Monograph on

Endemism in the Highlands and Escarpments of Angola and Namibia

Angola Cave-Chat *Xenocopsychus ansorgei*
Photo: M Mills

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Introducing the highlands and escarpments of Angola and Namibia

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ABSTRACT
Our paper outlines the key features that characterise and define the highlands and escarpments of Angola and Namibia (HEAN) and their topography, origins, drainage, landscapes, soils and climate. The highlands and escarpments stretch some 2,700 km from Cabinda and the Congo River southwards to the Orange River on Namibia's border with South Africa. Two plateaus above 1,700 masl cover large areas: the Angolan Planalto and Namibia's Khomas Hochland. Numerous inselbergs rise above the landscape, and many scarps form sharp margins between lower, western and higher, eastern areas. The highest peaks rise above 2,500 masl. As part of the Great Escarpment along the margins of southern and stretches of eastern Africa, the HEAN probably rose isostatically as the erosion of coastal crust reduced the mass of coastal Africa following the breakup of Gondwana. Three groups of rivers are associated with the HEAN: erosive rivers that flow rapidly off the highlands westwards to the coast; rivers that flow north or southwards, hugging the eastern flanks of the highlands until they turn west towards the coast; and rivers that flow eastwards and away from the highlands. Rivers in the northern third of the HEAN have perennial flows, those in the central third are ephemeral, and those in the southern third seldom carry water. The 11 landscape units defined in the HEAN are differentiated based on their topographical, geomorphological, ecological and climatic characteristics. Cambisols, Ferralsols, Leptosols and four other soils cover over 99% of the area. Most soils have limited plant nutrients, organic carbon and water-holding capacity. Average annual rainfall ranges from about 1,200 mm in the north of Angola and on the Angolan Planalto to less than 100 mm in the far south of Namibia. Rainfall is most variable in the southern and western areas. There are two peaks of rainfall in the northern half of Angola: in November and December and then in March and April. Within the HEAN, the southern areas are far more arid than those in the north because of the combined effects of high evapotranspiration and low rainfall.

Keywords: Angola, climate, drainage, escarpments, geomorphology, highlands, landscapes, Namibia, soils

INTRODUCTION

The highlands and escarpments of Angola and Namibia (HEAN) form a swathe of elevated land stretching approximately 2,700 km from Cabinda, just north of the Congo River, to the Orange River. The swathe is between 150 and 250 km in width for most of its length. The total area is around 488,000 km^2.

The HEAN is part of the much larger Great Escarpment of southern Africa, which stretches from northern Angola anticlockwise around the subcontinent to the eastern highlands of Zimbabwe (Figure 1). This Great Escarpment and its associated highlands are estimated to host over 8,500 plant species, of which 1,460 species are endemic, and among many endemic animals are at least 126 endemic vertebrate species (Clark *et al*. 2011). Viewed as a whole, the Great Escarpment is characterised by its simplicity: a conspicuous upland where narrow coastal plains of 50–200 km skirt rising foothills and sharp escarpments that lead to rugged mountain chains, with peaks frequently rising to elevations of over 2,500 masl. Inselbergs are also prominent features of the highlands, standing high above the coastal plains or the rolling hills of the

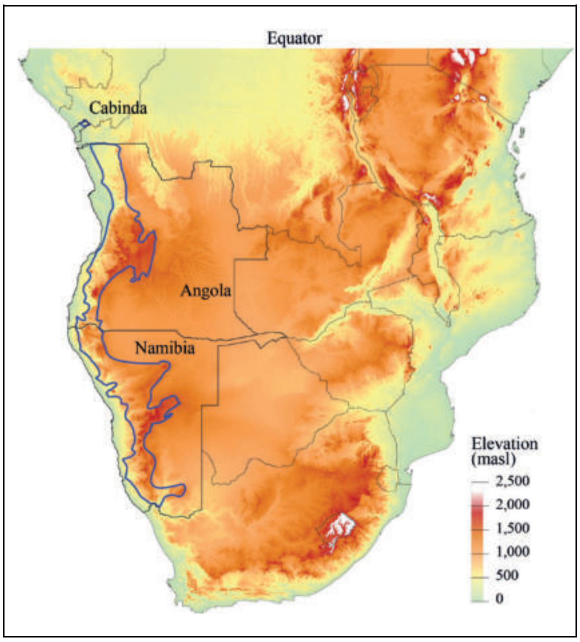

Figure 1: *Africa south of the equator, showing elevation, highlands (darker brown and white) and the area of the highlands and escarpments of Angola and Namibia (HEAN) demarcated by a blue outline. Black lines indicate the borders of Angola and Namibia.*

uplands. Inland of the mountain belts, elevations first drop quite steeply and then imperceptibly across interior peneplains that are drained by the great rivers of central and southern Africa (Moore & Larkin 2001).

On a grander scale, the HEAN and the Great Escarpment are part of the African Superswell, a feature that sets much of Africa apart from other continents (Nyblade & Robinson 1994). This is the broad tableland of elevated Africa stretching southwards from the Abyssinian Highlands in Ethiopia and across most of eastern and southern Africa. The tableland typically stands above 1,000 masl, whereas most other continental plains are below 500 masl (Figure 1).

Across the HEAN from about 5° South in Cabinda to 29° South along the Orange River, the climate ranges from tropical summer rainfall in the north to some temperate winter rainfall in the south, and from 1,300 mm of precipitation per year in the north to less than 100 mm in the south. The physiographic diversity and steep precipitation gradient from north to south have given rise to the extraordinary variety of biomes, ecoregions and vegetation types described by Huntley (2023) and animal and plant species found along the upland landscapes that extend across western Angola and Namibia, as described in many of the papers in this volume.

DEFINITION AND DELINEATION OF THE HEAN

The HEAN is an obvious physical feature on most maps (in Figure 1, for example), and to travellers on the ground or in the air because the inselbergs, scarps, escarpments, mountains and plateaus that constitute it are conspicuous. Figure 2 illustrates a selection of scarps, plateaus and inselbergs. However, defining a boundary that collectively encompasses these elements is challenging. The approach and terms adopted for this volume are explained below.

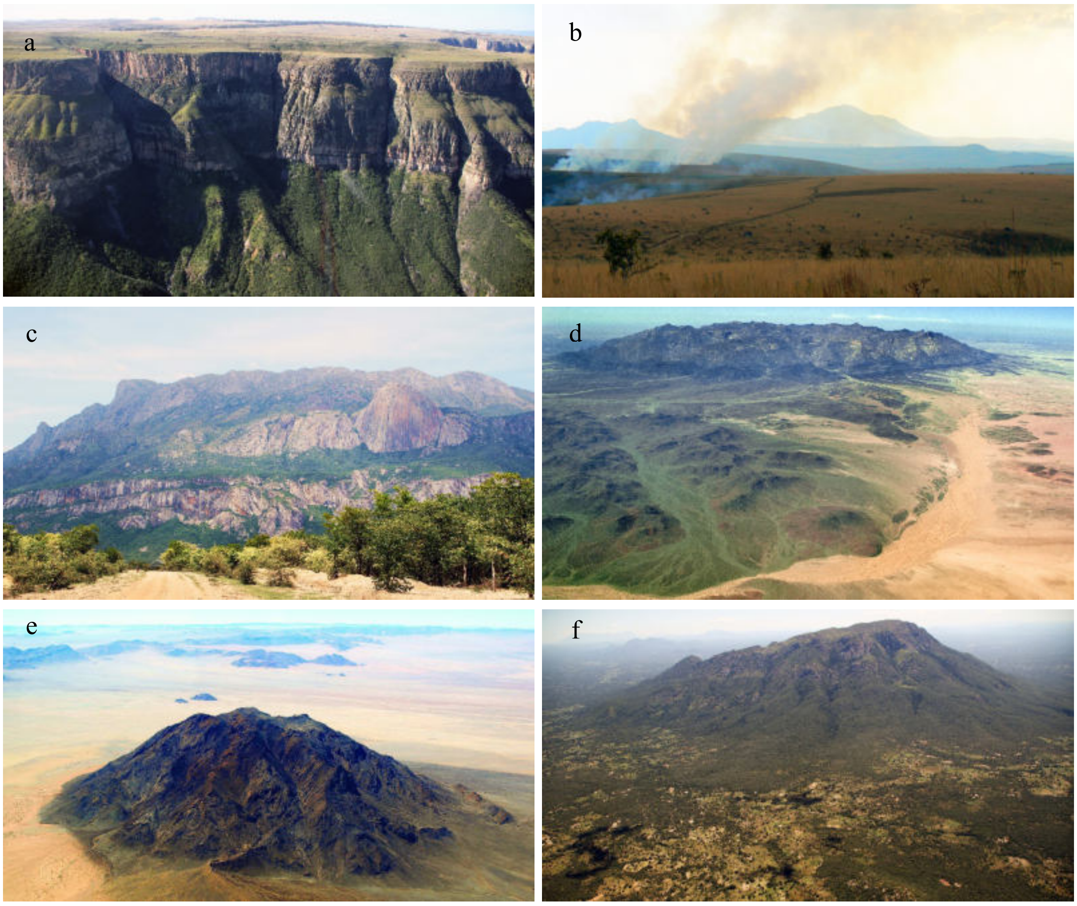

Figure 2: *A selection of scarps, plateaus and inselbergs in the highlands and escarpments of Angola and Namibia (HEAN): (a) the tallest scarp and escarpment and the plateau grasslands of Serra da Chela, just west of Lubango, Angola; (b) grasslands and human-caused dry-season fires around Serra do Môco typify the rolling hills of the Angolan Planalto; (c) Serra da Neve and (d) Brandberg are Angola's and Namibia's largest and tallest free-standing massifs, respectively, and both are located on the coastal plain; and (e) Namibia's Dikke Willem and (f) Angola's Serra Tchivira are typical of many isolated inselbergs on the lower western flanks of the highlands and escarpments, many of which rise 500 m or more above the surrounding lowlands. Photos: H Baumeler (Dikke Willem); T Figueira (Brandberg); others, J Mendelsohn.*

