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LATE CAINOZOIC DRAINAGE EVOLUTION IN THE ZAMBEZI BASIN : GEOMORPHOLOGICAL EVIDENCE FROM THE KALAHARI RIM

David S.G. Thomas* and Paul A. Shaw

*Department of Geography, University of Sheffield, Sheffield S10 2TN, U.K.
Department of Environmental Science, University of Botswana, Gaborone, Botswana

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Abstract--The development of the Zambezi drainage system is discussed within the framework of the post-Gondwana tectonic evolution of southern Africa. An internal drainage system, including the proto-Upper Zambezi, has been progressively captured during the late Cainozoic by a more agressive coastwise system. Supporting geomorphic evidence is presented from the eastern Kalahari rim. Drainage alignments and gradients, and terrace sequences are discussed. Lacustrine features found on the present watershed between the Middle Zambezi and internal systems are described and explained as remnants of the former proto-Upper Zambezi tributary system. Their interaction with linear dune activity is also examined. Despite the problems of dating the drainage changes described, it is concluded that their elucidation is important in understanding sedimentation and landform development in the eastern part of the Kalahari basin.

INTRODUCTION

Interest has been growing over the past two decades in environmental and climatic changes in central southern Africa, with much of the recent research in the region directed towards events in the late Quaternary (e.g. Cooke 1980, Cooke and Verstappen 1984), and palaeohydrological developments in particular. There is, also, however, a legacy of research which has attempted to place central African drainage evolution and environmental changes within a longer time perspective, partly in recognition of the importance of major tectonic events for the shaping of sub-continent as a whole.

In central Africa, earth scientists have been fascinated by the evolution of the Zambezi drainage system. The contrasts between the upper and middle reaches of its course (e.g. Du Toit 1933) and the development of the Victoria Falls e.g. (Dixey 1945) have contributed to this interest.

In its upper reaches, for almost a third of its total length, the Zambezi flows across the northeastern extremity of the Kalahari basin. This basin is occupied by Kalahari System sediments, dominated at the surface by the Kalahari sand which extends over 2.5 mil km^2 of central and southern Africa. The Kalahari has been described as a vast basin of internal drainage (Cooke 1980), which has received sediments since at least the early Tertiary (Dingle et al 1983). Yet today one of the most notable aspects of the southern half of this basin (latitude 18°S to 27°S) is the virtual absence of surface drainage. Therefore the evolution of drainage in this region is an important factor when the deposition of these Cainozoic sediments is considered.

In this paper, therefore, we firstly examine the development of ideas, which have often been speculative, about the evolution of the Zambezi drainage. Secondly, we present geomorphological evidence for late Cainozoic developments in the palaeodrainage of the eastern Kalahari rim, and examine their significance.

THE EVOLUTION OF THE ZAMBEZI SYSTEM

The present course of the Zambezi is relatively young, dating from the Pliocene (e.g. Lister 1979) or even the mid-Pleistocene (Bond 1975), and has evolved through the effects of drainage capture and tectonic activity. Early theories of the evolution of the Zambezi system, put forward by Du Toit, Dixey and Wellington, have contributed significantly to later views on the subject. The principles of their ideas are readily in accord with the model of post-Gondwanaland tectonic evolution of the sub-continent, proposed by, amongst others, De Swardt and Bennet (1974). This was first eluded to by Krenkel (1928), and recognises the significance of regional variations in the rates and nature of tectonic movements in southern and central Africa.

The final division of Gondwanaland in the mid-Jurassic left southern Africa with an uplifted marginal hingeline, often equated with the Great Escarpment (De Swardt and Bennet 1974), and a gently downwarped interior basin, which later provided the setting for the deposition of the Kalahari system (Fig. 1), including the extensive Kalahari sand (Thomas 1984). From this tectonic framework, a duality of drainage evolved; relatively short streams, with steep gradients, extending from the hingeline to the coast, and an endoreic system flowing in the opposite direction from the hingeline to the interior. The Okavango is the only major river which remains from this system today.

Ignoring the details imposed by climatic changes and further tectonic activity, drainage evolution since the late Jurassic has therefore essentially been a process of progressive capture of the internal system by the more agressive exoreic system (e.g. De Heinzelin 1963). Evidence for this comes from the Cunene in Angola (Beetz 1933), Fish River in Namibia (Wellington 1955), Orange - Vaal system (Schmitz 1968, Smit 1977) as well as from the Zambezi. The concept of an extensive early post-Gondwana endoreic drainage system becomes more significant when it is recognised that such a system is one of the few feasable mechanisms that can account for the initial deposition of the Kalahari System sediments.

It has long been recognised that the Upper Zambezi, above the Victoria Falls, and the Middle Zambezi must have evolved as separate systems only to be linked relatively recently. Du Toit (1927, 1933), Wellington (1955), Bond (1963) and Grove (1969) all proposed that the Upper Zambezi formerly continued its southerly course, crossing what is now Botswana to join the Orange system (Lister 1979) or Limpopo (Fig. 1b; Wellington 1955, Bond 1963. Bond (1963) cites the small catchment, small channel and large deep valley of the present Limpopo as evidence of it once being part of a larger drainage system. The Middle Zambezi was a separate river, being part of the Shire system (Bond 1963).

