A Brief Review of the Development of Gondwana Landscape Studies in Africa, the Centrepiece of the Former Gondwana

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Abstract This chapter presents a summary of the development of landscape studies in Africa since their inception in the 1930s. The role of Lester C. King in the progress and advancements of geomorphology studies in Africa, both in terms of processes and landforms, particularly the ancient landscape complexes and the evolution of geomorphological thinking, is herein highlighted. Later scientific developments in these fields are recognised as well.

Keywords Gondwana • Southern Africa • Lester King • Great Escarpment • Planation surfaces

Introduction

> 'Ex Africa semper aliquid novi' – Pliny, the Elder in 'Historia Naturalis', Pliny having been a notable Roman natural history and geography writer.

The Pliny quotation above continues to be applicable (usually in an adverse context) to the present day! What Pliny was unaware of, however, is that Africa, to the present day, carries some very old features in the form of some of its elevated, mainly high plain landscapes of erosional origin which have remained substantially unchanged, subaerially, since their initiation in the Cretaceous, about 100 Ma ago. That such landscapes could exist thus, effectively largely unchanged, for such a very long time and that they still exist today have been incomprehensible to most Europe-based geomorphologists, although in recent times, acceptance of this fact has become a little more widespread.

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J. Rabassa and C. Ollier (eds.), *Gondwana Landscapes in southern South America*,
Springer Earth System Sciences, DOI 10.1007/978-94-007-7702-6_5,

Fig. 1 Lester King (1907–1989)

This is in no small measure due to the works of Lester King in the field of landscape and related studies, this writer having been fortunate enough to have been one of his students (although described by him on occasion as one of the most 'misguided' thereof) during his main period of productive effort and publication in the 1950s and 1960s, as a result of which he acquired, later, the reputation of being one of the most influential (if at times controversial) geomorphologists of the twentieth century.

What follows below is a resume of the development of landscape studies in Africa since their inception in the 1930s, the contribution of Lester King thereto necessarily being concentrated on (Fig. 1).

Early Landscape Studies in Africa (1930–1942)

Unsurprisingly, because of their excellent development in places there, the high plains of Central and East Africa obviously drew the attention to themselves of the early workers in the landscape development field.

Probably the earliest worker in the field in Africa was Wayland (1931) who recognised three planation surfaces of different ages in the vicinity of the rift valley in Uganda, these being one of post-Karoo to Late Cretaceous age, one of Early Miocene age (dated from fossiliferous sediments around Lake Victoria), and one of Late Pliocene age. It is remarkable that these deductions have been largely confirmed to be the case in a wider context elsewhere in Africa by most of the later workers. The foundations for landscape development studies in Africa were thus well and truly laid.

Wayland was followed by Beetz (1933) who identified a sub-escarpment Namib surface in southern Angola which is warped down beneath Late Cretaceous marine sediments along the coast. He extrapolated this surface to South-West Africa (Namibia) and to South Africa and noted that it was there associated with deeply penetrating leaching and silicification – an early very perceptive and important observation in the light of subsequent work by others in this part of Africa (Partridge and Maud 1987).

Veatch (1935) described an extensive land surface of Cretaceous age, extending over much of Central Africa, which remained undisturbed until the Middle Miocene on the evidence of a continuous, undisturbed, Early Cretaceous to Middle Miocene coastal sedimentary sequences preserved in Angola. He also identified an end-Tertiary surface produced through the erosion of some 3,000 m of earlier sediments following the Middle Miocene up-warping of the coastal margin (shades of what was later to be found to be the case in South Africa).

Jessen (1936) recognised five main surfaces in Angola, which he believed to be produced by intermittent uplift of the region since the Middle Triassic. The main plateau surface he regarded as being of Jurassic to Early Cretaceous age, while higher remnants were considered to date to the Late Triassic and Early Jurassic. Below the plateau surface was a plain of Early to Middle Cretaceous age, which was followed at a lower elevation by a surface of Albian to Early Eocene age (the Namib surface of Beetz). Along the coast, a surface of Mio-Pliocene age was preserved.