Highlands and plateaus

Two large blocks that lie between 1,700 and 1,800 masl make up and dominate much of the HEAN. One is often known as the Huambo highlands, Bié highlands or Huíla highlands, or Bié swell or dome (Knight & Grab 2016) or more practically – and in this volume – as the Angolan Planalto (*Planalto de Angola* in Portuguese). This forms an upland orientated NE–SW between Mussende and Lubango. The Namibian block is known colloquially, and in this volume, as the Khomas Hochland. It, too, stretches along a NE–SW axis, between Steinhausen and the Naukluft Mountains. Gently rolling hills and plateaus interspersed with inselbergs, many rising above 2,000 masl, cover large expanses of the two blocks. Grasslands, sparse shrubs and small trees dominate the vegetation. Plateaus were delimited as areas with gentle slopes and elevations greater than 1,700 masl (Figure 3).

West of the highlands, the landscape drops across steep escarpments, scarps or gently graded hills and valleys, descending to the coastal lowlands at about 600 masl, and to the coastal plain of the Atlantic Ocean. Rainfall over the coastal plain and lowlands is lower, and the vegetation generally sparser, than that on the highest elevations and to the east (see section on climate below). On the opposite and east side of the highland plateaus, landscapes gradually descend into the wooded plains of the Kalahari Basin.

Scarps and escarpments

Several escarpments and scarps form sharp boundaries to the highlands, some long and high, others shorter or lower. The most prominent and well-known in Angola are those forming the escarpment of Serra da Chela, which extends in a broken wall of tablelands from north of Humpata south towards Oncócua; the long scarp that runs from inland of Benguela for about 400 km north towards Calulo; and the scarp between Quilengues and Gabela.

In Namibia, the escarpment abruptly separates the coastal plain from higher ground to the east in many areas. It is best developed in central and southern Namibia from Usakos southwards to the flat-topped Gamsberg (2,350 masl), Naukluft Mountains, the Tiras and associated mountains that overlook the Namib, and to Aus. In central and northern Namibia the escarpment is not as well defined. Between Usakos and Khorixas erosion has largely removed the highlands and escarpment, resulting in a much gentler slope inland. The perennial Cunene and Orange rivers cut through the escarpment, as do the ephemeral Huab, Ugab, Omaruru and Swakop rivers. Environmental conditions change rapidly between the relatively wetter and more vegetated top of the escarpment and the arid, sparsely vegetated areas below.

Inselbergs

While large parts of the HEAN have been eroded away, many free-standing highland blocks of more resistant rock remain, overlooking their lower surrounds. The largest are close to or on the Angolan Planalto and Khomas Hochland, while many other smaller inselbergs are at lower altitudes farther west. Some inselbergs formed long after the main highlands. Most of these are composed of intrusive igneous rocks, and several are impressive features of the landscape, notably Serra da Neve, Brandberg and the Erongo and Paresis mountains. Features that rise sharply by 200 metres or more above their immediate surroundings were mapped as inselbergs.

In places, tall mountains rise above the plateaus as massifs to form, for example, Angola's highest peak (Serra do Môco on the Angolan Planalto at 2,620 masl), and Namibia's second-highest point (Moltkeblick on the Khomas Hochland which overlooks Windhoek from 2,479 masl). The elevations of both are similar to those of their large inselberg counterparts on the coastal plain where Serra da Neve at 2,489 masl is one of the highest peaks in Angola, and the Brandberg at 2,573 masl is Namibia's highest mountain. Many of the highest inselbergs on the Angolan Planalto support patches of forest, an effect of higher orographic precipitation. These forests are home to many endemic organisms, as described in the papers on plants (Goyder *et al.* 2023) and birds (Mills & Melo 2023) in this volume.

While drawing the boundary of the HEAN was often easy, for example along the margins of plateaus and along major scarps, elsewhere a more cautious approach had to be adopted, especially where we sought a boundary that encompassed most major inselbergs scattered on lower elevations to the west of the highland blocks and scarps (Figure 3).

ELEVATIONS AND SLOPES

Variation in elevation within the highlands and escarpments is largely related to their major components: plateaus, inselbergs on top of plateaus and at lower elevations, and scarps, as described above. Thus, most large inselbergs rise by at least 200 m above their surrounds; plateaus are above 1,700 masl on relatively flat ground, while the major highlands are in two large blocks, the Angolan Planalto and the Khomas Hochland, respectively in Angola and Namibia (Figure 3).

The transects in Figure 3 are as follows:

A – This transect runs from the coast just north of Ponte-Noire in the Republic of the Congo along

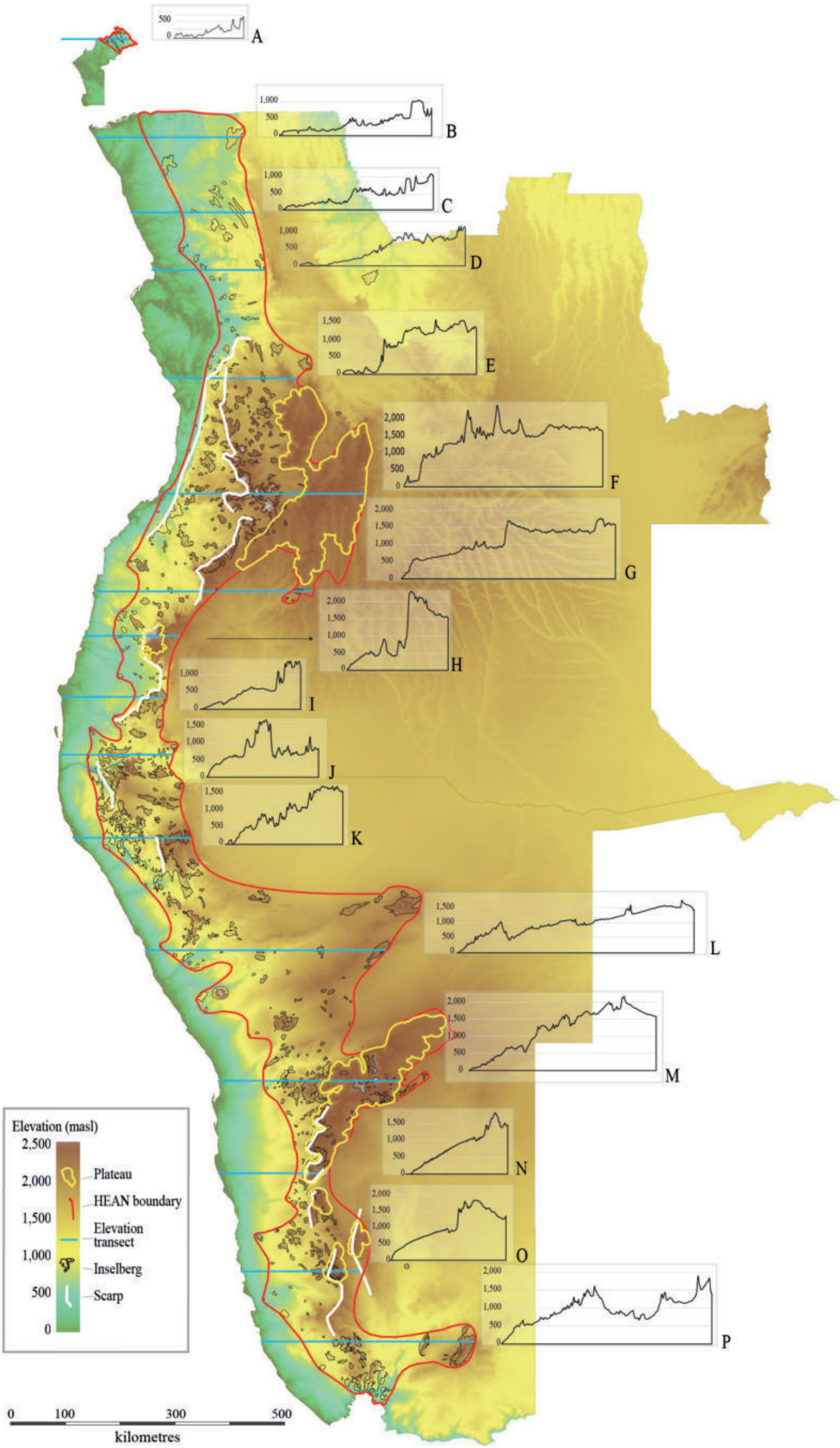

Figure 3: *Elevations in Angola and Namibia, and their highlands and escarpments (HEAN) together with scarps, plateaus and inselbergs, and profiles along select lines of latitude. The elevation profiles are described from west to east in the text.*

4.6° South to the northern border of Cabinda, and then cuts across the parallel ridges that run NW–SE through the Mayombe National Park. Elevations rise by about 500 metres from just west of Mayombe and the HEAN border up to the highest hills in the east.

