ECONOMIC GEOLOGY RESEARCH UNIT

University of the Witwatersrand
Johannesburg

THE ORIGIN OF THE PANS OF THE WESTERN ORANGE FREE STATE – A MORPHOTECTONIC STUDY OF THE PALAEO-KIMBERLEY RIVER

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by

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ABSTRACT

Although the pans of the western Orange Free State have been modified and propogated through processes of wind erosion, salt accumulation, and deflation, the fundamental reason for their presence has been poorly understood. Morphotectonic analysis of the panveld and interpretation of LANDSAT images shows that the pans are the remnants of a tectonically disrupted palaeoriver system, namely the palaeo-Kimberley River. The palaeo-Kimberley River flowed westwards across the Post-African I surface until its middle- and upper-reaches were disrupted by tectonic warping in the Pliocene. The tectonic event that disruputed the palaeoriver is related to uplift and warping along the marginal upwarp and Griqualand-Transvaal axis. An examination of the profiles of the reconstructed Kimberley River shows that the Precambrian basement between Kimberley and Wesselsbron forms a graben between two large subsurface domes. Tertiary movements along the bounding faults of this graben have been responsible for disrupting the palaeo-Kimberley River into the present-day panveld of the western Orange Free State. The pans have subsequently been modified by processes of deflation and salt accumulation.

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CONTENTS

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INTRODUCTION

Studies of the great Orange Free State panvelds have been dominated by investigations of distribution patterns and processes of modification and self-perpetuation (De Bruiyn, 1971; Le Roux, 1978). Until recently there have been few studies dealing with the fundamental origin of these pans. Although previous investigators (eg. Le Roux, 1978) have stated that their aims were to examine the nature of the origins of the pans, these objectives were never adequately addressed and, thus, the fundamental reason for the presence of the pans remained poorly understood and unexplained.

A recent morphotectonic analysis of the Wesselssbron panveld has revealed that the pans between the Vaal and Vet-Sand rivers, to the west of Welkom, are the remnants of a structurally disrupted, palaeo-drainage system (Marshall, 1987a). The pans to the south of the Vet-Sand and Vaal rivers were subsequently examined, in the light of the above study, in order to investigate the possibility that they, too, might be the result of structurally disrupted palaeodrainage. The panveld was analysed within a morphotectonic framework and the analytical techniques included fluvio-morphic reconstruction of palaeodrainage, LANDSAT interpretation, and an analysis of present and palaeostream profiles. Attention was also given to the concentration patterns of pans, both in terms of size and frequency distribution.

In this paper, the emphasis has been placed upon the morpho-tectonic analysis of the panveld between the Vaal and Modder rivers, to the southwest of the Vet-Sand rivers. In the first instance, it will be shown that these pans are the disrupted remains of a palaeodrainage system. Secondly, the nature of the disruption will be addressed, and finally, the effect of the disruption on geomorphic evolution will be discussed.

MORPHOTECTONIC ANALYSIS

The pans of the western Orange Free State and northern Cape do not occur randomly scattered across the landscape. Earlier studies have shown that the pans occur in distinct concentrations in terms both of size and percentage areal extent (Geyser, 1947; Le Roux, 1978). The distribution of pans is also zoned with respect to their numbers, or frequency of occurrence (Fig. 1). The pans were contoured by the number of pans that occur per 150km^2. The frequency distribution of pans on this scale shows two distinctly linear trends within the panveld. The panveld, as a whole, trends parallel the the Vaal River in NW-SE orientation. Within the panveld, however, secondary trends in the NE-SW orientation are obvious. These two trends, which describe the distribution of pans have been shown to express regional structural control on both the drainage lines and the topography of the Kaapvaal Craton (Marshall,1987b). This implies that the same structures are influencing the distribution patterns of the pans.

Fluvio-morphic analysis and interpretation of LANDSAT imagery indicates the presence of a well-intergrated palaeostream between the Vaal and Modder rivers (Fig. 2). The major palaeostream, the palaeo-Kimberley River, parallels the middle reaches of the Modder River is verified by channel scars, from its Vaal River confluence to at least 2 km upstream (Plates 1-4).

