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LANDSCAPE EVOLUTION IN SOUTHERN AFRICA AND ZIMBABWE: TRADITIONAL AND RECENT VIEWS

by

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INTRODUCTION

In cross-section Southern Africa is saucer-like in form with a broken escarpment zone around its margins, higher in the east (the Great Escarpment) than in the west, and a broad central depression including the inland drainage system of the Okavango Delta and Makgadikgadi Pans (Figure 1A). Much of the subcontinent comprises land over 1000 metres in altitude, with maximum elevations up to 3 400 metres in the Drakensberg ranges in the south-east. Geologically, it comprises an ancient shield area, formerly part of Western Gondwanaland (King, 1978), with associated basement complex rocks outcropping over about one-third of the present-day land surface (Figure 1B). Younger sedimentary formations overlie these rocks but are located mainly on the margins of the subcontinent. In some areas extensive folding and faulting have affected these sedimentary rocks, as in the Cape region, whilst in other areas the formations are more or less horizontally disposed. The western interior of Southern Africa is overlain by Kalahari Beds, mainly aeolian sediments on the surface, which locally reach depths of 300 metres but more commonly are less than 100 metres thick (Thomas, D.S.G., 1988).

Large parts of the subcontinent, especially inland of the escarpment zone, are characterised by gently undulating or planate land surfaces, the monotony of which is broken in some areas by residual hills and low ridges. Undoubtedly, these extensive plains are of considerable antiquity and are by no means restricted to Southern Africa (Butzer, 1976). The exact origin and mode of development of these landscapes has been a matter for considerable debate amongst environmental scientists in Southern Africa (Partridge and Maud, 1987, 1988). Until the mid-1970s the views of the late Professor L.C. King tended to dominate this debate, with landscapes being described in terms of pediplanation and erosion surfaces. In recent years, however, evidence from offshore drilling, borehole drilling logs and geomorphological mapping, for example, have questioned the traditional views on landscape evolution. Unfortunately, much of this scientific literature is widely dispersed and not readily accessible.

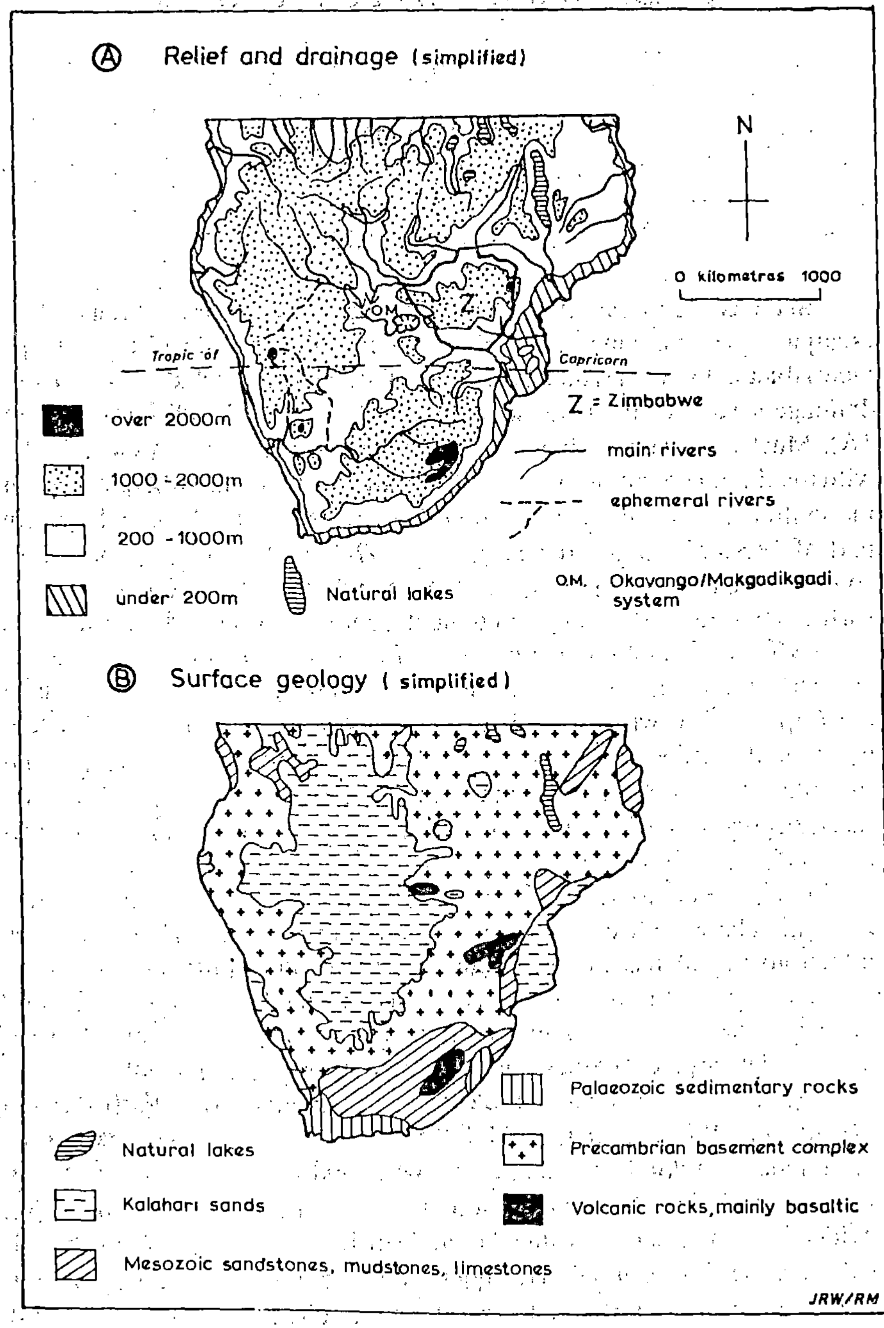

Figure 1: Physiography of Southern Africa

Consequently, the objectives of this paper are firstly, to outline traditional ideas on landscape evolution in Southern Africa; secondly, to present more recent views on landscape evolution of relevance to this part of Africa; and thirdly, to describe the Zimbabwe landscape covering both the traditional model and more recent analyses, including an investigation of long profiles of major rivers.

TRADITIONAL VIEWS ON LANDSCAPE EVOLUTION IN SOUTHERN AFRICA

In 1948, King proposed that pediplanation, involving scarp retreat and pedimentation, was the primary mode of landscape evolution in Southern Africa as opposed to the then-popular peneplanation model of the North American geomorphologist, W.M. Davis (King, 1948a). Subsequently, King developed the pediplanation concept to describe the physiography of Africa (and other continents) in terms of a series of planated or erosion surfaces of varying ages dating from the Jurassic, prior to the break-up of Gondwanaland (King, 1962). This scheme was accepted, with little criticism, by many scientists (especially geologists) concerned with the geomorphological history of Southern Africa. Hence King's ideas were repeated in numerous textbooks and geological bulletins related to this part of the world. In order to demonstrate the deficiencies of these traditional views in the light of more recent evidence, it is useful to outline the main arguments of the pediplanation model as envisaged by King.