B – The transect line along 6.3° South climbs from the coast through the hilly landscape of Angola's Zaire Province and then rises sharply by 500–600 m on to the relatively flat-topped Serra Canda.

C – Elevations are along 7.6° South between the coast and city of Uíge. The line traverses several parallel narrow ranges of sedimentary and carbonate rocks, among them Serra Calambinga, Serra do Pingano and Serra Uíge.

D – The transect along 8.6° South runs through Caxito, then climbs gradually across a broad ridge between Quibaxe and Bula Atumba and ends along the lower slopes of Serra do Combe.

E – From the Atlantic coast the transect along 10.47° South crosses about 80 kilometres of coastal plain between 200 and 300 masl. A sharp rise across the north–south escarpment that runs the length of Cuanza-Sul and Benguela provinces is followed by gently rolling countryside interrupted only by Serra do Ngueigi that rises some 600 metres from its surrounds.

F – From the coast along 12.48° South, the profile first ascends a small scarp and then transects the tall highlands of Serra do Mepo, Serra do Môco and Serra Cassoco. Eastwards, the profile crosses the gently rolling plateau grasslands of the Angolan Planalto.

G – Along 14.51° South, the profile rises gradually from the coast, and then climbs sharply over a moderate escarpment east of Quilengues. Elevations then drop slightly across the broad catchment of the Cunene River before rising over Serra Mocoti, an isolated inselberg largely covered in pristine miombo woodland.

H – About 110 km from the coast, elevations increase rapidly over the HEAN's highest scarp – in some places over 1,500 m – to the grassland plateau of Serra da Chela. To the west, the profile transects the Serra da Lua which rises several hundred metres above its surrounds. The profile line follows 14.94° South.

I – This profile transects a less prominent remnant of the Serra da Chela chert and dolomite plateau, again rising steeply up to a relatively flat tableland between 1,100 and 1,400 masl. The profile is along 16.0° South.

J – The profile along 17° South rises gradually across the Namib coastal plain in Angola, climbs part of the Serra Cafema massif and then the Serra Tchamalindi. Both mountains rise more than 1,000 metres above the surrounds and the nearby Cunene River which follows an ancient glacial valley (Martin 1965). The transect then follows the Cunene River valley upstream before crossing the smaller massifs of Serra Viluoviaengua.

K – From the coast, the profile along 18.44° South crosses several stretches of Etendeka basalt tablelands, as well as a major dip into the Hoarusib River valley. Farther east, the elevations record the northern ridge of the Otjikondavirongo range and then the Joubert Mountains.

L – After a sharp rise from the coast, elevations drop into the Huab River valley, then climb before a lesser drop into the Ugab River valley. It then follows the peaks of the intrusive granite Paresis Mountains, which rise several hundred metres above the surrounding landscape. In the far east, the elevations profile the sandstone Waterberg Plateau. The line follows 20.39° South.

M – Along 22.65° South, the line stretches across much of central Namibia, reaching the highest point in the Khomas Hochland. This is Moltkeblick, just south of Windhoek. The trough just west of this peak is the rift valley in which Windhoek lies.

N – After the flat coastal plain, the land rises steadily across the Namib Sand Sea before reaching the Naukluft, a dolomite massif which stands an average of 500 metres above its surrounds. The line of elevations is along 14.25° South.

O – Elevations rise gradually across the Namib Sand Sea along 25.95° South, and then climb steeply up the escarpment formed by the Tirasberge. The transect ends just south of Helmeringhausen and just west of another scarp known as the Schwarzrand.

P – The line runs from the coast along 27.17° South to the eastern border of the basalt-capped Karas Mountains. Elevations rise gradually from the west reaching about 2,000 masl on the Huib-Hoch Plateau before dropping into lower ground in the Fish River Canyon. The ground then rises to form the Klein Karasberge before reaching the higher Groot Karasberge.

The gentlest slopes (Figure 4) in the HEAN are on the plateaus of the Angolan Planalto and Khomas Hochland, the Central-Western Plains and in the landscape zones (see Figure 5) that flank the major highland blocks: Northern Escarpment, Central Escarpment, Southern Escarpment, the Nama Karoo Basin and Pro-Namib. By contrast, the steepest

***Figure 4:** Slopes or gradients in the highlands and escarpments of Angola and Namibia (HEAN).*

slopes and vertical cliffs are the scarps and associated hillsides between the highland blocks and flanking the landscapes listed above, and on inselbergs. The dark colours, which depict steep slopes, highlight the rapid changes in elevation of the Serra da Neve, Brandberg and other major inselbergs. This map also demonstrates the substantial differences in landform between the rugged, broken surfaces within 300 km of the coast and the relatively level surface of the eastern interior.

MAJOR LANDSCAPES

The ecological importance of the major physiographic divisions in Angola was recognised as early as the 1850s by the pioneer Austrian botanist Friedrich Welwitsch who categorised the 5,000 plant species he collected in Angola within three regions: *região litoral*, *região montanhosa*, and *região alto-plano* (Welwitsch 1858). Welwitsch also prepared detailed geological profiles across the landscapes inland of Luanda and Moçâmedes (Albuquerque & Figueirôa 2018), probably the first of such analyses in western Africa. A further detailed and indeed classic study of Angola's geomorphology and local ecology was published in 1936 by the German geographer Otto Jessen (Jessen 1936). He defined a series of 11 transects from the coast inland, traversing the escarpment to the interior plateau from Moçâmedes and thereafter at intervals northwards to Luanda. Describing, illustrating and mapping selected vegetation communities, geological exposures, landscapes, land use and ethnological features of the country, Jessen's Angolan work remains unique in its diversity of interest and originality (Huntley *et al*. 2019). Geomorphological studies in Angola continued during the 1950s to 1970s and are summarised by Costa (2006).

Based on extensive field surveys of the agroecological potential of Angolan landscapes, Castanheira Diniz produced a series of maps illustrating the key features of Angola's topography, geomorphology, geology, climate, soils, and phytogeographic and bioclimatic zones (Diniz & Aguiar 1966, Diniz 1973, 1991, 2006). Diniz's landscape (mesological) units provide a useful framework for discussions on Angola's ecology and biodiversity. Indeed, his mesological concept closely corresponds with current perceptions of ecoregions (Huntley 2023).

By contrast, Namibia has not enjoyed the benefits of early extensive surveys of soils, climate and other ecological zones and landscapes. The first country-wide assessments of geology were published in 1965 (Martin 1965) and of vegetation in 1966 (Volk 1966, Giess 1971), while the first comprehensive atlas of the country was published in 1983 (van der Merwe 1983). To our knowledge, the first assessment of Namibian landscapes – based substantially on the unpublished understanding of landscapes of geologist Roger Swart (pers. comm.) – appeared in Mendelsohn *et al*. (2002). Goudie and Viles' *Landscapes and landforms of Namibia* was published in 2015.

For the purposes of this volume, 11 landscape units are recognised within the HEAN (Figure 5). In Angola, these include Diniz's (1973) Escarpment Zone, which we subdivided into Northern Escarpment, Central Escarpment and Southern Escarpment, and his Marginal Mountain Chain and Ancient Plateau; the Ancient Plateau is renamed here as the Angolan Planalto. In Namibia, the HEAN includes seven landscape units, of which one is a continuation of the Southern Escarpment. For each of the 11 HEAN landscape units, outlines of their constituent biomes, ecoregions, fauna and vegetation are given below, using the enumeration of ecoregions of Dinerstein *et al*. (2017) as used by Huntley (2023).

1. Cabinda Escarpment (Ecoregion 5). From Gabon southwards through the Republic of the Congo, and inland of the coast, low hills give way to steep ridges of a narrow escarpment belt which ends just north of the Congo River (Figure 6). The geology of the Escarpment Zone, of which Cabinda Escarpment is the northernmost section is complex, comprising plutonic and metamorphic gneisses, schists, quartzites and amphibolites of Palaeoproterozoic age (2.5–1.6 giga-annums [Ga]) (Miller 2023, this volume). Few people live in the area.

2. Northern Escarpment, from the Congo River to the Cuanza River (Ecoregions 35, 63). South of the Congo River, the landscape comprises a highly dissected relief with hills and low mountains rising eastwards to 1,300 masl. The area is largely dominated by plutonic and metamorphic gneisses, schists, quartzites and amphibolites of Palaeoproterozoic age (2.5–1.6 Ga). Smallholders farm maize, beans, sweet potatoes, melons, cassava and bananas as major staples for domestic consumption. Incomes are mainly earned from the sale of charcoal, bushmeat and vegetables.

3. Central Escarpment, from the Cuanza River to the Coporolo River (Ecoregions 35, 77, 104). The Central Escarpment forms a low, narrow but stepped landscape from about 200–400 masl along the base, rising within 50 km from the coast to 1,000 masl (and to 1,690 masl at the highest point on Serra Njelo). It is of Ryacian age (2.4–2.05 Ga), with basement plutonic and metamorphic rocks. Crops and commodities sold for incomes here are similar to those in the Northern Escarpment zone.

