World Geomorphological Landscapes

Andrew Goudie
Heather Viles

Landscapes and Landforms of Namibia

Springer

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The Kuiseb River and Namib Sand Sea at Gobabeb

Andrew Goudie • Heather Viles

Landscapes and Landforms of Namibia

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Series Editor Preface

Landforms and landscapes vary enormously across the Earth, from high mountains to endless plains. At a smaller scale, nature often surprises us creating shapes which look improbable. Many physical landscapes are so immensely beautiful that they received the highest possible recognition—they hold the status of World Heritage properties. Apart from often being immensely scenic, landscapes tell stories which not uncommonly can be traced back in time for tens of million years and include unique events. In addition, many landscapes owe their appearance and harmony not solely to the natural forces. For centuries, and even millennia, they have been shaped by humans who have modified hillslopes, river courses, and coastlines, and erected structures, which often blend with the natural landforms to form inseparable entities.

These landscapes are studied by geomorphology—'the Science of Scenery'—a part of Earth Sciences that focuses on landforms, their assemblages, surface and subsurface processes that moulded them in the past and that change them today. To show the importance of geomorphology in understanding the landscape, and to present the beauty and diversity of the geomorphological sceneries across the world, we have launched a book series *World Geomorphological Landscapes*. It aims to be a scientific library of monographs that present and explain physical landscapes, focusing on both representative and uniquely spectacular examples. Each book will contain details on geomorphology of a particular country or a geographically coherent region. This volume presents the geomorphology of Namibia—a country that hosts superb landforms, many being the best examples of their kind in the world. Endless sand seas, tall inselbergs, majestic river canyons, pans teeming with wildlife—they can all be found across Namibia. Since Namibia is relatively easy to navigate, the book is not only suitable for scientists and students of Geography and Earth Science, but can also provide guidance to holidaymaking geoscientists as to where to go to enjoy the very best scenery.

The World Geomorphological Landscapes series is produced under the scientific patronage of the International Association of Geomorphologists (IAG)—a society that brings together geomorphologists from all around the world. The IAG was established in 1989 and is an independent scientific association affiliated with the International Geographical Union (IGU) and the International Union of Geological Sciences (IUGS). Among its main aims are to promote geomorphology and to foster dissemination of geomorphological knowledge. I believe that this lavishly illustrated series, which sticks to the scientific rigour, is the most appropriate means to fulfill these aims and to serve the geoscientific community. To this end, my great thanks go to Professors Heather Viles and Andrew Goudie for adding this book to their agendas and delivering such an exciting illustrated story to read and admire. The thanks are more than customary. Many years ago, I was invited to join Heather and Andrew on one of their Namibian research trips and benefited most from their expert knowledge of the country, now shared with the global geomorphological community.

Piotr Migoń

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Contents

Part I

Introduction to Namibia and its Landscapes

Landscapes

1

Abstract
Namibia has a wide range of landscapes and the classification provided in the *Atlas of Namibia* is adopted by way of introduction to their nature and diversity. This is followed by a description of three main landscape regions: the Namib Desert, the Kalahari Desert, and the Great Escarpment. Finally, the chapter includes a regional analysis of the river systems and the coastline of Namibia, with feature boxes on two iconic landscapes, the Fish River Canyon and Sandwich Harbour.

1.1 Landscape Types

Namibia is a vast and varied country with wonderful landscapes and landforms, many of which have been engagingly portrayed in words and pictures by Swart and Marais (2009). It is particularly notable because of the richness and beauty of its desert landforms, and because of what it can tell us about the long-term tectonic history and climate of this part of Africa. The major controls on landscape evolution are tectonics (and its influence on geology) and climate (and its influence on ecology) and their dynamic interrelationships over a range of timescales. However, before introducing the outlines of tectonic and geological histories (Chap. 2) and the dynamics of climate and ecosystems (Chaps. 3 and 4) this chapter introduces the major characteristics of Namibian landscapes and their diversity, including the nature of the two great deserts (the Namib and the Kalahari), the Great Escarpment which runs down its spine, its rivers, and its long coastline.

