SMA/6/73

# GEOLOGICAL SURVEY —— REPUBLIC OF BOTSWANA





# REPORT

**TITLE:** TO ASSESS THE VALUE OF SATELLITE PHOTOGRAPHS IN RESOURCE EVALUATION ON A NATIONAL SCALE.

ERTS - 1 Type II REPORT

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**CONTENTS:** 10 PAGES; 2 ILLUSTRATIONS AT BACK

DISCUSSION OF SIGNIFICANT RESULTS APPEARS ON TITLE PAGE.

SR 9643

# "To Assess the Value of Satellite Photographs in Resource Evaluation on a National Scale"

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Supplementary Notes: (1) This report was compiled and written by S.M. Akehurst, Project Manager, Botswana ERTS programme.
(2) The opinions voiced in this report are not necessarily those of the compiler or the Principal Investigator.

Brief discussion of significant results:

3M - Small scale ERTS imagery has enabled investigators to study large areas at a time. The imagery appears to confirm a new theory that Archean greenstone belts in NE Botswana and SW Rhodesia are co-extensive and that these so-called "schist relics" formerly covered a much wider area than is apparent now. The central parts of the region bounded by the "schist relics" are believed to have suffered granitisation.

A remnant of an older drainage system to the southwest of the Okavango Swamps, which seems to have been newly discovered on the imagery, may be an indication of the seismic instability of the region. Even quite small earth movements in the swamps could radically affect the direction of water flow.

7N - The imagery has proved successful in showing areas infested by the water weed Salvinia Auriculata in the Chobe and Zambesi rivers. This will be immensely valuable in later surveys on the ground. If the satellite was to have continued working, the imagery would have enabled workers to determine the extent of encroachment of the weed without recourse to field observations.

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1. Major Problems impeding the investigation

Participants in the Botswana ERTS-1 programme have been unable to devote as much effort to the analysis of ERTS data as is desirable because of other routine commitments. It is felt that complete research can only be performed by trained personnel assigned full-time to the task.

Delays in the arrival of the imagery have both hampered progress, particularly in the hydrological analysis of the Okavango Delta, and decreased interest in the project.

2. Accomplishments

The first imagery of Botswana received at Botswana Geological Survey was taken during the third cycle of the satellite's coverage of the Earth. MSS imagery only has been received.

The imagery has been studied to a varying extent by all participants except for those from the Agricultural Research Station.

For the first three months, all data was studied for geological information by staff of the Geological Survey. Detailed descriptions of their findings are recorded in the first ERTS-1 report from this Agency. Since then, it has only been possible to study limited areas of repeated cover although a major project being undertaken this field season intends to use 1:250 000 magnifications of the imagery as one of the data sources for a geological traverse of the northern Kalahari Desert.

Areas of specific interest discussed in this report include parts of N.E. Botswana, the bordering area in Rhodesia, and Ngamiland which is dominated by the Okavango Swamps.

Other contributions concern the correlation of vegetation boundaries mapped on the ground with the imagery. One particular aspect of this topic has proved ERTS-1 imagery to be very successful in delineating areas invaded by the waterweed Salvinia Auriculata and its gradual encroachment of river channels.

In early February, the U.S. Embassy in Gaborone was asked to contact NASA via C. Robinove immediately to ensure that imagery was taken of the Okavango Swamps on every successive cycle. Lack of rain in the Angolan Highlands during the previous rainy season and intense

2/ drought..

drought in Botswana this summer have caused serious desiccation in the region. No water is flowing past Maun into the Boteti River which supplies the Mopipi reservoir near Orapa. The diamond mine at Orapa depends on this water for its operation and the domestic supply for the township. Unfortunately, it has been impossible to attempt an adequate comparison of the data partly due to the incompleteness of imagery on previous cycles, the fact that no data of the area has been received since that which was taken in December 1972 and the prior commitment of the investigator in this discipline to the administration of his Department in the absence of a Director.

Indexing of the imagery has been reduced to annotation of very small scale maps. The card index was found to be too unwieldy in view of the continual shifting of the spacecraft's orbit.

## 3. Significant Results

3.1 Geological Investigation Our first conclusions were that the imagery has confirmed the existence of very definite NE-SW structural trends throughout the country with secondary NW-SE trends. Fault patterns in the Okavango region and the Makgadikgadi area are very clearly seen.

