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

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(2) The opinions expressed in this report are not necessarily those of the writer or the Principal Investigator.

Abstract and discussion of significant results:

This is the final report on the ERTS-1 project in Botswana.
It includes a description of the background to the project, the problems encountered and general remarks on interpretation of the imagery.
Specific reference is then made to individual investigations, and progress, incorporating results from earlier reports and seminar which was held late in 1973.
In the geological section additional descriptions are included of the Limpopo Mobile Belt, the

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Kalatraverse area and the practical use of ERTS imagery as a navigational aid in the Central Kalahari.
The Department of Surveys and Lands is working on the Cartographic use of ERTS imagery as a possible base to a 1:250 000 map series.
An ecological appraisal of ERTS imagery used in interpreting vegetation types in the Okavango region is presented by courtesty of D. Williamson (Spectral Africa.)
In conclusion, the advantages of ERTS imagery are assessed and recommendations are made on the future use and acquisition of ERTS imagery in Botswana.

CONTENTS

1. Background to the ERTS project in Botswana

An application to participate in the ERTS - A project was initiated by Dr. J. V. Hepworth, Director of Botswana Geological Survey in December, 1971. D. G. Hutchins, a geophysicist from the Geological Survey was deputed to advertise ERTS - A to other Government Departments with a special interest in evaluation of natural resources.

As a result, the Departments of Surveys and Lands, Water Affairs, Wildlife and National Parks and the Agricultural Research Station joined with the Geological Survey in submitting a proposal to NASA. Dr. Hepworth was nominated Principal Investigator (P.I.) and the Botswana Geological Survey (B.G.S.) as the sponsoring agency.

This proposal was accepted in May, 1972 only a month before the scheduled date of launch. At this time, Miss S. M. Akehurst was appointed Project Manager of the Botswana ERTS - A programme in place of D.G. Hutchins who was, by now, fully committed to the Geological Survey's geophysical programme.

Mrs. Hutton (formerly Miss Akehurst), who is Technical Records officer at the Geological Survey, is headquarters-based and was thus in a position to administer the programme more effectively.

Preparations for analysis of the data amounted to equiping a room at Geological Survey with two light tables and a Zeiss zoom stereomicroscope. An additional light table was kindly loaned by the U.S. Geological Survey. It was decided to store imagery in the same manner as aerial photographs i.e. pre-designed cardboard boxes.

The standing order for ERTS-A data was initially for black and white prints, positive and negative transparencies in all wavelengths (green, red and infrared) of the RBV and MSS systems.

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Arrangements were made with the U.S.A.I.D. officer in Gaborone for despatch of the ERTS material by diplomatic pouch to the Embassy there for onward collection by the Geological Survey.

Although the satellite was launched on July 23rd, 1972, the first imagery of Botswana, taken on the 15th September, 1972, was not received at the Geological Survey until the end of October, 1972, three days after the first progress report was due at NASA headquarters. No RBV imagery has ever been received of Botswana and supply of black and white prints was suspended by NASA very early on in the programme as it was considered that prints could be reproduced easily from the negative transparencies supplied to the P.I.

All geologists at BGS were required to analyse varying proportions of the imagery for geological information and most of the other co-investigators examined the first few batches of imagery. This initial surge of interest culminated in a visit to Botswana in January, 1973, by C. J. Robinove, a prominent official in the U.S.G.S. EROS programme, who inspired and stimulated a great deal of discussion during his 3-day visit.

Thereafter, enthusiasm waned quickly as investigators, became involved in other projects and departmental administration. Reports were submitted to NASA in January, May and August 1973 and a special request was made to NASA through the US. Embassy in February to arrange for constant monitoring of the dwindling water supply in the Okavango.

In December 1973, a 3-man team on contract to A.I.D. visited Botswana to make a cost/benefit analysis of the usefulness of ERTS and its potential contribution to resource development in developing countries. The team comprised Dr. D. S. Lowe, a physicist from the Environmental Research Institute, Michigan, Dr. R. Summers, a systems engineer who heads a firm called Systems Planning, and Dr. E. Greenblatt, an economist from Mathematica. Botswana was the fourth and final country on the team's list.

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A seminar and exhibition of ERTS imagery was organised at Geological Survey at which the Americans were intorduced to participants in the ERTS-1 project and intending participants in ERTS-B. Several statements and conclusions arising from the seminar will be incorporated into this report.

2. Problems encountered during the Project

Geological Survey was the data collection point. As BGS is situated in Lobatse, some 75 km South of the capital, Gaborone, where the majority of the investigator departments are based, the physical distance involved in travelling proved an effective barrier to access to the data. Imagery was provided on loan when requested, although few demands were made.

The project's administrator and other investigators were unable to devote unlimited time to the task of organisation, analysis etc.

Unfortunately, because NASA urged stringent control of the amount of data ordered, it was not deemed possible to ask for sufficient data for general distribution.

Botswana has no wide-ranging photographic services. Since the Department of Surveys and Lands and the Government Printer were not able to produce prints from NASA's 70 mm negatives, because they were of exceptionally poor quality, it was necessary to send 1:1 million positive transparencies abroad in order to acquire reasonable contact negatives. This process would take 2 to 3 months.

Although it was possible to perform interpretation by visual means, there was no know - how in Botswana at the time regarding simple enhancement techniques, such as preparation of colour composite simulations by diazo-chrome printing and so on.

There were (and still are) no facilities in Botswana for developing more sophisticated enhancement or analytical techniques. Even though it has been stressed that as much can be gained from ERTS imagery by careful trained visual analysis, it must be recognised that workers who will increasingly use ERTS imagery as one of their survey tools will require more detailed analysis in order to maximise the information which can be derived from ERTS.

On the other hand some investigators seem to find it difficult to change their view-point from looking at aerial photographs to looking at large areas on small-scale satellite imagery. The demand has often been for detail which ERTS quite simply cannot provide.

Black and white imagery is received from NASA some 2 to 3 months after acquisition by the satellite. False-colour imagery 6-8 months after ordering. This delay derogates the effectiveness of ERTS imagery as a real-time monitoring tool and has certainly dampared enthusiasm for its use.

One of the major complaints raised at the seminar was that there is no contact with officials in the U.S.A. Although Botswana was assigned a Technical Monitor, correspondence was infrequent and replies were usually terse when they eventually did arrive. In short, Botswana investigators felt very cut off from the mainstream of activity in the States.

