Part one

Physiography and history

Part 1 of this volume provides the physical, historical and biogeographical background that is necessary for a fuller appreciation of vegetation patterns and processes in southern Africa. It comprises four chapters, namely landscape evolution (Chap. 1), climate (Chap. 2), phytogeography (Chap. 3) and vegetation history (Chap. 4). Each chapter provides a different perspective towards understanding the enormous vegetational diversity of the subcontinent.

In Chap. 1, Partridge discusses the evolution of southern African landscapes. In common with other southern continents, many of these landscapes are extremely ancient. However, because of southern Africa's central location in Gondwanaland, it inherited more relief than the other fragments of the super-continent. A major feature of its geomorphic history was the erosion from the coast towards the interior, during the Cretaceous, of the ancient Gondwanan surface. This recession resulted in the formation of the Great Escarpment, a continuous arc that separates an elevated inland plateau from the dissected coastal margin, and a feature of great phytogeographical significance. Remnants of the pre-African surface persist as elevated areas such as the Cape Folded Belt and the Drakensberg uplands, both supporting very diverse contemporary floras. The planation of the African surface was associated with the formation of massive duricrusts of laterite, silcrete and calcrete. The shallow and sometimes infertile soils developed on these crusts provided a substratum suitable for the early diversification of xerophytic and sclerophyllous angiosperms, now such an overwhelming component of the southern African flora. Tertiary geomorphic history was characterized by successive cycles of uplift and erosion of this African surface. As a consequence, ancient and younger surfaces formed a complex mosaic of substrata. This geomorphic and associated edaphic complexity has undoubtedly played an important role in the development of southern Africa's vegetational diversity.

Schulze (Chap. 2) describes the contemporary climate of southern Africa (excluding Botswana and Namibia) by way of a wide-ranging series of computer-generated maps based on impressive databases of primary climatic and physiographic variables, which are used in conjunction with water and energy-budget simulation models. His analysis clearly shows the semi-arid nature of the subcontinent: less than 5% of the region receives an annual rainfall of greater than 800 mm and, on average, more than 90% of rainfall is returned to the atmosphere by evaporative losses. Biologically, the region is characterized by great uncertainty with most of southern Africa having an inter-annual variability in primary production in excess of 50%. These generalizations, however, tend to mask the high climatic diversity and steep climatic gradients of the subcontinent: from the hyper-arid and foggy Namib desert along the west coast to the hot and humid climate of the east coast; from the semi-arid and drought-prone Little Karoo basin to the cool and rain-soaked summits of the Cape mountains, only 1000 m higher. These patterns are largely the result of the region's transitional location with regard to tropical and temperate circulation systems; the juxtaposition of cold and warm ocean currents; and a varied topography. Thus, climatic diversity acts in concert with edaphic diversity to produce the complex vegetation patterns of southern Africa.

Cowling and Hilton-Taylor (Chap. 3) build on these themes of physiographic diversity to explain the exceptional concentration of phytogeographic units in southern Africa. The striking features of the region's flora are the high diversity and endemism at all taxonomic levels. Thus, southern Africa forms a discrete phytogeographic entity: a southern temperate flora with some characteristics more typical of an oceanic island than a continental landmass. The endemic component is not uniformly distributed across the subcontinent but is concentrated in an almost continuous arc below, and including, sectors of the Great Escarpment and elevated pre-African surfaces. Moreover, endemic species are overwhelmingly associated with a limited number of genera characteristic of the southern (Cape and Karoo–Namib) phytochoria; they are biologically uniform; and are the product of relatively recent diversification. Cowling and Hilton-Taylor suggest that the unusual richness of the subcontinent's flora is more a function of massive and incidental diversification within biologically peculiar lineages, than adaptive radiation in a spatially and temporally heterogeneous environment.

Scott, Anderson and Anderson (Chap. 4) conclude this part with an account of southern Africa's vegetation history, from the origin of land plants to the mid-Holocene. There is nothing in this account to suggest that, relative to other southern continents, there is anything unusual or exceptional about the region's history. Modern vegetation types first appeared in the Cainozoic and expanded, along with the extinction of archaic lineages, with accelerated climatic deterioration from the Miocene onwards. The ever-present saw-tooth fluctuations in climate over the last few million years have resulted in a long series of substantial changes in vegetation boundaries: glacial events favoured the temperate or 'southern' flora, whereas interglacials witnessed the expansion of subtropical savannas and forests. Scott *et al.* invoke climate change as the major driving force behind these shifts in vegetation boundaries and conclude that the timing and magnitude of these climatic cycles were sufficiently unremarkable to explain the region's exceptional plant diversity.