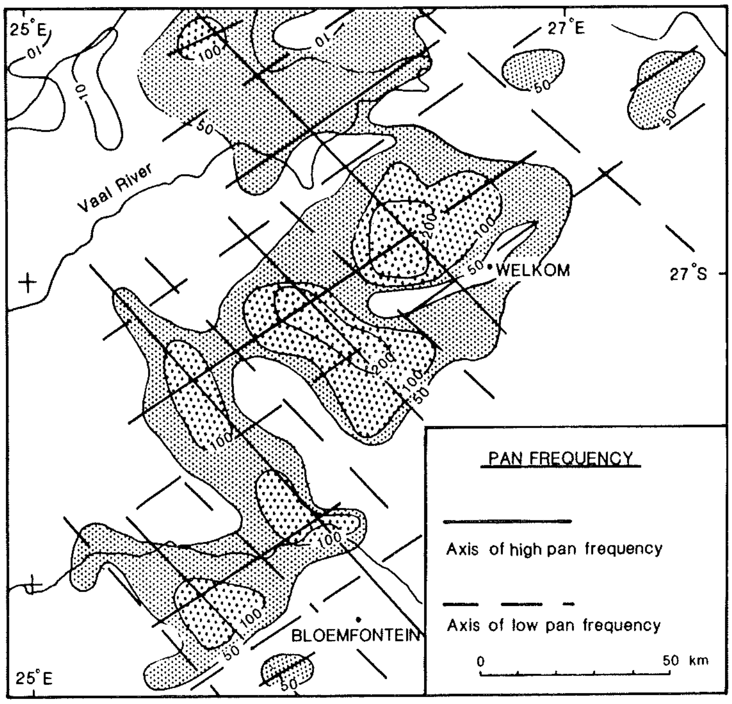


FIGURE 1: *Map of the western Orange Free State showing pans oriented in a NW-SE band parallel to the Vaal River (the pans are contoured by the number of pans per 150km²).*

