River and the Korannaberg. The waters are relatively high in bicarbonate and low in uranium, the latter correlating with TDS. There are no uranium anomalies in this group.

Group II (Fig. 7) are waters originating from outcrop areas and where surficial cover is usually less than 30 m. Uranium correlates with TDS.

Group III (Fig. 8) are waters restricted largely to western Gordonia and are generally more saline but with a relatively low bicarbonate content. There is a correlation between uranium and bicarbonate content, possibly due to the formation of the uranium-bicarbonate complex.

URANIUM POTENTIAL OF THE SAND COVERED AREAS

The solution geochemistry of uranium is well documented (Hostetler and Garrels, 1962 and Hambleton-Jones, 1978). Uranium in source rocks oxidises from the (IV) to the (VI) state to form the uranyl cation as follows:

$$UO_2 \longrightarrow UO_2^{2+} + 2e.$$

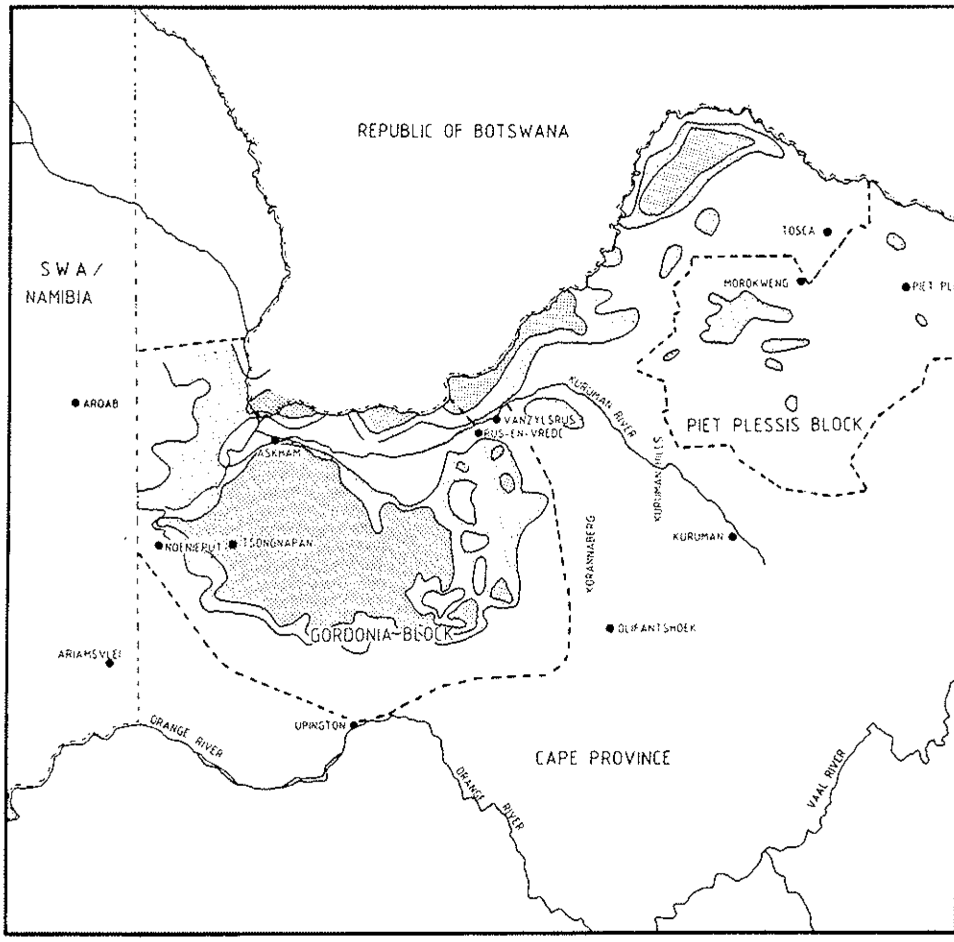

FIG. 5. TOTAL DISSOLVED SOLIDS DISTRIBUTION IN THE GROUNDWATER

LEGEND

< 2 500 ppm

2 500-5 000 ppm

> 5 000 ppm

AREAS SAMPLED