4. Angolan Planalto (Ecoregions 36, 77). This extensive plateau (the *Planalto Antigo* or *Planalto Central*) encompasses the headwaters of the south-flowing Cunene, Cubango, Cuchi, Cacuchi and Cutato Nganguela rivers, the west-flowing Queve, and the north-flowing Cutato River. The landscape consists of gently rolling grasslands, *anharas de ongote* geoxyle grasslands (see Meller *et al*. 2023, this volume), wetlands and low ridges with scattered granitic inselbergs. The plateau drops from 1,800 masl in the west to 1,400 masl in central Angola. These flat to gently undulating landscapes, together with the Congo and Zambezian peneplains, are part of the African and Post-African planation. Maize, pumpkins and cassava are grown on dry soils while vegetables are grown in moist fields around tributaries, known as *olanaka*.

5. Marginal Mountain Chain (Ecoregions 35, 77). These mountain lands, known as the Benguela and Huambo highlands, and Humpata Plateau or Serra da Chela, are underlain mostly by Precambrian rocks such as gneisses, granites and migmatites and lie above the escarpment along the western margin of Angola's extensive interior plateau at 1,800–2,620 masl. The highest peaks are Serra do Môco (2,620 masl), Serra do Mepo (2,582 masl) and Serra Lupangue (2,554 masl). The mountains are of biogeographic importance for their montane grasslands, with some elements of the Cape flora, and relict patches of Afromontane forests with endemic bird assemblages (Goyder *et al*. 2023, Mills & Melo 2023, both in this volume). Land uses are similar to those on the Angolan Planalto.

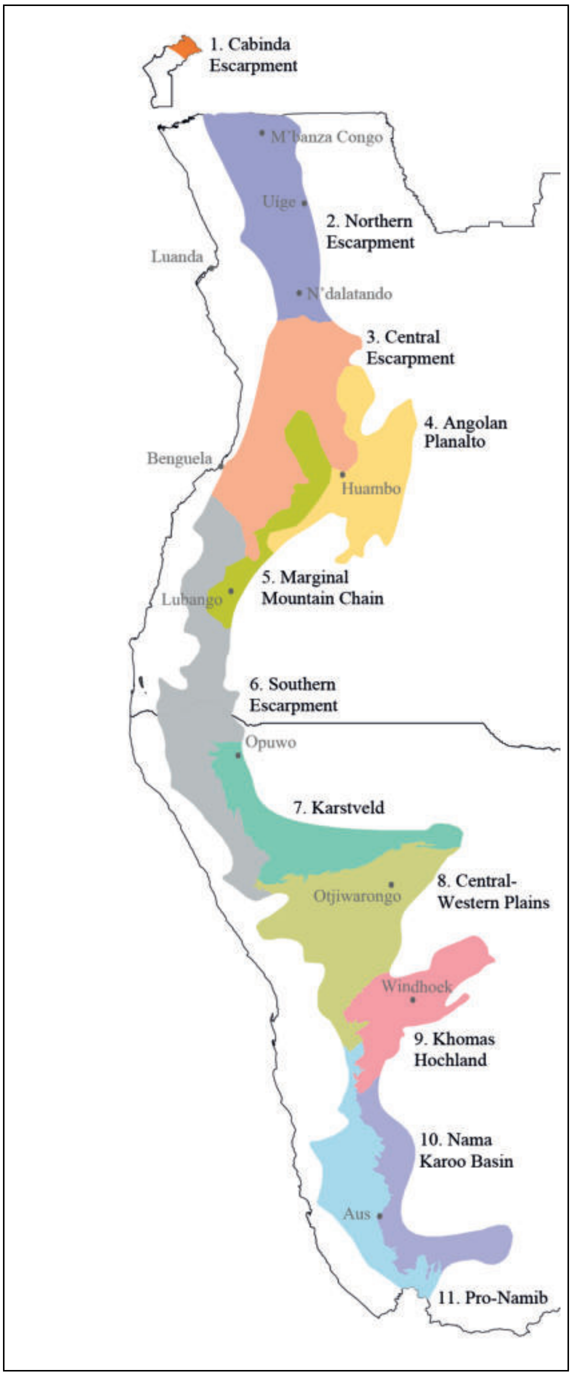

Figure 5: *The 11 major landscape units of the highlands and escarpments of Angola and Namibia (HEAN). The units are described in the text. Some towns are shown for orientation purposes.*

6. Southern Escarpment, from the Coporolo River in Angola southwards to about the Huab River in Namibia (Ecoregions 34, 98, 104). The escarpment becomes increasingly narrow, steep and high southwards from the Coporolo River and 100 km inland of the coast at Moçâmedes. Over much of the escarpment, the transition advances up a complex series of steep steps of between 100 and 600 m height. Between Moçâmedes and Lubango, the escarpment of the Serra da Chela is very sharp, rising 1,000 m in relief at Tundavala and Bimbe, where it is well defined by the Chela dolomites and cherts. The highlands above the escarpment form the Humpata/Huíla Plateau, within the Marginal Mountain Chain landscape unit.

To the south, a variety of substantial mountains protrude above this area, much of which is low lying. The best known are the Serras Cafema, da Lua, Capota, Viluoviaengua and Tchamalindi of southwest Angola, and the Baynes, Hartmann, Zebra, Otjihipa and Joubert mountains of northwest Namibia. These constitute the most rugged landscapes of both Angola and Namibia. The high carbonatite inselberg, Serra da Neve, lies in this landscape, rising to 2,489 masl. Similarly, some of the highlands between Lubango and Oncócua are capped with cherts belonging to the Serra da Chela formation. The landscape includes the Etendeka Basalts which form a distinctive landscape of flat-topped mountains underlain by layers of solidified lava that erupted during the breakup of Gondwana 132 mya (million years ago).

Few people live here, and there are only a few small towns in the area, such as Virei, Oncócua, Bibala, Camacuio, Orupembe, Purros and Okanguati. Livelihoods are based largely on remittances, social grants, tourism revenue, small stock and cattle.

7. Karstveld (Ecoregion 34). The Karstveld's hills and ridges are underlain exclusively by dolomites or limestones formed from sediments deposited 750–600 mya, and metamorphic and sedimentary products of dolomites, in particular calcretes and cherts. Extensive aquifers underlie the permeable dolomite formations. Fossils are abundant in tufa deposits, and endemic insects and fish occur in some of the Karstveld's many caves and underground lakes. Much of the hilly landscape is used for livestock and game farming and tourism, while crops are grown commercially in the lowlands around the hills.

8. Central-Western Plains (Ecoregions 34, 97). Much of the topography of this landscape unit is gentle in slope, rising gradually from the coastal lowlands in the west at about 500 masl to approximately 1,000 masl in the east at the western edge of the Kalahari Basin of aeolian sands. Acacia woodlands dominate the area. Many of the inselbergs that punctuate the area are intrusive granites formed during the breakup of Gondwana. The biggest of these are the Brandberg, and the Erongo and Paresis mountains. Many of the plants and animals that occur in these isolated highlands are restricted to them. Other prominent inselbergs are the Waterberg and other hills capped with Etjo sandstones. Most farms are used to produce or keep livestock, and for game farming and tourism.

9. Khomas Hochland (Ecoregions 97, 104). This plateau has a foundation of schists formed from sand and mud deposited on an ocean floor. The marine sediments were heated and folded into the rock formations of this plateau during the formation of Gondwana about 550 mya. The Auas Mountains form a conspicuous ridge which rises to over 2,000 masl. South of the mountains are the Rehoboth highlands of basement granites and complexes of metamorphic rocks. Livestock and game farming and tourism are the main rural economic activities. Windhoek, with its large population and various economic activities, is at the heart of these highlands which are largely covered in grasses and a sparse cover of shrubs and small trees. The tallest trees grow along drainage lines.

***10. Nama Karoo Basin* (**Ecoregions 94, 104). This broad basin is underlain by horizontal layers of sediments. Some highlands protrude in the western margins of the basin, close to and above the prominent escarpment, such as the Huib-Hoch Plateau and Nasepberg. Other highlands below the escarpment are included here even though their geological compositions are different. These include the Huns Mountains, Chumberge and Namusberge. To the east are the two Karasberge mountain blocks which are uplifted metamorphic basement rocks overlain by a thin cover of basalts. Orographic processes provide the highlands with slightly more rain than the rest of southeastern Namibia. Soil and vegetation in these highlands are concentrated in valleys among large blocks of rock. Sheep and goat production and conservation on large farms are the main economic activities.

11. Pro-Namib (Ecoregions 103, 104). The Pro-Namib forms an apron below and west of the escarpment. Much of the surface is low-lying and underlain by gravel and shallow sand, as well as dunes of the Namib. The landscape includes vegetation communities dominated by karroid succulents in the south. Highlands include inselbergs of varying origins, such as the Klinghardt Mountains, Dikke Willem, Aurusberg and Uri-Hauchab, as well as highlands alongside the escarpment, such as the Tirasberge, Losberg and Nubisberge. Much of the area is managed for conservation and wildlife.

ORIGINS OF THE HIGHLANDS

While the topography of the HEAN uplands is clearly visible, their history is by no means clear. Two aspects seem to be agreed among geologists, however. First, the hills, mountains, escarpments and plateaus of Angola and Namibia are underlain by a much larger plateau that stretches between eastern and southern Africa (Figure 1). This raised plateau, designated as the African Superswell by Nyblade and Robinson (1994), has markedly higher elevations (on average > 1,000 masl) relative to other continents (~500 masl).