3.1.1 Analysis of imagery of Ngamiland - Figure 1 has been compiled entirely from ERTS imagery. Only the positions of the three settlements marked have been inferred. The Okavango river meanders over a plain bounded by two, parallel, NW-SE faults before spilling over a linear NE-SW feature postulated to be an extension of the Rhodesia-Kalahari axis (Vermaak, 1962), and which may either be a fault and/or a line of warping. This feature, which has been called the Gomare 'fault' (Jones, 1962), certainly seems to be of tectonic significance in that it confines the Okavango drainage to the southeast : of it and the seif dunes of the region terminate abruptly against it. The lineament seems to die out towards the southwest where the dunes are unaffected.

A parallel lineament which appears to bound the southern shore of Lake Ngami also confines thedrainage of the Okavango Swamps to the northwest. Despite the low, flat-lying nature of the land, it would seem quite clear from the imagery that the swamp has formed in a sedimentary basin between rift-type structures. This theory has been postulated for some time by a number of workers. Tentative, preliminary results of a

seismic survey recently completed in the area show that the structures amount to only a few hundred metres in depth. Therefore, if they are proto-rift faults, they can only be of very recent origin although they may signify a rejuvenation of movement along a much older line. The youth of these lineaments is partly borne out by the geological history of the region as deduced from the imagery, which will be described later in this section.

The Ghanzi Ridge, comprised mainly of a group of late Precambrian/early Palaeozoic rocks is revealed to the southeast of the area where several workers have noted a NE-SW shear direction (notably Thomas, 1969 and Walker, 1973). Although evident from the satellite imagery and air photographs, exposures of the Ghanzi Ridge rocks are very poor on the ground. Unfortunately, the cover of Kalahari Beds is sufficient to inhibit the use of satellite imagery as a tool for the detailed elucidation of the structure of the region.

The right-angled bend taken by the Chobe river at the border of Botswana and the Caprivi Strip is certainly controlled by the consistent NE-SW tectonic trend found in this part of Southern Africa.

Co-linear features can be seen on imagery of the Wankie and Makgadikgadi areas and were identified in the previous report - 1052-07452, -07454 and - 07461.

Major folds in the Aha Hills can be seen which confirm Wright's deductions (1958) that the beds are folded on NE-SW and ENE-WSW axes pitching to the southwest or eastnortheast. Wright's conclusions were based on observations of drag folds on certain incompetent bands in a succession comprised largely of thick beds of massive, calcareous rocks. ERTS-1 imagery reveals the folds in their entirety.

The seif dunes, which form a field of very long sand ridges in the west of the area are thought to have been formed during a dryer period than the present when the trade winds reached further to the south, for, according to King (1951), the orientation of these dunes does not agree with present-day wind systems. All bands of the imagery demonstrate that the dunes have been fixed by vegetation but that the intervening ground is relatively bare. These observations are confirmed by field data.

The drying-up of the Okavango Swamps is quite visible on the imagery

4/and has..

and has been indicated on Figure 1 by the lack of marsh symbols among the drainage channels to the southwest. It can be clearly seen that the drainage traverses generally NNW-SSE but that a remarkably precise drainage divide, which roughly parallels a trend of secondary tectonic importance, marks off an apparently earlier drainage system diametrically opposed to the present one. This finding is regarded as significant. The channel pattern is similar to that seen in the Okavango Swamps and is probably a remnant from the time when inter-dune rivers flowed over/now dry, the Gomare 'fault'. It cannot be deduced from the imagery in which direction the water flowed in these channels, but it is suggested that the direction was towards the northeast. What is noteworthy is that, with possibly one exception, not a single channel from the present régime crosses the divide between the two systems. This divide may then represent an uplift in the surface which has been interpreted in Figure 1 as an uncertain tectonic lineament.

A middle-late Tertiary age and desert environment have been suggested for the formation of the dunes (Jones, 1962). Inter-dune drainage, a sign of wetter conditions after the desert period, cross the Gomare 'fault' but have been rejuvenated to the west of it. The Gomare 'fault' thus post-dates the dunes because they are truncated along its length, and the E-W, inter-dune, rejuvenated drainage system. After the faulting or warping along this line, the dunes to the east of it were washed away by the influx of water from the west, the south and the Okavango. It is tentatively proposed here that the drainage at this time flowed northeast towards the Mababe Depression and Lake Ngami from some considerable distance southwest of Tsau. The Mababe Depression is now dry and can only be distinguished by the trace of its former strandline. Lake Ngami, which was full of water last century, is now practically dry. Some idea of its former extent may be gleaned form the strand - lines shown on Figure 1. Earth movements, albeit only/of low magnitiperhaps tude, presumably shifted the drainage such that it follows the route travelled today. A drainage divide southwest of Tsau separates the older system from the present one. Gradual desiccation of the climate has resulted in the drying-up of swamp channels from the south northwards.