The southward course of the proto-Upper Zambezi was disrupted by gentle earth movements in the middle

Kalahari, probably a combination of uplift in the vicinity of the Makgadikgadi basin and downwarping in the Okavango region (Du Toit 1954, Bond 1963). This theory is given support by undisputed evidence of tectonism in the area today (e.g. Reeves 1972, Hutchins et al 1976, Cooke 1980).

The severance of the Upper Zambezi course may have caused endorism in the system (e.g. Du Toit 1926), prior to the link with the Middle Zambezi being established through the Livingstone syncline. This creates the interesting possibility of a source of water for an ancestral, pre-Pleistocene, Lake Paleao-Makgadikgadi (Fig. 1c). Evidence for such an ancient lake can be seen on Landsat imagery of northern Botswana (Mallick et al 1981). The linking of the two ancestral components of the Zambezi occurred before the late Pleistocene, but not earlier than the Pliocene (see Dixey 1950, Bond 1975, Lister 1979).

The history of the Middle Zambezi is equally important to the overall evolution of the drainage in this region. Renewed downwarping along the ancient Gwembe and Chicoa troughs caused the development of the proto-Middle Zambezi (Bond 1963, Williams 1975, Lister 1979). This river cut westwards along the trough line, through basal Kalahari and Karoo beds (Bond 1963), with local base levels being established when resistant bands of pre-Cambrian gneisses were encountered below the karoo sediments (Lister 1979).

Wellington (1955, p. 471) proposed that the Luangwa River was a tributary of the proto-Upper Zambezi, flowing south-westwards through the Gwembe trough before being captured as part of the evolution of the Middle Zambezi (Fig. 1). If so, this and the extension of the Middle Zambezi above the Chicoa Gorge, must have post dated the Cretaceous, for at that time part of the drainage in the area centred upon a shallow

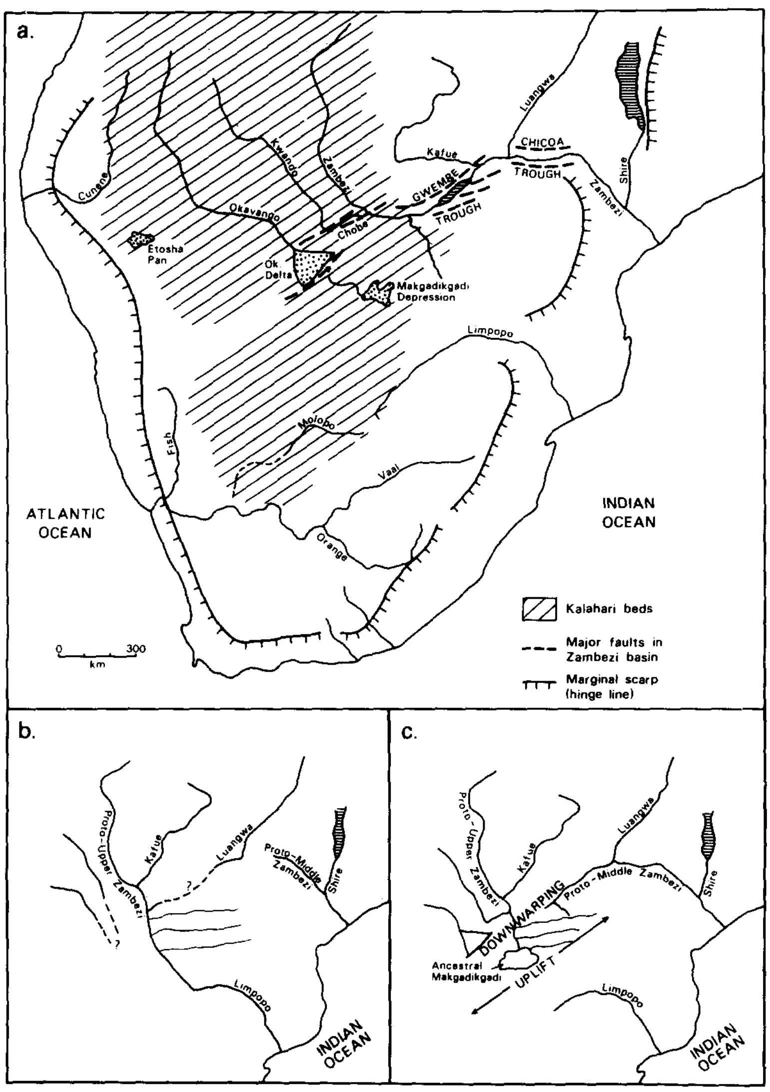

Fig. 1. Present day drainage in southern Africa. Earlier patterns are represented in b) and c): b) post-dates the division of Gondwanaland; c) existed prior to the union of the proto-Middle and proto-Upper Zambezi rivers, during the Pliocene - early Pleistocene.

depression in cental northern Zimbabwe, in which the calcareous Gokwe Beds were deposited (Lister 1979, Sutton 1979).