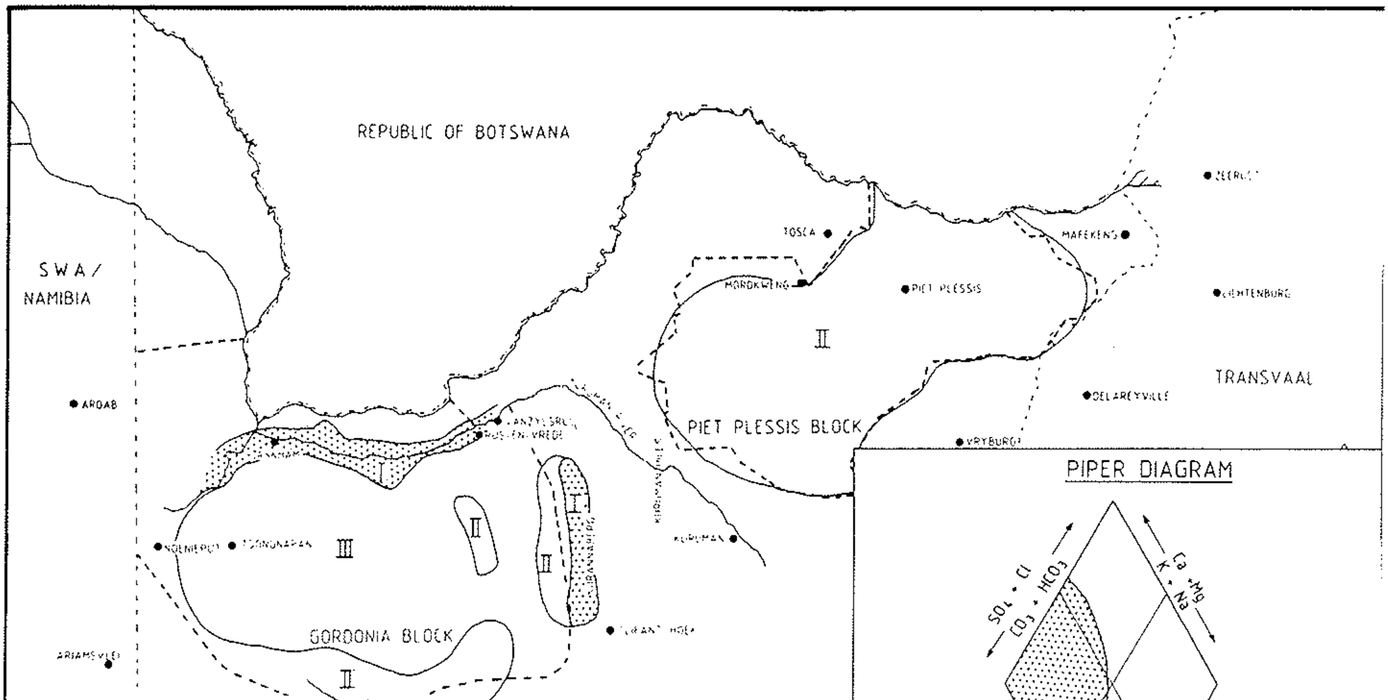

FIG 6 GROUP I GROUNDWATER REGIME

LEGEND

GROUP I DISTRIBUTION CORRESPONDING TO THE CHEMICAL CHARACTER AS INDICATED ON THE PIPER DIAGRAM

SCALE 0 50 100 km

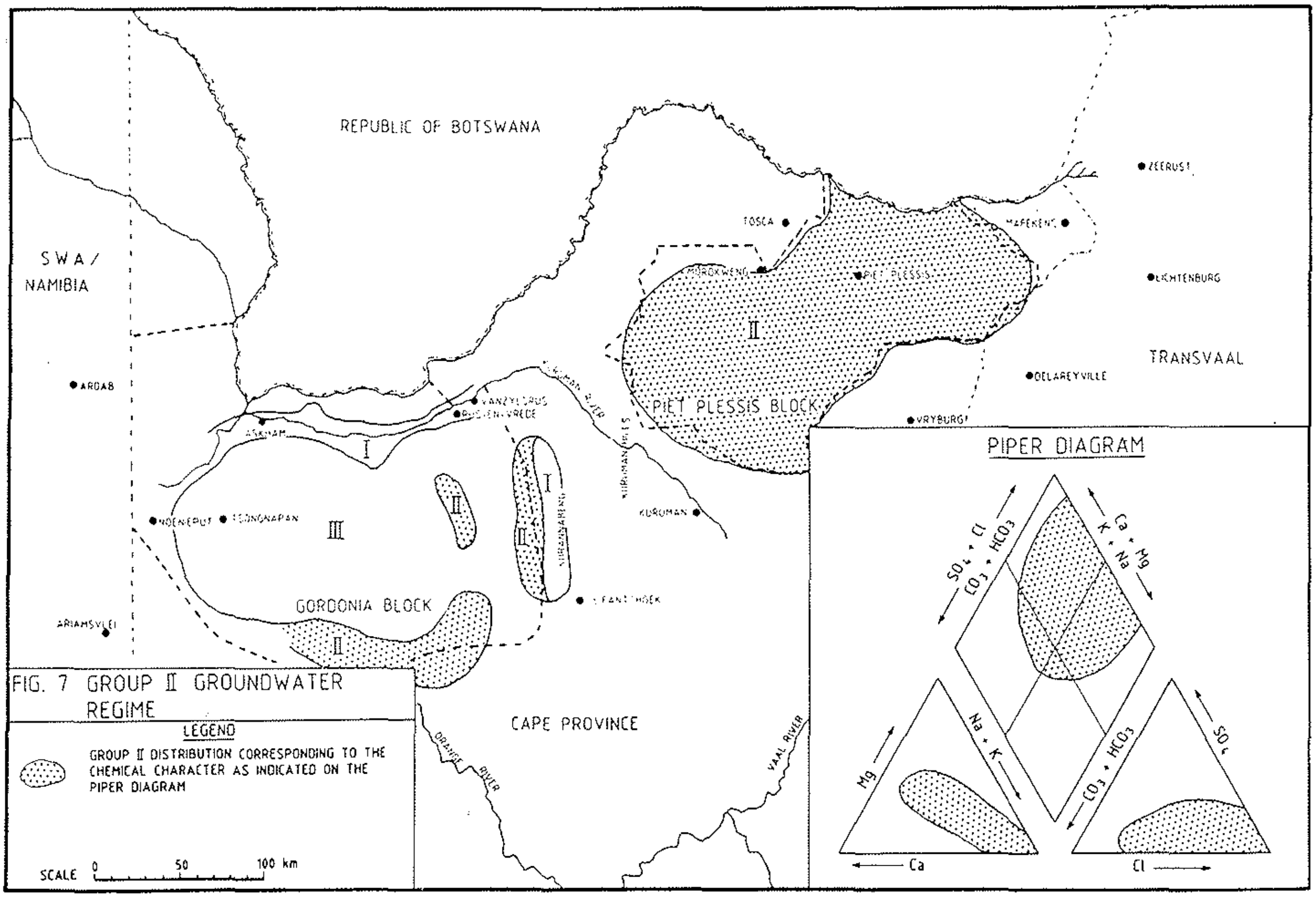

FIG. 7 GROUP II GROUNDWATER REGIME

LEGEND

GROUP II DISTRIBUTION CORRESPONDING TO THE CHEMICAL CHARACTER AS INDICATED ON THE PIPER DIAGRAM