In the second part of the book we present a series of regional studies illustrating some of the most dramatic and interesting landforms and landscapes of the country, and these are approximately arranged from north to south (Fig. 1.1). Chapter 25 is not marked on Fig. 1.1, as the phenomena it describes occur over much of Namibia. We have chosen to include landscapes and landforms for which there is a good array of scientific literature and which reflect the diversity of landscape types in Namibia. Other important and much visited landscape features, such as the Fish River Canyon and Sandwich Harbour, are described in boxes in Chap. 1, while another characteristic landform type—sandstone-capped mesas—is featured in box 3 in Chap. 2.

Covering an area of about 823,680 km^2, Namibia is up to 1,320 km long, and 1,440 km wide. It is, however, sparsely populated with only around 2 million inhabitants. To the north it is bounded by Angola and Zambia, to the east by Botswana, to the south by South Africa, and to the west by the cold waters of the Atlantic Ocean. Much of Namibia consists of a wide plateau at 900–1,300 m above sea level (Fig. 1.1). This plateau is bounded on the west by a large escarpment and on the east by the Kalahari Basin. Bordering the Atlantic in the west is the lower-lying coastal plain of the hyper-arid Namib Desert (Van Zyl 1992). Van der Merwe (1983) estimated that plains were the dominant landscape of Namibia, covering over 45 % of the country, with mountains covering c 19 %, dunes just under 14 %, plains with scattered hills over 13 %, and hills just under 8 %. Wellington (1967) divided the Namibian landscape into three main types —the Namib Desert, the Plateau Hardveld and the Kalahari Sandveld, within which he identified a number of more specific landscape types.

Recently, *The Atlas of Namibia* (Mendelsohn et al. 2002) has identified a range of landscape regions in the country, providing a useful framework to describe the geomorphological diversity (Fig. 1.2). These regions are described here heading from north to south, apart from two areas (the Kalahari sandveld and the Great Escarpment) which span large distances from north to south in the eastern and western parts of the country respectively, with which we begin.

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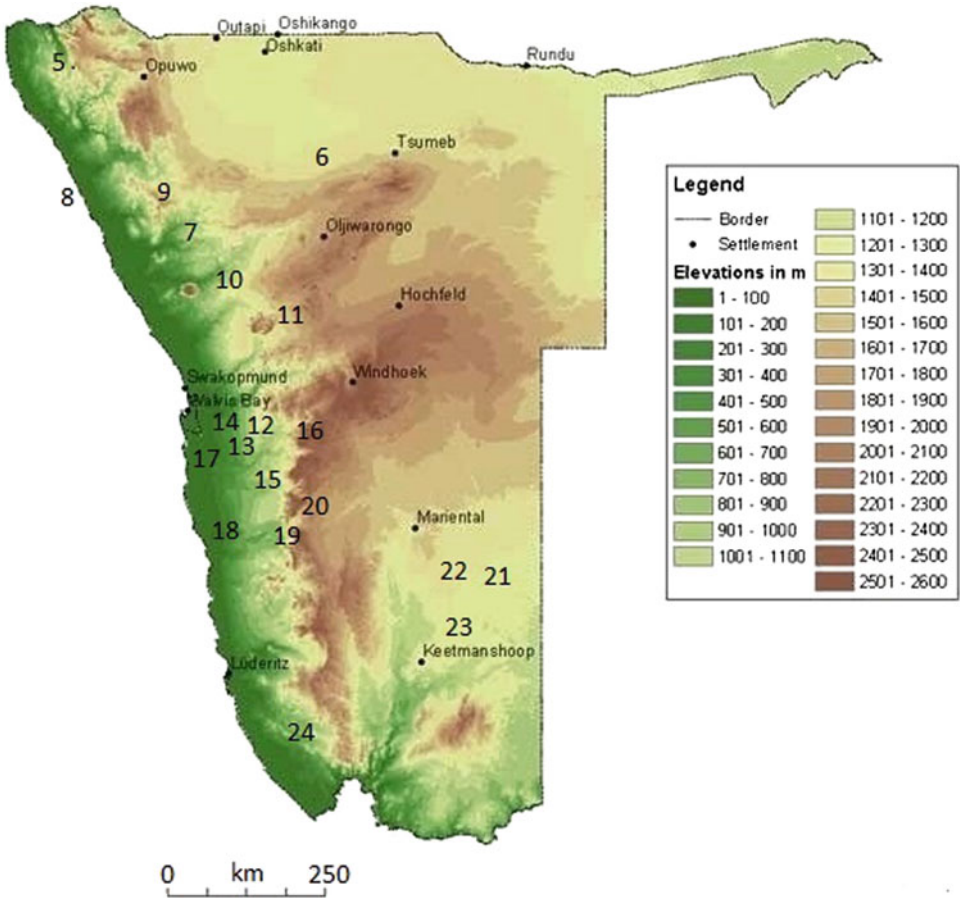