Lastly, the point was made that by the time data arrived in Botswana, it had, presumably, gone through many processing stages. As each stage inevitably leads to degradation of the image, we can only assume that we are not looking at the best ERTS products.

3. Significant Results

3.1 Introduction

General aspects relating to identification of natural and cultural features on ERTS imagery have been discussed in earlier reports. The limit of resolution on ERTS imagery is normally acknowledged to be about 60m although very long features such as roads and railways which are often less than 10m long are easily detectable, e.g. the N-S road and railway from Lobatse to Francistown.

Vegetation growth from winter to summer is readily monitored on false colour imagery. The predominant yellow and green hues of most of the imagery reflect the sparsity of vegetation and the prevalence of red sands in Botswana although "blushes" of spring vegetation as indicated on ERTS imagery could be very useful to rangland managers when making decisions on grazing land. The limits of government ranches and special farming areas can be quite accurately ascertained from ERTS imagery e.g. 1123-07414, the Dibeti Quarantine Camp, 1195-07411, the Tati Concession.

Another aspect to which ERTS imagery lends itself is the location and demarcation of bush fires, many of which were seen on the first imagery which was acquired at the end of the cold, dry season. However, bush fires in progress were not spotted until false-colour imagery was received, e.g. 1052-07452, 1052-07463. The irregular patchiness of the eastern Kalahari reflects old burn patterns and regrowth of vegetation. Small towns can be picked out on false-colour imagery - Lobatse, Francistown, and to a lesser extent, Gaborone, as blue - toned areas. Towns and villages which are occupied by dwellings made of natural material are much harder to detect but can generally be defined as areas where degradation, overgrazing and land clearance have occurred, e.g. Maun on 1054-07471, Mochudi on 1198-07420 and Seruli on 1195-07411, showing up white on false-colour imagery

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As a whole, MSS 7 offers maximum relectance contrast among the black and white imagery and is the wavelength used most for interpretation. False-colour imagery is favoured where it is available. MSS 5 imagery is useful as a supplement to the MSS 7 imagery particularly in defining dry river courses and pans which give maximum reflectance in the this wavelength.

3.2 Geology

3.2.1 Introduction and Summary results of earlier interpretation

The first sets of imagery received were examined in detail by most of the field geologists at Geological Survey. Thereafter, routine examination was discontinued and ERTS came to be used as an adjunct to specific projects in certain areas.

The scale of the imagery and insufficient resolution militate against the effectiveness of ERTS as a tool for detailed surface mapping. One geologist even suggested that ordinary aerial photography reduced to a scale of 1:1 000 000 would show more detail. On the other hand, it was also acknowledged that the regional view afforded by ERTS was of immense value since "large areas can be viewed and that large scale structures, changes in structure and relations between st ructures can be much more easily appreciated." (I.R. Walker). One instance of this is image 1050-07344-7, on which "the Central zone of the Limpopo Mobile Belt can be traced right across the area, and the edge of the Karroo System can be defined". (R. M. Key)

On the whole, linear features and structural elements, are much the easiest geological features to discern on ERTS imagery. Major lithologic differences are also easy to disti- nguish but are not as readily apparent as structural features.

To a varying extent, much of the geological information derived from ERTS depends on the interpreter's own knowledge of the area under study. Because it is entirely visual, interpretation is also of a highly subjective nature. Imagery of the Okavango area interpreted for the Type II report (May 1973) revealed more to some geologists than to the original interpreter. Some of the information was interpreted in a different way, and so on.

At the time the first set of imagery was received, study of MSS 7 imagery seemed to be the most profitable approach although it became apparent towards to the end of the investigation that MSS 5 imagery provided as much, if not more, information. Dry pans and fossil drainage features in desert areas of little surface contrast give maximum reflectance on MSS 5 imagery. MSS 5 imagery also best defines geological features in densely vegetated areas (and therefore, generally wetter areas) such as may be seen on image 1125 - 07515 which covers the confluence of the Chobe and Zambezi rivers at Kazungula (Zimbabwe) bordered by Botswana Zambia, Rhodesia and the Caprivi Strip, (Namibia).

Although very useful for studies in land utilization, false-colour imagery tends to confuse and understate geological detail, more particularly in areas where bedrock is at surface. Besides, some colour prints and transparencies do not bespeak a reasonable standard of processing and it was often preferable to work from black and white data.

The imagery arrived too late to be used as a source of data for the recently published national geological map at 1:1 000 000 scale which was compiled mostly from print laydowns. It had been hoped that quarter million enlargements would be available to field workers in the Kalahari during the past field season's major project. Unfortunately, it proved impossible to produce acceptable prints from NASA's negative transparencies and by the time suitable prints had been obtained through other sources, the field party had already returned.

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In general, interpration of ERTS imagery provides approximately the same amount of information as is shown on the national geological map. An illustration of this is included with this report, see the sketches of data (Figure 1) from images 1248 - 07355 and 1195-07411 together with comparative data drawn from the 1:1 million map (Figure 2).

Summary descriptions of the geology of Botswana, as revealed by ERTS imagery, were presented in the first Botswana ERTS Type I report of January, 1973.

A cursory geological and geomorphological analysis of the Okavango region was offered in the Type II report for May 1973 in which perhaps, the most important finding was that a deltaic drainage system once existed to the south-west of the Okavango Delta with a directional trend opposite to the present day channel direction.

M. Litherland also studied ERTS imagery of N.E. Botswana and proposed that the Vumba and Tati "Schist relics" were formerly co-extensive with the Bulawayan greenstone belt.

In the second Type I report, August 1973, it was noted that the course of the Boteti River North of the Kalatraverse area, suffered two changes of course in country with very low relief. It was supposed that the course of the Boteti may therefore be influenced by structural controls on NE and NNE trends.

3.2.2 Limpopo Mobile Belt

Image 1248 - 07355 was studied both in MSS 5 and 7. The area is part of Northeast Botswana-predominantly Basement Complex gneisses with numerous Schist Belt 'relics' (Litherland, 1973), intercalated amphibolites and some Karroo cover. The Limpopo Mobile Belt, characterised by deformation associated with the Tuli-Sabi straightening zone traverses the southern part of the area in an east-northeasterly direction.