The basic building block of King's scheme is a hillslope model comprising four major elements (Figure 2A). These include a convex waxing slope, a linear scarp face, a debris slope and a concave pediment. The most active of these slope elements was thought to be the scarp face which, subject to denudation forces, retreated parallel to itself thereby consuming the convex slope above and producing a debris or talus slope at its base (King, 1962). As the upper hillslope retreated so the basal pediment or waning slope extended, its inclination being reduced gradually by erosional regrading as shown by t_1, t_2 and t_3 in Figure 2A. In defining pediments, King (1967) comments that they are 'normally veneered with detritus, both residual and transported, ... essentially rock-cut features, and bare rock is not uncommonly exposed where the veneer thins away towards the base of the commanding hillslope' (p.43), a definition which accords with that of Young (1972). The hillslope model was developed initially, however, to account for slope forms in parts of coastal Natal and the Karoo area where cappings of dolerite sills, for example, gave rise to distinctive scarp features (Fair, 1947, 1948). Parallel retreat in these areas depended

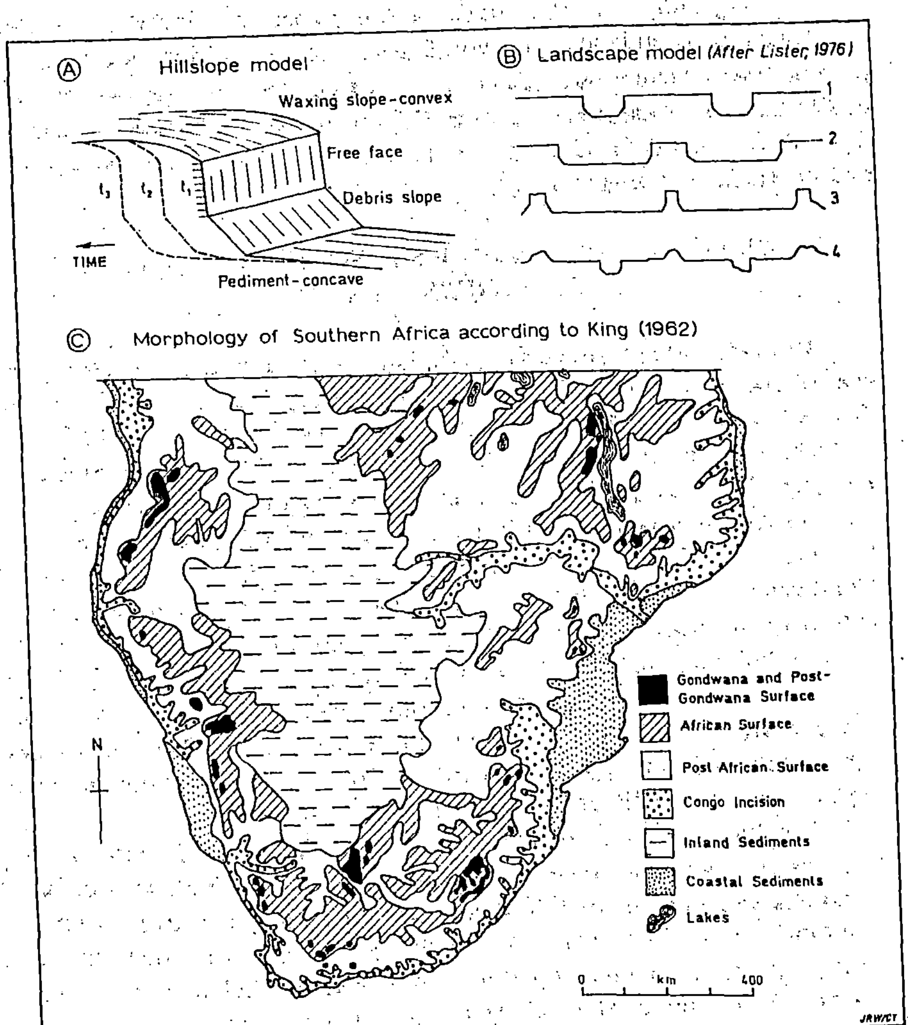

Figure 2: Landscape Development in Southern Africa According to L.C. King

on the presence of resistant caprock and efficient removal of debris from the base of the slope (Moon, 1988). Whilst recognising this, King (1953) regarded this hillslope model as universally applicable in areas of homogeneous bedrock being especially characteristic of, but not peculiar to, semi-arid climatic regions.

In his pedimentation cycle, King (1967) envisaged three main phases. Firstly, there was the incision of valleys working inland from the coast as a result of lowered base levels, consequent upon uplift of the subcontinent

(Figure 2B). Secondly, dissection of the former land surface would proceed through scarp retreat and pedimentation. Thirdly, with continued lateral extension the pediments would coalesce leaving unconsumed steep-sided residuals on interfluve sites (Figure 2B). The resultant pediplain, an erosional form, would then constitute the main feature of the landscape. King, however, noting the polycyclic nature of the Southern African landscape, envisaged that renewed incision associated with further base level lowering would not halt the progress of an earlier pedimentation cycle (Figure 2B4). Thus, one could have planated land surfaces of different ages co-existing, but separated by major erosional scarps transverse to the main river systems and minor scarps moving laterally away from the axes of the trunk valleys (King, 1962).

Following these basic assumptions or what he regarded as the 'cannons of landscape evolution' (King, 1953), six major erosional and depositional surfaces could be defined in Southern Africa (Figure 2C). General details on the origin of these surfaces are summarised in Table 1. This scheme was first elaborated fully by King in 1962, but in later papers (e.g. King, 1976) different terminology is used, although the essential principle of the 'destruction of older landsurfaces by encroaching younger surfaces operating at a lower level by the method of scarp retreat' (Lister, 1976, p.6) was retained. To account for the uplift of land masses required to change general base levels in the geological past, King (1959, 1961) proposed the concept of **cymatogeny**, and described it as being a mode of crustal deformation between epeirogeny and orogeny in which an undulating movement or warping of the earth's crust produces regional linear arching or doming but with minimal deformation, thus elevating the interior plateaux and initiating their dissection in the later stages of landscape evolution in Southern Africa (Table 1).

Given the state of knowledge on earth history in the 1950s and 1960s, King's (1962) scheme was an attractive and seemingly well-supported hypothesis. Apart from accounting for the gross morphology of the subcontinent, King's views could be applied to individual landforms. In particular, one can single out bornhardts, massive steep-sided hill features commonly associated with granitic rocks in Southern Africa (Twidale, 1988). King (1948b) described these as a product of the 'twin processes of pediplanation (scarp retreat and pedimentation) acting upon suitable rock types, following a geological history which involves stream rejuvenation' (p.83). Retreat of the steep flanks of bornhardts was achieved mainly by spalling and sometimes through chemical weathering, producing a pedimented slope at the base of each bornhardt. This hypothesis, repeated in later papers (King, 1975, 1976), became accepted as the traditional explanation of bornhardts in Southern Africa and, until recently, remained unquestioned (Whitlow, 1979). This issue is explored further at a later stage given that bornhardts offer clues on the general evolution of the landscape.