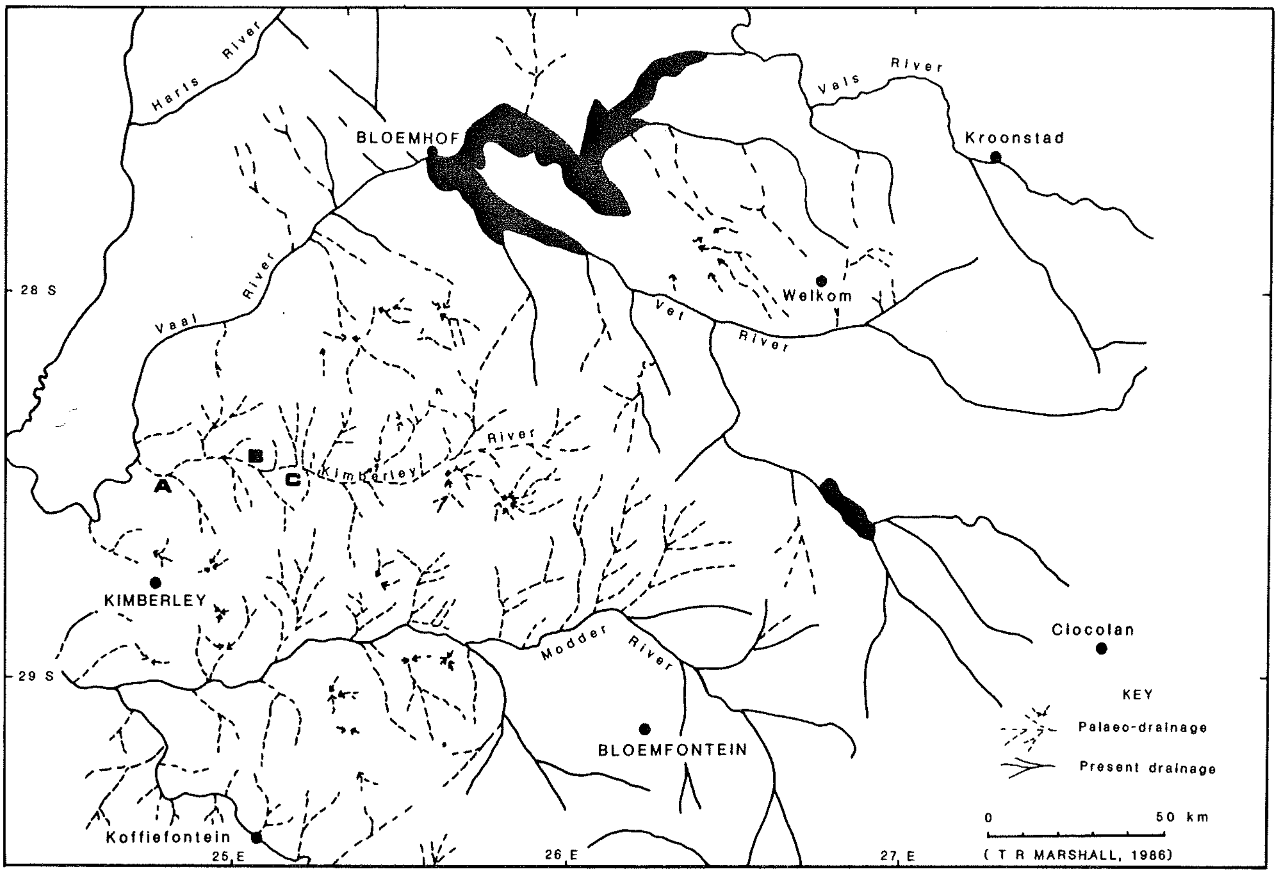


FIGURE 2: *Reconstructed palaeodrainage of the palaeo-Kimberley River and tributaries to the Vaal and Modder rivers.*

PLATE 1: *The confluence of the Vaal River with the palaeo-Kimberley River on the farm Zoutpansfontein, 34.*

PLATE 2: *The present-day extent of the palaeo-Kimberley River 10m from its confluence with the Vaal River. Note the larger channel in the middle distance.*

PLATE 3: *200m from the Vaal - Kimberley confluence, the channel of the palaeo-Kimberley River is still apparent, although totally desiccated.*

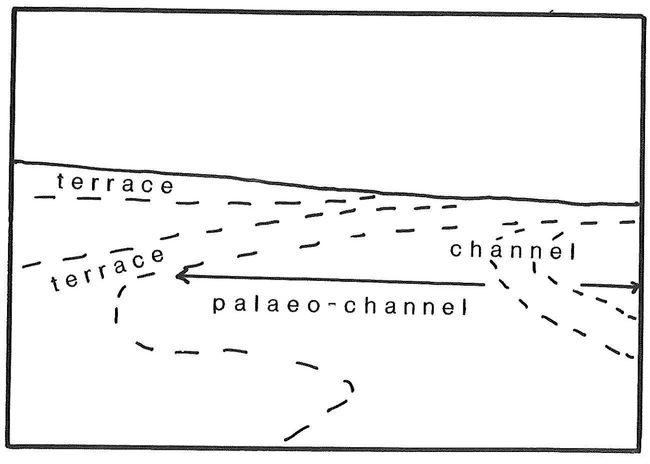
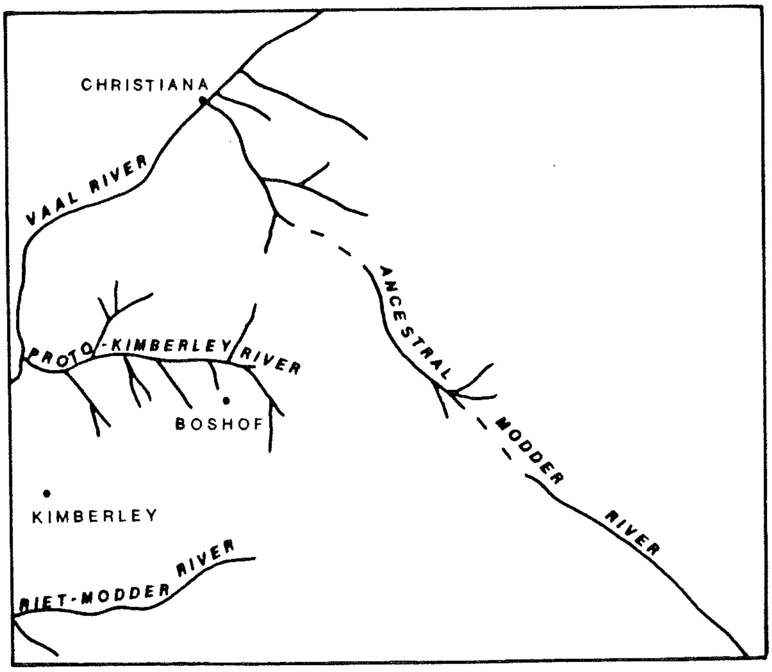


PLATE 4: *Almost 2km from the Vaal - Kimberley confluence, the palaeo-Kimberley channelis still visible. Note at least two terrace levels on the banks of the palaeochannel.*