Following the establishment of the present Zambezi course, further downwarping along the Gwembe trough led to renewed incision (Dixey 1945). This was part of a more general rejuvenation of coastward flowing rivers, caused by renewed uplift along the coastal hingelines (De Swardt and Bennet 1974). Consequently, the Pleistocene erosion achieved by the Middle Zambezi has been described as 'immense' (Dixey 1950, p. 11). This was responsible for the rapid evolution of the Victoria Falls and, in the space of about a quarter to half million years (Bond 1975), the formation of the incised Middle Zambezi Gorge.

The Kafue River, in Zambia, has also evolved an unusual course, taking an abrupt eastward turn at Hezhitezhi. This can also be explained by capture, related to the evolution of the Zambezi (Williams 1975). Bond (1963) noted how the early Kafue flowed south-westwards to join the Upper Zambezi. The course was along a gap, 2 km wide and at an altitude of about 1070 m.a.s.l. which now crosses the present Kafue - Zambezi watershed, between Hezhitezhi and Mambova. This is now an alluvial flat, poorly drained by the Nanzhila and Simatenga streams, but the alluvium is underlain by course current-bedded fluvial gravels (Clark 1950).

The capture of this river can not simply be explained in the same manner as that of the Upper Zambezi. The present easterly flowing section of the Kafue, below Hezhitezhi, has undergone drainage reversal (Dixey 1955), once being part of the system joining the Upper Zambezi. In this respect the process must have been similar to, but post-dating, the capture of the Luangwa. Williams (1975) notes how, on the divide between the Middle Zambezi and the Kafue, the south flowing tributaries of the former are more aggressive than those flowing north to the latter. It therefore seems likely that the Kafue system was captured by a Middle Zambezi tributary. This view is completely in keeping with the rapid Pleistocene development of the Middle Zambezi envisaged by Dixey (1950).

Although speculation has played a major role in the development of the ideas described above, central African ichthyological studies support the theory of separate evolution of the proto Upper and Middle Zambezi systems. Fish species in the Upper Zambezi and Kafue form part of an 'Okavangian' fauna, distinct from that of the Middle Zambezi (e.g. Jackson 1961). Bond (1963) and Jubb (1964) suggested that the Victoria Falls were an obstacle to integration of the two fish populations, but it has since been demonstated that the barrier to integration was ecological, not physical. Following the construction of the Kariba Dam, slow-water habitats, prevoiusly limited to the Upper Zambezi, were available in the middle reaches of the river. This facilitated a successful invasion below the Victoria Falls by **Alestes lateralis,** previously confined to the Upper Zambezi and the Kafue (Balon 1971, 1974).

DRAINAGE DEVELOPMENT ON THE EASTERN KALAHARI RIM

Important evidence of drainage development in the Upper and Middle Zambezi catchments occurs in northwestern Zimbabwe and northeastern Botswana. Drainage in this area today is divided between two very different systems: a low density system of emphemeral streams draining west towards the middle Kalahari region, and more numerous and agressive tributaries of the Middle Zambezi (Fig. 2). The watershed between these systems, coinciding approximately with the border between Botswana and Zimbabwe, reflects the extent of headward erosion by right-bank tributaries of the Middle Zambezi into the eastern flank of the Kalahari basin. This is related to the renewed incision of the Middle Zambezi along the Gwembe Trough (e.g. Dixey 1945, 1950) in the Upper Pleistocene, and has had the effect of causing the basin rim to have the appearance of a plateau edge, at 1050 - 1100 m.a.s.l.

Drainage patterns of the Middle Zambezi tributary system

East of Kalahari - Middle Zambezi watershed, in northwestern Zimbabwe, disparities between drainage patterns to the east and to the west of the Gwayi river have been discussed by Thomas (1983/4). The Matetsi and Deka systems have incised westwards into the rim of the Kalahari basin, exposing underlying

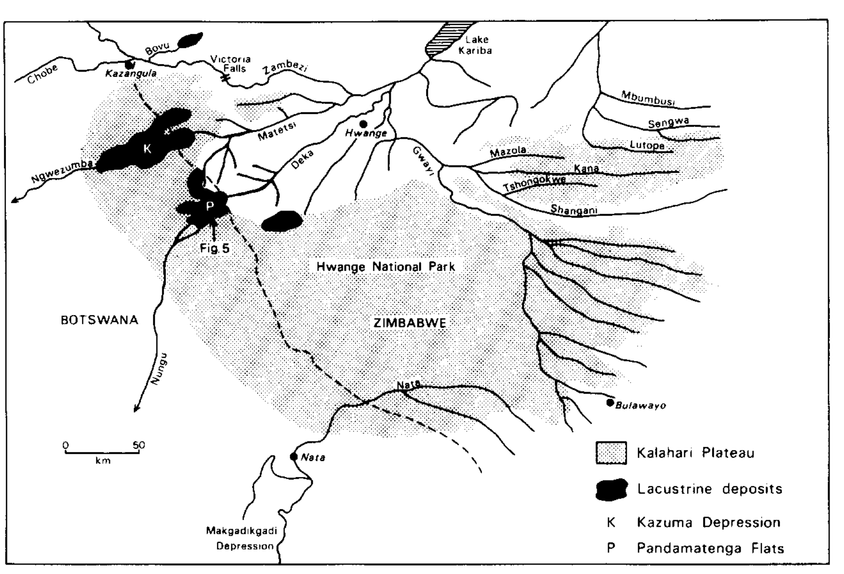

Fig. 2. Drainage in northeast Botswana and northwest Zimbabwe.