TABLE 1:
CHRONOLOGY OF UPLIFT AND PLANATION IN SOUTHERN AFRICA ACCORDING TO KING (1962, 1976)

Phase	Landscape Change*
1	Extreme planation of **Gondwana** landscape during Jurassic; disrupted the fragmentation of Gondwanaland some 145 M yrs ago and created new base levels.
2	**Post-Gondwana** landscape formed by dissection concentrated in upwarped areas during the early Cretaceous; disturbed by continent-wide uplift some 90 M yrs ago.
3	Extreme planation of **African** landscape during prolonged period of relative crustal stability; disrupted *c.*25 M yrs ago by widespread epeirogenic uplift.
4	Broad valley-floor pediplains of **Post-African** cycle are formed along with sedimentation in the interior Kalahari basin; affected by moderate cymatogeny some 5 M yrs ago.
5	Second phase of late-Cainozoic valley planation and associated coastal deposition, disrupted by strong cymatogeny *c.*2 M yrs ago.
6	**Congo** cycle of deep gorge cutting in coastal margins along with deposition of Kalahari Sands.

* M yrs = million years.

CURRENT VIEWS ON LANDSCAPE EVOLUTION

It was not until the mid-1970s that King's hypothesis on long term landscape evolution was questioned seriously. Thomas, M.F. (1974), for example, noted that likening the relief of Africa to 'a staircase of progressively higher and older surfaces ascending inland from the coasts (was) a gross oversimplification of a complex situation' (p.208). Certainly, the field evidence in West Africa does not support the notion of massive, widespread scarp retreat, one of King's major axioms (Thomas, M.F., 1974). During the last fifteen years or so a great deal of evidence concerning the evolution of Southern Africa has accumulated. Much of this has been derived from sediment cores obtained during petroleum exploration along the continental shelf, along with more comprehensive information on weathering profiles and tectonic movements. Consequently, it has been possible to correlate with greater certainty the history of onshore erosion and offshore deposition since the Mesozoic (Partridge and Maud, 1987).

The first major challenge to King's scheme was a study of the structural and physiographic development of Natal since the late Jurassic (De Swardt and Bennet, 1974). This study indicated that there was widespread downwarping and graben faulting during the fragmentation of Gondwanaland, thus producing an elevated hinge-line along the margins of the subcontinent. This resulted in the development of two distinct drainage systems, an inland system in the interior and a coastal system draining the seaward slopes of the rifted margin. Gradually, headward incision would have resulted in river capture of the inland system by the coastal system, as in the case of the Zambezi River; however, the dual drainage system appears to have persisted until the late Mesozoic (*c.*70 million years ago). Consequently, De Swardt and Bennet (1974) dispute the correlation of coastal and inland erosion surfaces insofar as the latter formed in response to local base levels in the interior basins independent of coastal base level changes. They reject also the possibility of the subcontinent being planed down to a surface of low relief, that is King's 600 metre African surface.

A second major challenge to King's hypothesis was presented by Helgren (1979) in the context of a reconstruction of the alluvial history of the lower Vaal basin. He noted that King's scheme depends on three axioms. These are that Southern Africa was subject to episodic uplift during the Cainozoic (last 65 million years), that all slopes not only retreat or 'backwear' but do so over long distances, and finally, that river knickpoints migrate upstream over considerable distances. Drawing on field evidence within and beyond the Vaal basin, Helgren (1979) rejects each of these axioms. For example, the six major planar landscapes in the lower Vaal basin cannot be accommodated in King's denudation chronology, whilst the major knickpoints on the Vaal River below the Highveld surface appear to pre-date the Cainozoic denudation which supposedly created the planated land surfaces upstream.

Further doubts on King's hypothesis have been cast by Summerfield (1985a, 1985b) in an evaluation of the tectonic history of Africa. Taking the issue of landscape rejuvenation, for example, Summerfield (1985a) notes that continent-wide manifestation of such incision has to be generated by a fall in the base level at the coast, whether this be through uplift of the landmass or eustatic in origin. Yet the recent evidence of offshore coastal sediments does not correlate well with King's denudation chronology (*cf.* Summerfield, 1985a, Table 1). Moreover, given continuing uplift along continental margins and low gradients on marine 'platforms' in some areas, it is unlikely that the effects of changes in base level at the coast would be transmitted uniformly inland or for great distances. Indeed the tectonic history of Africa is much more complex than that envisaged by King (1962), with further research required on the integration of tectonic and geomorphic processes (Morisawa and Hack, 1985). Certainly, interior subsidence and crustal warping influenced the progressive capture of the upper Zambezi river by the middle Zambezi during the late Cainozoic (Thomas and Shaw, 1988), thus effecting changes in the courses of main tributary channels as in the Gwaai River in Zimbabwe (Thomas, D.S.G., 1984a) and the Kafue River in Zambia (Mackel, 1976).

Notwithstanding these criticisms of King's scheme, Partridge and Maud (1987) have undertaken a major revision of evidence concerned with the geomorphic evolution of Southern Africa since the Mesozoic. The results of their study, summarised in Table 2 are broadly similar to King's scheme (see Table 1). Partridge and Maud (1988), however, emphasize a number of differences between their model and that of King. Firstly, they show that there is no evidence to support the preservation of ancient remnants of Gondwanaland, whilst benches above the African surface are of structural origin. Secondly, the African cycle initiated by the breakup of Gondwanaland was polycyclic and, given its long duration, resulted in widespread deep weathering and duricrust formation. Thirdly, later erosion cycles were initiated through episodic uplift and progressive westward tilting of the subcontinent, but with incision operating to different levels in the interior plateau and coastal areas. Fourthly, the most recent cycles of valley erosion were influenced strongly by local base levels and bedrock structure. Partridge and Maud (1987), therefore, provide a more complex picture of long term geological history in the subcontinent, emphasising the importance of prolonged weathering and erosional stripping of land surfaces.

Whereas King (1962) regarded pediplanation as the primary mode of landscape development, many geomorphologists have adopted the concept of **etchplanation** as a more appropriate explanation of landscape genesis (Thomas, M.F., 1974; Ollier, 1984; McFarlane, 1989), at least within humid tropical regions. The term 'etched plain' was first applied by Wayland in the early 1930s to account for plains in parts of Uganda that appeared to form through alternate deep weathering and stripping of a pre-existing peneplain

TABLE 2: GEOMORPHIC EVOLUTION OF SOUTHERN AFRICA ACCORDING TO PARTRIDGE AND MAUD (1987)

Period	Event	Landscape changes
Late Jurassic to early Cretaceous	break-up of Gondwanaland	new base levels formed and rapid erosion
Late Jurassic/early Tertiary to end of early Miocene	African erosion	large-scale planation of the land surface and deep weathering
End of early Miocene	Moderate uplift 200 to 300m	interruption of African erosion cycle and westward tilting of African surface
Early Miocene to late Pliocene	Post-African I erosion	formation of imperfectly planed lower level erosion surface and major deposition in the Kalahari basin.
Late Pliocene	Major uplift up to 900m	asymmetric uplift and westward tilting of the continent
Late Pliocene to Holocene	Post-African II erosion	incision of gorges and local formation of erosion surface at a lower level
	Climatic change, sea level fluctuations and local tectonism	inland and coastal dunes, marine beaches and river terraces

(Thomas, M.F., 1969). Whereas Wayland envisaged relatively shallow penetration of weathering and more or less complete stripping to expose the underlying bedrock plain, recent applications of the concept accept weathering depths of tens of metres or more (Ollier, 1984). A closely related concept is that of the 'double surface of levelling' proposed by Budel in

1957 (Thomas, M.F., 1974). In this model (Figure 3A) denudation of the land surface proceeds through deep decomposition of the bedrock, progressively lowering the basal surface of weathering, and associated surface stripping of the regolith. Where rates of weathering are slow and bedrock is poorly jointed, it is likely that erosion would remove the weathered material so exposing etched rock platforms or residual hills.