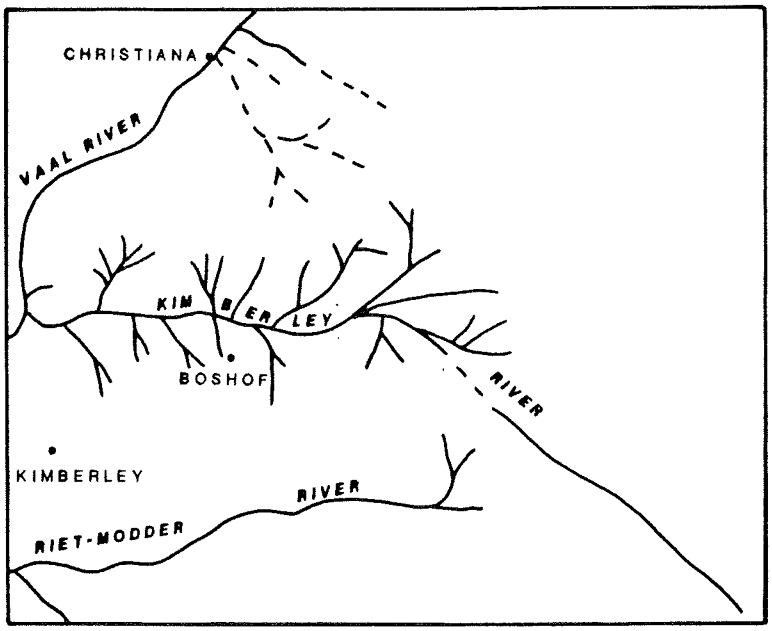
The reconstructed portions of the palaeo-Kimberley River pass through numerous pans, showing these to be remnants of the original stream system. Fluvio-morphic analysis indicates that portions of the original stream channel reflect negative, or reversed, gradients often associated with barbed and centripetal drainage patterns. Aside from the palaeo-Kimberley River, drainage reconstruction shows the presence of a number of palaeotributaries to both the Vaal and Modder rivers.

A more detailed examination of the palaeodrainage and the concentration of pans between Christiana and the Modder River indicates that the evolutionary history of the palaeo-Kimberley-Modder river system has been complex (Fig. 3). A linear zone of pans stretches southwestwards from Christiana to the Modder River. at which point the Modder River channel has a right-angled elbow of capture. The linear zone of pans, along with the elbow of capture and patterns within the reconstructed palaeodrainage, indicate that the upper reaches of the Modder River initially flowed northwestward into the Vaal River at Christiana, and that it has been pirated by both the palaeo-Kimberley and Modder rivers.

The influence of structural and tectonic events on the evolution of the palaeo-Kimberley River can be understood by analysis of both river- and topographic-profiles. The topographic profile through the maximum development of the panveld indicates that the surface on which the pans are developed has been downwarped (Fig. 4). The pans are developed on the Miocene, Post-African I surface (Partridge and Maud, 1987). The Post-African I landscape cycle was disrupted in the Pliocene by reactivated uplift along the marginal upwarp and Griqualand-Transvaal axes (see Fig.6 for the location of the features), and it is suggested that this tectonic event was responsible for the downwarping of the palaeo-Kimberley River.