Fig. 1.1 The approximate locations of Chaps. 5–24 and the relief of Namibia (from Mendelsohn et al. 2002, p. 39 in http://www.uni.koeln.de/sfb389/e/e1/download/atlas_namibia/) (accessed 30th January 2014)

The *Kalahari sandveld* occupies a huge part of northern and eastern Namibia. It is a generally monotonous, flat, basin of sedimentation, much of which is characterised by aeolian landforms, including linear dunes and pans (Thomas and Shaw 1991). It is discussed further in Chap. 21. The *Escarpment* (or Great Escarpment), discussed later in Chap. 1, runs roughly parallel to the coast and divides much of the country up into two general landscapes: the low-lying coastal plain to the west, and the higher inland plateau to the interior. It is not a continuous feature, and is largely absent from the Central-Western Plains.

In the far north east is a small area called the *Caprivi Floodplains*, created by the Zambezi and Kwando rivers and consisting of a network of channels, spectacular oxbow lakes and grasslands. In the late Pleistocene it may have been occupied by a lake, called Lake Caprivi (Shaw and Thomas 1988). Further east, the *Okavango Valley* occurs as a narrow strip along Namibia's northern border. The *Karstveld* of northern Namibia covers a scatter of areas in the east and west and is underlain by soluble carbonate rocks, including limestones and dolomites, and has an array of karstic forms including caves and sinkholes, of which Guinas and Otjikoto are the most dramatic examples (see Chap. 6). *Pans* are a typical Namibian landscape element, represented most notably in the north by Etosha Pan (see Chap. 6). The *Cuvelai system* which lies between Etosha Pan and the Angolan border, is dominated by a network of curious, shallow channels, called 'Oshanas', which in wet years obtain much of their water from the Angolan Highlands. The *Kunene Hills* in the far north west of Namibia, sometimes called the Kaoko Highlands, are a rugged area of dissected ancient rocks, commonly 1,000–1,900 m above sea level (Sander 2002). The hills include the Baynes, Steilrand, and Zebra Mountains. The Zebra Mountains are so called because they consist of a mass of interlayered, relatively unaltered dark leucotroctolite with relatively altered, "white," anorthosite (Maier et al. 2013). Glacial features, originating in the Dwyka phase (c 200–270 million years ago), have been exhumed and are widespread. These include U-shaped valleys with striated walls. The *Etendeka Plateau* (discussed further in Chap. 9) consists of flat-topped hills underlain by great expanses of volcanic lava and some sedimentary Karoo age rocks. The lavas were spewed out when Africa and South America split apart some 132 million years ago (as discussed in more detail in Chap. 2). The *Kamanjab Plateau*, mostly underlain by ancient granites and gneisses, is in the north west of the country and is drained and dissected by the Huab and Ombonde rivers.