Why then, when compared to the other southern subcontinents at similar latitude, is southern Africa so rich in plant species and, consequently, floristically characterized vegetation types? Is it because there is something unusual about the region's biota or physiography, or both of these? These four chapters go some way to answering this question, but more comparative biogeographical and evolutionary studies are required to solve this enigma.

Evolution of landscapes

1

T.C. Partridge

1.1 Introduction

Large parts of Africa, like Australia and South America, differ from most northern hemisphere land masses in preserving extensive tracts of ancient landscapes. These have exerted a profound influence on the evolution and distribution of vegetation. An understanding of landscape history is therefore as important as the chronicle of changing climates for comprehending the development of southern African plant communities and their current distributions.

Southern Africa is, in many ways, typical of the face of ancient Africa. It is characterized by a high interior plateau, bounded on three sides by the horseshoe rampart of the Great Escarpment. Above the plateau stand several elevated mountain massifs, among them the highlands of Lesotho, which exceed 3000 m in places. Other parts of the interior are dished into large basins, such as the Kalahari and Transvaal Bushveld. Away from the foot of the Great Escarpment, a plinth 50 to 200 km wide slopes to the coast; its undulating surface is cleft by deep gorges, through which rivers find their way from the interior to the ocean.

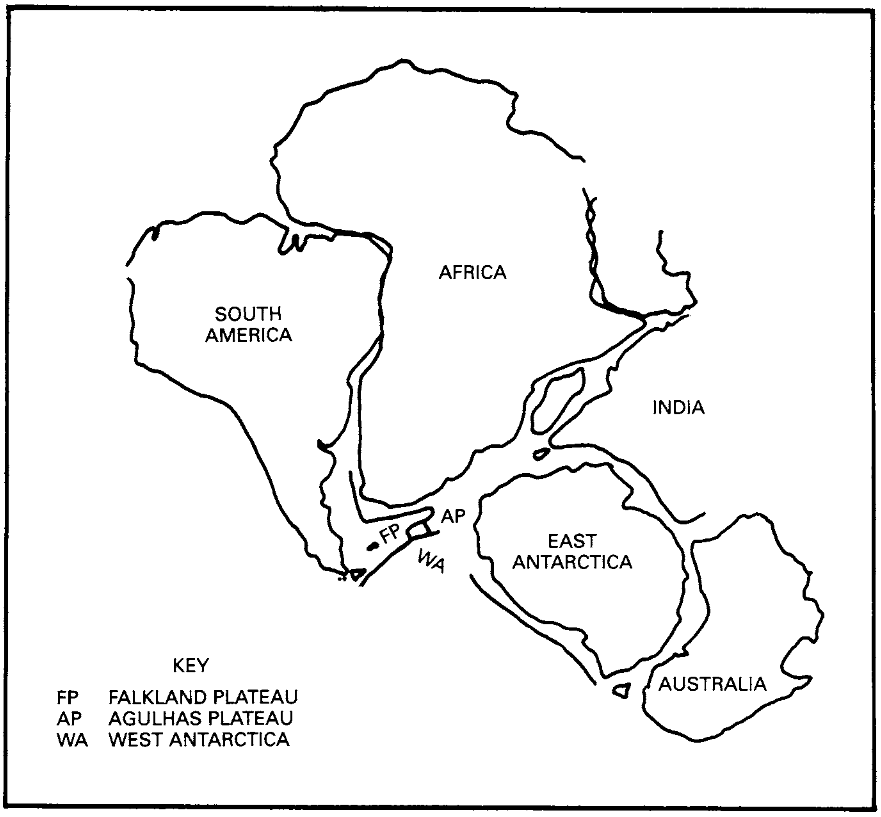
The broad physiographic symmetry of southern Africa contrasts with the meridional distribution of its principal climatic belts. These are so aligned that much of the subcontinent grades, west to east, from hyper-arid to humid (Chap. 2, this volume). The imprint of this climatic gradient is evident in both recent landforms and soils, but other relict features indicate that the contrast between the western and eastern seaboards is not of particularly great antiquity. The legacy of past changes in climate is, indeed, readily apparent in the landscapes of the now arid west of southern Africa.

1.2 Early history: Gondwanaland and its fragmentation

Although most of the present landscape of southern Africa postdates the break-up of the Gondwanaland super-continent, some major elements of its architecture have been inherited from earlier periods. From Proterozoic times much of Africa has been characterized by a gross structure of interior basins separated by upwarped zones or ‘swells’. Cahen *et al.* (1984) have shown that these zones of doming and tensional stress, first formed during the ‘Pan-African’ episode of uplift within mobile belts which ended about 560 million years ago (Myr), were rejuvenated repeatedly during the Phanerozoic. In the course of these uplifts the intervening stable shield areas, or cratons, lagged behind to form large basins. In southern Africa the Kalahari Basin has been the principal focus of continental sedimentation since the late Cretaceous (Partridge & Maud 1987). Although influenced in its form and location by very much earlier geological events, the present Bushveld Basin is considerably more recent, having been lowered along marginal faults as recently as the Pliocene (3–5 Myr) (Partridge, Wood & de Menocal 1995b).