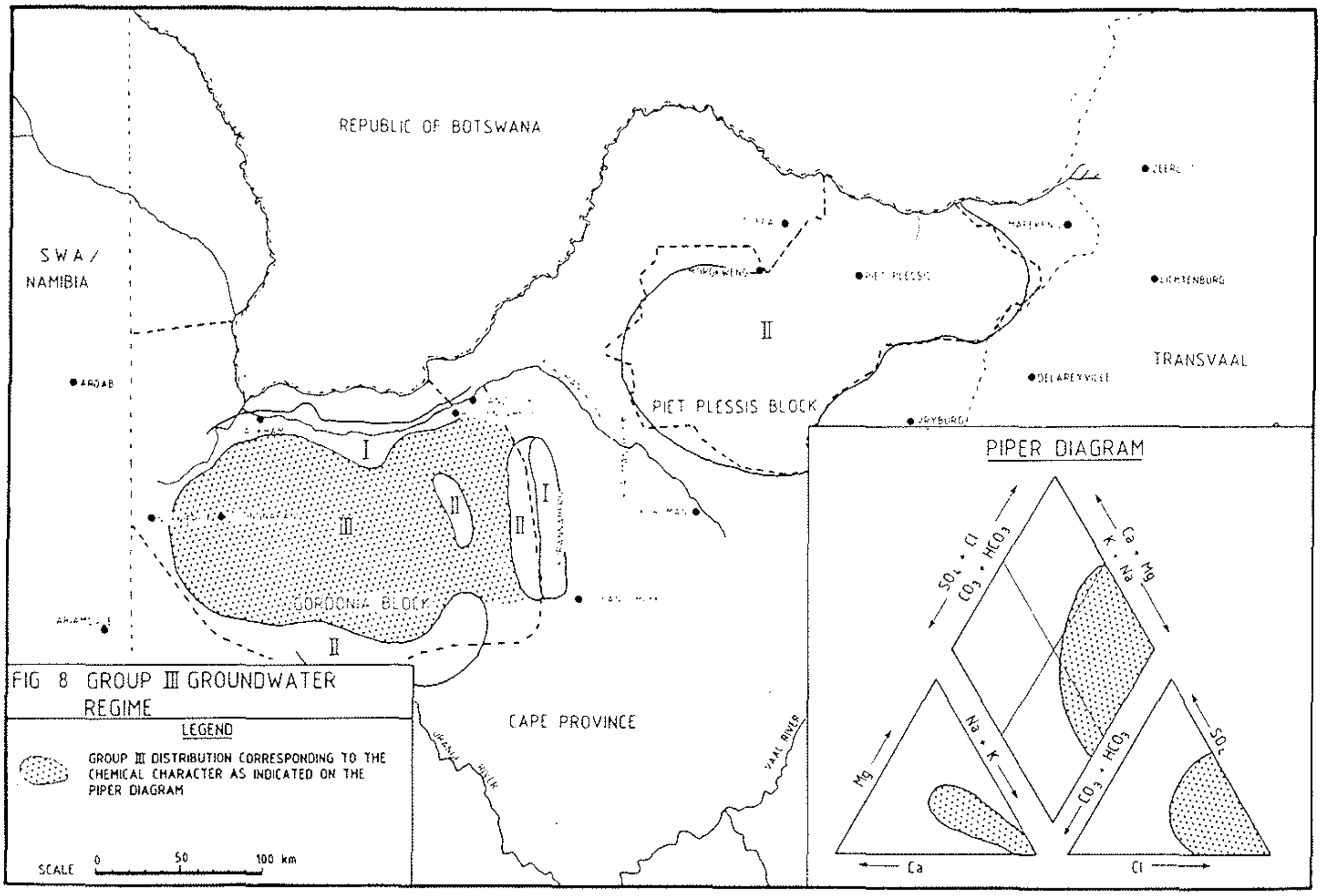

FIG 8 GROUP III GROUNDWATER REGIME

LEGEND

GROUP III DISTRIBUTION CORRESPONDING TO THE CHEMICAL CHARACTER AS INDICATED ON THE PIPER DIAGRAM

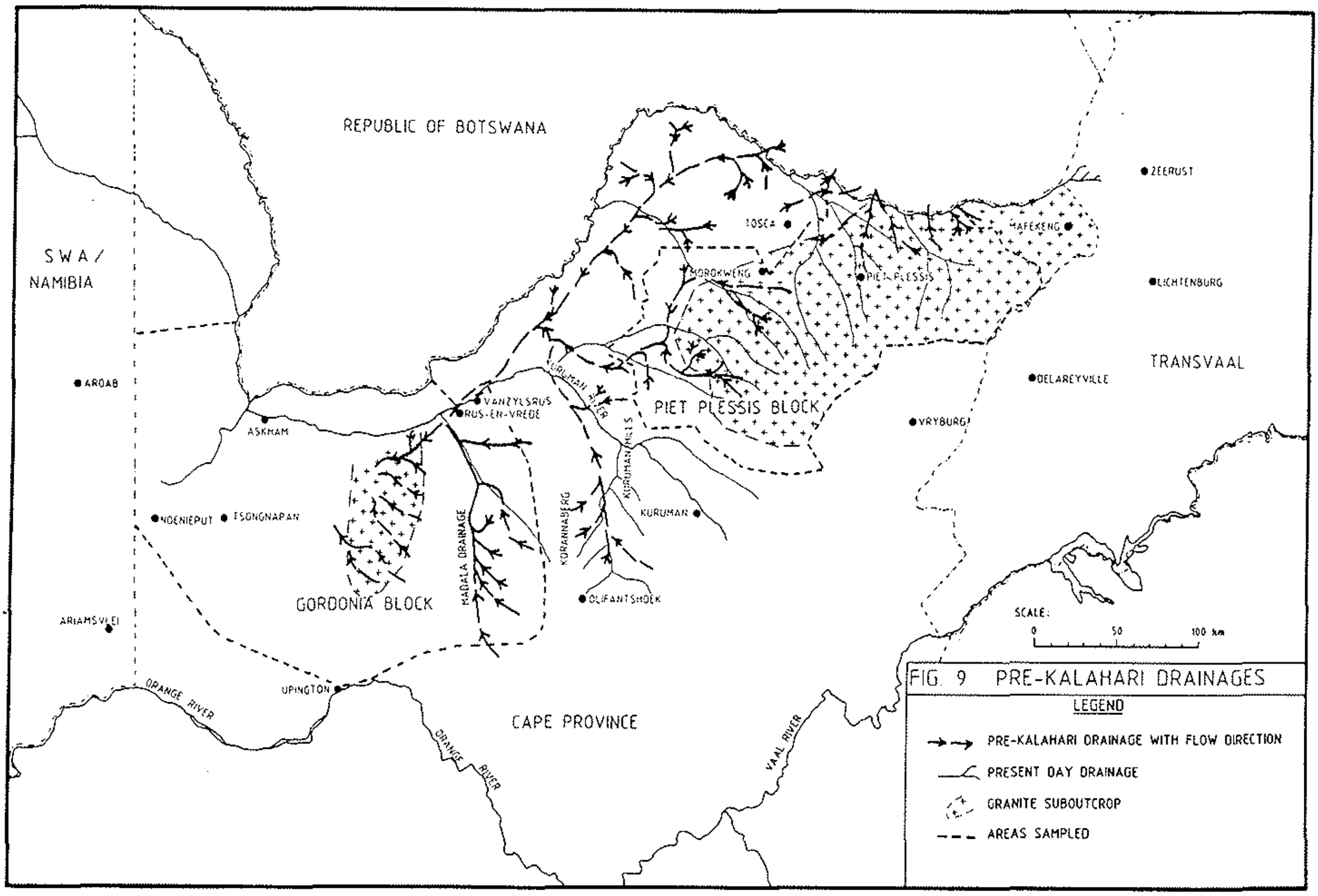

FIG. 9 PRE-KALAHARI DRAINAGES

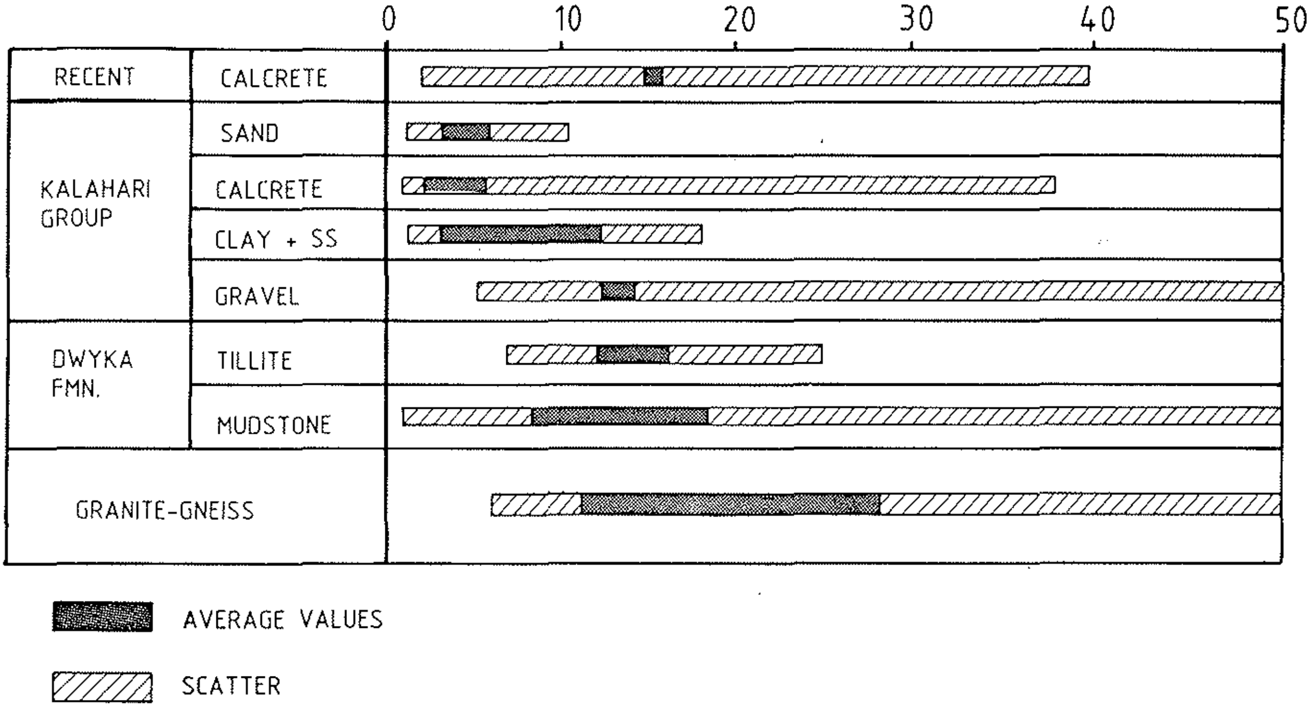

FIG.10 GAMMA RESPONSES IN BOREHOLES (ppm eU_3O_8)