Lithology has not been differentiated in detail on the ERTS interpretation. However, most of the amphibolites and quartzites in the area and the Matsiloje ironstones in the Tati Schist 'relic' can be easily detected. The most striking difference between ERTS and the map is simply that much more

FOLDOUT FRAME 1

FOLDOUT FRAME 2

FIG 1
ERTS-1 IMAGERY INTERPRETATION OF THE LIMPOPO MOBILE BELT IN BOTSWANA

SCALE APPROX 1:1 000 000

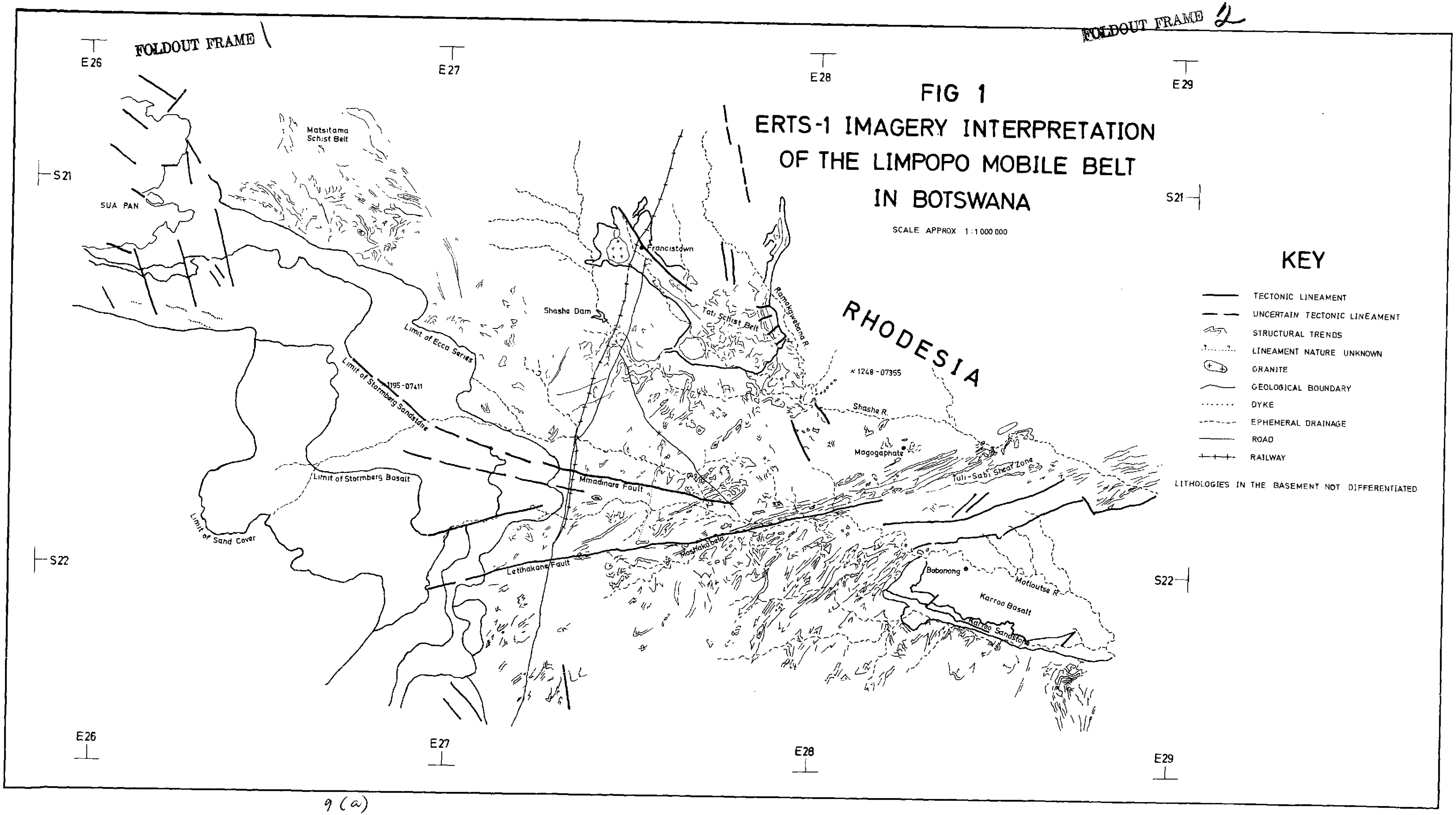
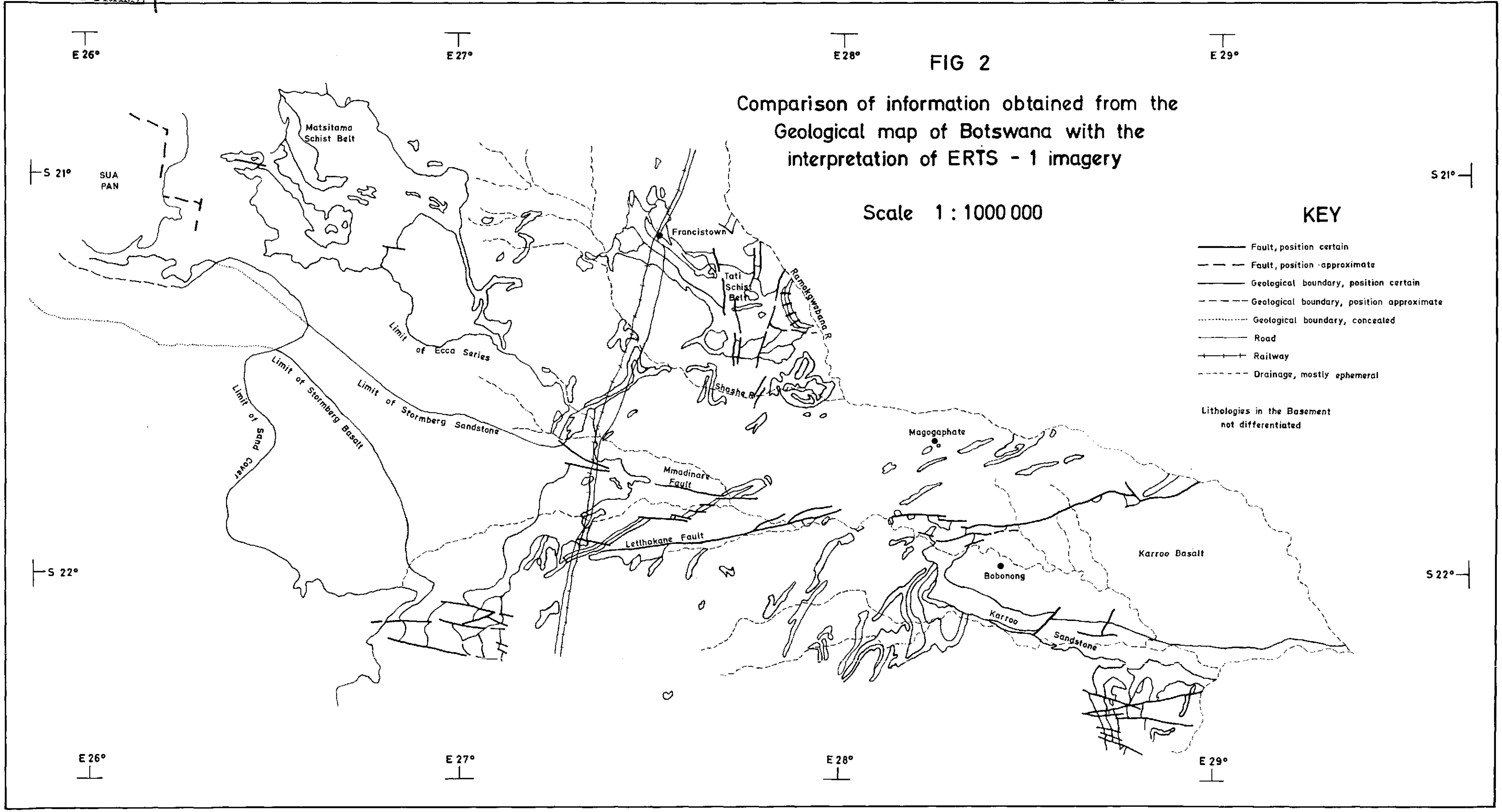