Willis (1936) postulated a high-level planation surface based on a remnant feature in Tanzania which he regarded as being of Jurassic age. The main plateau of Tanzania was considered to be produced by an erosion cycle which culminated in the Miocene. He also described a Late Tertiary surface more than 100 m below the main plateau surface.

Dixey (1938) (later Sir Frank Dixey, a geologist in the British Colonial Service, in Central Africa, who was later to become the main disputant with Lester King in the matter of African erosion surfaces and landscape development) entered the scene. On evidence chiefly from Central Africa, but also from southern Africa, he proposed the existence of a late Jurassic peneplain which truncated Karoo boundary faults in the vicinity of the Nyika-Vipya plateau in Malawi. Valleys incised into the Jurassic surface, as well as the down-faulted Nyasa-Shiré and Luangwa-Zambezi troughs, were filled with sediments of Early Cretaceous age. The main plateau surface was formed by a cycle lasting from the Early Cretaceous to the Middle Miocene, but most of the planation occurred at the beginning of this interval and was interrupted by warping and volcanism in the Middle Cretaceous, which resulted in a new planation of the surface during the Early Tertiary. A lower end-Tertiary surface, in the form of broad valleys, was developed chiefly on softer lithology in response to uplift along both the east and the west coasts at the end of the Pliocene and the beginning of the Pleistocene.

Dixey (1942) added to his 1938 list of erosion surfaces an end-Cretaceous-Early Tertiary surface and an incised Early Pleistocene surface (typified by gorge cutting below the Victoria Falls). The earlier of these accommodated the high remnants above the main plateau surface, which had previously been ascribed to end-Tertiary up-warping. Hence, a distinction was drawn between an Early Cretaceous ‘trough’ surface and an end-Cretaceous upland surface. The latter was recognised as occurring around the margins of Lesotho, in South Africa, at 2,250–2,300 m elevation. Attention was also drawn to the stripping of large areas of Karoo sediments during the main cycle which ended in the Middle Miocene, resulting in the exposure of a pre-Karoo surface. Previous continuity between the main plateau surface and its coastal equivalent was proposed and was ascribed to up-warping along an axis coinciding generally with the ‘Great Escarpment’. Tectonic influences were considered to be limited to Middle Cretaceous faulting, with little subsequent disturbance until the main period of uplift at the end of the Tertiary.

Thus, by the beginning of the 1940s, the basic groundwork regarding the development of the African erosional landscapes had been laid by diverse authors in a short period of only some 10 years. Having had its origin in Central and East Africa, with time its focus moved south in large measure to Southern Africa.

In effect all later work in this regard comprised refinement to varying degree of this groundwork, with the addition to, or the subtraction from, the pre-existing lists of landscape erosional and depositional cycles, and the refinement of their ages.

The stage was now set for the bursting on to this scene of one, Lester King who was to leave an indelible mark on both the African, and the general worldwide, geomorphological scene.

Lester C. King (1907–1989; Publishing Activity: Major African and General Erosion, 1942–1983)

Lester Charles King was born in London in 1907, but in 1909 his family migrated with him to New Zealand, where he obtained his B.Sc. and M.Sc. degrees in due course. Initially his main interest was in palaeontology, but he also had a peripheral interest in geomorphology while a lecturer at the then Victoria University College, Wellington. During this time he published a number of papers in these, his subjects of interest.

In 1935, he migrated to South Africa taking up an appointment as lecturer in geology and geography at the then Natal University College in Pietermaritzburg. In 1946, he was appointed professor in geology; in 1948, he transferred to Durban to a new Department of Geology and Mineralogy, the institution becoming the University of Natal the following year. He was to remain in this position until his retirement therefrom in 1973.

He published one of his first papers in South Africa on the ‘Monoclinal Coast of Natal’ in 1941. In 1942, he published his first geomorphological book, ‘South African Scenery’ (King 1942), which later ran to three editions, two revised, but this first edition being very probably the best. In all, King published personally (mainly), and in collaboration, of the order of some 50 major papers and books in his field of geomorphology, the last, in 1983, being entitled ‘Wandering Continents and Spreading Sea Floors on an Expanding Earth’. He also produced numerous ‘minor’ local publications.