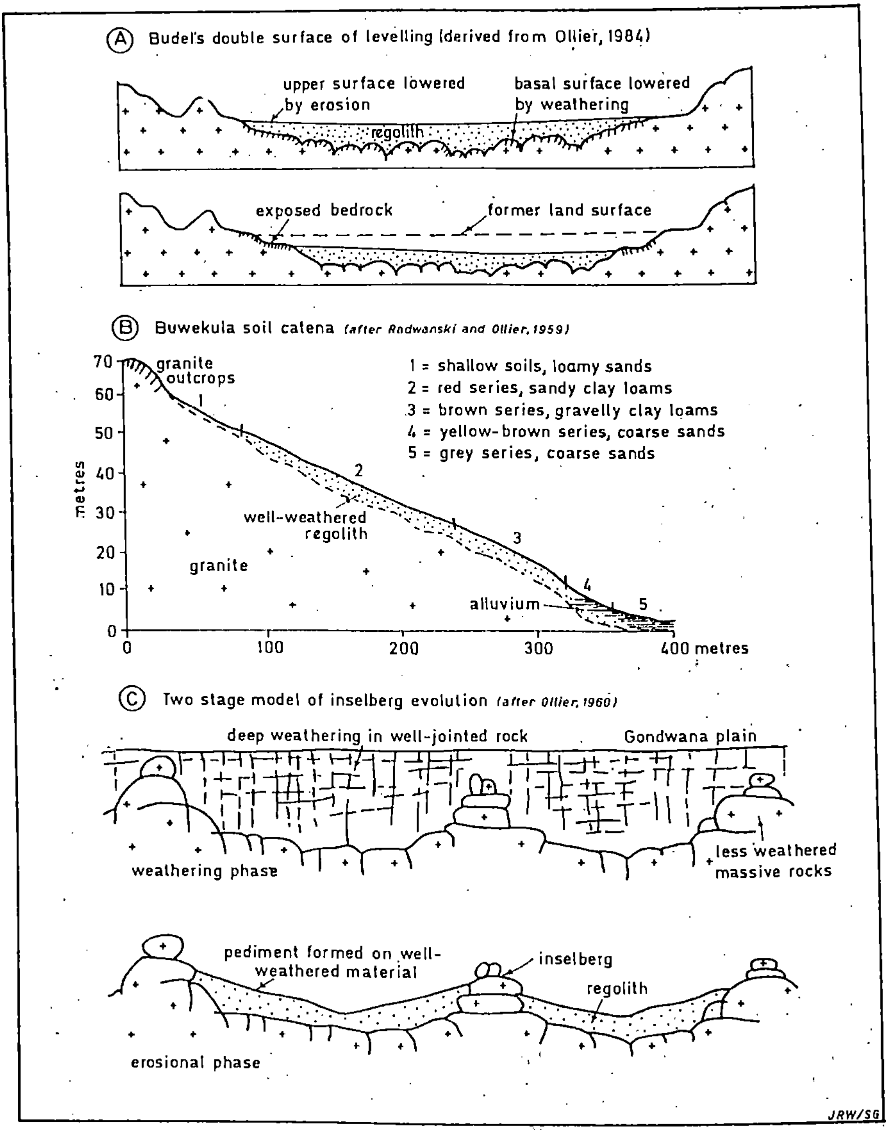

Figure 3: Weathering and Landscape Development

The same basic principle was applied in Uganda by Radwanski and Ollier (1959) and Ollier (1960) to account for variations in soils and the development of inselbergs, respectively. In an investigation of the Buwekula soil catena in Uganda (Figure 3B), it was discovered through mineralogical examination that the main members of the catena, the red and brown series, were derived from intensely pre-weathered granite, whilst the lower members of the catena, the yellow-brown and grey series, were formed on alluvium derived from pre-weathered granite. Only on the upper slopes was there evidence of soils formed on freshly weathered bedrock. Consequently, Radwanski and Ollier (1959) concluded that prolonged weathering took place prior to the development of the present-day landscape and its associated soils. Insofar as this pattern of soil formation on well-weathered rock was prevalent in granitic inselberg landscapes, Ollier (1960) proposed a two-stage model of inselberg evolution (Figure 3C): that is, prolonged weathering of a stable land surface, the Gondwana surface in Uganda, followed by erosion stripping to form a landscape of residual hills and pediments underlain by regolith. This concept of differential weathering along well-jointed bedrock and erosion is still regarded as central to hypotheses concerning the origin of bornhardts on granitic rocks (Twidale, 1980), albeit more complex sequences of landscape genesis have been proposed (e.g. Thomas, M.F., 1978).

In an evaluation of evidence on the origins of pediments in tropical shields, Thomas, M.F. (1974) indicated that there was an apparent absence of rocky pediments over large areas of Africa. Indeed, it seems that 'many pediments are cut across pre-weathered materials, and this is a different situation from that which would arise from deep weathering of truncated rock surfaces' (Thomas, M.F. 1974, p.219), as postulated in King's model of slope retreat. The etchplain concept offers a more plausible explanation of contemporary landscapes, albeit there are still issues that require further study (Thomas, M.F. and Thorp, 1985). Consequently, one can differentiate various types of etchplain dependent on the depths of weathered material and degree of erosion of the regolith (Thomas, M.F., 1969). This variability may be related to differing ages of land surfaces, such that older landscapes are associated with deeper weathering whilst younger landscapes are characterised by shallower weathering insofar as the regolith has been stripped away (*cf.* Partridge and Maud, 1987). At a more local scale, however, differences in bedrock lithology and structure may determine the extent of dissection.

Overall, therefore, recent evidence on geomorphological evolution in Southern Africa points towards a complex history of tectonic uplift and tilting, prolonged stability and active phases of erosion. The resultant landscapes of the interior plateaux are undoubtedly polycyclic in origin, giving rise to differences in depths and degree of weathering across these surfaces.