In the presence of carbonate ions two stable uranyl carbonate complexes form at 25^{o}C and 100 kPa.

$$UO_2^{2+} + 2CO_3^{2-} + 2H_2O \longrightarrow UO_2(CO_3)_2 \cdot 2H_2O^{2-}$$

Uranyl dicarbonate

$$UO_2^{2+} + 3CO_3^{2-} \longrightarrow UO_2(CO_3)_3^{4-}$$

Uranyl tricarbonate

Studies by Levin (1980) of the pre-Karoo and pre-Kalahari geology of the Gordonia Block have depicted depositional areas (basins, channels or troughs) in which possible uranium mineralisation may have taken place. A map of the pre-Kalahari drainages (Fig. 9) was compiled from the work of Smit (1977), Willemink (1983) and Levin (1980). The presence of a granite-gneiss ridge in the Gordonia Block could have acted as a source area for uranium deposition to the west of it. The general east-to-west drainage of the groundwater may have aided the process of mineralisation.

In the Piet Plessis Block, target areas for groundwater sampling were specifically selected on evidence of pre-Kalahari drainage. The area sampled covered converging drainages, which have a higher potential as depositional environments for uranium mineralisation.

Radiometric borehole logging was performed in certain boreholes within the anomalous areas and gamma-log responses for the various rock types are given in Figure 10. Unfortunately some of the key boreholes were not available and should be included in any future program. Some of the results were published by Levin (1978) for Gordonia and Smit (1981) for the Piet Plessis Block. In both areas anomalous responses were given by the granites and values up to 50 ppm eU_3O_8 were recorded.

The Dwyka Formation was radiometrically logged in Gordonia and several boreholes gave anomalous values of up to 252 ppm eU_3O_8 over 310 mm at a depth of 225 m. Four boreholes covering 100 km^2 consistently gave anomalous values at the base of the Dwyka Formation. Work in this area led to the discovery of an anomalous zone outcropping at Tsongnapan in the west where phosphatic nodules containing up to 1 000 ppm uranium occur. The uranium is associated with apatite occurring in a calcitic matrix (De Waal, 1979 and Brynard, 1981).

The Kalahari Group gave no anomalies in the Piet Plessis Block, but in Gordonia, boreholes logged within anomaly 1 (Fig. 3) indicated concentrations up to 95 ppm eU_3O_8 between 54 to 101 m in the basal gravels, and anomalies of up to 38 ppm eU_3O_8 were intersected in the calcretes. In the Vanzylsrus area uranium was intersected above the water table in anomalies 2 and 3. Severe disequilibrium is known to occur in the area and therefore no accurate grades could be determined. On the farm, Rus-en-Vrede, uraniferous organic-rich diatomaceous earth was discovered, which is very similar in appearance to the ore from Henkries (Fig. 1) in the north-western Cape. Grades were low and further exploration was disappointing. The natural isotopes, ^{14}C, ^{18}O, and the $^{234}U/^{238}U$ ratio in the groundwater along the Madala