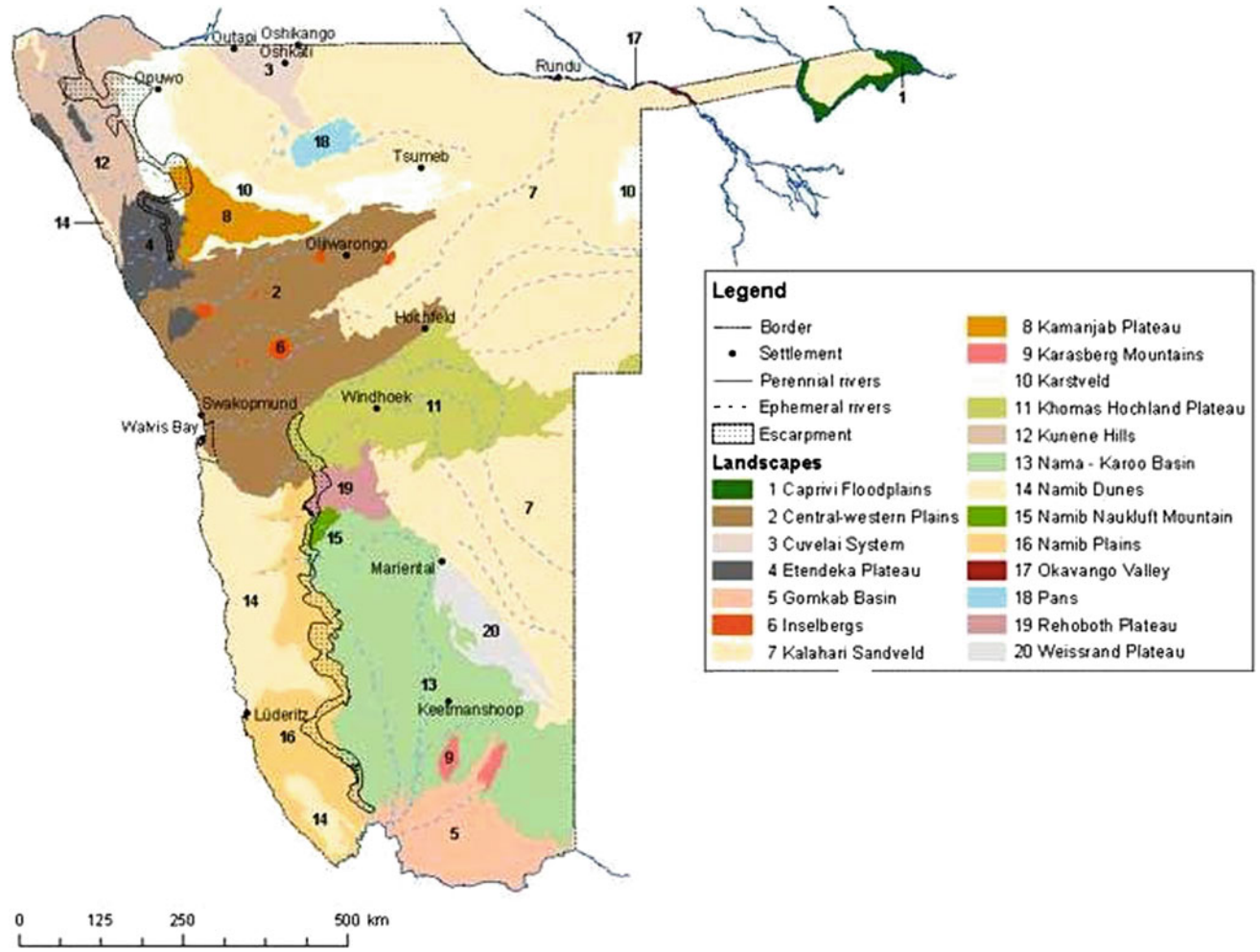

Fig. 1.2 The landscape divisions of Namibia (from Mendelsohn et al. 2002, p. 14, in http://www.uni-koeln.de/sfb389/e/e1/download/atlas_namibia/) (accessed 30th January 2014)

A large landscape unit within central Namibia is the *Central-Western Plains*, much of which lies between 500 and 1,000 m above sea level, stretches inland from the Atlantic coast and has been formed by rivers such as the Khan, Omaruru, Swakop and Ugab cutting back eastwards into higher ground. The area is studded with upstanding granite hills called inselbergs (Mabbutt 1952). These *Inselbergs* are large, free-standing mountain masses that punctuate the Central-Western Plains, and include Brandberg (at 2,579 m, the highest point in Namibia), Erongo (see Chap. 11), Paresis and Spitzkoppe (see Chap. 10). The *Khomas Hochland Plateau* is located in the centre of the country around Windhoek, and consists of a ridge of rolling hills and deep valleys. Much of it lies at altitudes between 1,700 and 2,000 m above sea level and it receives sufficient rainfall to feed such rivers as the Nossob, the Kuiseb and the Swakop. It is the remnant of a once-great mountain chain created towards the end of the Damara stage (c 550 million years ago) as a result of the collision of continents. This area contains one somewhat anomalous landform curiosity, a field of late Pleistocene dunes neither connected with the Namib or the Kalahari, up to c 7 m tall, located at Teufelsbach, some 20 km south of Okahandja (Eitel et al. 2004). The *Naukluft Mountains*, which largely consist of limestones and shales, occur on the edge of the Great Escarpment within central Namibia. The mountains are highly dissected by small, steep valleys in which extensive spreads of calcareous tufa occur (see Chap. 20). The *Rehoboth Plateau* lies in the centre of the country to the south of Windhoek at an altitude of between 1,500 and 1,700 m above sea level. It is an area of inselbergs and rolling terrain underlain primarily by granites and complexes of metamorphic rocks.