FIG 2

Comparison of information obtained from the Geological map of Botswana with the interpretation of ERTS - 1 imagery

Scale 1 : 1000 000



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structural detail is immediately visible on the ERTS frame. The compilers of the map have been specific in their choice of detail. The Letlhakane shear extends further to the east than is shown on the map. Other faults correspond, some do not.

Field evidence suggests that the straightening zone "disappears" at Moshakabela in the west where the plunge steepens to the SW at an angle of 30°. The field evidence is supported by examination of the ERTS image.

There also seems to be some dextral displacement of the Tuli-Sabi straightening zone on a line trending NNW approximately 15 km from the Shashe River, which also marks the international boundary between Botswana and Rhodesia.

An ENE trending fault which strikes for about 50km some 40km north of and parallel to the Letlhakane fault displaces Stormberg basalt and sandstone with downthrow to the south. It has not been indicated on previous geological maps and may be an extension of the fault first discovered by N. Robins in his resistivity traverse from Serowe to Letlhakane, although Robins believes the fault is a shear.

The interpretation was undertaken by S. M Hutton who has not been able to visit the area. Caution should be exercised in treating the sketch map as a geological reference since it is known that it is not an entirely true representation of the geology of the area particularly with respect to the extent of the Karroo System.

Nevertheless, certain lineaments are revealed on ERTS imagery which have not been previously identified or have been much more tenuously indicated on the 1:1 million geological map. This is most evident in the north-eastern quadrant of the country where large NE-SW trending lineaments strike for much greater distances than shown on the map.

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3.2.3. Serowe - Letlhakane traverse - a comparison of geophysical results with examination of ERTS imagery

N. Robins, a hydrogeologist who left Geological Survey in July, 1973 submitted the following account of his geophysical resistivity work in the Serowe - Letlhakane area. Although ERTS imagery revealed three new faults, Robins' geophysical work indicated a further ten.

"The purpose of the resistivity survey was to determine faults and dykes as part of a regional geohydrological project to establish recharge areas and the possibility of groundwater flow along hydraulic gradients - predominantly towards the northwest. The main aquifer is the Cave Sandstone Aquifer confined by the Stormberg Lavas which are, in turn, overlain by Kalahari Beds.

ERTS images 1069-07402 and 1052-07461 covering degree squares 2125, 2126 and 2226 were studied.

Provisional analysis of the geophysics has disclosed the position of 12 minor faults and one large shear zone possibly infilled by a minor intrusive. A 16km portion of the northwest section of the route appears to traverse an igneous environment.

Evidence of each vertical feature located by geophysics has been searched for on aerial photographs and ERTS imagery; 96% of the traverse is blanketed by Kalahari Beds and no faults have been located on the aerial photographs under this recent deposit. One minor fault near Serowe, where Kalahari beds have been removed can be seen on aerial photographs.

Two minor faults and the large shear zone are, however, clearly visible on ERTS imagery. The shear zone trends ENE from a point west of the traverse to a point north of Seruli, a distance of about 125 km.

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It has since been proved that the shear zone area is an active recharge agent. Thus, by following the zone on the ERTS image, the recharge area is instantly defined and a belt of relatively high transmissibility delineated. The line of the shear follows a high ridge on the peizometric contour map.

The other two faults that can be seen on ERTS image 1052-07461 appear to delineate a graben downthrown some 20 metres, though the throw of the northwestern fault cannot be determined from the resistivity analysis. They are located immediately to the northwest of the Makoba Veterinary Camp and can be traced on the image from a point 5 km SW of the traverse splaying NE and ENE for a distance of 20 km each. They do not appear to effect a barrier to groundwater flow and, as yet, recharge or transmissibility is not determinable owing to the absence of boreholes.

None of the faults under the Kalahari Beds were known before the geophysics was undertaken. The igneous environment near Letlhakane was also unknown though not wholly unexpected because of the proximity of the Letlhakane Kimberlite Field.

ERTS imagery appears to be of great value for the extrapolation of large regional features but of little value for the location of local features. There is no way of differentiating these linear features on ERTS i.e. whether they are faults, shears or dykes. In this case, detailed geophysics was necessary to determine the character of the features.