The present configuration of the southern African landscape is overwhelmingly the product of a sequence of events set in motion by the break-up of Gondwanaland. Recent reconstructions confirm the central position occupied by Africa in the assemblage of southern hemisphere continents (Dingle, Siesser & Newton 1983; Fig. 1.1). This central location was, in large measure, responsible for the high altitude of southern and eastern Africa before the fragmentation of Gondwanaland in late Jurassic and early Cretaceous times. Reconstructions

Figure 1.1 **The configuration of the southern hemisphere continents at the time of the break-up of Gondwanaland (after Dingle *et al.* 1983).**



based on the summit elevations of little-lowered remnants of the pre-rifting landsurface (e.g. the crests of the Lesotho Highlands), and on the extent of subsequent erosion as determined from the morphology of kimberlite pipes (Hawthorne 1975; Partridge & Maud 1987), indicate that elevations on this surface probably ranged from about 1800 m in the interior to about 2350 m in zones of upwarping adjacent to the rift margins. The amplitude of marginal downwarping and scarp formation during rifting must therefore have been of considerable magnitude. Their legacy has been preserved during the subsequent evolution of southern Africa in the Great Escarpment, now driven back by erosion between 50 and 200 km from the coastline, which forms a continuous arc separating the inland plateau from the more deeply dissected coastal margins. The interior plateau now ranges in elevation between about 1000 and 1700 m.

These inferences on the extent of erosion since the disruption of Gondwanaland are supported by computations of the volumes of terrigenous marine sediments which have accumulated since the ocean basins surrounding southern Africa were first formed (Rust & Summerfield 1990). Independent confirmation comes from the measurement of fission tracks in apatite crystals in rocks now exposed on the surface (Brown *et al.* 1990); these indicate the thickness of overlying material removed since the occurrence of particular geological events. Both sources show that between 1800 and 3000 m has been removed from different parts of the interior since continental separation.

Although there is good evidence that several kilometres of material have been eroded from southern Africa since the fragmentation of Gondwanaland, a few upland areas of significant extent are preserved locally above the new landsurfaces which resulted from this denudation. These include the Namaqua Highlands, the Cape Fold Mountains, the Lesotho Highlands and the Transvaal Drakensberg (for a key to areas and localities referred to in this chapter see Fig. 1.2). Of these the Lesotho Highlands are the highest, exceeding 3000 m in places. Examination of the kimberlite pipes at Letseng Le Terai, near the crest of the Lesotho mountains, suggests that some 300 m of material have been eroded since the emplacement of these pipes (Hawthorne 1975) which, according to Davis (1977), occurred some 87 Myr. It is thus clear that the pre-rifting Gondwana landsurface is nowhere preserved within the present landscapes of the subcontinent.