King based his interpretations of landforms and landscapes very firmly in the concept of erosion by parallel scarp retreat, for although he acknowledged the

Fig. 2 Dynamic geomorphology – scarp retreat in action! Note landslide on lower near slope and rockfall above it in right middle distance, Drakensberg escarpment with crest at 3,000 m on left skyline, near Bergville, KwaZulu-Natal

possibility of slope decline in certain (lithological) circumstances, he used that mechanism little, if at all, in understanding landscape. Rather, pediments and inselbergs, for instance, as well as entire landscapes, he construed in terms of scarp recession. He considered pediplanation (scarp retreat and pedimentation) to be active in varying degree in all regions where running water is responsible for shaping the land surface. King's studies in denudation chronology are consistent with his commitment to scarp retreat, implicit in which is the possibility of the survival of very old, flat or near flat land surfaces (Fig. 2).

Perhaps the best known single paper to the wider audience of geomorphologists interested in landscape evolution and chronology is King's 'Canons of Landscape Evolution' published in 1953 in the Bulletin of the Geological Society of America,

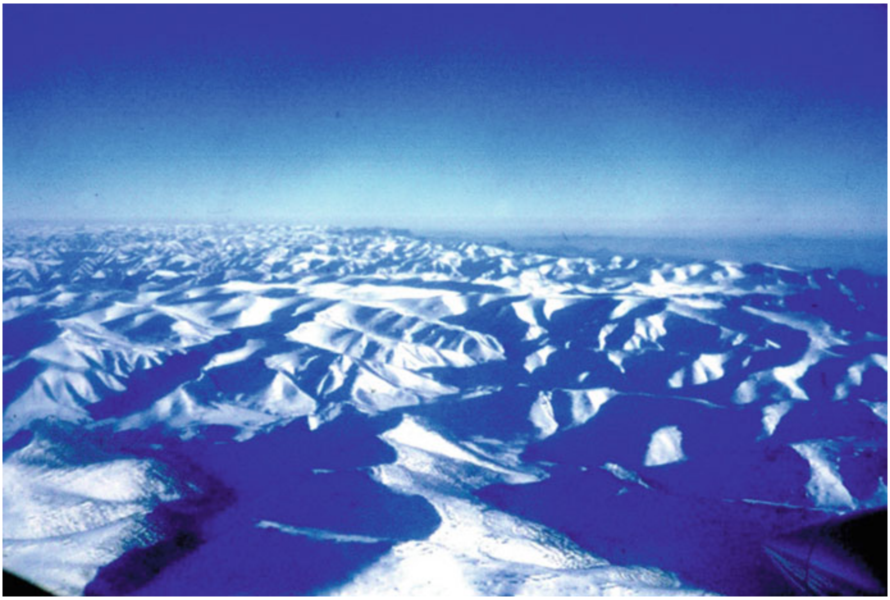

Fig. 3 The summit of the Lesotho Highlands ±3,000 m originally considered by King to be of Jurassic age. Actually of structural origin on flat-lying basalt. Near Underberg, KwaZulu-Natal

a paper in which he developed the concept of backwearing of slopes and spelled out his geomorphological credo in 50 laws or canons. His 'magnum opus', a weighty tome, *The Morphology of the Earth* (1962) consolidated his tectonic and geomorphological interpretations on a global scale and to every continent.

Some of the more important other publications of King include the following: King (1950, 1957, 1966 and 1976). See also King (1950, 1951, 1953, 1956 and 1963).

Regarding landscape development in Southern Africa, King's views changed significantly with time. Thus, in his 1942 book, King concluded that the landscape of Southern Africa could be resolved into three major cycles and surfaces. These were the Gondwana surface of Cretaceous and Late Miocene age; the African surface of Early to Middle Tertiary age, frequently carrying laterite or silcrete duricrusts; and the multiphase Late Cenozoic surface. In his early 1944 paper, he considered that the crests of the Lesotho Highlands represent a Jurassic erosion surface that has survived since prior to the break-up of Gondwana in Late Jurassic to Early Cretaceous time and that the disparity of elevations of erosion surfaces below the Great Escarpment and on the interior plateau (Highveld) was due to the respective differences in distances to base level in each case (Fig. 3).

