



Succulent Karoo Biome

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Klein Winterhoek Mountains) and those forming barriers in the south (Langeberg, Outeniqua, Tsitsikamma, Baviaanskloof and Groot Winterhoek Mountains). Notable outliers of the biome are found on and around inselbergs of northern Bushmanland (embedded within the Nama-Karoo), in the deep rainshadow valley of the Olifants River (sheltered by the Graafwater and Olifants River Mountains in the west and the Cederberg Mountains in the east), in the upper Breede River Valley in the rainshadow of the Cape Fold Belt mountains and in the form of small patches east of Piketberg, embedded within West Coast renosterveld.

The Succulent Karoo Biome is found mostly west of the western escarpment from the Lüderitz District of Namibia through the western belt of the Northern Cape and Western Cape Provinces, and inland of the Fynbos Biome to the Little Karoo. The biome covers approximately 111 000 km, making it the fourth largest biome in southern Africa after the Savanna, Nama-Karoo and Grassland Biomes. Much of the terrain is flat to gently undulating, such as the western coastal platform, Knersvlakte and Tanqua Karoo. Hilly and more rugged topography occurs in Namaqualand, the Robertson Karoo and Little Karoo and parts of the western escarpment. The extreme altitudinal range is from sea level to about 1 500 m, but most of the area lies below 800 m.

The nomenclature of this biome is probably the most difficult to determine since no single regional, traditional name exists for the whole area. The term Succulent Karoo is regarded as appropriate since, although by no means all the plants of the biome are succulent, succulence is a recurring feature at varying levels of abundance throughout the biome. The term should not be regarded as being limited to the Acocks's (1988) 'Succulent Karoo' Veld Type No. 31.

The Succulent Karoo Biome interfaces with the Fynbos Biome—the biome with which it shares its greatest floristic affinity (Hilton-Taylor 1987)—to the south and east. It borders on Albany Thicket to the east, Nama-Karoo to the north and west, and the Desert Biome to the north. That the former 'Karoo Biome' of South Africa comprised two distinct biotic areas was recognised by Huntley (1984) and each was raised to full biome status by Rutherford & Westfall (1986). Their biotic division corresponded to the greater proportion of winter rainfall in the Succulent Karoo and the greater proportion of summer rainfall in the Nama-Karoo. This general association with the continuous variable of rainfall seasonality also accords with gradients between the two biomes which our demarcating lines on the map do not reflect. Where soil types are distinct, biome boundaries can be distinct. This is obvious especially in the case of SKr 19 Aggeneys Gravel Vygieveld and SKr 18 Bushmanland Inselberg Shrubland embedded within the NKb 3 Bushmanland Arid Grassland (Nama-Karoo).

Globally there are few other places that can claim to be as biologically distinct as the Succulent Karoo Biome. Unrivalled in its status as the world's only entirely arid region diversity hotspot (Mittermeier et al. 2000, Myers et al. 2000), this biome experienced numerous adaptive radiations and associated endemism for a wide range of faunal and floral groups. Worldwide, four geographically remote regions have mediterranean-type climatic regimes with transitions to desert environments like that of the Succulent Karoo (Cowling et al. 1996). These occur in Western USA & Baja California, Central Chile, the Mediterranean Basin and Western Australia. Floristically, however, none of these deserts is dominated by dwarf leaf-succulent shrubs, making the Succulent Karoo quite unusual among winter-rainfall deserts. The winter-rainfall Mojave Desert and western Sonoran Desert of California and Baja California as well as parts of the winter-rainfall Atacama Desert of Chile have vegetation that