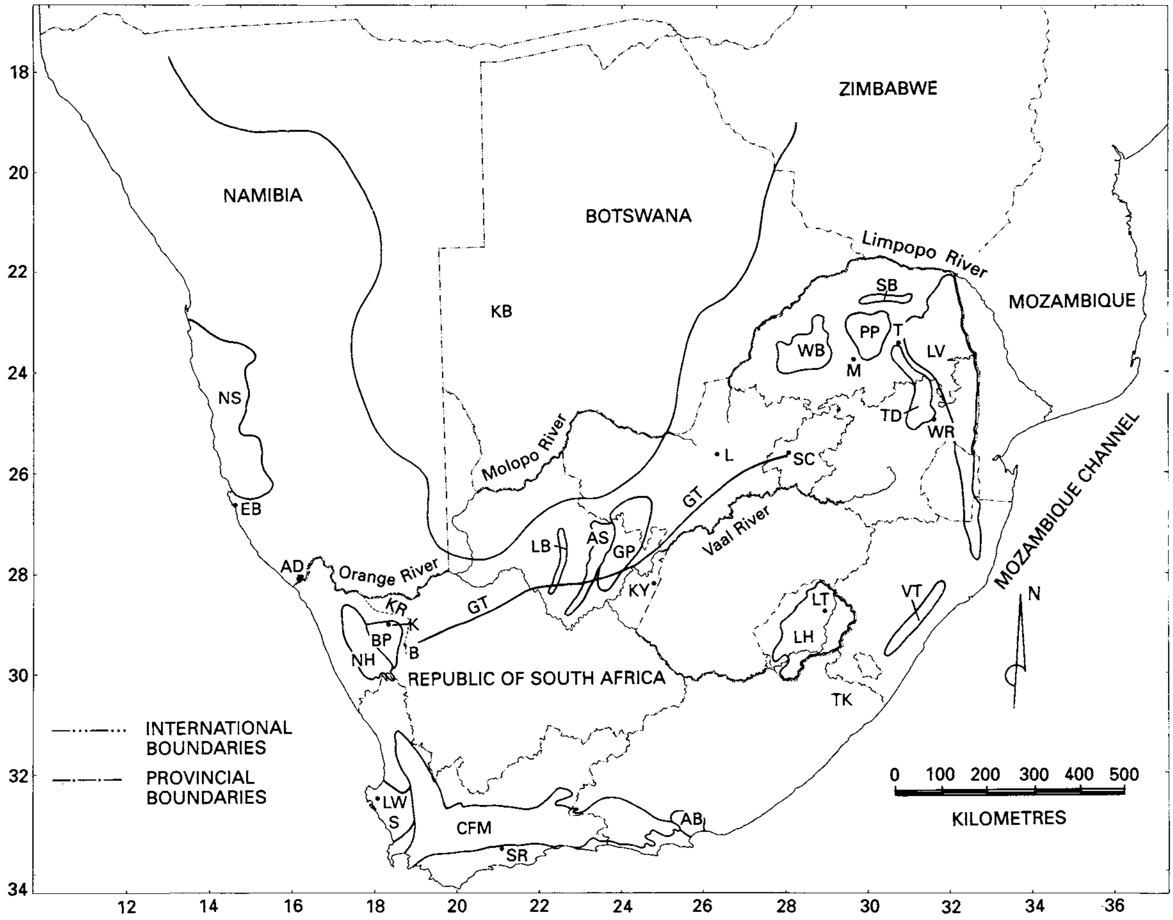


Figure 1.2 **Areas and localities referred to in this chapter. AB, Algoa Basin; AD, Arrisdrift; AS, Asbesberge; B, Bosluispan; BP, Bushmanland Plain; CFM, Cape Fold Mountains; EB, Elisabeth Bay; GP, Ghaap Plateau; GT, Griqualand–Transvaal Arch; K, Kangnas; KB, Kalahari Basin; KR, Koa River; KY, Kimberley; L, Lichtenburg; LB, Langeberge; LH, Lesotho Highlands; LT, Letseng Leterai; LV, Lowveld; LW, Langebaanweg; M, Makapansgat; NH, Namaqua Highlands; NS, Namib sand sea; PP, Pietersburg Plain; S, Swartland; SB, Soutpansberge; SC, Sterkfontein Caves; SR, Spiegel River; T, Tzaneen; TD, Transvaal Drakensberg; TK, Transkei; VT, Valley of a Thousand Hills; WB, Waterberge; WR, White River.**