In 1949, King argued that the coexistence of land surfaces of different ages is possible only if landscape evolution proceeds through backwearing under a process of pediplanation. For the first time, names were proposed for the various erosion cycles as expressed by the land surfaces: Miocene, Gondwanaland; end-Tertiary, African; Pleistocene, Victoria Falls; and present, present. In 1951, he more or less reiterated the same situation adding a Gondwanaland surface which also predated the break-up of Gondwana, it occurring at different levels above and below the Great Escarpment. The African surface originated with the fragmentation of Gondwana, the subsequent Victoria Falls and Congo cycles being manifested in river incision. Fair and King (1954) renamed the 'marginal' Gondwanaland surface the 'post-Gondwana', it having been initiated in the Middle Cretaceous based on the evidence of coastal marine sequences. Subsequent cycles were the 'African' (Middle Tertiary), 'Victoria Falls' (end-Tertiary), 'Congo' (Pleistocene) and the 'Latest' (recent).

King and King (1959) (the second King being Lester King's daughter, Linley) postulated that the African surface was carried across the Great Escarpment by end-Tertiary uplift that in the continental marginal areas having been continuous with the higher Highveld surface of the interior. The summits of the Lesotho Highlands were now considered to represent the Gondwana cycle of Jurassic age. The post-Gondwana was initiated by the fragmentation of Gondwana in the Early Cretaceous. Epeirogenic rejuvenation of the marginal monocline, with some faulting, in the Middle Cretaceous gave rise to the African cycle. Uplift in the Early Miocene produced renewed incision and planation in the post-African cycle, these cycles being correlated with unconformities in coastal marine sediments of Cretaceous and younger age. Rejuvenation and enlargement of the marginal monocline during the Pliocene produced local planation in a Late Tertiary phase II cycle. Finally major up-warping at the end of the Pliocene initiated major gorge incision in the sub-escarpment zone.

In a subsequent paper (1976), and in his final synthesis, King (1983) proposed a new (somewhat bizarre) nomenclature for the various surfaces which he considered as being of global applicability, he having correlated the African landscape development with what he had observed on visits to eastern Australia (1950) and Brazil (1956). This was his last erosional chronology scheme in which he identified six major surfaces and cycles: the 'Gondwana' planation of Jurassic age, the 'Kretacic' (Early-Middle Cretaceous), the 'Moorland' (Late Cretaceous to Middle Cenozoic), the 'Rolling' (Miocene), the 'Widespread' (Pliocene) and the 'Youngest' (Quaternary, essentially modern). Needless to say this last scheme of King's has not received the same degree of support as did his original one. It is not surprising that King's many of views frequently generated controversy in certain more conventional quarters. (The reader of all the above is to be readily forgiven, if at the end of it, he finds himself more than a little confused.)

Lester King himself was an excellent lecturer, his lectures being clear, informative, well organised and laced with amusing anecdotes. He was very versatile, his expertise extending over the whole range of the geological sciences. In later life, however, as is often the case, sadly, he became more than a little authoritative. This writer earned the title of 'his most misguided student' by questioning (Maud 1961) his interpretation of his beloved Natal 'hard rock' Monocline (1941, 1972) and showing that in fact the region in question is of tensional faulted origin (break-up of Gondwana age), it being part of what is now termed a rifted passive continental margin. Lester King died in 1989 after a long illness, and his ashes were scattered at the foot of the erosional Drakensberg Mountains which form part of the Great Escarpment in what is now KwaZulu-Natal; a more fitting place for Lester King's ashes to rest in, below a mighty erosional scarp, could not be found.