(S.M. Akehurst)

3.1.2 Recognition of Archean Stratigraphy by ERTS-1 imagery.

M. Litherland postulates a new mechanism for the formation of Archean

5/Greenstone..

greenstone (schist) belts in which he considers that the greenstone belts are relics of a much larger F1-folded greenstone terrain since broken up into schist (greenstone) relics by granitisation. He believes the theory to be confirmed by study of ERTS-1 imagery.

The field mapping, from which these ideas originated, was carried out under the auspices of the Botswana Geological Survey in an area of the Archean Rhodesian craton (c. 3 500 - 2 500 m.y.) adjacent to the Rhodesia/Botswana border. A threefold regional stratigraphy trends into Rhodesia at this border and is composed of two volcanic groups (Maitengwe-Matsitamma and Vumba-Tati), in which schist relics lie in tonalitic gneiss, separated by the Totume Meta-Arkose Group which contains meta-arkose layers in granite gneiss. Dips are subvertical and each unit measures 20-50 km in thickness. Litherland studied the relevant ERTS-1 imagery in order to formulate a regional stratigraphic framework for the Rhodesian craton as whole, using the thesis outlined above as his foundation. He hoped to link up his three-tier stratigraphy with the lithobgical pattern on the other side of the border. It must be pointed out here that persistently the Rhodesian craton has been interpreted in terms of 'granitic nucleii', i.e. orthogneiss rather than paragneiss.

Early imagery of the area was cloud covered but 1123-07405 shows that area of north-east Botswana which includes Litherland's mapped region. Schist relics stand out as dark toned areas. The important conversion of the Totume Meta-Arkose Group to granite as it crosses the border can be noted in the granite kopje range on the Rhodesian side which clearly continues in the form of the Matopos range south of Bulawayo on image 1158-07345. Thus the Totume Meta-Arkose Group can be traced as a 40 km thick band from Botswana through at least 150 km of Rhodesian territory. To the north of the granite kopje range the Bulawayo schist relic occurs along the strike of the Maitengwe -Matsitama Volcanic Group. Two important lineaments form the key to the remaining puzzle:

(i) In the southwest corner of 1158-07345, a WNW trending lineament cuts off the kopje granite of Matopos from non-kopje country. The lineament is both a WNW trending appendage of the Gwanda schist relic and an ESE projection of the Vumba schist relic of Botswana. The kopjes cease because the schist relics are set in non-kopje-building

6/tonalitic..

tonalitic gneiss. The lineament is therefore the continuation of the contact between the Totume Meta-Arkose Group and the Vumba-Tati Volcanic Group.

(ii) In the NW quadrant of image 1158-07352 the Antelope schist relic , south of the Gwanda area, sends out a southwest projection to the Tati schist relic of Botswana. This is clearer on the MSS4 band.

ERTS-1 imagery has therefore vindicated Litherland's regional interpretation. The Tati, Vumba, Antelope and Gwanda schist "belts" are linked relics of a vast terrain of schist approximately 20 000 sq. km in area. To the north and west of this area the schist is underlain by the Totume Meta-Arkose Group which is in turn overlain by a belt of granitised volcanic group containing the Matsitame, Maitengwe and Bulawayo schist relics. Litherland (1973) has predicted a 'hidden' F1 isoclinal closure in the Totume Meta-Arkose Group which can be inferred from the imagery to be southeast of Bulawayo. Thus the two major volcanic groups are stratigraphically equivalent. (M. Litherland)

3.1.3 Geological comparison of ERTS-1 positive transparencies 1050-07344 and 1122-07353 - The images named in the title both cover the area to the east and south-east of Francistown. MSS 6 images of both sets of imagery were compared.

No extra geological information was found on the later image. However, the darker tone of the later image enabled certain geological features, visible on 1050-17344, to stand out more clearly on 1122-07353. These were the Tati schist belt, amphibolites in the gneisses to the south and the Karroo volcanics in the east. All these features are shown as dark bands or patches in the pale gneiss which predominates in the area. The ironstones within the schist belt stand out as black bands on both images. The appearance of the burnt areas was the major difference in the two images. Those visible on the first image had disappeared on the later one, and new burnt areas had appeared. The rivers were still white on the later image which indicates that there was no water flowing in them.