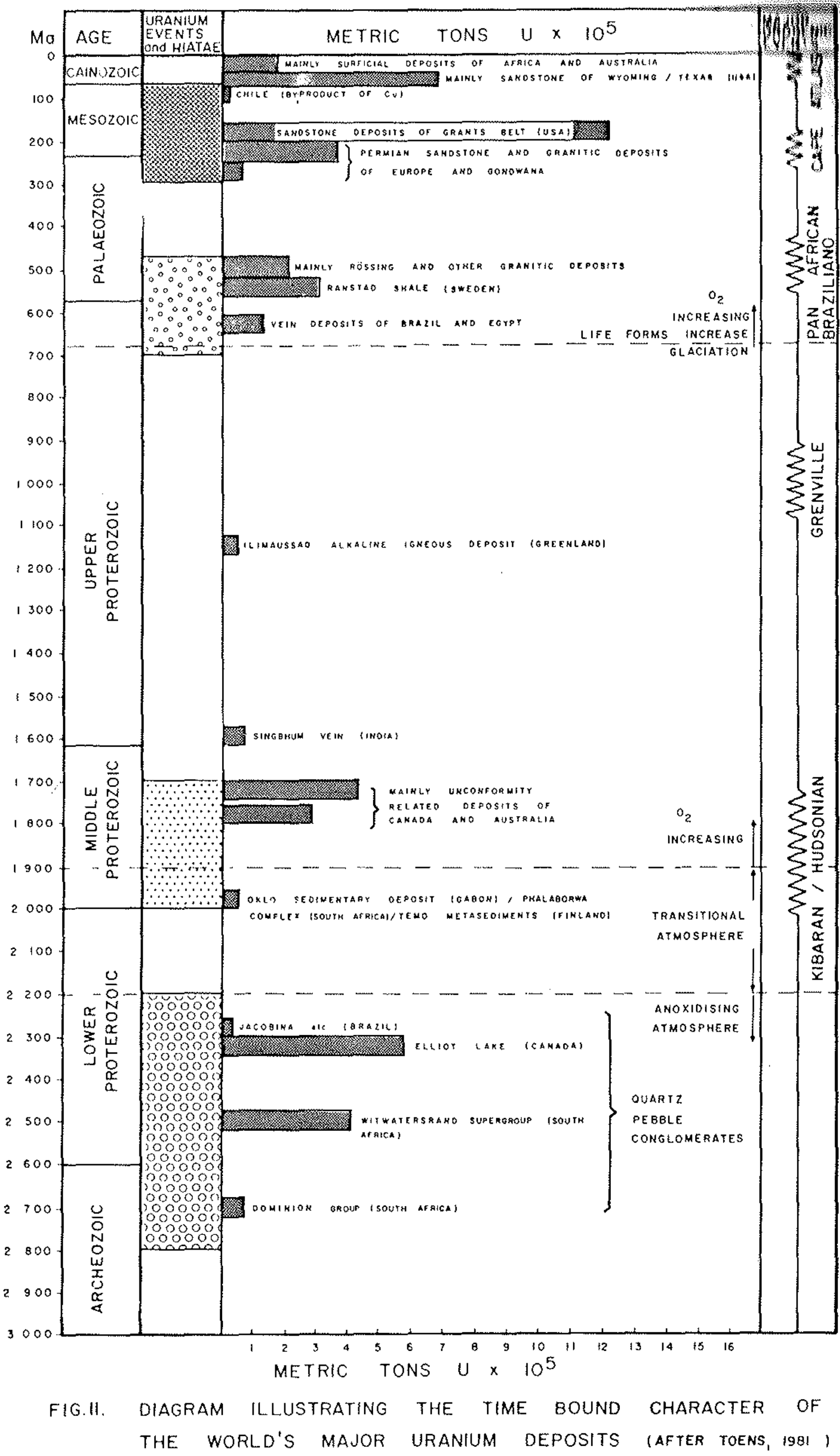

FIG. II. DIAGRAM ILLUSTRATING THE TIME BOUND CHARACTER OF THE WORLD'S MAJOR URANIUM DEPOSITS (AFTER TOENS, 1981)