Later Landscape Studies in Africa

Given the prominence of work of Lester King, mainly in Southern Africa, it must not be supposed the similar landscape and related studies were not being undertaken elsewhere in Africa. Thus, in West Africa, Pugh (1954) worked in northern and eastern Nigeria (Jos State there is known as the 'Plateau State') as did Thomas (1994), while in East Africa, Uganda and Kenya notable workers included Ollier (1959) and Macfarlane (1976) (Figs. 4 and 5).

No doubt many other workers were active in these parts of Africa whose publications are unknown to this author. This author though has visited those parts of Africa and observed the close similarity of the landscape features prevailing there to those extant in the southern portion of the continent.

Fig. 4 Residual of laterite duricrusted African surface with underlying deep weathering. Kano, Northern Nigeria

Fig. 5 Islands of laterite duricrust of the African surface downwarped as part of Lake Victoria basin, near Entebbe, Uganda

The Works of Partridge and Maud (1987, 1989, 2000), Partridge (1998) and Maud (2012)

Partridge and Maud modified and revised the work of King in Southern Africa in the light of more recently available relevant information and their own extensive observations throughout this part of the continent.

Thus, the idea of King that landscape on the top of Drakensberg had survived since prior to the disruption of Gondwana was rejected on the evidence of the morphology of diamondiferous kimberlite pipes of Middle Cretaceous age which penetrated to at least this level (3,000 m), the indication therefrom being that at least 300 m of basalt has been removed by erosion from above this surface.

On the same basis and in the light of xenoliths in such pipes of country rock and of relevance in alluvial diamond exploration in Central Southern Africa, it has been established that at least 2,500 m of Karoo basalt and sediments which formerly covered this area has been removed by eastward scarp retreat since the Cretaceous (Hanson et al. 2009; in Maud 2012). Since the Late Cretaceous the landscape over much of the central portion of the subcontinent has suffered negligible erosion as is shown by the survival on the present landscape surface of silicified wood of Late Cretaceous age in fluvial gravels (diamondiferous) at Mahura Muthla west of Kimberley (Partridge 1998).

Fig. 6 Outcrop of duricrust laterite on the African surface on right. African surface also on distant flat skyline. Post-Africa I surface at lower level in the middle distance with younger river incision. Total relief approaching 1,800 m. Valley of 1000 Hills northwest of Durban

Fig. 7 Near flat skyline of African surface etchplain with remnants of deep weathering (kaolinisation) in road cutting. Eastern Transvaal, near Ermelo

Fig. 8 Silcrete duricrust overlying deep weathered (kaolinised) rock. About 50 m above sea level, sea visible in the distance. Near Hermanus, Western Cape (east of Cape Town)

Fig. 9 Massive silcrete duricrust on intermontane valley-ride African surface shoulder, as can be seen in the middle-far distance. Near Oudtshoorn, Western Cape

Fig. 10 African surface with duricrust silcrete capping and deep weathering (kaolinisation). Note: large granite core-stones in weathered material which will become tors with further backwearing erosion. Lower surface on left, post-African I. Near Platbakkies (Springbok), Northern Cape Province

Fig. 11 Remnant of marine Eocene, shelly limestone on African surface at 400 m elevation, 25 km from present coastline. Note the rise of the planed skyline from right to left, in an inland direction, of the African surface. Near East London, Eastern Cape