Karoo sediments and basalts with the local base level controlled by the height of the Middle Zambezi. These rivers have very steep gradients, the Matetsi having a mean gradient of 4.34m km^{-1} over the 122 km from the watershed to the Zambezi, and the Deka a gradient of 4. 69m km^{-1}. Incision below the Kalahari plateau is up to a maximum depth of 500m, and has created a series of Kalahari outliers to the north and east of the palteau rim.

The Gwayi, which joins the Zambezi at Devil's Gorge has, on the other hand, cut south-eastwards into the plateau. This river is notable for the lack of significant left bank tributaries, whereas it is joined from the east by remarkable straight sub-parallel streams. The largest, the Shangani, has incised 130m through the Kalahari sediments near its confluence with the Gwayi. The others, however, display only limited downcutting, with the Tshongokwe, Kana and Mazola having relatively low gradients (1.94m km^{-1} for the Kana) and courses mainly flowing on Kalahari sand. Further north, the Sengwa, Lutope and Mbumbusi, which are not tributary to the Gwayi, also display significant straight westward components in their courses.

Thomas (1983/4) proposed that the straight, sub-parallel drainage to the east of the Gwayi had evolved upon a linear dune landscape on the Kalahari sand. We can now add that these rivers were formerly part of the tributary system of the proto-Upper Zambezi, which is in accord with the history of regional drainage evolution put forward by Lister (1979). Headward erosion by the Gwayi, in conjunction with the evolution of the Middle Zambezi drainage, has contributed signigicantly to the progressive capture of the east-west system, formerly tributary to the proto-Upper Zambezi. This also accounts for the lack of significant Gwayi west bank tributaries, for south of the Deka system, the watershed of the Middle Zambezi network is parallel, and a few kilometres west of the Gwayi valley.

Terrace sequences.

It may therefore be hypothesised that the streams to the west of the watershed, for example the Ngwezumba, draining into the Mababe depression, and the Nata, which enters Sua Pan, are remnants of the left bank tributaries of the proto-Upper Zambezi. Evidence to support this theory comes from terrace sequences in Sikumi vlei and on the Ngwezumba River.

Sikumi vlei is a short, 15 km long west bank tributary of the Gwayi, its floor 40m below the Kalahari plateau and situated just to the east of the boundary of Hwange National Park (Fig. 3). It is typical of many Zimbabwean dambos (Whitlow 1984), having a relatively broad, low gradient floor, containing relatively thick peat deposits and poor channel development with little lateral flow. Three kilometres from the confluence with the Gwayi, a terrace sequence is exposed on the north side of the valley, which at this point is cut into the Karoo sandstone that underlies the Kalahari sand.

The sequence is shown in Fig. 3 and described in table 1. It is unknown whether the basal Kalahari beds, represented by conglomerates and siliceous sandstone, were deposited in a valley with the same alignment as the one present today, or whether they are more extensive, with the present valley cut down into them. As Karoo sandstone is exposed higher up the valley side, above the outcrop of basal Kalahari Beds, it is suggested their depostion was within a pre-existing valley. This is analogeous with the situation in the Middle Zambezi valley described by Dixey (1950). The surface of much of the terrace sequence is mantled by a poorly sorted colluvium. This is mainly composed of angular silcrete pieces in a matrix of reworked Kalahari sand, derived from the plateau surface.

The most significant units of the sequence, however, are the upper and lower gravels and the white and pink alluvia, which are all fluvial deposits. It is beyond the bounds of reason to account for these deposits in terms of fluvial activity related to the present vlei. Furthermore, there is not a suitable source for the gravels within its Kalahari plateau catchment.

The second section of fluvial gravels comes from the Ngwezumba in north eastern Botswana. This ephemeral sand river drains westwards from one of the alluvial areas on the Zimbabwe - Botswana to the Mababe depression (Shaw 1985). Although the lack of detailed height data recludes greater accuracy, this stream falls approximately 100m over the 70 km from source to the Mababe depression, giving a mean gradient of 1.43m km^{-1}.