The western parts of central and southern Namibia are dominated by sand and plains. The *Namib Sand Sea* (see Chap. 18) stretches for 400 km north from Lüderitz (now officially known as #Naminus) to Walvis Bay and is up to 100–140 km in width. It contains a wide array of large and mobile dunes. The *Namib Plains* (see Chaps. 12 and 14)

consist of gravel and gypsum covered surfaces, rocky outcrops and hills, which together with the Namib Sand Sea make up a large proportion of the coastal plain seaward of the escarpment. Sand ramps are often banked up against hills (Bertram 2003). The *Karas Mountains* of southern Namibia consist of uplifted blocks of sandstones, limestones and shales that rise up above the surrounding plains. The highest peak in the Gross Karas Mountains reaches 2,203 m above sea level. The *Gamchab Basin* is an area to the north of the Orange River, with large valleys created by river erosion. Over much of the area drainage densities (the amount of stream channel per unit area) are high and there are extensive fan systems. The *Islands*, of which there are 12 main ones, occur just offshore between Walvis Bay and the Orange River and have been noted for their rich guano resources (Watson 1930). Whilst they are small and inconspicuous features, they have been given intriguing names such as Plumpudding and Roastbeef. The *Nama-Karoo Basin* is a predominantly flat-lying plateau underlain by sedimentary rocks, which slopes from 1,400 m above sea level in the north to 900 m in the south. This region includes the Schwarzrand to the south of Maltahöhe. It is drained by rivers such as the Fish, which flows to the Orange. Some ancient inselbergs have been exhumed from beneath the former Late Proterozoic to Cambrian Nama sedimentary cover (Stengel 2000; Stengel and Busche 2002) either because of river erosion or groundwater-related weathering effects (Twidale and Maud 2013). Fossil landslides have been extensively developed (Stengel 2001), probably as a result of higher precipitation amounts than today. Brukkaros forms the only major mountain in this area (see Chap. 24). Finally, the *Weissrand Plateau* is an intriguing area of solution hollows (dayas), calcrete, aligned drainage and old dunes sandwiched between the Nama-Karoo Basin and the Kalahari sandveld (see Chap. 22).

1.2 The Namib and the Kalahari Deserts

Of the composite landscape types of Namibia, two of the largest and most important are the two great deserts, the Namib in the west and the Kalahari in the east. The Namib Desert landscape comprises a range of landscape types from hills to gravel plains and dune fields, whereas the Kalahari Desert is dominated by stabilised dunes (Fig. 1.3).

1.2.1 The Namib Desert

The Namib, one of the world's driest and most beautiful deserts, extends for more than 2,000 km and eighteen degrees of latitude along the Atlantic coast of southern Africa from the Olifants River in South Africa (latitude 32°S) to the Carunjamba River (latitude 14°S) in Angola. Being on the west side of the continent, in a zone of subsiding anticyclonic air, and bounded by the cool Benguela current offshore (Dingle et al. 1996), the Namib is hyper-arid (see Chap. 3). On its inland side it is bordered by a portion of the Great Escarpment which forms the western edge of the interior plateau and basin of southern Africa. Thus the Namib Desert forms a rather narrow strip some 120–200 km wide.