1. Introduction: Regional and Global Position

The Succulent Karoo Biome covers an interrupted belt of unequal depth spanning the coastal regions near Lüderitz (Namibia), Namaqualand (on and west of the Escarpment), the Hantam, Tanqua and Roggeveld region as well as the Little Karoo (in a broad sense). The latter is a composite region, including karoo landscapes of the western Great Karoo Basin (surrounds of Laingsburg) and northern piedmonts of the Swartberg Mountains (surrounds of Prince Albert) and a series of valleys embraced by west-east stretching Cape Fold Mountain ranges, including those bordering the Succulent Karoo in the north (Witteberg, Klein Swartberg, Groot Swartberg, Grootrivier and

boasts an abundance of succulents (mostly stem-succulent cacti and leaf-succulent *Yucca*). The mediterranean/desert transition zone in Western Australia is virtually nonexistent, as the transition to summer rainfall is abrupt in this area. Finally, the winter-rainfall deserts of the Mediterranean Basin (e.g. Negev Desert) do not have an equivalent succulent flora, and are largely dominated by annual species. Esler & Rundel (1999) suggest that it is the unique seasonal and interannual rainfall reliability of the Succulent Karoo that sets it apart from other mediterranean-type deserts.

2. Major Physical Environmental Features

2.1 Climate

The Succulent Karoo is a semidesert region with a strong maritime influence characterised by an even, mild climate. Most of the biome falls within a typical unimodal winter-rainfall region (Namaqualand and the western Great Escarpment), while the greater Little Karoo region (encompassing vegetation units SKv 8 to 14) shows either all-year-round precipitation (SKv 8 to 11) or bimodal (equinoctial) precipitation regimes (SKv 12 to 14). The features of the latter regime can also be seen in the climate data for the Roggeveld Karoo (SKt 3)—a unit with a transitional character between the Succulent Karoo and Nama-Karoo Biomes (Figure 5.2). The Summer Aridity Index (SAI) is greater than 4.8 (Rutherford & Westfall 1986).

The Mean Annual Precipitation (MAP) for most of the units is between 100 and 200 mm. Some of the Richtersveld units (SKr) adjoining the Namib and Gariiep Deserts as well as part of the Tanqua Karoo (SKv 5) and part of some west coast units, for example Namaqualand Coastal Duneveld (SKs 8), have a MAP below 100 mm, while most of the valley rainshadow units (Little Karoo) have a precipitation higher than 200 mm; the unit with the highest precipitation is Robertson Karoo (SKv 7), reaching almost 300 mm. The overall biome average is about 170 mm. A distinctive characteristic of the rainfall regime is its relatively high predictability (Hoffman & Cowling 1987) and prolonged droughts are very rare (Desmet & Cowling 1999). This element of climatic stability (pronounced also when Succulent Karoo is compared to analogous winter-rainfall semideserts of the world) plays an important role in fostering and preserving the high species diversity of the biome (Cowling et al. 1999). Rainfall is usually cyclonic—derived from depressions associated with the circumpolar westerly belt (Schulze & McGee 1978). Its kinetic energy is lower for the biome as a whole compared to the other biomes and the rain events tend to be widespread, mostly gentle showers—while much of the rainfall of the Nama-Karoo is highly localised, intense and short thunderstorms (Schulze 1997). Hailstorms are rare in the Succulent Karoo. Milton & Collins (1989) pointed out that the frequency of hail events

can account for the richness of the succulent flora (succulents being extremely sensitive to mechanical damage). Along the Namaqualand coast and along the west-facing escarpment, the low rainfall is supplemented by frequent coastal fog. High air humidity in places (especially) along the coast and relatively cool nocturnal temperatures generate copious dewfalls which may occur all year round (Von Willert et al. 1990, 1992, Cowling et al. 1999, Desmet & Cowling 1999).