DEVELOPMENT OF THE ZIMBABWE LANDSCAPE

Physiographically, Zimbabwe can be divided into four main units. These are a narrow belt of mountains and high plateaux, locally reaching altitudes of over 2 200 metres, in the eastern region (Figure 4A); a central 'watershed plateau' separating the Save–Limpopo and Zambezi drainage systems and referred to sometimes as the highveld (land over 1 200 metres); a zone of more dissected terrain between 900 and 1 200 metres, but including an extensive plateau blanketed with Kalahari Sands in the south-west, constitutes what is known as the middleveld; below 900 metres altitude, the lowveld region includes heavily dissected terrain to the west of Lake Kariba, areas below the Zambezi Escarpment in the north and broad plain landscapes in the south-east of the country.

Geologically, much of the central and eastern regions are underlain by granitic rocks of Precambrian age intruded into now deformed and fractured schist belts, locally known as the Greenstone belts (Figure 4B, Phaup, 1973; Stagman, 1978). Basaltic lavas and sandstones of the Karoo system (Jurassic age) flank the granitic core in the north-west and south-east of the country, with a large island of Karoo rocks in central Zimbabwe, suggesting a more extensive covering of these materials in the past. The Great Dyke, really a series of elongated lopolithic complexes, which cuts across central Zimbabwe comprises ultramafic rocks (mainly serpentine and pyroxenite) intruded into the granitic craton some 2.5 billion years ago (Stagman, 1978). Crustal stresses associated with this emplacement resulted in numerous fractures developing parallel to the Great Dyke (Stowe, 1980). Some of these fractures are marked now by doleritic dykes and sills but elsewhere in the granitic rocks such intrusions are generally much older than the Great Dyke. The Kalahari Sands, largely of aeolian origin, cover some 44 000 square kilometres mainly in the west, but include one small island of sands to the east of the Great Dyke (Figure 4B). These are of Quaternary age, but represent the surface member of the Kalahari Beds which accumulated in the interior of Southern Africa throughout the Cainozoic (Thomas, D.S.G., 1988).

The geomorphological evolution of Zimbabwe has been described by Lister (1976, 1979, 1987) in terms of six cyclic erosion surfaces and a pre-Karoo fossil surface (Figure 5). This scheme was essentially an elaboration of King's pediplanation concept about which doubts have been raised earlier. Notwithstanding the subjective methods used by Lister (1976), it is

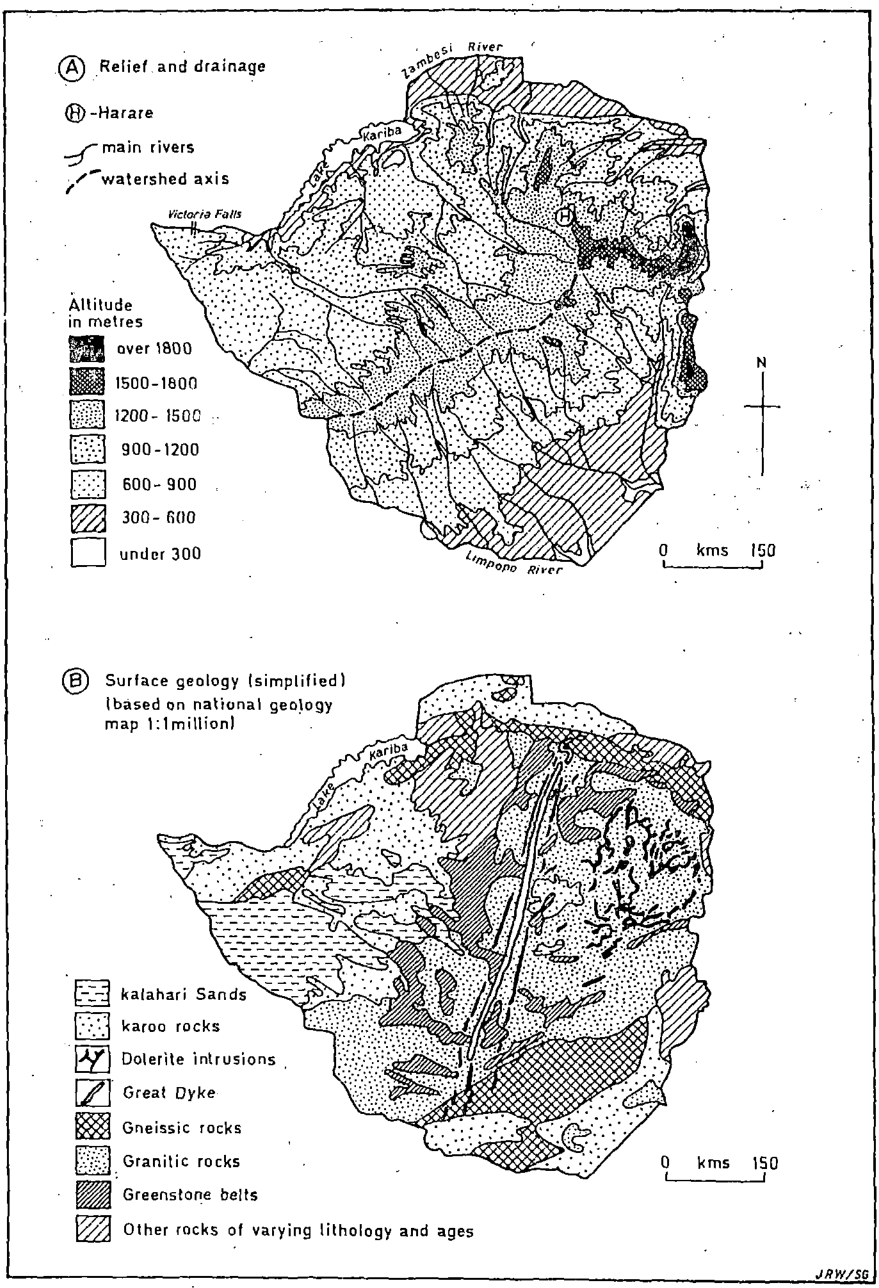

Figure 4: Physiography of Zimbabwe

difficult to escape the observation that there are a series of planated surfaces fashioned by the incision of the Zambezi and Save–Limpopo drainage systems into the elevated (and by implication oldest) central plateau region (compare Figures 4A and 5). As observed by Thomas, M.F. (1974), it is not the existence of these planated land surfaces which is in doubt, only their origin. A recent study of the watershed region south of Harare has shown that the landscape is certainly polycyclic in nature, but the boundaries between the African and Post-African surfaces (and sub-units within these) are more complex than those defined by Lister (McFarlane, 1989). Indeed, in the Transvaal, morphometric analysis of topographic maps has also confirmed the existence of polycyclic surfaces as envisaged by King (1962), but with locally varied patterns (Brook, 1978a).