The geomorphology of the Namib Desert has been described by a number of workers (e.g. Gevers 1936; Cloos 1937; Logan 1960; Spreitzer 1965; Beaudet and Michel 1978; Hövermann 1978; Wilkinson 1990; Lageat 1994, 2000; Besler et al. 1994) and its context within the Cenozoic history of southern Africa is treated in Partridge and Maud (2000). The landforms in proximity to Gobabeb, the base for much of the work that has been done on the desert, are described in Eckardt et al. (2013). The Namib Desert can be subdivided into four main landscape types. In the area south of Lüderitz there is 'The Southern or Transitional Namib', which includes coastal Namaqualand and the diamond mining lands of the Sperrgebiet (Pallett 1995). This zone is cut through by the Orange, the last perennial river until the Kunene is reached on the Angolan border. It includes the rugged terrain of the Richtersveld and some areas of dunes —the Obib Dunes—to the north of the Orange. The area around Lüderitz and Elizabeth Bay has high velocity winds and there is extensive yardang development, rock fluting and deflation (Lancaster 1984; Corbett 1993).

The second Namib Desert landscape is that of the 'Namib Sand Sea' (see Chap. 18) which extends between Lüderitz and Walvis Bay and contains some of the world's biggest dunes. This area has been the subject of a detailed review by Lancaster (1989). The third Namib Desert landscape is the 'Central Namib Plains'. These lie between the Kuiseb River and more dissected terrain that lies to the north of the Brandberg. The plains have a low gradient of only 1° between the coast and the 1,000 m contour, and are studded with marble and dolerite ridges, some isolated inselbergs and complexes of shallow pans (Eckardt et al. 2001; Eckardt and Drake 2011). The plains show many windstreaks oriented with the easterly 'berg' winds which generate some dust plumes, which head out across the South Atlantic. Although the area is hyper-arid, the plains are also crossed by a very dense and intricate network of shallow drainage lines. This is very evident, for example, on the gently sloping rock surface immediately behind the coastal dunes between Walvis Bay and Swakopmund. Locally, ephemeral rivers such as the Swakop are more deeply incised into the plains, producing gorges and areas of badlands (called *gramadullas* or a moon landscape) (Fig. 1.3). In places these gorges truncate groundwater aquifers so that seepage occurs. This produces tufas made either of lime or of halite. The fourth landscape —'The Northern Namib and Skeleton Coast'—includes a