1.3 Erosion and recession of the Great Escarpment during the Cretaceous

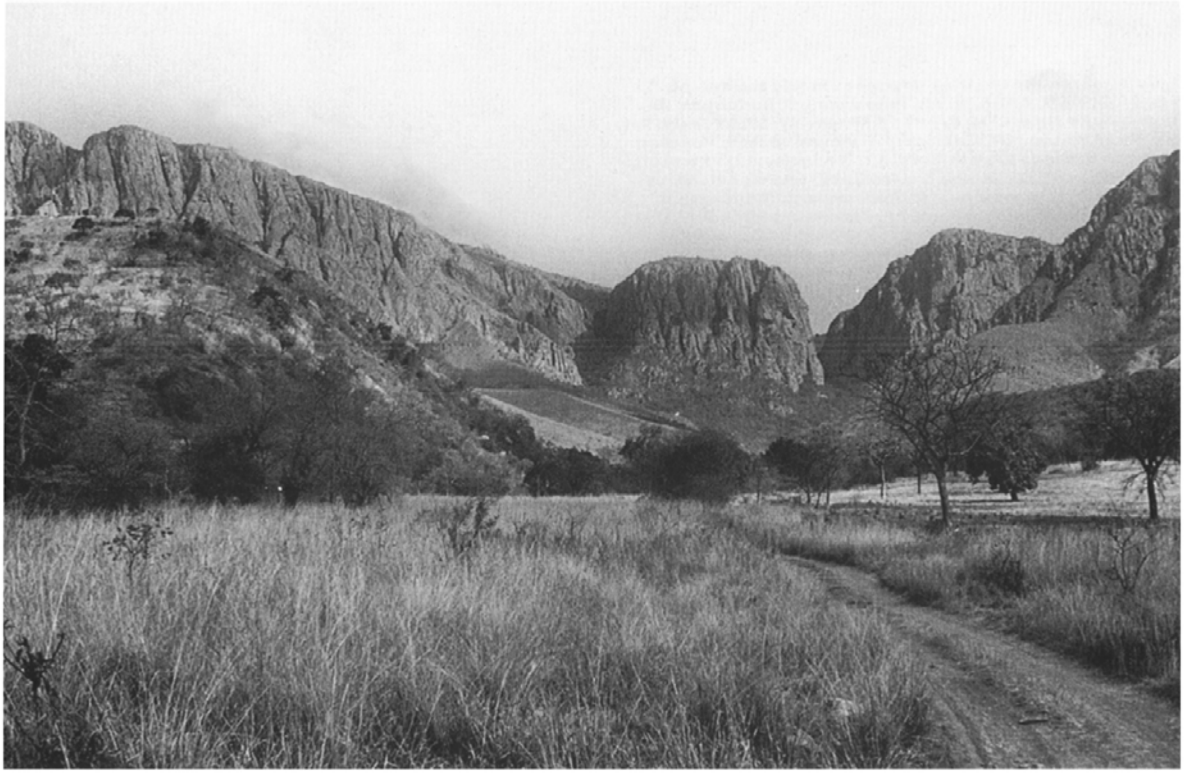
Because of the high elevation of much of southern Africa, a substantial marginal escarpment was created as the adjoining continental masses of South America and Antarctica drifted away from Africa. Rivers operating to the newly created local oceanic base level soon produced an erosional face. Although, during the Cretaceous, southern Africa occupied a position at least 14° further south than at present (Smith & Briden 1982), the subcontinent evidently enjoyed a humid, tropical climate, and offshore sedimentation rates were high, in keeping with the newly created energy potential, enhanced weathering and high runoff rates (Dingle *et al.* 1983; Partridge 1990). A comparison of the size distribution of basalt clasts of the Drakensberg Formation encountered today in river channels of the southeastern hinterland with those preserved in coastal marine sediments indicates that, by the mid-Cretaceous about 100 Myr, the Great Escarpment in this area had receded some 100 km from the coast; by the end of the Cretaceous this distance had increased to approximately 120 km – i.e. to a line not far seaward of its present position (Matthews 1978; Partridge & Maud 1987; Fig. 1.3). In short, as is reflected by sedimentation rates on the continental shelf, the sculpturing of the marginal zone below the Great Escarpment was largely a product of Cretaceous erosion (i.e. erosion which took place before about 65 Myr).

Simultaneous with denudation in the coastal hinterland was the removal of large volumes of material from the continental interior, as already noted. The bulk of these sediments was transported to the sea via the Limpopo and Orange/Vaal river systems, whose early exits through elevated rift shoulders are confirmed by the presence of Cretaceous sediments within their lower valleys (Partridge & Maud 1987). Although erosion has proceeded simultaneously above and below the Great Escarpment throughout the Cretaceous and the Cainozoic, the base levels which controlled this denudation differed for each zone: that of the interior plateau has been determined by the elevation of the exit points for the major river systems through the Great Escarpment (Partridge & Maud 1987). The resulting erosion surfaces, although formed over the same period, thus occur at different levels above and below the Great Escarpment (Fig. 1.4). This dichotomy has, in fact, been maintained throughout the geomorphic history of southern Africa. Attempts to correlate surfaces altimetrically between the coastal and inland areas have been at the root of many of the controversies which are recorded in an extensive literature (for a summary see Appendix A in Partridge & Maud 1987).

1.4 The African planation surface and its distribution

The massive removal of material from most parts of the subcontinent was overwhelmingly the work of Cretaceous erosion. Not only was the Great Escarpment driven back almost to its present position during this period, but the extensive African surface was planed to its ultimate level before the beginning of the Cainozoic, some 65 Myr. Although it has been lowered and dissected over large areas by subsequent erosion, sufficient remnants of this surface remain for its previous extent to be reconstructed and its elevation over much of the sub-

Figure 1.3 **The Great Escarpment in the eastern hinterland of South Africa. Here the quartzitic cliffs of the Transvaal Drakensberg overlook the rolling savanna country of the lowveld, which belongs to the Post-African I erosion cycle** *(Photo: T.C. Partridge).*