At Ngwezumba dam in Chobe National Park, basal Kalahari beds are exposed on the southern side of the present channel. On the north side, a section displays 3.5m of loosely cemented bedded gravels and alluvium

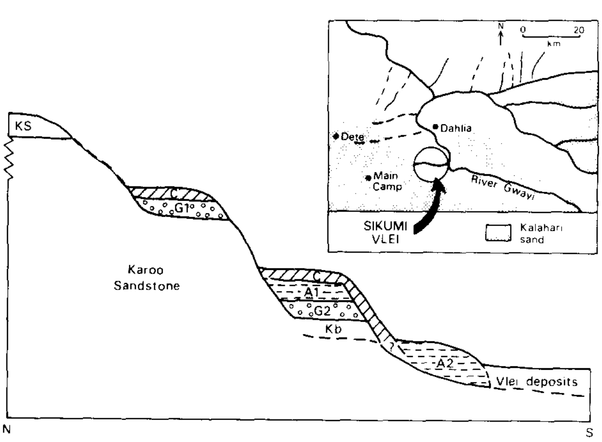

Fig. 3. The terrace sequence at Sikumi Vlei. Inset: location of Sikumi Vlei.

UNIT	DESCRIPTION	MAX. THICKNESS OF UNIT
Kb	Basal Kalahari beds. Siliceous sandstone and ferruginous cemented conglomerate	1m
Ks	Kalahari sand. On plateau surface	--
G 1	Upper gravel terrace. Unconsolidated, primarily quartz pebbles, up to 5cm in diameter	1m
G 2	Lower gravel terrace. Largely unconsolidated, but some cementing at base. Mixed lithologies inc. quartz, jasper, agate, basalt, chert. Rounded, max. diameter 6cm, av. 2cm.	1.8m
A 1	Pale alluvium.	1m
A 2	Pink alluvium. 4% clay, 26% silt, 70% sand	3m
C	Colluvium. Reworked Kalahari sand and angular silcrete fragments. Inc. gravels downslope from G 1.	0.4m

Table 1. Description of Sikumi Vlei terrace sediments (see figure 3).

(Fig. 4) which are clearly distinct from the Kalahari conglomerate. The gravels are largely composed of well rounded green and white silcretes, jasper, chert and agate, and more angular pebbles of Kalahari conglomerate. Some of the clasts in the gravel section are up to 0.3m in diameter.

The silcrete and conglomerate pebbles were probably derived from sources within the Kalahari plateau, and both are exposed **in situ** in sections in the present Ngwezumba channel. Agate is found in association with Karoo basalt, of which there are small exposures in the Kazuma depression. The degree of rounding of the gravels suggests considerable fluvial transport. Although the Ngwezumba was an active river during late Quaternary high lake stages in the Mababe depression (Shaw 1985), only fine deltaic sediments were deposited. We therefore suggest that the gravels are bedload deposits associated with high flow at a time when the Ngwezumba had a more extensive catchment.

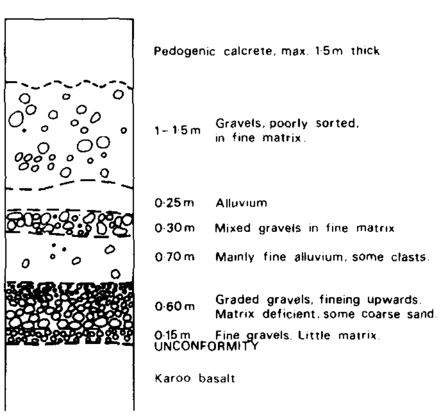

Fig. 4. Gravel sequence at Ngwezumba dam.

Other gravel exposures occur as thin surface spreads further down the course of the Ngwezumba, and on the Kalahari plateau edge near Pandamatenga. It is not possible, however, to distinguish these from **in situ** weathered basal Kalahari conglomerate.

We consider though that the Sikumi vlei terraces and Ngwezumba dam gravels are evidence for the existence of more extensive drainage into north Botswana from an easterly direction, pre-dating incision of, and capture by, the present Middle Zambezi tributaries. Our hypothesis is supported by the asymmetry of the Gwayi tributary network, and the strong east - west directional trend of the rivers to the east of the Gwayi (Thomas 1983/4), and is in agreement with the published theorising concerning the evolution of the Zambezi drainage system in the late Cainozoic.

SURFACE SEDIMENTS AND DRAINAGE CHANGE

Mallick et al (1981) identified and mapped from Landsat imagery 'possible lacustrine developments' (p. 28) in eastern Botswana. These are situated on the watershed between the internal and Middle Zambezi drainage systems, and are hitherto uninvestigated. They are significant in the context of this study because their development in that location can not be explained in terms of the present drainage of the region.

The largest of these, known as the Kazuma Depression where it extends into Zimbabwe, covers about 1000 km (Mallick et al 1981), whilst 50 km south a second, near Pandametenga, extends over about

800 km^2 (Fig. 2). Other smaller, lacustrine developments occur on the northern edge of the sand plateau in Hwange National Park, Zimbabwe. In all cases the margins of the depressions are being eroded, as part of the retreat of the Kalahari rim effected by the Middle Zambezi system.

In places, Karoo basalts and basal Kalahari Beds are exposed on the depression floors. It is not surprising, therefore, that soils are in part composed of weathered basalt, and they have been described as such in a recent FAO report (FAO 1986), and an earlier one produced by the Rhodesian Soil Survey (Sweet 1970). However, over large areas they also contain a significant alluvial component, derived at least in part from reworked Kalahari sand (Thomas 1987). The floors of the depressions are up to 20m below the height of the surrounding sand plateau. Because of their watershed position, the origin of these lacustrine features can only be explained as part of the former westward draining proto-Upper Zambezi tributary system.