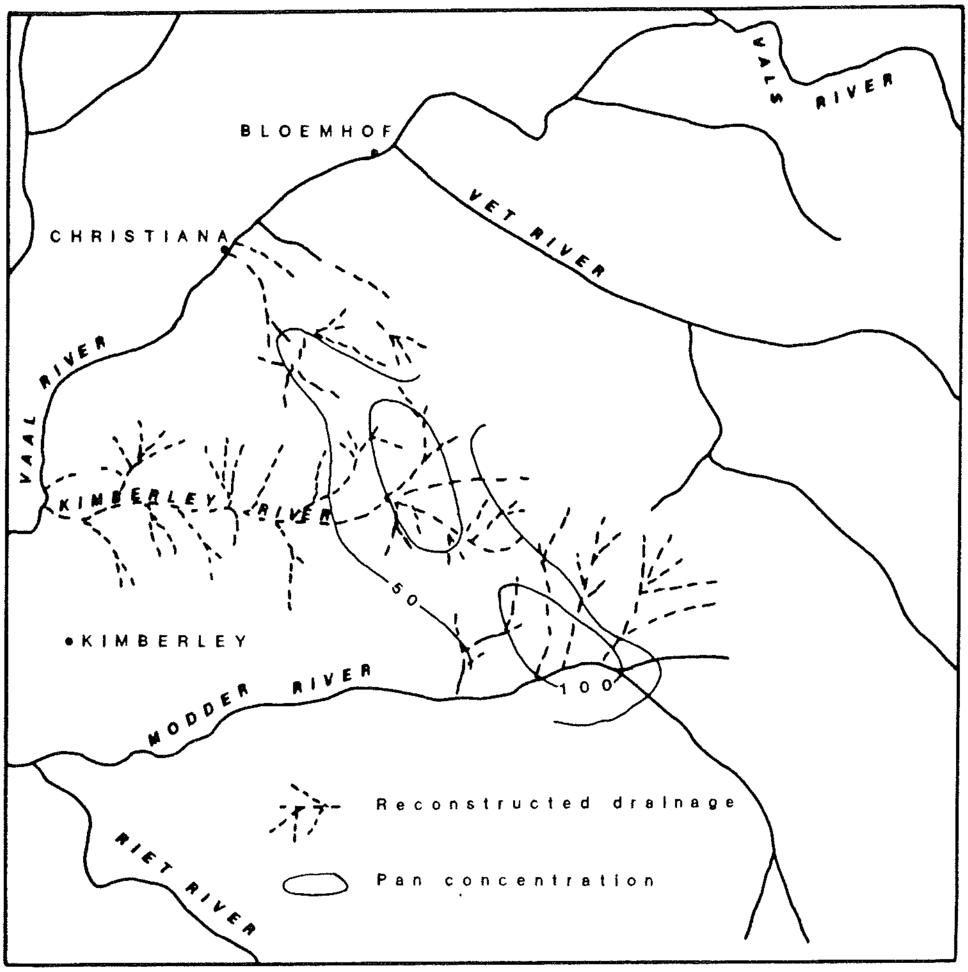


STAGE 1: *The ancestral Modder River flowed northwestwards, parallel to the ragional structural grain, to enter the Vaal River at Christiana.*



STAGE 2: *Headward erosrion of the palaeo-Kimberley River pirated the middle reaches of the ancestral Modder River. The lower reaches of the pirated stream, deprived of its headwaters, slowly dried up. The maximum development of the palaeo-Kimberley River occurred on the Post-African I surface, following structural upheaval on the marginal upwarp in the Miocene.*

FIGURE 3: *The three stages in the evolution of the palaeo-Kimberley River.*



STAGE 3: *Continued headward erosion of the lower Modder River, as a result of Pliocene uplift, pirated the upper reaches of the ancestral Modder River at the present-day elbow of capture. The Pliocene structural event also downwarped the Post-African I surface over which the palaeo-Kimberley River flowed, resulting in its disruption. Desiccating Pleistocene climates dried up the palaeostream remnants into the present-day panveld.*

FIGURE 3 (continued): *The three stages in the evolution of the palaeo-Kimberley River.*

The downwarping of the Post-African I surface in the Pliocene gives a minimum age for the palaeo-Kimberley River, i.e. it must have been at least Miocene in age.

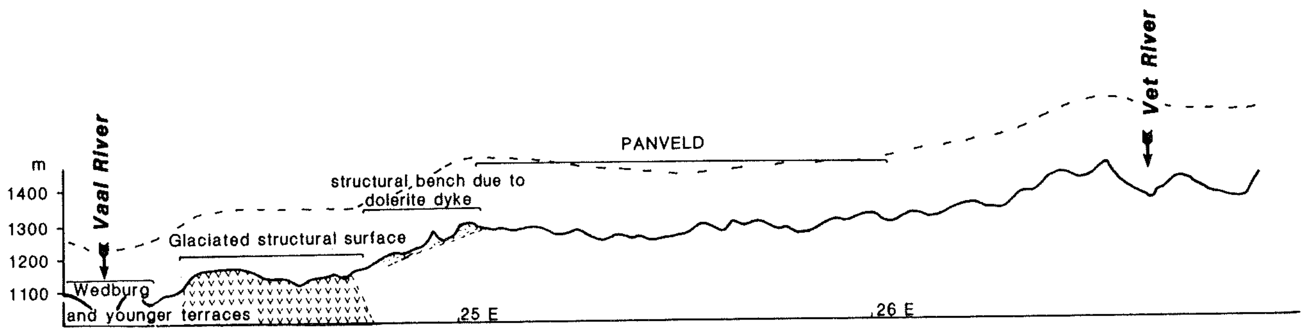


FIGURE 4: West to east topographic profile along 28°38'S, showing the downwarped-Post African I surface on which the panveld is developed.

The structures responsible for the downwarping of the palaeo-Kimberley River can be more accurately determined from an analysis of the longitudinal- and cross-profiles of the palaeo-Kimberley River (Fig. 5). Between points A and B on the profile (corresponding to points A and B on Fig 2) the cross-profiles of the palaeo-Kimberley River indicate local widening of the valley as well as the development of marshes. Furthermore, the longitudinal profile between A and B is slightly steepened, relative to elsewhere, indicating the presence of a subsurface topopgraphic high. East of C (also in Fig. 2) the profile is, however, intensely disrupted by pans, and exhibits negative, or reversed, gradients indicative of a downwarped surface. An interpretation of the Bouguer gravity anomalies between the Vaal and Modder rivers suggests a basement granitic upwarp between points A and B, and a basement graben or trough, east of C (Marshall, 1987b).