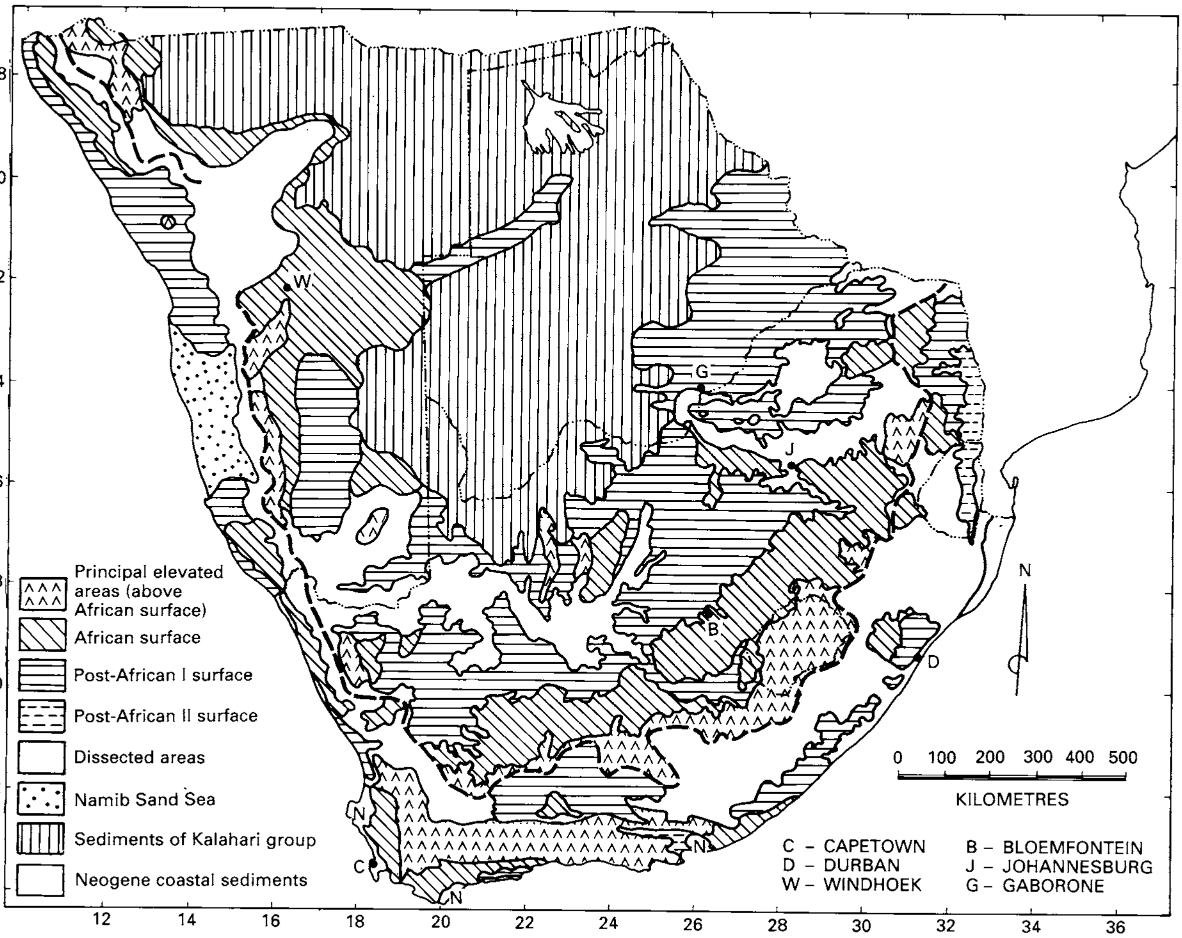


Figure 1.4 **Simplified map of the principal cyclic landsurfaces of southern Africa (modified from Partridge & Maud 1987). B, Bloemfontein; C, Cape Town; D, Durban; G, Gabarone; J, Johannesburg; W, Windhoek. Bold dashed lines indicate the Great Escarpment.**

continent to be contoured (Partridge & Maud 1987). Capping all of these pristine remnants are well-developed duricrusts. To the east of a line extending roughly from the Transkei to southeastern Botswana, these are of laterite; in the southern and western coastal hinterland they are preponderantly of silcrete, and in the semi-arid interior they are chiefly calcrete (caliche). This distribution is reflected in Fig. 1.5, but it is important to note that this map depicts the occurrence of pedocretes of all ages and stages of development, whereas those capping African remnants are generally mature (exceeding 2 m in thickness in many cases), frequently themselves weathered, and almost invariably underlain by deeply kaolinized regolith, which in places exceeds 30 m in thickness. These mature duricrust remnants, underlain by deep weathering profiles, serve to identify the African surface unambiguously in many highly dissected areas where other evidence is lacking (Fig. 1.6).