The art of locating useful hydrogeological zones with ERTS imagery is not very practicable. Firstly, the features has to be located on the ground. Considering the substantial overburden of Kalahari sand and calcrete, this is no easy task. Secondly, the portion of the feature suspected to have the greater transmissibility has to be determined i.e. the width and nature of the feature, and this can only be done on the ground with follow-up test drilling. However, areas of good groundwater potential can be traced from ERTS imagery if they owe their existence to regional features, and then can be precisely located with geophysics",

3.2.4. Kalatraverse

Kalatraverse was the code name adopted for the Geological Survey field project in 1973 during which is was intended that a half degree strip from 21°30'S bounded by longitudes 23°E and 26°E should be surveyed both geologically and gemorphologically, supported by an intensive programme of geophysics and geochemistry. Although ERTS imagery was only used to a minor extent on the project, a geological and geomorphological analysis was undertaken at headquarters and a sketch of the results at 1:1 000 000 is included (Figure 3).

The strip is bounded to the east by Basement Complex gneisses and greenstone remnants. To the West is the NE trending Ghanzi ridge of late Precambrian age. Structural elements just visible in the Ghanzi Ridge have been indicated on the diagram. The traverse crosses the northern fringe of the Kalahari Basin which is entirely covered by sand. Bedrock outcrops only in the east of the traverse where there is an agglomeration of Kimberlite pipes in Karroo rocks (thus the Kimberlites are post-Karroo) clustered around Letlhakane and Orapa, where the world's second largest diamond mine outside the USSR is now in operation. It was not possible to define Kimberlite pipes from visual interpretation of ERTS - 1 imagery.

The Mosu Sandstone scarp stands out quite clearly to the south of Sua Pan. A geological (?) boundary of uncertain significance has been traced from the extreme east of the area to southwest of Mopipi Pan where it abuts on to an old strandline.

The most striking geological features are the major lineaments. Four directional trends are obvious, N 20°, N 45°, N 110° and N 320°. Of these the field workers have established that the N 110° trend is the most dominant particularly in the east of Kalatraverse where sand cover is comparatively thin and lineanments can be detected on aerial photographs and print laydowns. These features are mainly dykes which have been implaced in fractures in the bedrock.

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On the other hand, the most dominant feature on the ERTS imagery interpretation is the Mopipi lineament trending N 45° (Massey, 1974) which was first recognised on ERTS imagery. This lineament can be traced as far northeast as the border between Botswana and Rhodesia where it swings round to a direction of N 30°; it appears to extend to Takatshwane on the road between Ghanzi and Kang.

Where this lineament crosses the Okwa river valley, it is offset by another lineament on a N310° trend which appears to link up with another lineament further north through Deception Pan. Faulting on the N 310° trend has been proved by resistivity surveys at the pan. Tentative re-interpretation of seismic data also suggests that earthquake epicentres may correlate with this line. (Reeves, 1974, Massey op. cit.)

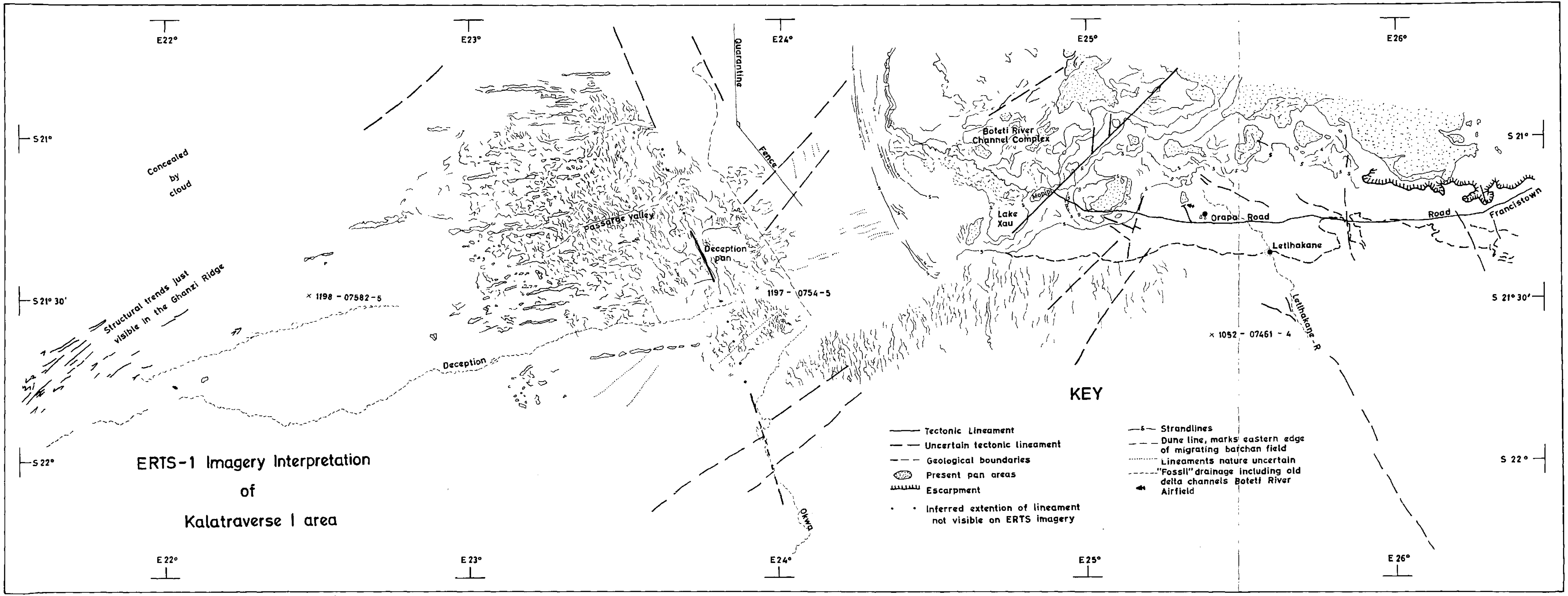
Several physiographic environments in the Kalatraverse area can be delineated. The great salt pans of the Makgadikgadi are dominant, showing as large areas of white on both black and white and colour imagery. Bluish tones on the colour imagery may indicate ground moisture. Former strandlines are revealed very clearly as curved linears. These observations have been substantiated on the ground by heighting differences. The straight - sided nature of many of the pan boundaries suggest fault control.