However, given the paucity of geomorphological research in Zimbabwe, there is very little information apart from the work of Lister (1976) concerning the development of the landscape and surficial materials overlying bedrock. A notable exception to this is the recent study by Thomas, D.S.G. (1984b, 1985, 1987) on Quaternary landforms and environmental change including the Kalahari Sands areas in western Zimbabwe. Under

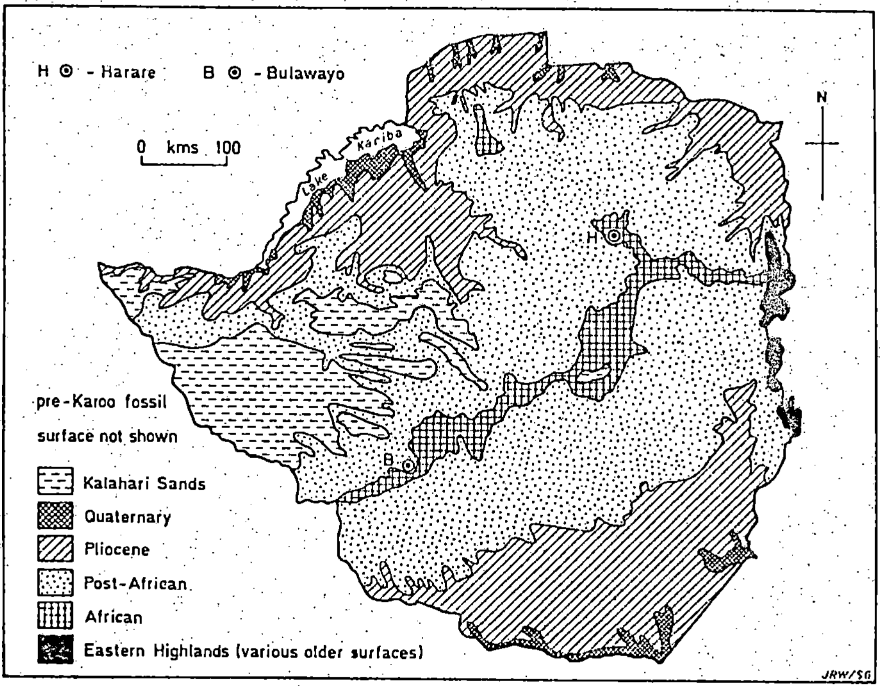

Figure 5: Erosion Surfaces in Zimbabwe (after Lister, 1976)

these circumstances, the remainder of this section is devoted towards firstly, a demonstration of the varying degrees of landscape dissection in Zimbabwe by means of analysis of longitudinal profiles of selected major rivers, and, secondly, an illustration of the significance of weathering through a description of bornhardt landscapes.

Despite the fact that examination of long profiles of rivers can assist in reconstructing geomorphological history, as shown in parts of the United States by Hack (1973) and De Graaf (1981), very little research on this aspect of rivers has been carried out in Southern Africa (Dardis *et al.*, 1988). Generally, the longitudinal profiles of rivers outside desert and semi-arid regions are concave upwards, but may be smooth or broken (Morisawa, 1968). The concavity of profiles can be viewed as a product of hydraulic factors and downstream diminution of grain size of sediments or a function of inherited conditions related, for example, to regional slope and base levels (Lee and Henson, 1977). Of particular concern in the present study is the existence of knickpoints or major breaks in channel gradient. These may be lithologically or structurally controlled (Morisawa, 1968), but they necessarily require the independent relative lowering of the channel floor downstream (West, 1978).

Data on the longitudinal profiles of fourteen major Zimbabwe rivers were derived from 1:50 000 topographical maps (Sithole, 1987). To enable systematic comparison of channels of varying lengths a technique of plotting inter-contour distance against altitude was used, based on a method developed to distinguish different altitudinal groupings of lateritic surfaces in southern Uganda (McFarlane and Brock, 1983). Taking, for example, the Macheke River in eastern Zimbabwe (Figure 6A), a river which has at least two major breaks marked by numerous rapids and waterfalls, it is possible to construct a long profile histogram (Figure 6B). A concave upwards channel segment would be represented by progressively longer 'bars' in a downstream direction to create a distinctive peak (P1 in Figure 6B). The knickpoint, which in this case is associated with granitic rocks, not doleritic intrusions, downstream shows up as a trough (T1) in the histogram. The distance along the x-axis is also a measure of channel gradient, but is not an arithmetic scale (Figure 6B). The data collected by Sithole (1987) was reworked for the fourteen rivers shown in Figure 6C and the results are presented in Figure 7 and Table 3.

If the pediplanation hypothesis is valid, then one would expect a series of major peaks and troughs corresponding respectively with erosion surfaces and scarp zones separating them. There is some evidence of this when comparing, for example, the upper reaches of the Manyame and Mupfure–Sanyati rivers (Nos. 4 and 5 in Figure 7) and the lower reaches of