The age of overlying deposits is obviously crucial in defining the duration of the African erosion cycle. In the coastal zone silcrete caps are locally overlain by sediments which range in age, on palaeontological grounds, from early Eocene to Miocene; one such remnant overlies a weathered olivine melilitite pipe at Spiegel River in the southern Cape Province, which is part of a cluster of more than 270 whose K/Ar ages lie in the range 68–63 Myr (Moore 1979). In the interior the same surface is associated at Kangnas, on the northern edge of the Bushmanland Plain, with Cretaceous sediments containing dinosaur remains (Haughton 1915; Rogers 1915); further inland, on the Ghaap Plateau north of Kimberley, it is crossed by channel deposits containing silicified logs

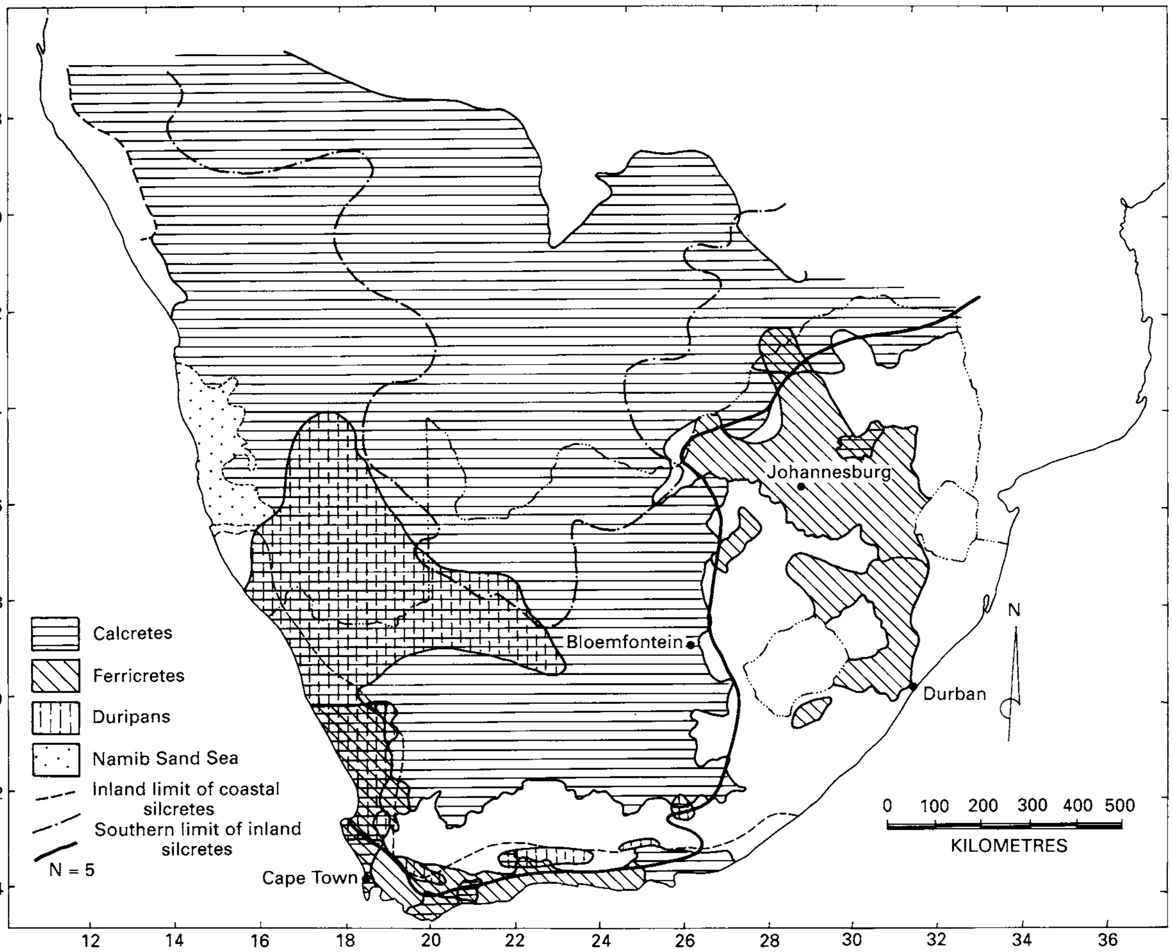


Figure 1.5 **Distribution of common occurrences of pedocretes in southern Africa (modified from Du Toit 1954; Weinert 1980; Ellis & Schloms 1984 and Schloms & Ellis 1984). N, Weathering Index (*sensu* Weinert 1974): east of the line, where N < 5, the moisture regime is such that chemical decomposition of rock and soil predominates over mechanical disintergration; west of the line, where N > 5, mechanical disintegration predominates.**