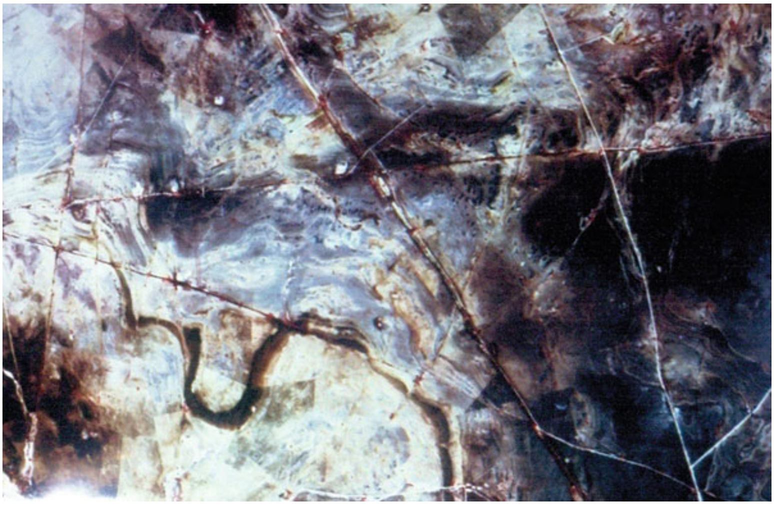

Fig. 12 Landsat view of former river meander of Cretaceous age on the etched African surface. This has survived subaerially for some 80 Ma, which is incomprehensible to most European geomorphologists. Many such palaeo-river channels, in their calcreted fluvial gravels, are diamondiferous. Mahura Muthla near Vryburg west of Kimberley, Northern Cape Province

The findings of Partridge and Maud, as given in the publications indicated above, may be briefly summarised as follows:

1. Africa in the centre of Gondwana stood relatively high in relation to surrounding areas.
2. Break-up of Gondwana in the Late Jurassic to Middle Cretaceous by rift faulting, after associated increase in elevation of the rift shoulders, initiated the African cycle of erosion, which is multiphase, the resulting surface of advanced planation being characterised by duricrust laterite in the north and silcrete in the south, together with deep weathering (kaolinisation) of underlying rocks. Some minor lowering of the surface due to removal by erosion of weathered material (etching) has taken place in some areas. Corresponding sedimentation has taken place off continental margins.
3. The African cycle was terminated by moderate epeirogenic uplift of varying amount along axes parallel to and in the hinterland of the coast. The east coast hinterland experienced greater uplift than the southern and west coasts, leading to topographic asymmetry of the subcontinent.
4. The African cycle was succeeded by the post-African I cycle of erosion which did not achieve the advanced planation of the African cycle.
5. Termination of the post-African I cycle of erosion by major epeirogenic uplift in the Early Pliocene along some axes in the coastal hinterland previously occurred. Total amount of combined uplifts on the east coast was about 1,150 m, on southern coast about 400 m and on the west coast about 250 m.

Fig. 13 Silicified fossil wood in the fluvial gravels at Mahura Muthla of Late Cretaceous age, on the etched African surface. Near Vryburg, west of Kimberley, Northern Cape Province

6. The post-African I cycle was terminated by the post-African II erosion cycle of major valley incision, especially in the southeastern coastal hinterland.
7. The post-African II erosion cycle was terminated in the Late Pliocene and Pleistocene by river valley erosion consequent on climatic and glacio-eustatic changes of ocean and local base levels, which situation continues to the present day (Figs. 6, 7, 8, 9, 10, 11, 12, 13 and 14).

As far as possible, Partridge and Maud attempted to recognise the succession of erosion cycles first described by King and, where appropriate (as in the name of the African cycle), continue his nomenclature. However, his more exotic nomenclature was replaced, where applicable, by one of a more easily understandable chronological type.

Acknowledgements This writer wishes to acknowledge with thanks some of the information contained in a manuscript version of a paper given to him by C.R. (Rowl) Twidale, Australia, some years ago now, entitled 'Lester King – Last of the Explorer Scientists'.

He also acknowledges with deep gratitude all the work and companionship of his long-time friend and colleague Tim Partridge (1942–2009), who was also a very observant scientist and who researched and published in quite a few scientific disciplines other than geomorphology (archaeology, soil science, palaeoanthropology, palaeoclimates, engineering geology and geology).

Fig. 14 Outcrop of pipe of volcanic alnoite (melilite basalt) 63 Ma. Formerly capped by silcrete duricrust on Africa flat surface visible in the background. Near Swellendam, Eastern Western Cape Province

He was indeed a prolific publisher, like King, but sadly he died of a sudden heart attack, all too soon, while still in his productive prime.

This writer also wishes to thank Mrs. Sandy du Toit and Mrs. Sally Padayachee for their valuable assistance in the production of this review.

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