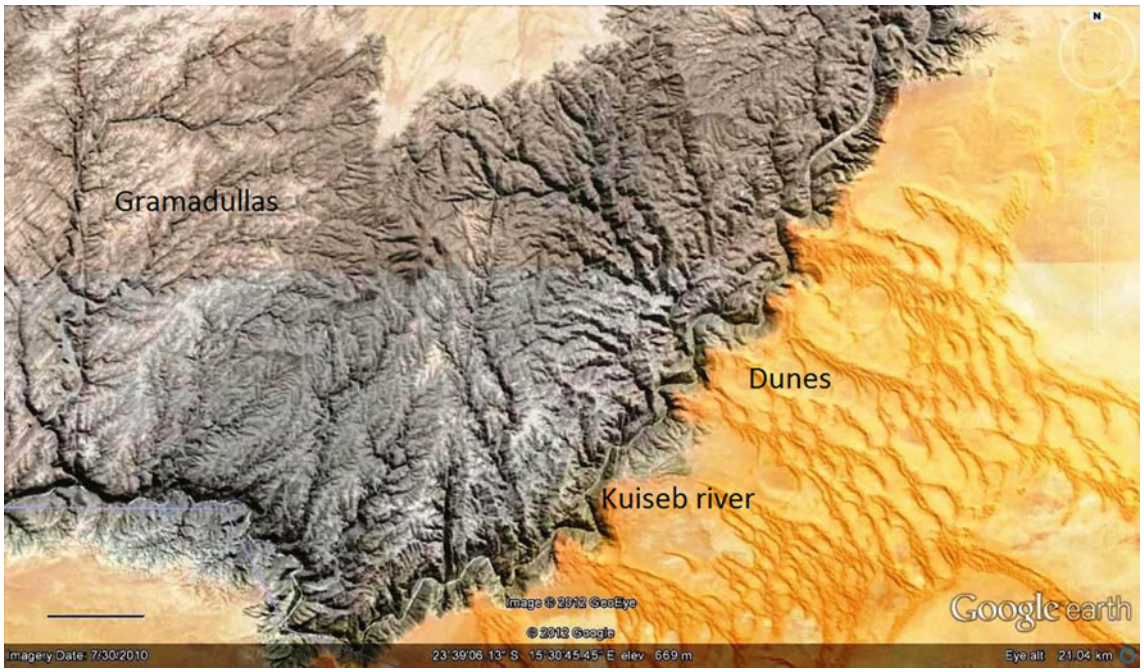

Fig. 1.3 Google Earth image of gramadullas to the north of the Kuiseb River. Scale bar 2 km (© 2013 GeoEye, Google)

dissected area of sandstone and lava hills, known as the Kunene Hills (also called Kaoko Highlands or Kaokoveld), together with some coastal dunefields (Lancaster 1982). The Kunene Sand Sea, which extends into Angola, is cut through by the perennial Kunene River (see Chap. 5).

It is also possible to divide the Namib Desert on the basis of its climate. Besler (1972), for instance, related weathering and other phenomena to the fog environment, introducing three divisions: the cool fog desert at the coast, the desert steppe in the east and the warm (alternate) fog desert in the middle.

One important landscape type, related to desert conditions, is found in between the Namib and Kalahari deserts in northern Namibia. Here, there are some quite extensive deposits of loess. Loess is a largely non-stratified and non-consolidated silt, containing some clay, sand, and calcium carbonate. It consists chiefly of quartz, feldspar, mica, clay minerals and carbonate grains in varying proportions. The grain size distribution of typical loess shows a pronounced mode in the range 20–40 μm and is generally positively skewed towards the finer sizes. It was the great German geographer, Ferdinand von Richthofen (1882, pp. 297–298), who had travelled to the classic deposits in China, who cogently argued that these intriguing deposits probably had an aeolian origin and that they were produced by dust storms transporting silts from deserts and depositing them on desert margins. Thus, it is likely that the Namibian loess deposits on the margins of the Kalahari and Namib Deserts have been produced from dust originating in these arid environments.

Namibian loess locations include the Opuwo basin and Omungunda in the Kaokoland area, where they were originally thought to be of late Holocene age (Brunotte and Sander 2000). However, Brunotte et al. (2009) have recently asserted that in the Opuwo area loess deposition commenced around 55,000 years ago (i.e. in the Pleistocene rather than the Holocene). Loess, up to 5 m in thickness, also forms a fill in large basins in the valleys of the Huab and Hoanib rivers in the Khorixas district (Eitel et al. 2001), and appears to be of largely late Pleistocene age. It is believed that the loess is formed from material transported by westward moving dust storms from the eastern Kalahari under drier conditions than today. Even today, dust is generated in substantial quantities from the surfaces of the Mkagadikgadi depression in Botswana (Washington et al. 2003), and the Etosha Pan in Namibia (Bryant 2003). The loess is now being eroded by water to give areas of badlands.

1.2.2 The Kalahari Desert

In the interior of southern Africa, much of it in Botswana but a substantial part in eastern Namibia, lies the Kalahari Desert (Thomas and Shaw 1991). This area was the subject of a major study by the Prussian geographer Passarge (1904), though most of his observations took place in what in his day was called Bechuanaland. However, he did describe the stratigraphy and landforms of the Gobabis area in eastern Namibia.