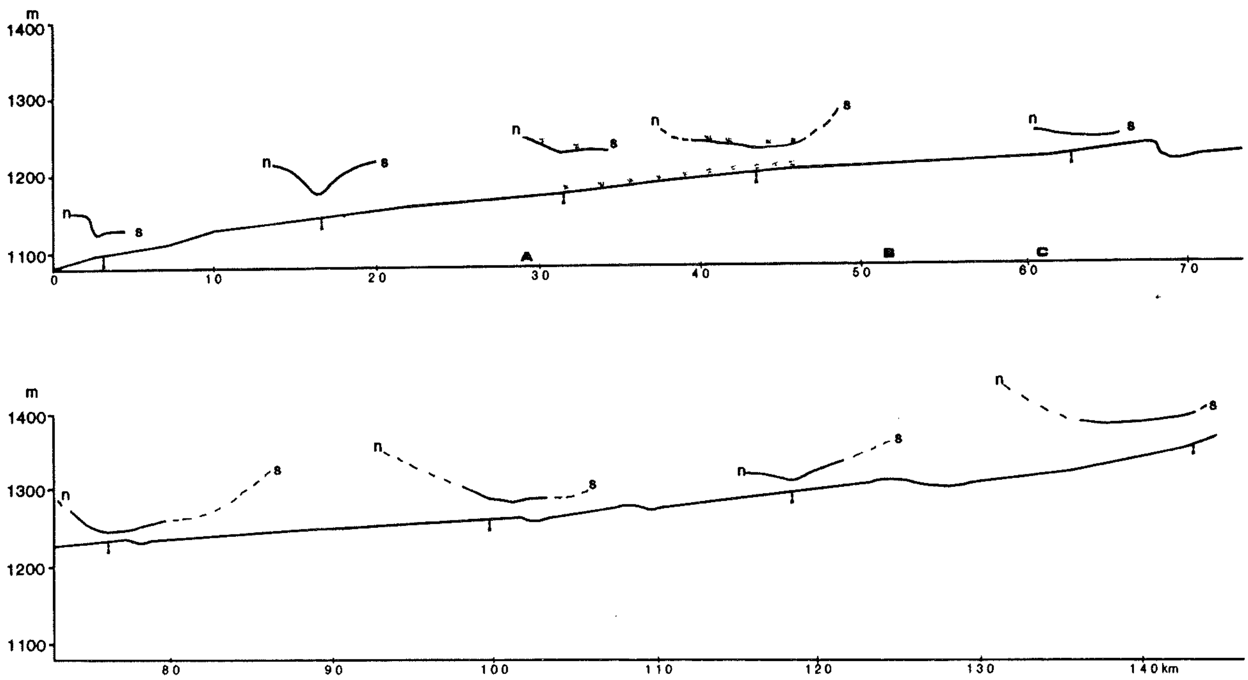


FIGURE 5: Longitudinal- and cross-profiles of the reconstructed palaeo-Kimberley River (VE = 10,5X).

DISCUSSION

Synthesis of the drainage and topographic features, along with a number of reference boreholes, indicates that the downwarped section of the Post-African I surface is controlled by fundamental basement topographic features and lineaments (Fig. 6). The northern and southern structural blocks are determined by two faults lineaments, the Bloemhof and Winburg lineaments respectively. The sense of movement on both these faults indicates that the central portion has been relatively downthrown. This is verified at the surface by drainage basin asymmetry indices. These measurements indicate that the regional plunge of the present land-surface is to the north-northwest, a result of uplift along the marginal upwarp (Marshall, 1987b). This plunge direction, however, is reversed along the

Vaal-Harts interfluve, indicating that uplift has taken place along the Griqualand-Transvaal axis. Uplift along the marginal upwarp, in the south, and the Griqualand-Transvaal axis, in the north, would necessarily indicate that the land in-between is relatively downwarped.