(R. M. Key)

3.2 Ecological Investigation

3.2.1 Use of ERTS-1 imagery in a survey to investigate the presence of Salvinia Auriculata on the northern boundary of Botswana.

7/The area of the..

The area of the survey was the whole extent of the eastern Caprivi Strip. Salvinia had been reported in the Chobe river and the area affected by the weed had increased markedly in recent years. Details of the region are shown on Figure 2.

Basic information of the area under survey was lacking. The northern area of Botswana is an area of National Parks. It is poorly mapped apart from a 1:250 000 sheet produced in 1968. Print lay-downs based on 1962 aerial photography are available at a scale of 1:125 000. South African mapping of the Caprivi Strip is restricted for use.

The purpose of the survey was to visit the riverine areas of the block and to study and map the extent of the growth of Salvinia. Helicopters and Land Rovers were available for the field work. Due to the lack of comprehensive mapping of the whole area no real overall planning was possible before the field work was begun.

The field work undertaken was as follows:

(a) Helicopter flights along the Chobe river, with landings to check the visual records obtained.

(b) Helicopter flights along the Kwando river.

(c) Land Rover reconnaissance along the Zambesi and thence southwest down a flood channel to Lake Liambesi.

Data obtained from these reconnaissances were then transferred to maps and air photographs.

On return to Headquarters, investigations were made of the results. Comparisons were made with earlier photography and some information of the encroachment of the weed over certain periods of time was recorded.

Receipt of ERTS-1 imagery shortly after the field survey work enabled correlations to be made for further investigations. The results were as follows:-

(i) ERTS imagery gave an overall picture of the bulk of the Survey area with the exception of the western extremity. This imagery would have proved useful for preliminary planning of the survey had it been available earlier.

8/(ii) The infra-red

(ii) The infra-red imagery (MSS 7) is helpful in showing open water areas, thus cutting gown the actual survey area. Small open water areas can be located and invesigated thus dispensing with the need for helicopter flights to establish their existence.

(iii) Water channels covered by Salvinia can be identified on the 1:1 million imagery and on 4 x enlargements. With successive ERTS imagery, an estimate of the growth rate of the weed can therefore be determined.

(iv) Details of Salvinia growth, recognised on the ERTS imagery can be followed up on standard aerial photography and if required, ground survey can be carried out on specially selected test areas.

(v) Further investigations are in progress in the Lake Liambesi area to compare conventional aerial photography and 7 x enlargements of ERTS imagery in order to obtain data on the growth rate of the weed over large open water areas.

Conclusion: The survey of this area for Salvinia infestation would have been much simpler had ERTS-1 imagery been available before the survey. However, data obtained on the survey has now been related to detail on the imagery available and the importance of ground truth cannot be over-emphasised.

(J.A. Raffle)

3.2.2 The following comment on Botswana's first Type I report was received from A. Blair Rains of the Directorate of Overseas Surveys, U.K., who has done considerable field work in Central and Southern Botswana as part of a Land Resources Study. He looked at some of the ERTS-1 imagery when he was in Lobatse in early February.

"I have attempted to fit some of the vegetation boundaries (mainly MSS 7) which I traced from your film positives to a 1:1 000 000 scale map. The results agreed remarkably well for the southwest up to 24°S with my physiognomic vegetation boundaries (Central and Southern State Lands Report) and fairly well for the area to the north of this latitude up to the Kuke fence. I must confess that I found some of the changes on successive orbits puzzling - Wolfgang von Richter's observations (p. 15 of Type I-1 report) on vegetation changes being due to rainfall are probably correct but I am not sure that I understand the implications of the tonal changes".

3.2.3 The following comment was received from I.N. Lancaster of the Department of Geography, University of Cambridge, U.K. He is undertaking post-graduate studies on the characteristics of pans in Botswana.

"ERTS-1 imagery, especially the MSS 4 wave band, is particularly useful for recognition of pan surface characteristics in the southern Kalahari. It is known that 3 different types of pan surface exist - grassed pans, ungrassed pans and saline pans - but these are difficult to identify precisely on conventional air photographs. ERTS imagery enables classification of pan surface types to be carried out over a wide area, particularly as conventional air photography of southern Botswana is taken at several widely spaced dates and pan surface characteristics may change from year to year. It may be possible to monitor changes in pan surfaces or whether pans contain water when sufficient imagery is available."

## 4. Publications

There have been no publications connected with the Botswana ERTS investigation for the period January-May, 1973.