Barchan dunes can be identified on Ntwetwe pan and the contorted patterns on the diagram west and south of the pans have been deduced to represent the result of interference of a barchan field migrating WSW with long seif dunes trending in the same direction. The absence of these degenerate barchans for some 40 km west of the pans presumably indicates that they are no longer forming. The dune line which marks the eastern limit of the dune field is, in fact, more irregular than indicated on the diagram.

FOLDOUT FRAME 1

FOLDOUT FRAME 2

FOLDOUT FRAME 3



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Massey (1974) has observed that the strandlines of Lake Xau cut the interference dunes and thus the strandline formation post-dates the dunes. Linear features on an ENE trend such as Passarge Valley, may have some connection with the seif dune formations which are more prominent to the west and northeast of the area.

However, in the monotonously flat stretch of country between the dune field and the pans, similarly oriented linears which are dark toned on ERTS imagery have not been satisfactorily explained. Massey (1974) suggests that they are either "sand stains" formed by wind blowing from the ENE or that they are dune bedding planes revealed by deflation of the seif dunes.

The flood plain of the Boteti River has also been described as a distinct physiographic region. It can be demarcated on ERTS imagery. Former channels of the Boteti are visible just west of Lake Xau. The pattern indicates a deltaic environment in the past which has since dwindled owing to decreasing water flow from the Okavango. The river is inpounded against the Mopipi lineament at Lake Xau where it turns abruptly north and spills its water out into Ntwetwe Pan.

3.2.5. <u>ERTS as a navigation aid</u>

Finally, ERTS imagery was put to practical use as a navigational aid in the closing stages of the National Gravity Survey when a helicopter was used in terrain that could have been covered only very slowly on the ground in the Central Kalahari

The following account has been abstracted at length from a report by C. V. Reeves, geophysicist in charge of the operation (1973).

"The helicopter was flown on compass courses from one known point in the direction of another. The need to determine the position of gravity observation points where the helicpter landed, nominally at 10 km intervals along the flight path, was paramount to the success of the operation, as accuracy of a few kilometres in latitude is required if Bouguer anomalies are to be calculated to $\pm$ 20 g.u.

Since the helicopter was working to the limit of its endurance, there was little fuel margin available for searching for the target area if it was not found at once. Therefore, the safety of the working party depended on it being able to apply on - course corrections using information from in flight experience of the observed rate of drift of the aircraft to left or right of track.

Furthermore, the spacing of the gravity observation points, nominally 10 km determined by elapsed flight times between landings, had to be adjusted as ground-speed (112-128 km/h) varied considerably with wind-speed and direction.

Direction - finding aids available were:

(i) Maps at 1:1 million and 1:500 000 scales.

(ii) ERTS positive prints at 1:500 000 scale. (2 x enlargement of 1:1 million contact negatives) MSS 7.

(iii) Uncontrolled PLDS at 1:125 000 scale.

(i) Conventional MAPS in Botswana suffer from a lack of topographical features which can be shown on them. Positional representation of trig. beacons is accurate, but often the positional accuracy of other features shown can be demonstrated to be inaccurate by up to 10 km, e.g. the dry river System in the Central Kalahari on the 1:1 million map.

(ii) ERTS 1:500 000 enlargements are far superior to PLDS where positional accuracy is concerned. Latitude and Longitude fiducials can be shown to be incorrect by up to a few km - but if the start and finish of any flown track is identifiable on ERTS and fixed by land navigator on ground, their absolute accuracy is unimportant - relative accuracy is excellent. The 1:500 000 scale was very convenient to use in the restricted space of a small helicopter and points could be marked off on overlays sufficiently accurately.

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Difficulties arose, however, from the inability to recognise ERTS features on the ground, particularly when flying at only a few hundred feet, and seem to be due to the fact that the prints were monochromatic. Thus tonal contrasts in the MSS 7 infra-red band were emphasised. It proved easier to recognise distant features than those close to, and generally, one was not working at the limit of resolution of the enlargement. Panchromatic or true colour images may well have been much better for identification of features. Some very obvious features on the ground did not appear on the ERTS MSS 7 enlargement as there was no contrast in that wavelength e.g. large pans and dry rivers South and West of Deception Pan".

Discussion at the seminar pointed out that MSS 7 was probably the wrong wavelength to have used for this project and that MSS 5 would probably have been more useful. False-colour prints were not available. (SMH).

"Burning patterns of grass fires could be recognised, but one had to detect subtle changes in the grass growth. It is therefore, important that ERTS imagery is recent.

In areas where ERTS enlargements were of poor quality, or where an insufficient number of features could be identified, use of ERTS became a safety hazard and it was necessary to resort to PLDS.

(iii) PLDS have the advantage of being conventional, panchromatic photography and thus, progress along a prescribed track can be followed fairly easily and course corrections applied. Therefore, despite the geodetic inaccuracy of the PLDS, which means that a through line drawn across them is not necessarily straight on the ground, there is a fair guarantee that the navigator would not get lost.

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PLDS are much less convenient to use than ERTS enlargements in the confined space of a helicopter, usually 5 or 6 of them being required for just a few hours flying.

It is possible to reidentify features seen first on PLDS and then on ERTS imagery which would improve the geodetic accuracy of track eventually plotted out on maps. The tonal dissimilarity between ERTS and PLDS means that this is not often possible although the comparison varies from area to area, being, for example, very poor over the "featureless" (save for grass burning) area between Lephepe and Orapa and very good over the pan country S.W. of Tshane.

As a result of these considerations and with a view to the utmost safety, the PLDS were used more than ERTS imagery at a small sacrifice to scientific accuracy.

Apart from the practical difficulties of acquiring ERTS imagery in a more acceptable format ERTS appears to have more potential as a navigational aid than PLDS, and certainly maps, in Botswana".

3.2.6. Comparison of ERTS with aerial photography

To conclude, the following comments on the practical use of ERTS imagery and conventional photographic mosaics in the field were put forward by J. V. Hepworth at the Botswana ERTS seminar.

"The object of this discussion is to compare uncontrolled masaics ('Print Laydowns') of air photography reduced to a scale of about 1:125 000 and covering 30 minute squares, with black and white enlargements of single waveband ERTS imagery at scales of 1:1 million, 1 to half million and 1 to quarter million covering degree squares.