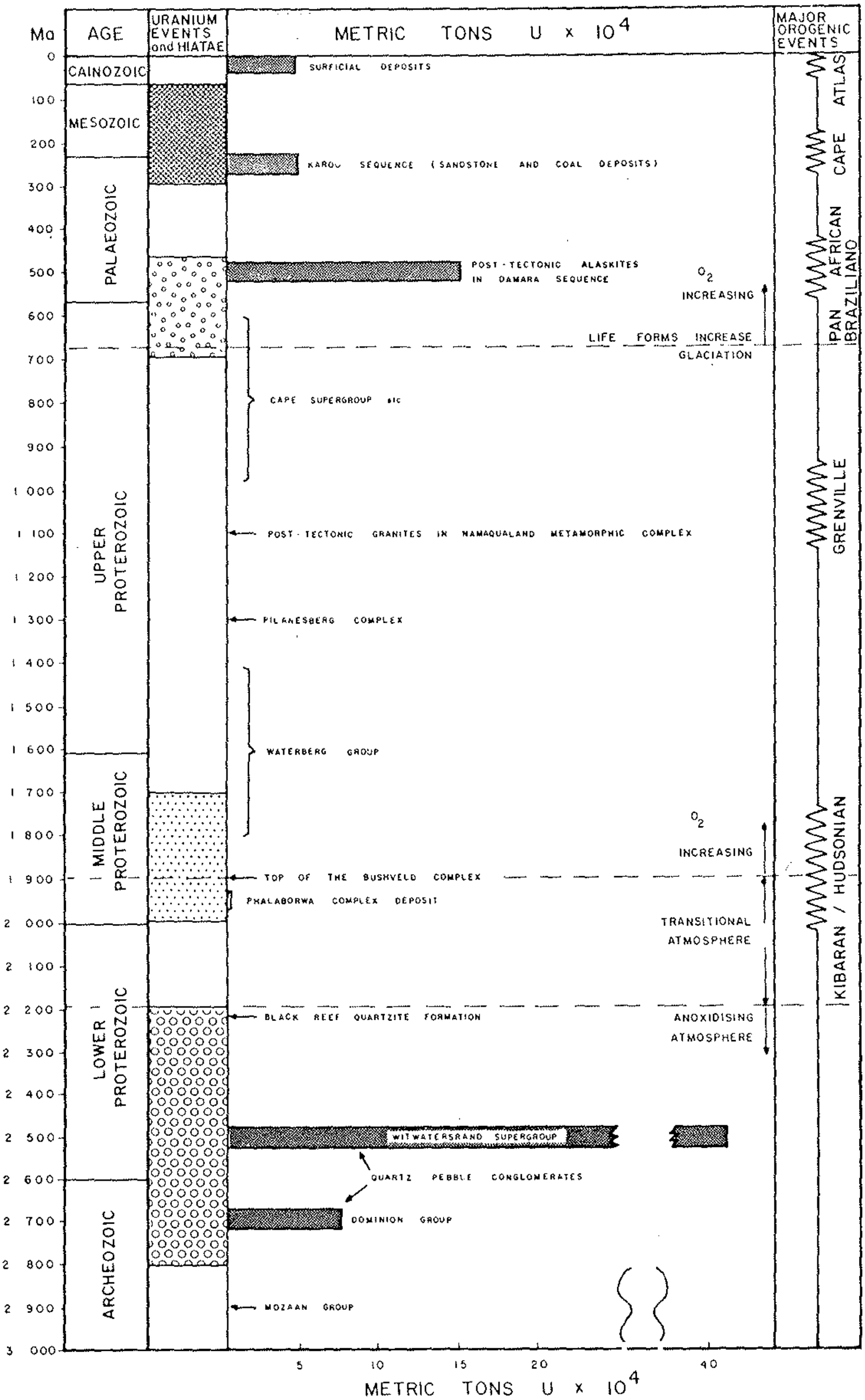

FIG.12. DIAGRAM ILLUSTRATING THE TIME BOUND CHARACTER OF SOUTHERN AFRICA'S URANIUM DEPOSITS AND OCCURRENCES (AFTER TOENS, 1981)

palaeodrainage were used to study the original anomaly (Levin, et al.,1983). It was found that rainfall and local infiltration slowly enriched the underlying groundwater with uranium from local sources: the highest concentrations of uranium in the surficial material and the groundwater are at the lower end of the drainage near the confluence with the Kuruman River.

Although the results of this study are at present not encouraging, one should keep in mind that 48 % of the free world's uranium resources are tied up in rocks younger than 300 Ma (Fig. 11) (Toens, 1981). For southern Africa the resources amount to 12 % (Fig. 12) which may be an indication that these rocks still remain potential hosts for undiscovered uranium deposits in this age group.

CONCLUSIONS

The presence of source rocks and uranium anomalies in the groundwater of the sand covered areas are positive indications of the uranium potential of the area. With the uranium discoveries at Tsongnapan in the Dwyka Formation, the presence of uranium-bearing rocks has now been shown to occur throughout the sedimentary formations of the Karoo Sequence in South Africa. This fact may be relevant to Botswana, as Karoo formations occur under sand cover.

The uraniferous diatomaceous earth occurrence on Rus-en-Vrede is possibly just one of several similar occurrences hidden below surficial cover. Smit (1977) mentions several diatomaceous earth occurrences north of Vryburg but none have as yet been sampled for uranium.

Uranium in Recent and Kalahari calcretes should be investigated further. Disequilibrium above the water table may lead to anomalies being missed during radiometric logging. Shallow drilling and sampling may be costly but worthwhile, especially in the southern portion of anomaly 2 (Fig. 3). This anomaly is continuous across a very prominent watershed, a fact which seems peculiar and requires further investigation.

Looking at the distribution of uranium provinces and their time-bound characteristics, the contribution of the Karoo and surficial deposits to South Africa's uranium resources seems low compared to the rest of the free world. The Kalahari region with vast sedimentary deposits may contribute in future towards a more balanced picture.

Although no major new uranium deposit was located as a result of this study, several new occurrences of uranium were indicated in the basement granite, the Dwyka Formation and the Kalahari Group. With the present recession in the uranium industry no further investigations are envisaged, but should the market improve, some of the anomalies located may warrant further attention.

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