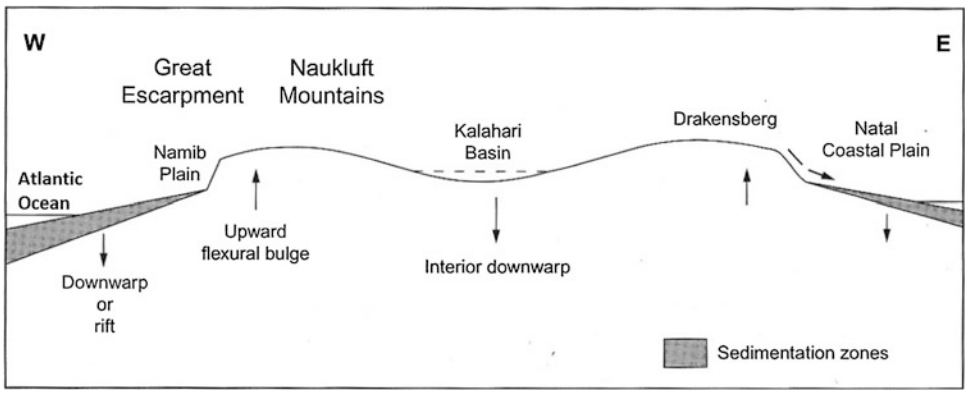

Fig. 1.4 The structural context of the Kalahari

It is difficult to say what precisely the borders of the Kalahari Desert are, not least because it has expanded and contracted during the last few million years. Much of it is a relict of a more extensive desert that once extended equatorwards well into the Congo Basin. It also merges with the Namib in the west and the Karoo in the south, and its boundary with the latter is often taken as the Orange River. The Kalahari, most of which lies at an altitude of around 1,000 m, derives its name from the Setswana word 'Kgalagale', which means 'always dry', but there are in a sense three Kalaharis, some drier than others:

(a) *The Kalahari dune desert in the arid south west interior of Botswana and adjoining parts of Namibia and South Africa*. The primarily summer rainfall is less than 200 mm per annum and is just sufficient to stabilize the plinths of a major field of dominantly linear dunes. The dune crests are often active.

(b) *The Kalahari region (or thirstland) approximately delineated in the north by the Okavango Swamps and in the south by the Limpopo and the Orange rivers*. This is an area of little or no surface drainage despite a relatively higher rainfall (c 600 mm per annum). Rates of groundwater recharge are very low (De Vries et al. 2000). It is almost entirely covered with grass and woodland, and has extraordinarily low relief.

(c) *The Mega-Kalahari, which is an extensive area consisting of a basin filled by the continental sediments of the Kalahari Beds.* This extends from the Orange River as far as the Congo. Precipitation may be as high as 1,500 mm, but it displays the evidence of former aridity in terms of the development of ancient dune systems, drainage alignment, and pans (Shaw and Goudie 2002).

The Kalahari contrasts with the Namib Desert because of its relatively high rainfall and because of its basinal form. Because the climate of the Kalahari is semi-arid to sub-humid, most of it is not a true desert but an extensively wooded 'thirstland'. Over enormous distances the relief is highly subdued and the landscape monotonous. The Kalahari owes its gross form and subdued morphology to the fact that following the break-up of Gondwanaland it became an area of down-warping bounded on the west by the highlands of Namibia and Angola, and on the east by mountains such as the Drakensberg and Lubombo (Haddon and McCarthy 2005) (Fig. 1.4). It became a basin of sedimentation and this largely accounts for its flatness. The Kalahari Beds that fill this basin are often over 100 m in thickness and in parts of the Etosha region of northern Namibia they are over 300 m thick (Fig. 1.5). Differences in thickness are related to graben (fault) structures. The sediments consist of terrestrial conglomerates, breccias, clays, dune sands, diatomaceous interdune deposits, alluvium, calcretes, silcretes and marls (Wanke and Wanke 2007). Depositional settings included braided rivers, sheet flood areas, shallow lakes and pans, and dune systems.

Apart from its relict linear dunes (Thomas 1984) (see Chap. 21), the Kalahari contains large numbers of pans and associated leeward lunette dunes (Goudie and Thomas 1985) (see Chap. 23), together with two large closed depressions—the Etosha Pan of Namibia (see Chap. 6) and the Mkgadikgadi Depression of Botswana. Today these are major sources of dust plumes (Washington et al. 2003). In the mid to late Tertiary, palaeolake Etosha received water via the Cubango, Kunene and Cuvelai drainage systems. It largely dried up at about 4 million years (Ma) under conditions of progressively increasing aridity, though it still occasionally floods (Miller et al. 2010). The Kalahari shows excellent development of calcrete, silcrete and combinations of the two (Watts 1980; Nash et al. 1994; Shaw and Goudie 2004). The reason why calcretes in particular are so well developed probably relates to the structural context. The long history of gentle sedimentation within the Kalahari basin has created suitable conditions for the preservation of