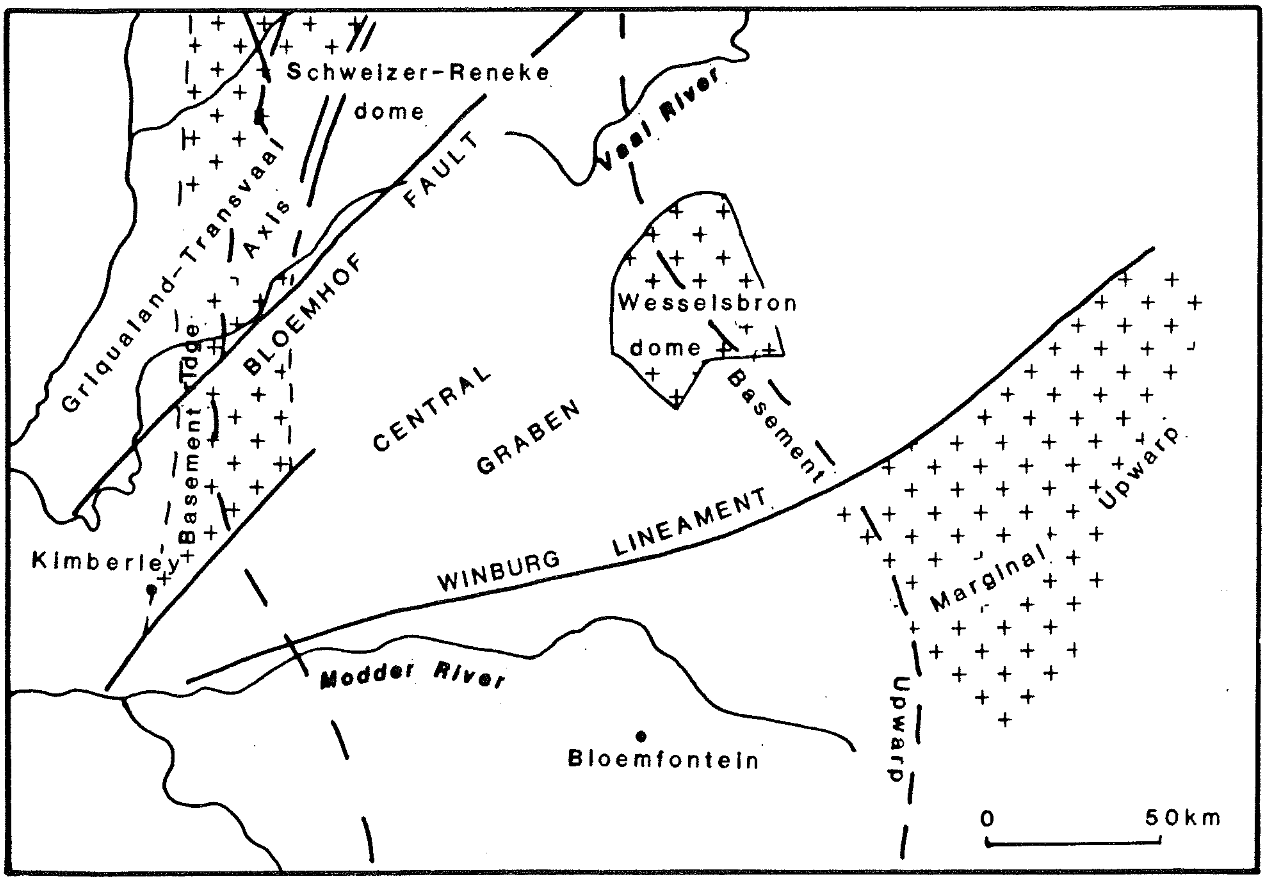


FIGURE 6: *Morphotectonics of the susbsurface features that controlled the disruption of the palaeo-Kimberley River.*

A basement ridge, between Kimberley and the Schweizer-Reneke dome, defines the western edge of the subsurface graben (the Central Graben, Fig 6). The eastern edge of the graben is defined by a second basement ridge that trends northwards through the Wesselsbron dome. Reactivated uplift, however slight, along these four basement features was responsible for the downwarping of the Post-African I surface in the centre. The subsequent backwarping eastwards of the palaeo-Kimberley River was responsible for the disruption of the river channel into the present-day panveld. Under different climatic conditions a large lake may have developed in the downwarped area (the Central Graben, Fig.6), but given the semi-arid conditions that appear to have dominated the Quaternary climates, only dry lakes or pans have survived.

It was shown earlier that the linear zone of pans between the Modder River and Christiana represented the lower- and middle-reaches of an ancestral Modder River, probably developed on the African surface, following the final rifting of Gondwanaland. The tectonic quiescence that dominated this period was broken in the Miocene by the first of two Tertiary structural events. It is postulated that uplift along the marginal upwarp in the Miocene was responsible for accelerated headward erosion of both the palaeo-Kimberley and lower Modder rivers, and that the palaeo-Kimberley River eventually captured the middle reaches of the ancestral Modder River northeast of Boshof (see Fig. 3). Continued headward erosion of the lower Modder River eventually captured the headwaters of the river at the present-day elbow of capture. The timing of this event is unclear - it may have occurred before the second Tertiary upheaval in the Pliocene, or it may have occurred as a result of this uplift. Whatever its timing there was a drastic reduction in the volume of water that flowed through the palaeo-Kimberley valley, and this may have been a major factor in the subsequent desiccation of the pans.