of the Upper Cretaceous (80–75 Myr) (T.C. Partridge, M.C.J. de Wit, J.D. Ward and M. Zavada, unpubl. data); and near Lichtenburg in the western Transvaal potholes within analogous palaeo-channel remnants contain late Cretaceous pollens (R.M.H. Smith, pers. comm.). The significance of this evidence is that, at widely separated localities within the Orange/Vaal catchment, which drains much of the interior of southern Africa, the African surface is overlain by deposits of Cretaceous (mostly late Cretaceous) age. On the basis of this and various other evidence it can, in fact, be deduced that the duricrusts which armour the African surface are of end-Cretaceous to Palaeocene age (Partridge & Maud 1989), and that erosion within the African cycle was largely complete by the end of the Cretaceous.

This accords well with the marine evidence (Dingle *et al.* 1983), but the record of significant peaks in sedimentation during the Cretaceous suggests that several sub-cycles, probably initiated by local tectonic disturbances, may have occurred during the interval of more than 60 million years, during which the African cycle of erosion was current. However, the great antiquity of these events has resulted in the merging of any separate local responses to form a surface which, for practical purposes, must be regarded as a single unit within the southern African landscape. Contrasting interpretations to the effect that significant denudation persisted into the Palaeogene (Rust & Summerfield 1990) must be rejected in the light of both the geomorphic and terrestrial palaeontological evidence (Partridge *et al.* 1995b).

As indicated in Fig. 1.4, remnants of the African sur-

Figure 1.6 **Silcrete duricrust overlying deeply kaolinized granite: the Kookoppies on the Bushmanland plain in the Nama-karoo biome. The upper surface is the African surface** *(Photo: T.C. Partridge).*

face are widespread in southern Africa, both above and below the Great Escarpment. In the coastal hinterlands, the early Cainozoic landscape was dominated by a gentle, multi-concave pediplain, linking the foot of the escarpment to the coast, and punctuated by isolated coastal ranges in KwaZulu-Natal and the Eastern Cape (e.g. the Amatole Mountains), and by high-standing ridges of the Cape Fold Mountains further to the west. Above the Great Escarpment, elevations on the African surface were probably of the order of 600 m, increasing somewhat in the upwarped areas inland of the present scarp front and adjacent to inland massifs such as the Lesotho Highlands, the Langeberge and Asbesberge of the Northern Cape, and the Waterberge and Soutpansberge of the northern Transvaal. Over most intervening areas a subdued, duricrust-armoured pediplain characterized the interior plateau; but in a zone extending about 800 km southwestward from the western border of Lesotho (Fig. 1.4), where erosion in the African cycle had not consumed all upland remnants, numerous flat-topped koppies and *tafelberge* (table mountains), formed by resistant strata of the Karoo Supergroup, imparted considerable relief. Soils were correspondingly less mature, with a strong colluvial component and a lesser degree of deep weathering and duricrust development.

The humid, tropical conditions which evidently prevailed in southern Africa during the Cretaceous (Partridge 1990) were undoubtedly responsible for the development of the deeply kaolinized weathering profiles which characterize most surviving remnants of the African surface. The genesis of the lateritic cappings that characterized the eastern areas of the subcontinent, by processes of relative enrichment of iron and aluminium oxides, can be readily comprehended in the context of tropical weathering processes; the nature of the genetic link between kaolinization and the formation of silcrete cappings is, however, more ambiguous. Most authors believe that these mature silcretes formed both in Australia and in southern Africa under humid conditions and low soil pH (e.g. Beckmann 1983; Summerfield 1983a,b; Twidale & Hutton 1986). At a pH of 4 or less, both silica and titanium (which is significantly enriched in silcretes associated with deep weathering profiles) are reasonably soluble (Summerfield 1983a,b); silica also shows enhanced solubility at very high pH. Partridge & Maud (1989) have argued that, although advanced weathering and uptake of silica into solution would undoubtedly have been favoured by the torrid Cretaceous climates, there is abundant evidence for cooling and desiccation at the end of the Cretaceous, which were evidently associated with an increase in pH. This would have led, inevitably, to silica precipitation. Indeed, many of the southern African silicretes overlying deeply weathered profiles display relict columnar or prismatic structures indicative of a sodic soil environment. In the semi-arid to arid western parts of the country an incipient form of silcrete known as 'dorbank' (red–brown hardpan) has formed more recently on lowered remnants of the African surface and on the Post-African I surface through cementation of soil particles by silica and iron oxides under eutrophic conditions. It is considered significant