Although they have not been investigated in the field, similar lacustrine developments can be identified from Landsat imagery of Western Zambia. These features occur within the Kalahari sand too, and are found in association with east bank tributaries of the Zambezi. For example, the Bovu River, which enters the Zambezi from due north about 10 km east of Kazangula, crosses a flat alluvial-floored depression of some 100 km^{-2}, before abruptly deviating from its southwestward orientation to decend the flank of downwarped Zambezi trough.

The evolution of many features of the hydrological system of the Middle Kalahari has been controlled by faulting and gentle tectonic activity. The 1978 Photogeologic map of Botswana indicates that parts of the southern margins of the Kazuma and Pandametenga lake flats are fault controlled. However, the 1984 Botswana geological map shows that in the vicinity of the flats there are relatively few faults in the underlying basalt, and therefore tectonisism alone can not account for their location. From Landsat imagery, it can be seen that their margins are partially defined by linear dunes, part of the extensive fossilised erg which continues eastwards on the sand plateau into Zimbabwe (Thomas 1984).

The relationship between dunes and lacustrine features is in fact complex. The edges of the bounding dunes have been trimmed by water action, and process is probably continuing to a limited extent today, for during years of good local rains the depressions may be temporarily inundated by shallow water bodies. However, stabilised dunes also extend down onto the lake flats, and on the southern margin of the Pandametenga depression, a water-trimmed dune stump

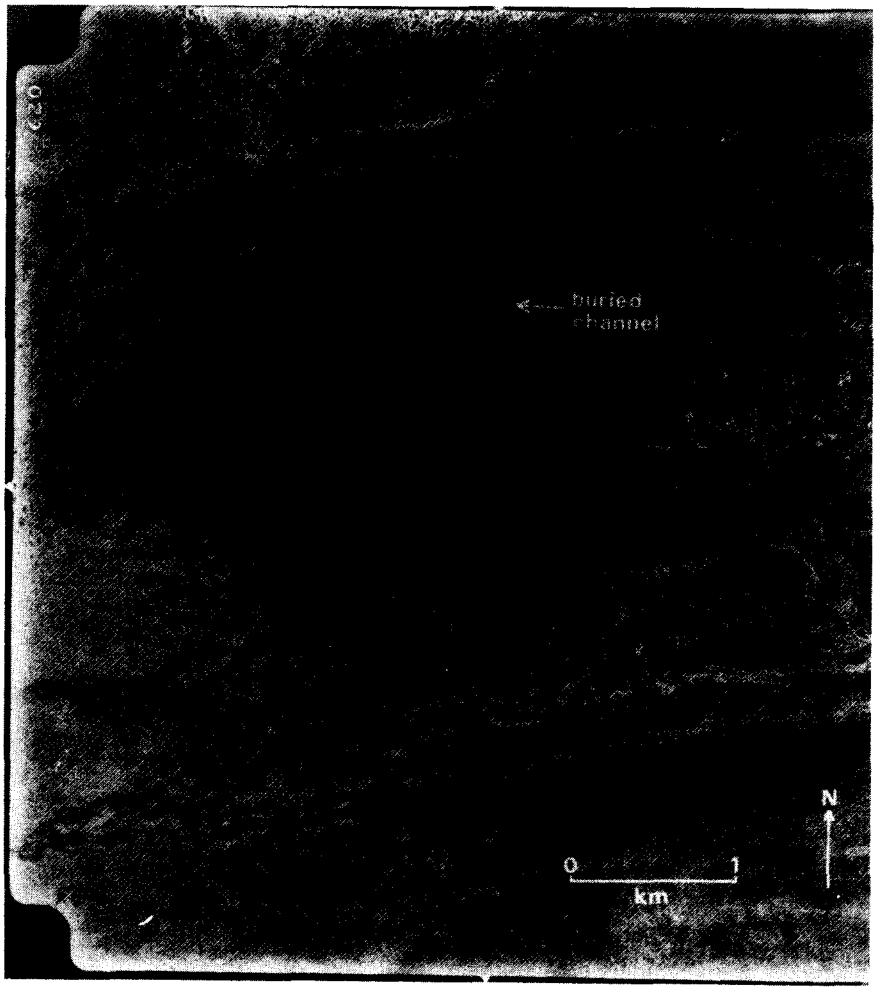

Fig. 5. Aerial photograph showing relict linear dune stump overlying a former channel of the Nungu River, eastern Botswana.

can be seen overlying an old abandoned channel of the Nungu River (Fig. 5). There have clearly been alternations between periods of aeolian activity and periods of permanent or semi-permanent water in the depressions since the Pliocene, but we are currently unable to shed any light on the details of chronologies.