Second, the uplands of Angola and Namibia, and the wider expanse of African Superswell highlands, probably formed after the breakup of Gondwana 180–120 mya. Additionally, Gondwana's breakup led to a phase of rapid erosion of Africa's then recently formed continental margin. The removal through erosion of 2–4 km of soft crust material above and adjacent to the surrounding coast probably triggered a rapid isostatic rebound, with uplift of the continental margin resulting in the development of the Great Escarpment on the margins of the African Superswell surrounding an inland depression or basin (King 1963, Gilchrist & Summerfield 1990). The escarpment divided, and continues to divide, most river catchments draining to the coast from those which drain inland (see Figure 6).

Two other aspects of the highlands' history are more contested. The first concerns the processes that caused the uplift of the HEAN and other highlands of the African Superswell. One widely held view is that plumes of hot magma pushed the mantle and crust upwards (Nyblade & Robinson 1994, Fishwick & Bastow 2011). One broad and massive plume may have forced up the entire African Superswell and/or smaller plumes may have separately raised more localised uplands such as the Angolan Planalto and Khomas Hochland (Paul *et al*. 2014, Klöcking *et al*. 2020), perhaps during the breakup of Gondwana (R Miller pers. comm.). Another view is that uplift occurred along anticlinal flexures (in effect, buckled ridges or axes) caused by stresses within tectonic plates. These axes formed the major watersheds in southern Africa (du Toit 1933, Moore 1999). As noted earlier, the Great Escarpment which formed the axis that separated coastal and inland rivers has been ascribed to the isostatic rebound linked to deep erosion along the coastal plain. Two other axes transect the interior of the subcontinent of southern Africa. Uplift along one, called EGT (Etosha–Griqualand–Transvaal axis), is thought to have formed the Orange–Limpopo watershed and initiated the Kalahari Basin where fluvial sediments of the Kalahari Group were first deposited followed by the aeolian deposition of sands during episodes of Plio-Pleistocene aridity (Moore *et al*. 2009). The other axis, termed OKZ (Ovambo–Kalahari–Zimbabwe Axis), probably separated the Limpopo from the Kalahari Basin and impounded other major rivers, such as the Zambezi, within the Kalahari Basin.

The other contention concerns the timing of uplift. Proponents of the plume theory suggest that uplift occurred about 30 mya (Burke & Gunnell 2008, Klocking *et al*. 2020). By contrast, advocates of the tectonic plate buckling theory hold that uplift along the three axes occurred at different times: about 120 mya along the axis forming the southern African escarpment, about 85 mya along the EGT axis of the Orange–Limpopo watershed and Kalahari Basin, and about 40 mya along the OKZ axis (Moore *et al*. 2009).

DRAINAGE

Rivers associated with the HEAN can be grouped into three distinct categories. First, there are those that drain the western slopes of the highlands. They are relatively short and steep, with rapid flows to their nearby base levels on the Atlantic coast. Thus these are the most erosive rivers and many have cut back into the highlands where they formed distinct amphitheatre-like catchments. Cumulatively, rivers have done much to move the escarpment and spine of the HEAN steadily eastwards (Miller 2023, this volume). Twenty-two of these short, fast-flowing rivers are mapped schematically and named in Figure 6. Fourteen rivers are in Angola and eight are in Namibia (to avoid clutter, a similar number of other short, coastal rivers were not mapped). Between Angola's Coporolo River and Namibia's Kuiseb River all the coastal drainage lines are now ephemeral rivers which at times flood energetically after heavy rain. South of the Kuiseb River there are no local ephemeral or other rivers, except the Orange River which obtains its water in the South African interior and from the Fish River. The decrease in regularity of coastal flow and drainage from north to south reflects the corresponding decline in rainfall and increase in evaporation (Figures 8 & 9).

Second, is the category of rivers that drain the eastern areas and flanks of the highlands. Their large catchments are elongated from north to south. There are four such rivers, the Cuango, Cuanza, Cunene and Fish. They too have their base levels on the coast, but their river mouths are much farther from their catchments than the short, western rivers. Just why these four rivers seemingly hug the eastern flanks of the HEAN is not clear. It is likely that each of these four rivers turned west as a result of river capture by, respectively, the Congo, the coastal antecedents of the present Cuanza and Cunene, and perhaps the Orange River.

Third, are several rivers that drain the lower flanks of the HEAN including the elevated Angolan Planalto and Khomas Hochland Plateau in the east. Three of these rivers take an even longer route to their coastal base levels: the Zambezi, which flows eastwards into the Indian Ocean in Mozambique, and the Chicapa and Cassai which flow northwards to join the Congo River. Eight others never reach the coast: the perennial Cubango, Cuito and Cuando, and the ephemeral Cuvelai, Omatako, Eiseb, Nossob and Auob. Their base levels are between 900 and 1,000 masl in the Kalahari Basin, and their flows are thus slow and non-erosive.

Major rivers and their tributaries have eroded and bisected the HEAN in four areas: the Congo River between Cabinda and the Northern Escarpment landscape (see Figure 5), the Cuanza River in the southern area of the Northern Escarpment, the Cunene River between Angola and Namibia, and the Ugab, Omaruru and Swakop rivers across the Central-Western Plains landscape in Namibia. The southern extreme of the HEAN has also been truncated by erosion of the Orange River.

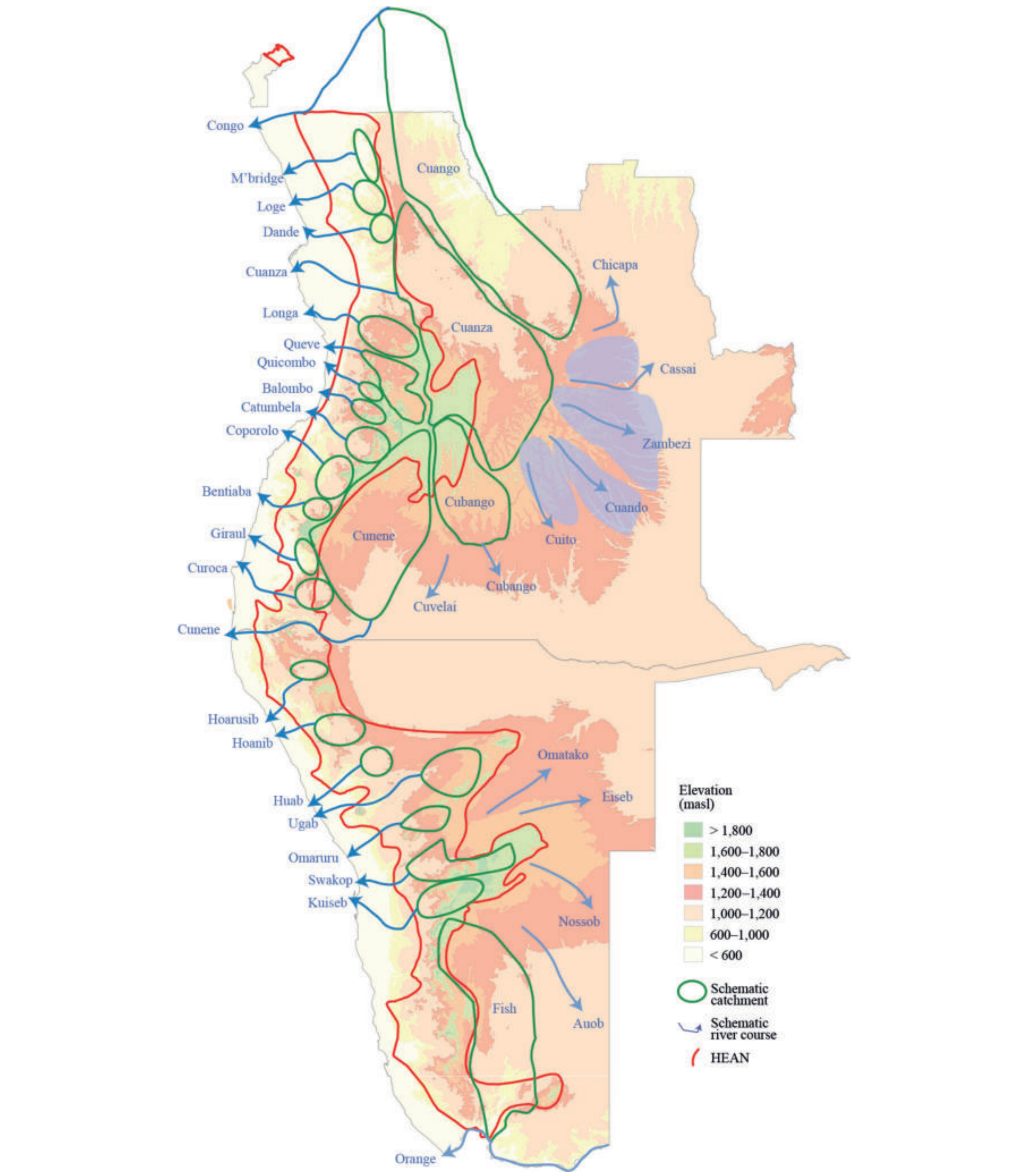

Figure 6: *Schematic portrayal of the major rivers and their catchment basins on and around the highlands and escarpments of Angola and Namibia (HEAN).*

SOILS

Only seven soil families cover more than 1% each of the HEAN area (Table 1). The two largest soil units dominate the surfaces of Angola (Ferralsols) and Namibia (Leptosols), respectively (Figure 7). Most Cambisols, Calcisols and Regosols are in Namibia, where the soils are less diverse than in the highlands of Angola, which is where most Luvisols, Phaeozems, Nitisols, Lixisols, Gleysols, Acrisols and Fluvisols are found. Arenosols cover much of the Kalahari Basin east of the HEAN in Angola and Namibia. The dominant soils in the HEAN have limited potential for arable agriculture, often because they were derived from rocks formed hundreds of millions of years ago. Such old soils are therefore well-weathered, leached and considerably deficient in nutrients. This is particularly true of Ferralsols. While they are usually deep, stable and easy to work with, Ferralsols have limited value for cultivation because of their low water-storage capacity and low natural fertility. They are used mostly for shifting cultivation of maize, sorghum, millet and cassava. Leptosols cover much of the hilly areas of Namibia and southern Angola. They are stony and often extremely shallow soils that hold little water and offer limited rooting space for plants. Cambisols are younger soils that form in recently deposited or exposed colluvial, alluvial and aeolian parent materials. They are often present in semiarid areas and can be relatively productive. Regosols are undeveloped, their formation often having been inhibited by aridity.