## 5. Recommendations

The writer feels that insufficient use has been made of the imagery when it eventually arrives. The various investigators are committed in any case to their full-time routine tasks and it has been difficult to afford the ERTS project realistic research priority.

Although the intention of the EROS programme is stated to be a realisation of the Earth's natural resources by use of satellite imagery, the writer feels that it might be more profitable if the U.S. were to provide suitable technical assistance on the ground with respect to the evaluation of the data. This would have two purposes:

(i) to actually perform the analysis

(ii) to stimulate the interest of potential users of ERTS imagery in Botswana such that they could make proper use of it.

S.M. Akehurst
9th. May 1973.

10/References..

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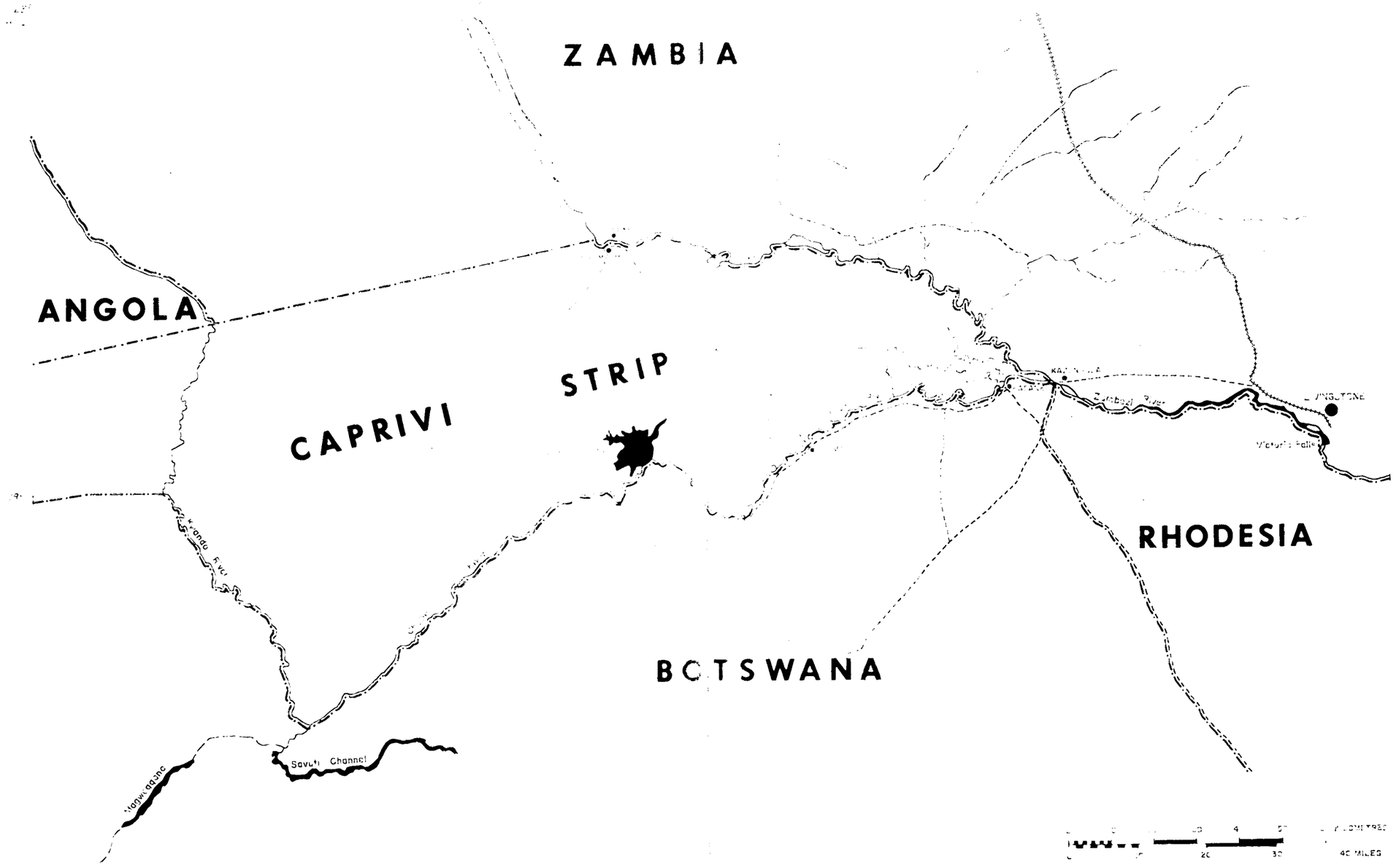


Figure 2

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