DISCUSSION

Drainage evolution in central Africa has evoked interest since the time of Livingstone (1858). During the ensuing period there has been considerable speculation, but a general concensus of opinion, that the present Zambezi course was established no earlier that the Pliocene, and perhaps as late as the middle Pliestocene. The present system of tributaries has been evolving since then and represents a process of superimposition on and capture of the pre-Zambezi drainage that had evolved since the Jurassic.

This process has been affected and in part determined by tectonic movements which have operated in favour of enhancing the power of the Middle Zambezi and its tributaries, resulting in the capture of the proto-Upper Zambezi, and its tributary system. Thus Wiliams (1975) describes the capture of the Kafue by a left bank Middle Zambezi tributary, and we assign the capture of the westward flowing rivers in northern Zimbabwe to steep gradient right bank tributaries of the Middle Zambezi, including the Gwayi,Deka and Matetsi.

The effect has been to deprive the few westward flowing streams in northern Botswana of their former headwaters, which are now east-bank tributaries of the Gwayi. Both these systems retain the relatively low gradients inherited from their ancestral protoUpper Zambezi tributaries. Their capture has also had the effect of isolating the lacustrine developments south of the Zambezi, on the Botswana - Zimbabwe border, from the streams which previously drained towards them.

As well as determining drainage patterns, this process is currently causing the westward retreat of the eastern rim of the Kalahari plateau, exhuming underlying Karoo basalts previously revealed in the Hwange area. In broader terms, the drainage changes are part of the replacement of the central southern African endoreic system by a more extensive exoreic one (c.f. De Swardt and Bennet 1974), reflected in the gradual westward movement of the watershed dividing the right bank tributaries of the middle Zambezi and today's internal drainage.

Dating the major changes described above, and therefore the Sikumi terraces and the Ngwezumba gravels, in anything other than general terms is difficult. From the studies of the tectonic evolution of the subcontinent, they obviously occurred no earlier than the late Pliocene, and before the late Quaternary environmental changes identified from palaeohydrological studies in the Middle Kalahari (Shaw and Cooke 1986).

During the period in which the east - west drainage flowed into northern Botswana and the proto-Upper Zambezi, it is probable that major changes in flow regimes occurred. This is indicated by the variations in the size of material forming the different terraces within the Sikumi sequence, and the fact that periods of incision occurred to create the terraces. Presumably, tectonic movements causing changes in base level and climatic changes were responsible. In the absence of further corroborating evidence, however, it is currently not possible to make further deductions about river regimes.

Relationships between drainage development and the Kalahari beds are potentially of interest, but the age of these sediments largely remains a matter of speculation (e.g. Dingle et al 1983). That rivers to the east of the Gwayi were dune-aligned, and lake depressions now on the Kalahari rim were at least partially delimited by the same control may be more significant. The problems of directly dating the dune systems (e.g. Thomas 1984, Shaw and Cooke 1986) and the occurrence of multiple periods of aridity during the Pleistocene in the Kalahari basin do not, however, assist in objective assessments of the age of these features or of the drainage changes.

Nevertheless, in spite of these problems, the importance of the drainage changes evidenced by the lacustrine developments and the terrace sequences in northwestern Botswana and northeastern Zimbabwe can not be over looked. Not only do they reflect major aspects of the Cainozoic tectonic and hydrologic evolution of the sub-continent, but it is only through their recognition and interpretation that a better understanding of certain aspects of regional landforms and sediments can begin.

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REFERENCES

Balon, E.K. 1971. Replacement of **Alestes imberi Peters, 1952** by **A. lateralis** Boulenger, 1900 in Lake Kariba, with ecological notes. **Fish. Res. Bull. Zambia 5, 119-162.**

Balon, E.K. 1974. Fish production of the drainage area and influence of ecosystem changes on fish distribution. In: Balon, E.K. and Coche, A.G. (eds) **Lake Kariba: a man-made tropical ecosystem in central Africa.** Junk, The Hague. 459-523.

Beetz, P.F.W. 1933. The geology of south west Angola between Cunene and Lunda axis. **Trans. Geol. Soc. S. Afr. 36: 136-176.**

Bond, G. 1963. Pleistocene environments in southern Africa. In: Howell, F.C. and Bouliere, F. (eds): **African ecology and human evolution** Viking Fund Publications in Anthropology. Aldine, Chicago. 648-654.

Bond, G. 1975. The geology and formation of the Victoria Falls. Chapter 2 In: Phillipson, D.W. (ed): **Mosi-oa-Tunya-a handbook of the Victoria Falls region.** Longman, London. 19-48.

Clark, J.D. 1950. **The stone age cultures of Northern Rhodesia. S. Af. Archeol. Soc. 157p.**

Cooke, H.J. 1980. Landform evolution in the context of climatic change and neo-tectonisism in the middle Kalahari of northern central Botswana. **Trans. Inst. Brit. Geogr. N.S.5: 80-99.**

Cooke, H.J. and Verstappen, B. Th. 1984. The landforms of the western Makgadikgadi basin of northern Botswana, with a consideration of the chronology of Lake Palaeo-Makgadikgadi. **Z. Geomorph. NF 28: 1-19.**

De Heinzelin, J. 1963. A tentative Paleogeographic map of Neogene Africa. In: Howell, F.C. and Bouliere, F. (eds): **African ecology and human evolution** Viking Fund Publications in Anthropology. Aldine, Chicago. 648-654.