Arenosols occur on the eastern margins of the HEAN, particularly the Angolan Planalto and Khomas Hochland, and in areas adjacent to the coastal plain. These are deep windblown sands, consisting largely of quartz, and they hold little water and few nutrients. Calcisols are widespread in arid and semiarid environments that have distinct dry seasons. They form from deposits rich in calcium and magnesium.

Table 1: *Areas covered by major soil families in the highlands and escarpments of Angola and Namibia (HEAN). (Derived from Jones* et al. *2013.)*

Soil family	Area (km^2)	Percentage (%) of HEAN
Leptosols	154,723	31.7
Ferralsols	125,125	25.6
Cambisols	67,624	13.9
Regosols	45,534	9.3
Calcisols	33,069	6.8
Arenosols	26,427	5.4
Luvisols	19,743	4.0
Other soils	15,903	3.3
TOTAL	**488,147**	**100**

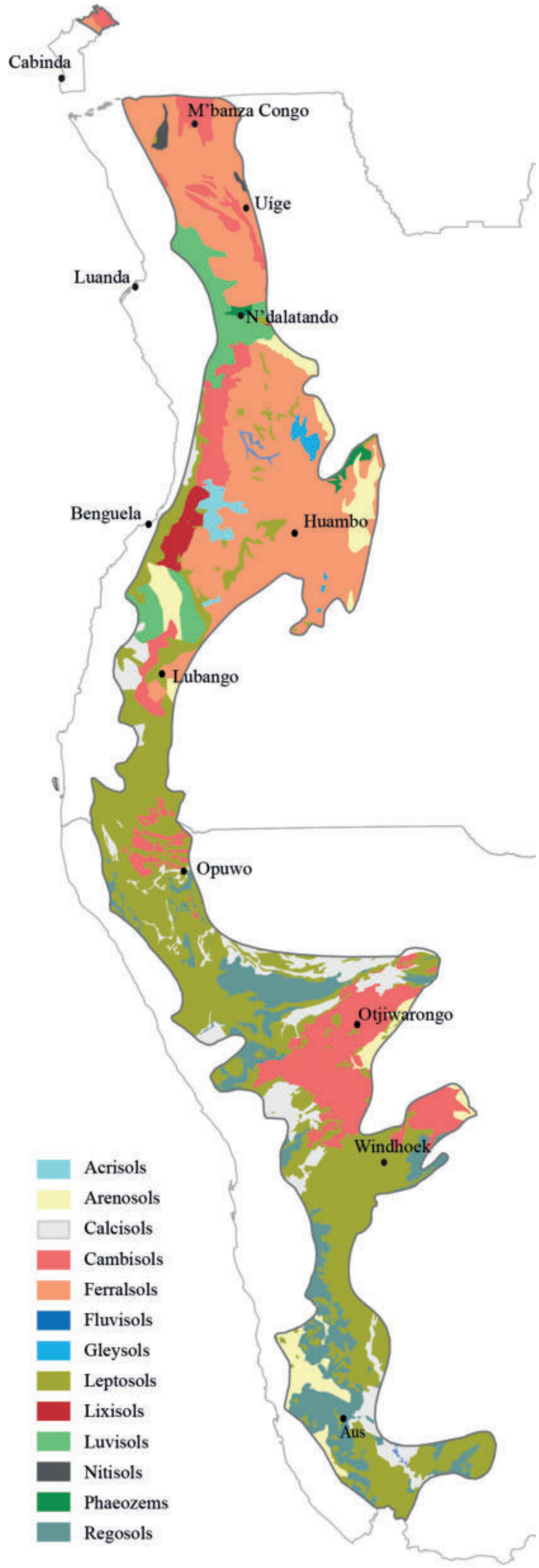

Figure 7: *Distribution of major soil families in the highlands and escarpments of Angola and Namibia (HEAN). (Adapted from Jones* et al. *2013.)*

Significant amounts of calcium carbonate (lime) form below the surface where it may be concentrated into calcrete.

More fertile, deeper soils are limited to smaller areas of such soil families as Luvisols, Fluvisols, Gleysols, Nitisols and Phaeozems. The degree to which they are used for agriculture depends on factors such as rainfall, appropriate management and access to markets, for example. These enabling conditions are absent in certain areas.

CLIMATE

Most aspects of the climate in the HEAN vary along two axes: latitude and altitude. Thus, rainfall is highest in the northern, low latitudes and at high altitudes, especially over the Angolan Planalto. The lowest rainfall is in the extreme south of Namibia, where annual totals are many times lower than in the wettest areas of the highlands in Angola (Figure 8a). Annual variance in rainfall increases several-fold from north to south, and from east to west, but is less affected by elevation (Figure 8b). It is close to the coastal plain and the Namib Desert between southern Namibia and southern Angola that rainfall is most variable, and therefore least predictable.

The timing of rainfall also varies from low to high latitudes (Figure 9). In the northern half of Angola there are two distinct peaks: in November and December and then in March and April. From about Lubango south there is a single peak, usually in March but also in February in northern and central Namibia. In the southern quarter of Namibia rain falls in similar, small amounts throughout the year.

The antithesis of rainfall is the loss of water through evaporation and transpiration, known as potential evapotranspiration (PET). PET is about twice as high in the south than in the north, thus having a disproportionate effect on moisture availability. For example, annual PET is slightly lower than annual rainfall in northern Angola but more than ten times greater than annual rainfall in southern Namibia (Figure 10a). Aridity in the HEAN is therefore much greater in the south than in the north (Figure 10b).

Temperatures on the uplands of the HEAN are usually and on average lower than those to their west and east (Figure 11). However, minimum temperatures recorded early in the morning are somewhat higher than those to the east. In general, air temperatures are mild in the HEAN.

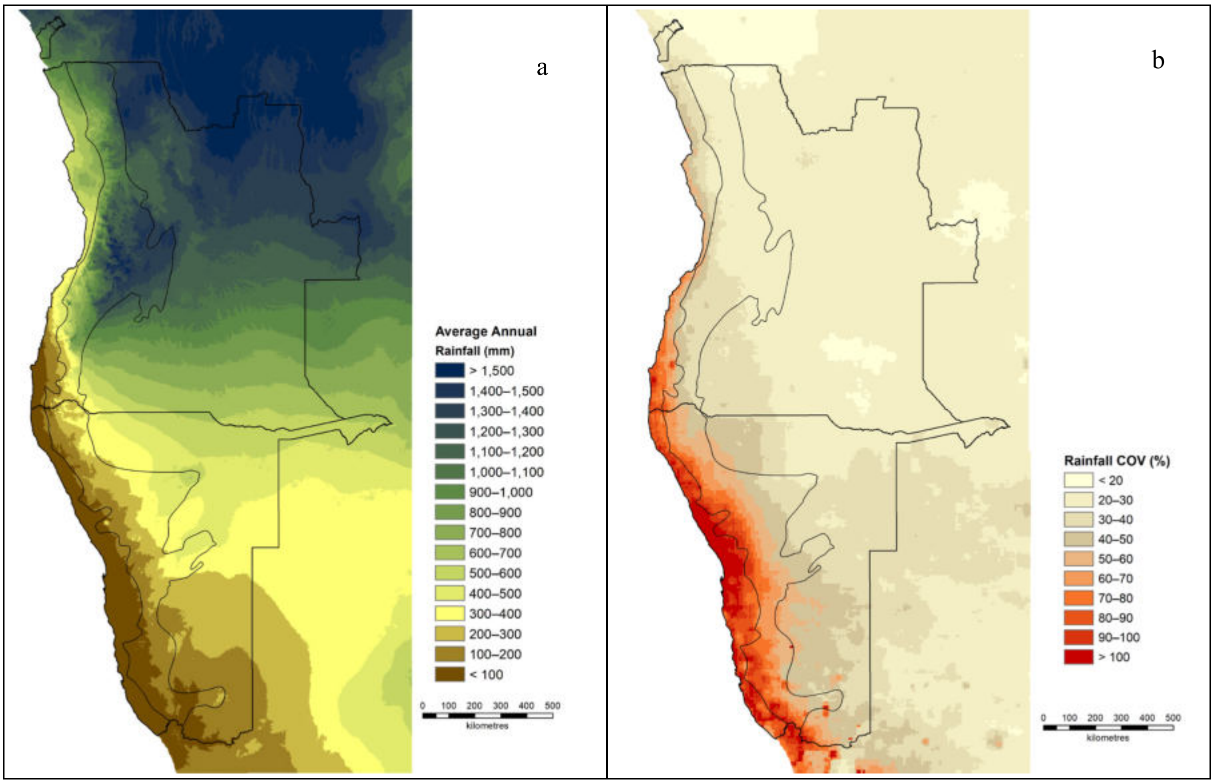

Figure 8: *Rainfall in Angola and Namibia: (a) average annual rainfall in millimetres and (b) average rainfall variance as the coefficient of variation (COV). Data from Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) data for the period 1981–2022. Annual rainfall totals were aggregated by rainfall season (July–June). Rainfall estimate (RFE) dekadal data from the Famine Early Warning Network (FEWS NET) were used for rainfall variance estimates.*