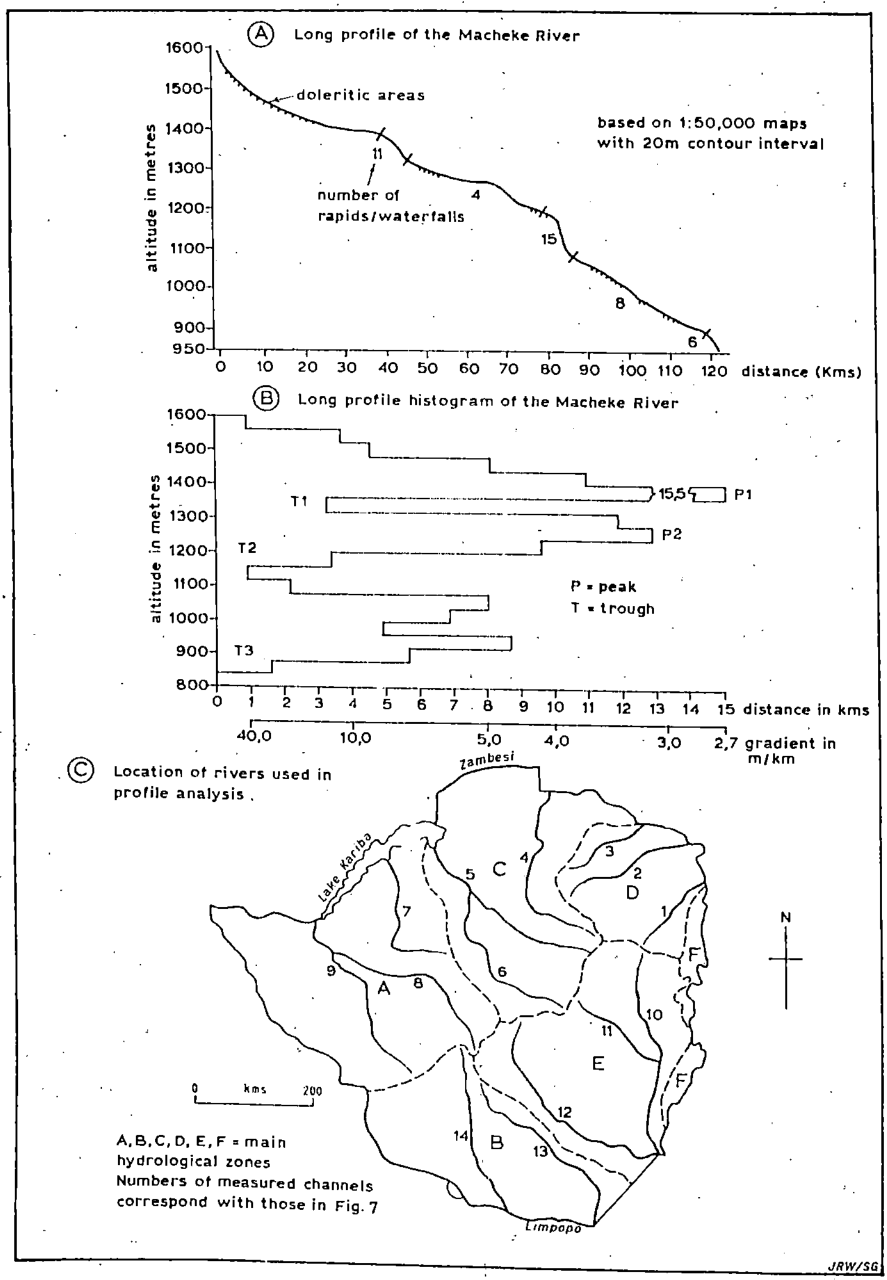

Figure 6: River Profile Analysis

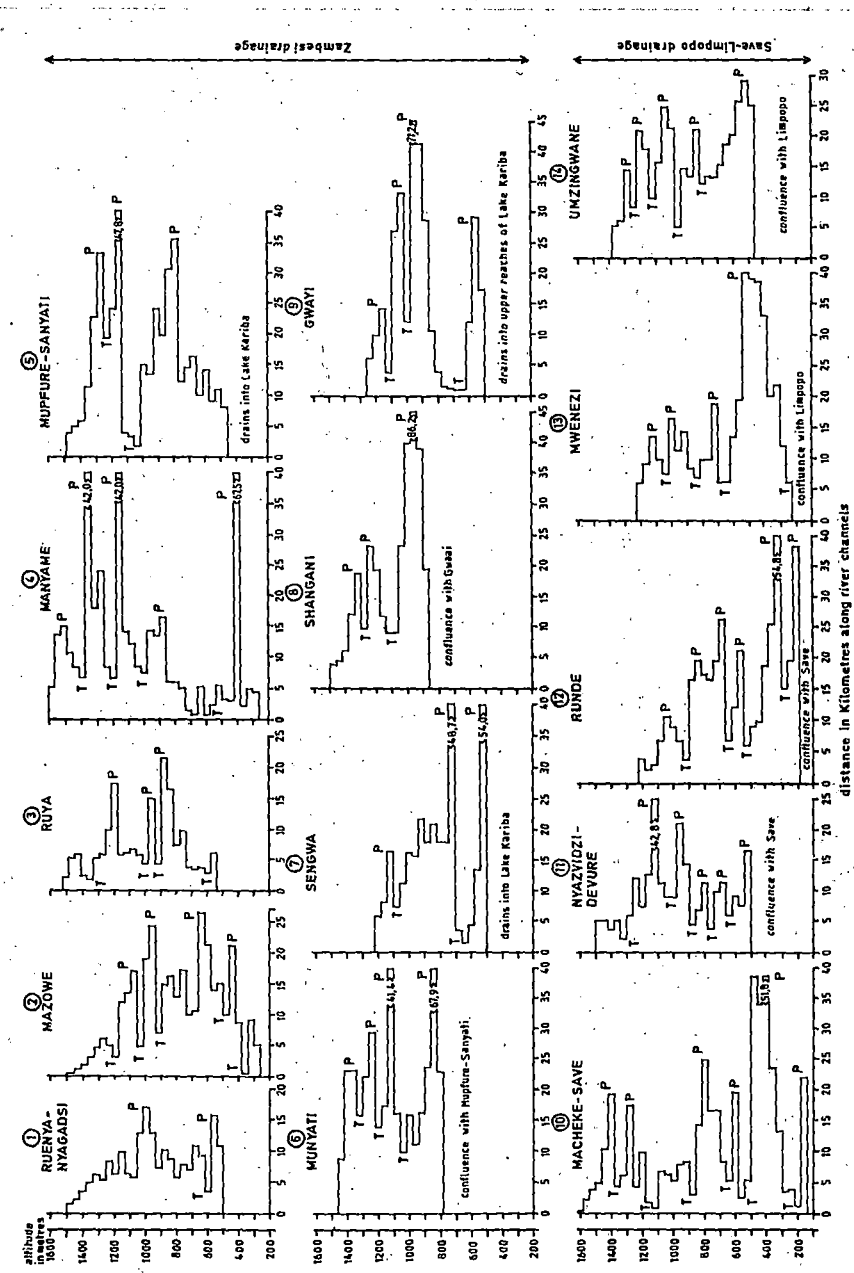

Figure 7: Long Profile Histograms of Major Rivers in Zimbabwe

TABLE 3: COMPARISON OF GRADIENT PROFILES ON SELECTED ZIMBABWE RIVERS

Altitude Range (m)	Number of sampled rivers 1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total Number of Peaks	Troughs*
1580–1620															–	–
1540–1580															–	–
1500–1540				P											1	–
1460–1500															–	–
1420–1460															–	–
1380–1420				Tm		P				P					2	1
1340–1380			T	P						T					1	2
1300–1340						Tm		P			T				1	2
1260–1300					P			Tm		P				P	3	1
1220–1260					Tm	P		P						Tm	2	2
1180–1220		T	P	Tm		Tm								P	2	3
1140–1180				P	P				P						3	–
1100–1140						P	P	Tm	T	T	P		P	Tm	4	4
1060–1100		P					Tm								1	1
1020–1060		T			T	Tm			P			P	Tm	P	3	4
980–1020	P		T	Tm					Tm		Tm		P		2	4
940–980		P	P					P	P		P			T	5	1
900–940		Tm	T									T			–	3
860–900			P	P						T	T				2	2
820–860						P						P	Tm	P	3	1
780–820					P					P	P			Tm	3	1
740–780											T				–	1
700–740							P						P		2	–
660–700											P	P			2	–
620–660		P					T		T	Tm	Tm	Tm	Tm		1	6
580–620	T		T	T						P					1	3
540–580	P								P	T		P			3	1
500–540							P				P	Tm	P	P	4	1
460–500		Tm													–	1
420–460		P													1	–
380–420				P						P					2	–
340–380		T													–	1
300–340												P			1	–
260–300												Tm			–	1
220–260													T		–	1
180–220										T		P			1	1
140–180										P					1	–

* both major and minor troughs included in this total; minor trough taken as one where gradient is less than 4 m/km, or distance of over 10km along the x-axis.
T = trough; Tm = minor trough; P = peak.

the Macheke–Save, Mwenezi and Umzingwane rivers (Nos. 10, 13 and 14 in Figure 7). Similarly, there are marked peaks on the Shangani and Gwayi rivers in the 940–980 metre altitude range (Nos. 8 and 9), but these rivers flow across gently dipping Karoo rocks. Major troughs occur on the lower Manyame river as it drains through the Zambezi escarpment, whilst the lower Gwayi river also has a marked steepening of its channel prior to joining the Zambezi. On balance, however, there is considerable altitudinal variation of the troughs and peaks (Table 3). This suggests a more complex pattern of incision of river systems influenced not only by tectonic uplift and tilting as described earlier, but also by local differences in bedrock, a factor noted also by Baillie (1970) in Swaziland. The implication is that differing degrees of erosional stripping have occurred within and between the major catchments insofar as surface lowering is affected by local and regional base levels.