The comparison is not, therefore, objective, but the aim in the use of each medium is to obtain the best available photomap, in the absence of any other, or, in place of obviously inadequate conventional maps.

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The Print Laydowns have the following limitations: low quality original photography, poor reproduction including incorrect exposure and degraded negatives, uncontrolled laydown with an inaccuracy of up to 5 miles along the margins.

Enlarged ERTS imagery suffers from original low resolution and presence of scan lines, together with loss of further detail on enlargement on coarse paper.

The advantages of the PLDS are greater resolution and detail arising from reducing better original material.

The advantages of the enlarged ERTS imagery lie in the convenience of a picture without joins, and in an orthographic, cartographically corrent representation.

The comparative costs of producing both media are unknown but in practical terms, the PLDS are easier to acquire from existing organisations.

A subjective assessment of the two media suggests that even a bad PLD gives more information for geomorphological and geological interpretation than a good ERTS imagery enlargement. However, this is based on presently available material, and it may be that if 1:250 000 ERTS colour composites were available, the opinion would be reversed.

Both media are enormously better than nothing and their best use is probably complementary."

3.3. Cartography

Small scale topographic maps of Botswana were produced in 1905, 1935 and 1969. Those maps at scale 1:500 000 which were produced in 1935 were updated in 1969 when they were still found to be largely accurate. The current edition of the 1 million map was produced in 1969.

The Department of Surveys and Lands is now committed to a mapping programme at the scale of 1:50 000. However, only the eastern half of the country in general, comprising approximately 250 sheets, is amenaable to this scale of mapping since this is the most densely populated area and the rest of the terrain is largely flat, uninhabited scrubland.

J. A. Raffle, speaking at the ERTS seminar on behalf of co-investigator W.L. Dickson, the Director of Surveys and Lands, explained that a 1:250 000 map series would be very useful as an administrative (working) map series especially in areas where there is very little surface detail. At present, the British Military Survey are compiling 1:250 000 sheets of Northern Botswana. The cost to Botswana of launching a traditional mapping programme was estimated two years ago to be R1.8 million and has probably increased substantially since then.

The intention of the present excercise is to use enlarged ERTS imagery as a background to the 1:250 000 series.

The Directorate of Overseas Surveys, U.K., is producing photo-reductions to match 1:250 000 ERTS enlargements, although positional accuracy on the ERTS data poses difficulties at this scale.

Staff of the Department of Surveys and Lands are now working on an experimental topographic sheet of the Okavango Region at a scale of 1:250 000.

ERTS imagery would provide an acceptable background to the 1:250 000 series and to flight-line diagrams.

The major problem faced by the Department of Surveys and Lands in utilising ERTS imagery is that 1:1 million negatives are not supplied by NASA. The limited capability of the Department's equipment means that it has had to look elsewhere for the production of usable negatives.

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Government Printers were unsuccessful in their efforts in this respect and the task was ultimately undertaken by a local firm almost a year after first receipt of the imagery.

3.4. Ecology

3.4.1 W. von Richter of the Department of Wildlife and National Parks made a preliminary examination of the first two sets of data from which he concluded that ERTS imagery would be extremely useful for mapping district vegetation types in various National Parks and Game Reserves in Botswana. At the same time, the study showed that existing vegetation maps of several Game Reserves are insufficient in detail for use as ground truth objects for vegetation mapping of other unmapped conservation areas.

Unfortunately, no further progress was made towards establishing ground truth areas. At the seminar in December, 1973, von Richter re-iterated his earlier statement that the imagery would be most useful in monitoring the spread and occurrence of bush fires and land degradation by over - grazing.

3.4.2 Both he and I N. Lancaster of the Department of Geogrpphy, University of Cambridge U.K., who is studying pans in Botswana, noted that pans were clearly visible on ERTS imagery more so on MSS 4 and 5 data when dry and on MSS 7 and false-colour after rain. Lancaster appreciated the wide, regional view afforded by ERTS imagery and hopes that ERTS could be used for the recognition and classification of pan types along with regular monitoring of the changes in pan characteristics.

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3.4.3. ERTS imagery of Botswana has also been evaluated for vegetation mapping purposes by at least two other workers outside the present investigation and was also compared with ground observations made in the Chobe area on the extent of the water-weed Salvinia Auriculata. An account of the Salvinia project submitted by J. A. Raffle was included in the type II report, May 1973, and may be summarised as follows.

ERTS imagery gave an overall view of the survey area which could have been extremely useful for planning the operation had it been available earlier.

Small, open water areas could be located on the infra-red band (MSS 7) which meant that the time and expense of locating these on the ground could have been considerably reduced, especially as a helicopter had to be hired for this part of the operation.

Since water channels covered by Salvinia could be identified on 1:1 million imagery and 4 x enlargements, successive ERTS imagery could be used to estimate the rate of growth of the weed. Such an investigation is, in fact being continued in the Lake Liambezi area by comparing the conventional aerial photography and 7 x ERTS enlargements,

Once Salvinia has been detected on the ERTS imagery, details of the extent of the weed can be followed up by close examination of standard aerial photography and further ground survey on especially selected areas.

Although Raffle acknowledges the value of ERTS imagery in planning the Salvinia survey and extracting results, he stresses that the support of ground-truth cannot be over-emphasised.

3.4.4. A Blair Rains of the British Directorate of Overseas Surveys commented that some of the vegetation boundaries (mainly from MSS 7), which he traced from positive transparencies on to a 1:1million scale map, coincided remarkable well for the southwest of Botswana up to 24°S with the physiognomic vegetation boundaries described in his report on the Central and Southern State Lands.

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The boundaries do not fit so well north of this latitude to the Kuke fence. Blair Rains was puzzled by the tonal changes seen on successive coverages and tentatively agrees with von Richter that they may be due to rainfall.

3.4.5. The most intensive ecolological work in Botswana conducted with the aid of ERTS imagery has been done by D. Williamson who is attached to Spectral Africa and it is assumed that his results may well have already seen presented to NASA in one of Spectral Africa's own ERTS reports.

However, Williamson did speak at the Seminar at Geological Survey in December 1973 at which he described his results to date.