De Swardt, A.M.J. and Bennet, G. 1974. Structural and physiographic evolution of Natal since the Late Jurassic. **Trans. Geol. Soc. S. Afr. 77: 309-322.**

Dingle, R.V., Siesser, W.G. and Newton, A.R. 1983. **Mesozoic and Tertiary geology of southern Africa.** Balkema, Rotterdam.

Dixey, F. 1945. The geomorphology of Northern Rhodesia. **Trans. Geol. Soc. S. Af. 48: 9-45.**

Dixey, F. 1950. Part 1. Geology. In: Clark, J.D. **The stone age cultures of Northern Rhodesia. S. Af. Archeol. Soc. 929.**

Du Toit, A.L. 1926. The Kalahari and some of its problems. **S. Af. J. Sci. 24: 88-101.**

Du Toit, A.L. 1933. Crustal movements as a factor in the evolution of South Africa. **S. Af. Geogrl. J. 16: 3-20.**

Du Toit, A.L. 1954. **The geology of South Africa 3rd. edn.** Oliver and Boyd, Edinburgh. **463p.**

FAO 1986. Report on the reconnaissance soil survey: **Kasane sheet. FAO / UN devel. project / Govt. Botswana BOT/80/003.**

Grove, A.T. 1969. Landforms and climatic change in the Kalahari and Ngamiland. **Geogl. J. 135: 191-212.**

Hutchins, D.G., Hutton, S.M. and Jones, C.R. 1976. The geology of the Okavango Delta. **Proceedings of the symposium on the Okavango Delta and its future use.** Botswana Society, Gaborone. 15-19.

Jackson, P.B.N. 1961. **The fishes of Northern Rhodesia. A check list of indigenous species.** Government Printer, Lusaka. 140p.

Jubb, R.A. 1964. **Some fishes of the Victoria Falls region. In: Fagan, B.M. (ed) A handbook to the Victoria Falls, the Batoka Gorge and part of the Upper Zambezi River.** Comm. Pres. Nat. Hist. Mon. Northern Rhodesia. 129-140.

Krenkel, E. 1928. **Geologie Afrikas Vol. 2.** Leipzig, Germany. 677p.

Lister, L.A. 1979. The geomorphic evolution of Zimbabwe Rhodesia. **Trans. Geol. Soc. S. Af. 82: 363-370.**

Livingstone, D. 1858. **Missionary travels and researches in South Africa. New York.**

Mallick, D.I.J., Habgood, F. and Skinner, A.C. 1981. A geological interpretation of Landsat imagery and air photography of Botswana. **Overseas Geol. Miner. Res. 56: 36p.**

Reeves, C.V. 1972. Rifting in the Kalahari? **Nature 237: 95-96.**

Williams, G.J. 1975. Geomorphology of the Southern Province of Zambia. **Zamb. Geogl. Ass. Handbook Series 4: 19-40.**

Schmitz, G. 1968. **The plateau area of South Africa. Schmitz, South Africa. 15p.**

Shaw, P.A. 1985. Late Quaternary landforms and environmental change in northwest Botswana: the evidence of Lake Ngami and the Mababe Depression. **Trans Inst. Br. Geogr. N.S. 10: 333-346.**

Shaw, P.A. and Cooke, H.J. 1986. Geomorphic evidence for the late Quaternary palaeoclimates of the middle Kalahari of northern Botswana. **Catena 13: 349-359.**

Smit, P.J. 1977. **Die geohidrologie in die opranggebied van die Molopo rivier in die noordelike Kalahari. Unpubl. Ph. D. Thesis, University of the Orange Free State, South Africa.**

Sutton, E.R. 1979. The geology of the Mafungabusi area. **Bull. Rhod. Geol. Surv. 81: 318p.**

Sweet, C.P. 1970. Report on the soils of the N.W. section of Wankie National Park. **Dept. Res. Special Services, Branch of Chem. and Soil Sci. Report CS/3/2/32.** Salisbury, Rhodesia. 16p.

Thomas, D.S.G. 1983/4. Geomorphic evolution and river channel orientation in north west Zimbabwe. **Proc. Geogl. Ass. Zimb. 15: 12-22.**

Thomas, D.S.G. 1984. Ancient ergs of the former arid zones of Zimbabwe, Zambia and Angola. **Trans. Inst. Br. Geogr. N.S. 9: 75-88.**

Thomas, D.S.G. 1987. Discrimination of depositional environments, using sedimentary characteristics, in the **Mega Kalahari,** central southern Africa. In: Frostick, L.E. and Reid, I. **(eds): Desert sediments, ancient and modern geol. Soc. Lond. Spec. Publ.**

Wellington, J.H. 1955. **Southern Africa, a geographical study. Volume 1 Physical Geography. Cambridge. 528p.**

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