There have been very few studies on weathering in Zimbabwe, apart from research on pedogenesis on granitic rocks (Watson, 1965; Purves, 1976; Owens and Watson, 1979). Whilst records on boreholes are kept in the government hydrological offices, they do not provide adequate information on regolith depths and characteristics. Consequently, one can only demonstrate the significance of weathering in the Zimbabwe landscape in an indirect way, in this case based on a survey of bornhardt terrain (Whitlow, 1979). The distribution of this terrain was determined from examination of 1:50 000 topographical maps covering the areas of granitic rocks in Zimbabwe. Bornhardt features occur in a broad arc varying from 90 to 130 kilometres in width on the eastern and southern flanks of the ancient craton which forms the central part of the country (Figure 8A). Nearly 70% of the bornhardt terrain occurs on the potash-rich younger granites (adamellites), although these only comprise about 45% of the granitic areas. In contrast, only 19% of the bornhardt terrain is located in areas underlain by the older gneiss complex (mainly tonalites), although these make up 36% of the granitic areas (Whitlow, 1979).

King (1948b), drawing on examples from Zimbabwe, accounted for the evolution of bornhardt landscapes in terms of his pediplanation hypothesis. It has been shown, however, that differential weathering and erosion are more likely processes in the development of domes (Thomas, M.F., 1974). The association of bornhardts and potash-rich granitic rocks has been reported elsewhere in Southern Africa (Brook, 1978b). The reason for this relates to the poorly developed joints and massive rock compartments within adamellites, for example, as compared with well-jointed tonalites. Certainly, patterns of jointing and fractures through their influence on weathering penetration, determine the distribution and orientation of domes

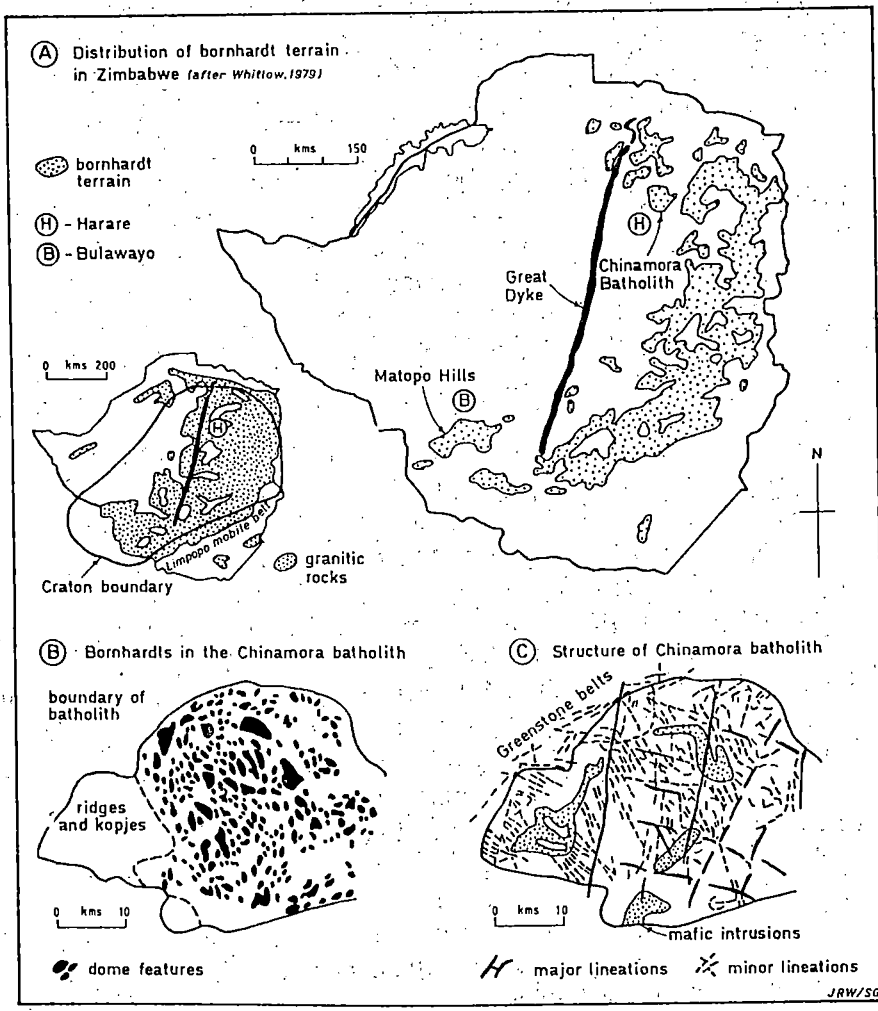

Figure 8: Bornhardt Landscapes in Zimbabwe

as in the Chinamora batholith north of Harare (Figure 8B and C). Domes in this area vary from 350 metres to under 50 metres in height, with many of the lower domes having regolith-covered, boulder-strewn surfaces. Twidale (1988) stresses the occurrence of bornhardts within Lister's (1976) Post-African surface. This does not necessarily mean that the domes are a product of pediplanation, only that regolith in areas away from the watershed axis has been removed, so exposing domes. Episodic exposure of domes (Twidale and Bourne, 1975) is suggested by micro-valley forms on some bornhardts (Whitlow and Shakesby, 1988), thus supporting the notion that weathering is a key factor in the evolution of these granitic landscapes. Equally, therefore, weathering must play an important role on the regolith-covered, well-jointed granitic rocks of the central watershed region.

CONCLUSION

This review demonstrates that the traditional view of landscape evolution in Southern Africa, as presented by L.C. King and others, is no longer tenable in the light of recent evidence of offshore sediments, weathering profiles and tectonic activity. Observations in the subcontinent and elsewhere in Africa support, the concept of etchplanation rather than pediplanation for the origin of the present landscapes. That is, chemical weathering and leaching are of greater importance than surface processes such as sheetwash erosion and soil creep (McFarlane, 1989).

In Zimbabwe, recent observations on the somewhat irregular long profiles of major rivers and the distribution and characteristics of bornhardt terrain indicate that landscapes cannot be accounted for readily in terms of the traditional erosion surfaces scheme. Rather, there has been a sequence of differential weathering and incision of river systems influenced, in part, by bedrock lithology and structure. Cartographic techniques such as inter-contour distance measurements, used here on river profiles, and relative relief measurements (McFarlane, 1989) provide a means for more detailed, objective analysis of landscape morphometry at both local and regional scales. Only when we have defined, in a reasonably objective manner, the basic units of the landscape can we begin to delve into the possible processes, past and present, that have fashioned it. There is great deal of scope for such geomorphological research in Zimbabwe, given its good coverage of topographical and geological mapping.

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