His aim was to map the physiognomic differences of vegetation in the Okavango area i.e. to differentiate between savannah, woodland and mosaics of grassland and woodland. He prepared a map at scale 1:250 000 from ground observations followed by checks made from a light aircraft from which he took pictures with a hand-held camera using infra-red film. Print Laydowns were used as another check source against the ERTS data.

Williamson is confident that he can differentiate between broad vegetation types on ERTS imagery, such as wetland and upland (where the differences of habitat are particularly clear), open and closed woodland and areas of mosaic. However, vegetation <u>boundaries</u> are very difficult to distinguish although this is understandable in view of the considerable interdigitation of vegetation types in boundary zones.

This interpretation can be refined when seasonal variation can be studied on successive ERTS coverages. Sequential coverage should also be an aid to distinguishing between bush fire patterns and vegetation patterns. False-colour imagery is especially useful in determining areas where one species is dominant and which is the first to develop leaves. Eventually it is hoped that this study will assist prediction of the areas where trees will first "olush" thereby also indicating where game will congregate.

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3.5 Hydrology

The invedtigator in this field, B. H. Wilson of the Department of Water Affairs, reviewed the first two batches of imagery received here but was thereafter hampered in his task by being assigned extra administrative work in his Department until the arrival of a new Director, and proceeded on three months overseas leave in June 1973.

At the seminar in December, 1973 he summarised his thoughts about ERTS-1 as follows.

He had hoped that ERTS would show the annual floods advancing along the dry river beds of the Okavango Delta between May and October and that he would be able to measure the extent of the flooded areas. As a whole, ERTS imagery revealed flood encroachment quite clearly particularly on false-colour and MSS 7 data. The value of monthly monitoring was arguable as monthly coverage could not always be obtained. The prospects for annual monitoring seemed distinctly better but would require a sequence of satellites to be launched regularly to ensure a constant supply of data.

Methods of analysis of the kind of data received now i.e. transparencies and prints, would have to be kept simple. The technique favoured would be to make comparison of successive batches of imagery in the infra-red wavelength (MSS 7) of key areas that have already been defined and established as a ground truth reference. Some low-oblique photographs had been obtained for this purpose prior to the launch of ERTS-1. Unfortunately, access to these areas is often hinders difficult and staffing difficulties at the Water Affairs Department regular field checks. Enlarged prints of the key areas would be needed but only if the quality of resolution could be improved, which in Wilson's opinion, was absolutely critical.

In fact, it seemed that to improve resolution below 30m in order to pinpoint localities and flood fronts, selective aerial cover would probably be trying necessary rather than trying to make do with satellite imagery.

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False-colour imagery would be preferred if there was to be difficulty in interpreting different tones on data obtained on different days. It was obvious from some prints etc. that the quality of processing varied from cycle to cycle. Burnt areas are easily confused with areas of water on black and white data; false-colour is preferable in this respect.

Wilson concluded that, if nothing else, ERTS-1 data was useful for delimiting evaporranspiration boundaries and as a series of base-data maps describing the state of the Okavango Swamps during the 1972-73 summer season.

Preparations for the ERTS-2 project would have to begin now if maximum use is to be made of the data specifically in conjunction with the U.N. Okavango Project taking place between 1974 and 1976.

ERTS data would probably be of optimum benefit as a supplement to other remote sensing methods. If some of the major problems such as frequency in supply of data and the quality of prints could be improved, the data would certainly be invaluable.

In his first report, Wilson mentioned that aquatic vegetation concealed flooded areas and that in one case, ERTS imagery just did not show the actual position of the flood front.

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4. Advantages of ERTS imagery

The regional view of a large area at small photographic scales has the potential to give a much-needed insight and perspective to resource evaluation projects.

Furthermore, ERTS frames cover such a large area at any one time that the disadvantages of aerial photography, such as changes in sun angle, time of year etc. are obviated; because the data is acquired at a great height above the Earth's surface, the imagery is also orthographic. This enables maps to be compiled from the imagery very simply, providing there are sufficient accurately sited control points on the ground. Unfortunately, Botswana has a dearth of such points which can be recognised on the imagery.

Since a maximum of 40 frames cover the country, the imagery takes up little storage space and it is possible to keep pace with the inflow of data. The imagery has been indexed on very small - scale maps and it is hoped that a complete Botswana ERTS-1 index will be published shortly.

Of course, the fact that the imagery has been supplied free of charge by NASA has meant that the results of ERTS interpretation have been produced at virtually no cost to Botswana at all.

The range of wavelength bands in which ERTS imagery is obtained enables investigators in different disciplines to select and compare different types of data.

Since an initial interpretation can be turned out very rapidly by a skilled worker, at least a quick look at ERTS imagery justifies savings in time and money.

Although the amount of information derived from ERTS imagery, for example, in geology, seems to be proportional to the interpreter's own field knowledge of the area, it cannot be denied that the regional view is invaluable where little or no mapping has been previously undertaken.

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5. Recommendations

To utilise ERTS effectively, Botswana needs to have a centre where data is properly stored and indexed, which is freely accessible to interested parties, where trained interpreters are on hand and preferably where there is a more than adequate photographic service and other facilities for carrying out image enhancement. The University in Gaborone would be an obvious first choice for locating such a centre. Geography students and others should, hopefully, receive instruction in image interpretation so that they are aware that ERTS exists and can be used as one of the many tools in resource surveys. The centre should also advertise the availability of ERTS data. At the very least, the Department of Surveys and Lands could hold and make available ERTS imagery in the same way that it is responsible for the distribution of aerial photography and topographic maps.

In turn, we would hope that NASA would work towards providing consistently better products (70 mm negatives and some false-colour imagery are of very poor quality) possibly with better resolution for those workers who require more detail.

To be effective for on the spot decisions, the imagery should be available within a few weeks of its acquistion, and if, as is the case with Botswana, there are no facilities for reproducing the imagery in quantity, we would hope that NASA would supply copies more freely.

The false-colour imagery ordering system is irksome. It is the most popular form of imagery and half the advantage of it is lost if it can only be obtained a year after acquisition.

The major problem for Botswana is the lack of photographic services - this is why we are so dependent on NASA for supply of the colour imagery.

As a final point, the American ERTS catalogues are ponderous and well-nigh impossible to interpret except for the more dedicated amongst us. We suggest, that for Botswana at least, a picture index is much more legible.

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