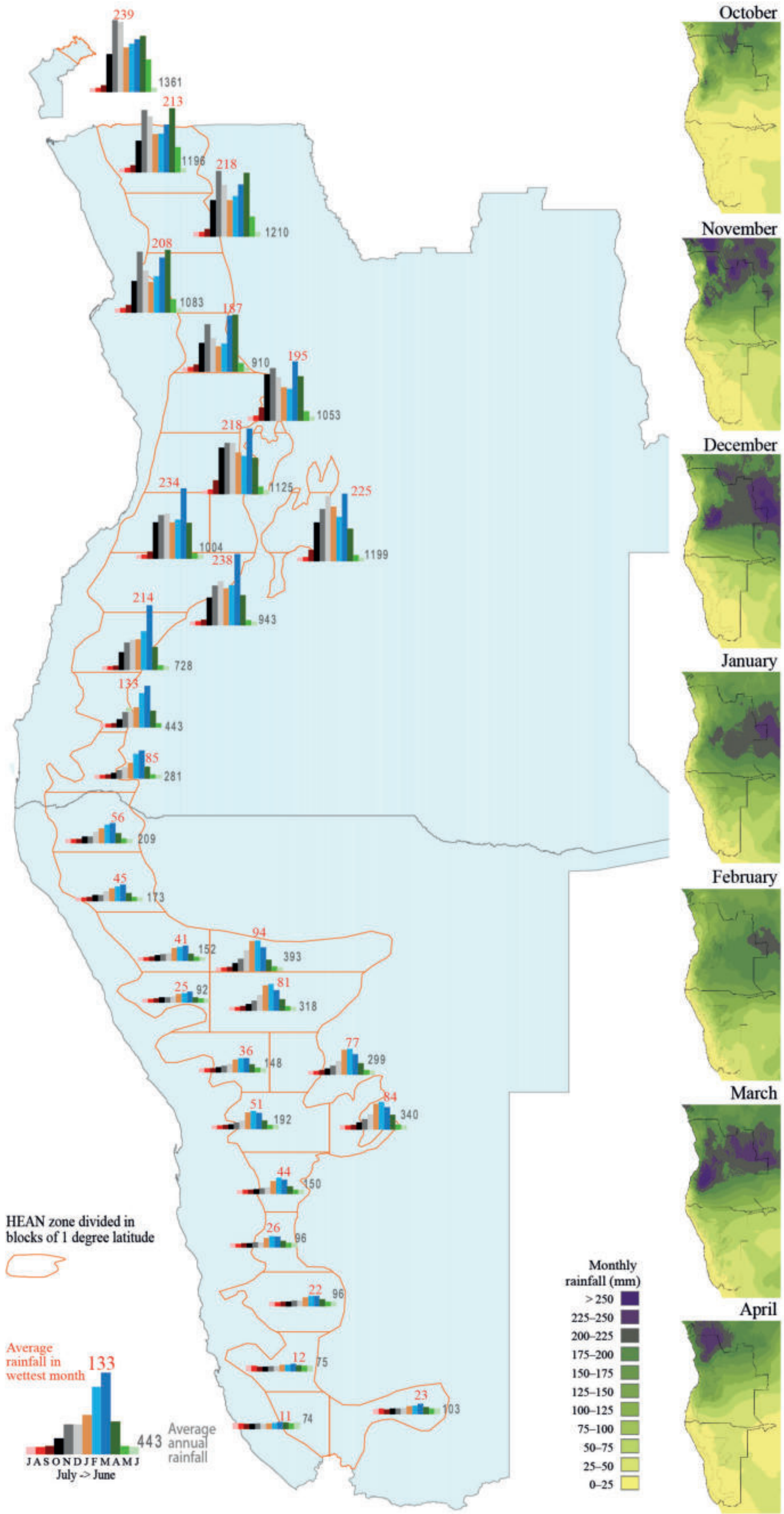

Figure 9: *Average monthly rainfall in millimetres per one-degree latitude block within the highlands and escarpments of Angola and Namibia (HEAN) (left) and average monthly rainfall in Angola and Namibia in the wet season between October and April (right). Data from Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) data for the period 1981–2022.*

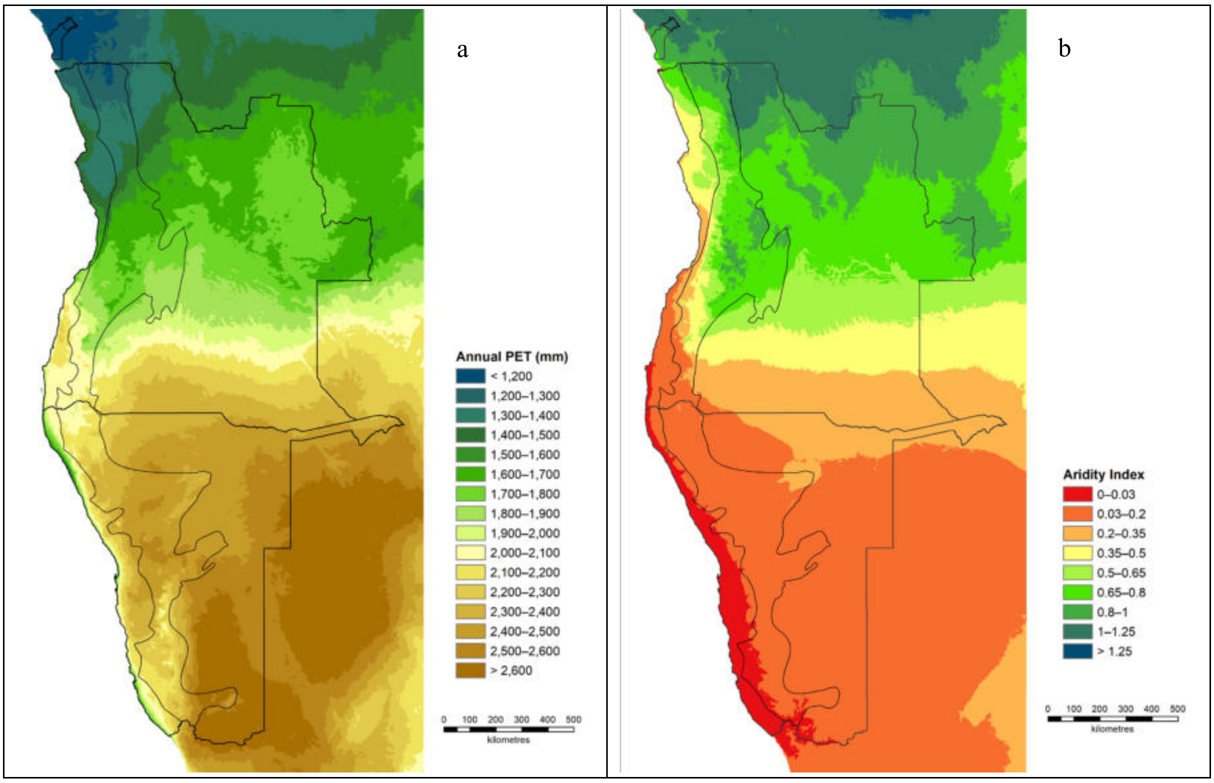

Figure 10: *Annual potential evapotranspiration (PET) in Angola and Namibia as millimetres of water lost (a) and an index of aridity calculated as annual average rainfall (Figure 8) divided by PET (b). Data from the Global Reference Evapotranspiration (Global-ET0) and Global Aridity Index (Global-Aridity_ET0) Version 2 dataset downloaded from CGIAR (2023).*