The second structural upheaval in the Pliocene downwarped both the Post-African I surface and the beheaded palaeo-Kimberley River that flowed across it. Subsequent to the tectonic disruption of the palaeo-Kimberley River and all the right-bank tributaries of the Modder River, the pans were modified and selectively propogated by processes of wind erosion, deflation, and salt accumulation.

The ancestral Modder and palaeo-Kimberley rivers may also be of economic interest. These rivers flowed over a late-Cretaceous-to-Tertiary landscape that was intruded by numerous kimberlite pipes and fissures. The strong possibility exists that the palaeorivers carried alluvial diamonds in their bedloads. The gravel terraces of these rivers, although down-warped and covered by metres of Quaternary cover, soil, or cultivated fields, may be diamondiferous and therefore require further investigaion.

CONCLUSIONS

1. The pans that occur in the western Orange Free state and northeastern Cape are the remnants of a tectonically disrupted, palaeodrainage system.
2. Palaeodrainage reconstruction indicates that a well-integrated, major river system (the palaeo-Kimberley River)flowed east-west across the Miocene, Post-African I plain to its confluence with the Vaal River north of Kimberley.
3. The longitudinal profile of the palaeo-Kimberley River indicates that its middle and upper reaches have been downwarped, along with the Post-African I surface, probably as a result of reactivated structural uplift along the marginal upwarp and Griqualand-Transvaal axis in the Pliocene.
4. Morphotectonic studies further indicate that the subsurface basement

topography consists of a large graben (the Central Graben) flanked, in the north and south, by two upfaulted blocks along the Bloemhof and Winburg faults respectively, and by two basement ridges in the west (through palaeo-Kimberley and the Schweizer-Reneke dome) and in the east (through the Wesselsbsron dome).

5. In the initial drainage pattern that developed on the African surface, following the final rifting of Gondwanaland, the ancestral Modder River flowed parallel to the Vet River to its confluence with the Vaal River at Christiana. Following Miocene structural displacements along the marginal upwarp, and possibly the Griqualand-Transvaal axis, the ancestral Modder River was pirated by headward erosion of the palaeo-Kimberley River. The maximum development of the palaeo-Kimberley river was, thus, in the mid-Tertiary, on the Post-African I surface. In the Pliocene, structural movement once again occurred along the marginal upwarp and Griqualand-Transvaal axis. The effects of the structural event were twofold. First, the middle and upper reaches of the palaeo-Kimberley River were downwarped east of Kimberley, thus preventing the river from flowing into the Vaal River and second, the renewed energy of the lower Modder River, supplied by uplift along the marginal upwarp, enabled it to erode headwards and capture the headwaters of the ancestral Modder River north of Bloemfontein. Desiccating Quaternary climates and a much reduced volume of water resulted in the conversion of a disrupted drainage system into a major panveld. The pans have subsequently been modified and propogated through many different surface processes.

6. Since the ancestral Modder and palaeo-Kimberley rivers existed in late-Cretaceous-to-Tertiary times, the possibility exists that they may have transported alluvial diamonds, from the many Orange Free State

kimberlite occurrences, across both the African and the Post-African I surfaces. The gravels of these rivers are, thus, of economic potential and deserve closer attention.

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REFERENCES

De Bruiyn, H. (1971). *'n Geologiese studie van die panne in die westerlike Oranje Vrystaat.* M.Sc. thesis (unpubl.), Univ. of the Orange Free State., Bloemfontein, 120pp.

Geyser, G.W.P. (1947). *'n Ondersoek na die verspreiding en ontstaan van panne op die plato van Suid Afrika.* M.Sc. thesis (unpubl.), Univ. of the Witwatersrand, Johannesburg, 140pp.

Le Roux, J.S. (1978). The origin and distribution of pans in the O.F.S. *S.A.Geographer,* **6**: 167-176.

Marshall, T.R. (1987a). Morphotectonics of the Wesselsbron Panveld. *S.Afr. J. Geol.,* **90**(3)(in Press).

Marshall, T.R. (1987b). *Morphotectonics of the Orange Free State.* M.Sc. thesis (unpubl.), Univ. of the Witwatersrand, Johannesburg, 137pp.

Partridge, T.C. and Maud, R.R. (1987): Geomorphic evolution of Southern Africa since the Mesozoic. *S. Afr. J. Geol.,* **90**(2)(in press).