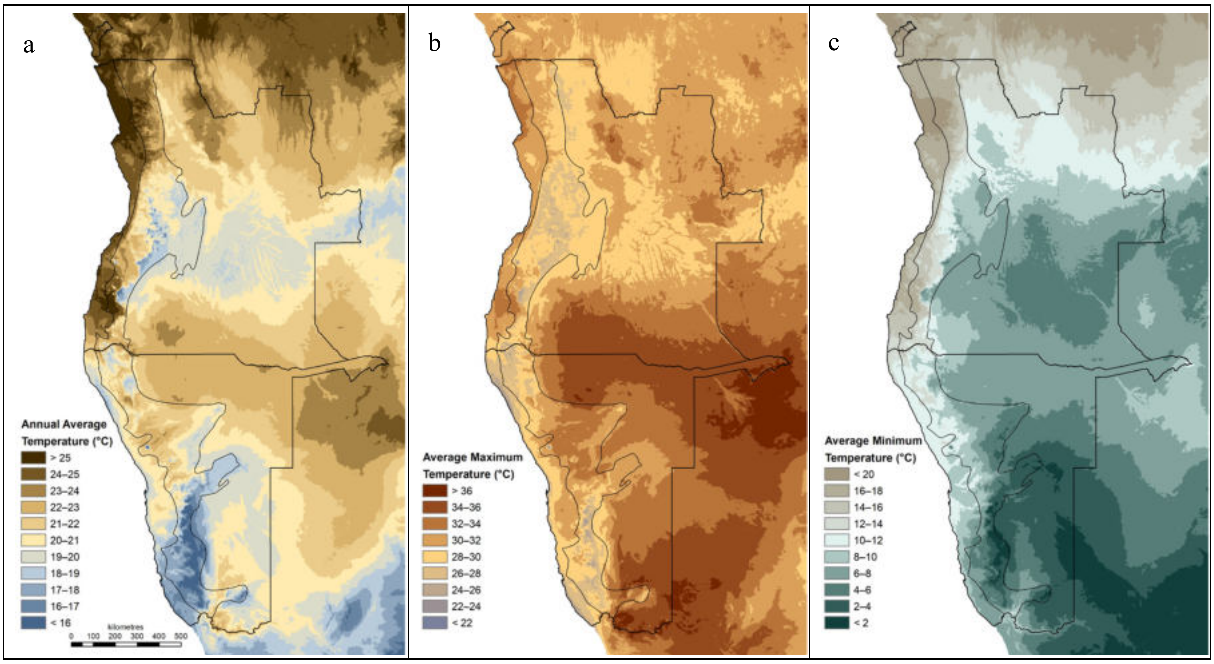

Figure 11: *Temperatures in Angola and Namibia: (a) average annual temperature; (b) average maximum temperature in the warmest month; and (c) average minimum temperature in the coldest month. Data from WorldClim http://worldclim.org (June 2016). The averages are created from monthly averages, maximums and minimums between 1970 and 2000.*

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REFERENCES

Albuquerque S, Figueirôa S (2018) Depicting the invisible: Welwitsch's map of travellers in Africa. *Earth Sciences History* 37(1): 109–129. https://doi.org/10.17704/1944-6178-37.1.109.

Burke K, Gunnell Y (2008) The African erosion surface: a continental-scale synthesis of geomorphology, tectonics, and environmental change over the past 180 million years. *Geological Society of America* 201: 1–66. https://doi.org/10.1130/2008.1201.

CGIAR (2023). Global Aridity and PET Database. https://cgiarcsi.community/data/global-aridity-and-pet-database/

Clark VR, Barker NP, Mucina L (2011) The Great Escarpment of southern Africa: a new frontier for biodiversity exploration. *Biodiversity and Conservation* 20(12): 2543–2561. https://doi.org/10.1007/s10531-011-0103-3.

Costa FL (2006) O conhecimento geomorfológico de Angola. In: Moreira I (ed) *Angola: agricultura, recursos naturais e desenvolvimento rural*. 477–495. ISAPress, Lisboa, Portugal.

Dinerstein E, Olson D, Joshi A, Vynne C, Burgess ND, Wikramanayake E *et al.* (2017) An ecoregion-based approach to protecting half the terrestrial realm. *BioScience* 67(6): 534–545. https://doi.org/10.1093/biosci/bix014.

Diniz AC (1973) *Características mesológicas de Angola*. Missao de Inqueritos Agricolas de Angola, Nova Lisboa.

Diniz AC (1991) *Angola, o meio físico e potencialidades agrárias*. Instituto para a Cooperação Económica, Lisboa.

Diniz AC (2006) *Características mesológicas de Angola: descrição e correlação dos aspectos fisiográficos, dos solos e da vegetação das zonas agrícolas angolanas*. Instituto Português de Apoio ao Desenvolvimento, Lisboa.

Diniz AC, Aguiar FB (1966) Geomorfologia, solos e ruralismo de região central angolana. *Agronomia Angolana* 23: 11–17.

Du Toit AL (1933) Crustal movement as a factor in the geographical evolution of South Africa. *South African Geographical Journal* 16(3): 20.

Fishwick S, Bastow ID (2011) Towards a better understanding of African topography: a review of passive-source seismic studies of the African crust and upper mantle. *Geological Society, London, Special Publications* 357(1): 343–371. https://doi.org/10.1144/SP357.19.

Giess W (1971) A preliminary vegetation map of South West Africa. *Dinteria* 4: 1–114.

Gilchrist AR, Summerfield MA (1990) Differential denudation and flexural isostasy in formation of rifted-margin upwarps. *Nature* 346(6286): 739–742. https://doi.org/10.1038/346739a0.

Goudie A, Viles H (2015) *Landscapes and landforms of Namibia*. Springer Netherlands, Dordrecht. https://doi.org/10.1007/978-94-017-8020-9.

Goyder DJ, Gomes AL, Gonçalves FMP, Luís JC & Darbyshire I (2023) A botanical assessment of Mt Namba, Cuanza-Sul, Angola: an isolated mountain towards the northwestern limits of the Great Escarpment of southern Africa. In: Mendelsohn JM, Huntley BJ, Vaz Pinto P (eds) Monograph on endemism in the highlands and escarpments of Angola and Namibia. *Namibian Journal of Environment*: 77–92.

Huntley BJ (2023) Biomes and ecoregions of the highlands and escarpments of Angola and Namibia. In: Mendelsohn JM, Huntley BJ, Vaz Pinto P (eds) Monograph on endemism in the highlands and escarpments of Angola and Namibia. *Namibian Journal of Environment*: 29–41.

Huntley BJ, Russo V, Lages F, Ferrand N (eds) (2019) *Biodiversity of Angola: Science & conservation: A modern synthesis*, 1st ed. 2019. Springer International Publishing, Cham.

Jessen O (1936) *Reisen und Forschungen in Angola*. Dietrich Reimer Verlag.

Jones A, Breuning-Madsen H, Brossard M, Dampha A, Deckers J, Dewitte O *et al.* (2013) *Soil atlas of Africa*. European Commission.

King LC (1963) *South African Scenery*, 3rd Edition. Oliver and Boyd, Edinburgh.

Klöcking M, Hoggard MJ, Rodríguez Tribaldos V, Richards FD, Guimarães AR, Maclennan J, White NJ (2020) A tale of two domes: Neogene to recent volcanism and dynamic uplift of northeast Brazil and southwest Africa. *Earth and Planetary Science Letters* 547: 116464. https://doi.org/10.1016/j.epsl.2020.116464.

Knight J, Grab SW (eds) (2016) *Quaternary environmental change in southern Africa: physical and human dimensions*, 1st ed. Cambridge University Press. https://doi.org/10.1017/CBO9781107295483.

Martin H (1965) *The Precambrian geology of South West Africa and Namaqualand*. Precambrian Research Unit, University of Cape Town.

Meller P, Lages F, Finckh M, Gomes A & Goyder D (2023) Diversity and endemism of geoxylic plants on the Angolan Planalto. In: Mendelsohn JM, Huntley BJ, Vaz Pinto P (eds) Monograph on endemism in the highlands and escarpments of Angola and Namibia. *Namibian Journal of Environment*: 93–109.

Mendelsohn J, Jarvis A, Roberts C, Robertson T (2002) *Atlas of Namibia: a portrait of the land and its people*. David Philip Publishers.

Miller RM (2023) Geology and landscape evolution of the highlands and escarpments of western Angola and Namibia. In: Mendelsohn JM, Huntley BJ, Vaz Pinto P (eds) Monograph on endemism in the highlands and escarpments of Angola and Namibia. *Namibian Journal of Environment*: 23–28.

Mills MSL & Melo M (1963) Birds of the highlands and escarpments of Angola and Namibia: ornithological significance, avifaunal patterns and questions requiring further study. In: Mendelsohn JM, Huntley BJ, Vaz Pinto P (eds) Monograph on endemism in the highlands and escarpments of Angola and Namibia. *Namibian Journal of Environment*: 293–309.

Moore AE (1999) A reappraisal of epeirogenic flexure axes in southern Africa. *South African Journal of Geology* 102(4): 363–376.

Moore AE, Larkin PA (2001) Drainage evolution in south-central Africa since the breakup of Gondwana. *South African Journal of Geology* 104(1): 47–68. https://doi.org/10.2113/104.1.47.

Moore A, Blenkinsop T, Cotterill F (Woody) (2009) Southern African topography and erosion history: plumes or plate tectonics? *Terra Nova* 21(4): 310–315. https://doi.org/10.1111/j.1365-3121.2009.00887.x.

Nyblade AA, Robinson SW (1994) The African Superswell. *Geophysical Research Letters* 21(9): 765–768. https://doi.org/10.1029/94GL00631.

Paul JD, Roberts GG, White N (2014) The African landscape through space and time. *Tectonics* 33(6): 898–935. https://doi.org/10.1002/2013TC003479.

Van der Merwe JH (1983) *National atlas of South West Africa (Namibia): Nasionale atlas van Suidwes-Afrika (Namibië)*. National Book Printers, Cape Town.

Volk OH (1966) Die Florengebiete von Südwestafrika. *Journal of the South West African Scientific Society* 20: 25–58.

Welwitsch F (1858) Apontamentos phytogeográphicos sobre a flora da província de Angola na África Equinocial. *Anais do Conselho Ultramarino, parte não oficial*: 527–593.