The overall Mean Annual Temperature (MAT) of 16.8°C for the biome indicates the warm-temperate climate regime. Indeed most of the vegetation units show a MAT ranging between 16°C and 18°C, with notable exceptions of some SKt units, including the high elevation Roggeveld Karoo with a MAT of only 14.5°C. The occurrence of frost is apparently a function of the distance from the sea (continentality) and altitude. In the low-lying coastal regions (Sandveld, western Richtersveld and Knersvlakte) frost is a rare phenomenon, while along the Namaqualand escarpment frost may occur 7 to 13 days per year. The vegetation units found in deep valleys surrounded by high mountain ranges can have frost most often (mainly due to thermal inversion)—15 to 30 days per year. The units found on the continental plateau beyond the escarpment also have a high incidence of frost (20–25 days per year), with SKt 3 Roggeveld Karoo again a notable exception reaching almost 60 frost days per year. Absolute temperature values greater than 44°C have been recorded in low-lying coastal regions (e.g. west coast) that experience catabatically warmed berg winds that descend from the interior plateaus of the country (Rutherford & Westfall 1986). A characteristic of autumn, these conditions can persist for several days and are suspected to have a profound effect on the vegetation (Von Willert et al. 1990, 1992, Cowling et al. 1999, Rossa & Von Willert 1999).

The biome has the shortest summers with duration of less than 198 days (Schulze 1980). Incoming radiation in summer ranges from 270–280 J m⁻² day⁻¹, which is higher than that for the other biomes according to Schulze & McGee (1978).

2.2 Geology

The Succulent Karoo Biome covers a large area characterised by complex geology. The northernmost parts of the biome occur on rocks of the Richtersveld Terrane, the Namaqua-Natal Metamorphic Belt and the Gariiep Metamorphic Belt. These different geological areas became juxtaposed during two orogenic events of supercontinent assembly and break-up (Hoffman 1999), namely the Kibaran (during which the supercontinent Rodinia was assembled) and the Pan-African (during which the supercontinent Gondwana was assembled).

The volcanic and sedimentary rocks of the Bushmanland Terrane were probably deposited on older crust very similar to that found in the Richtersveld Terrane. During the Namaqua-Natal metamorphism (approximately 1 100 mya), these rocks

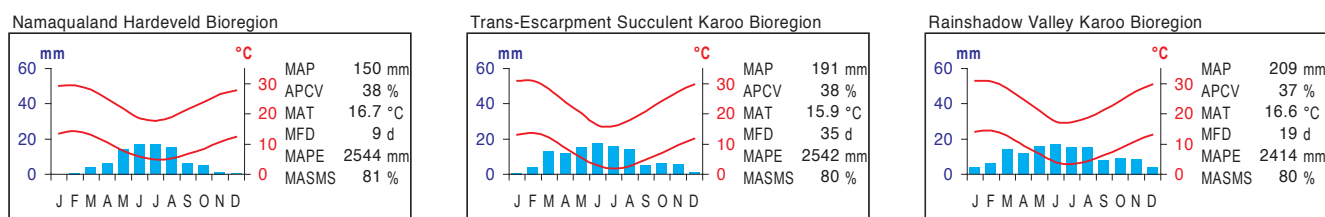


Figure 5.2 Climate diagrams of selected bioregion units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

became strongly deformed except a small area at the core of the Richtersveld, which escaped the event (Thomas et al. 1994). In northern Bushmanland the characteristic landscape of inselbergs on a vast peneplain is the result of extensive erosion since the drifting apart of Gondwana.

Voluminous magmatic material is found in these two terranes, including the Vioolsdrif Suite in the Richtersveld and the younger granites and gneisses of Bushmanland, which stretch as far as Vanrhynsdorp. The intrusive rocks of the Bushmanland Terrane include older gneisses that formed well before the metamorphic event and include examples such as the Kamieskroon Gneiss and those of the Stalhoek Complex. The younger group of intrusive rocks formed shortly before and during the event and include the Spektakel and Little Namaqualand Suites.

To the west of the Richtersveld and the Bushmanland Terranes lies the Gariiep Metamorphic Belt which formed during the assembly of the supercontinent Gondwana. The belt hugs the northwestern coast of South Africa and formed approximately 500 mya (Frimmel 1995, Frimmel & Frank 1998). This Pan-African event was related to the Saldanian Orogeny in the Western Cape, which also included the formation of the Cape Granite Suite. The Kuboos-Bremen Suite represents a similar, but less extensive, suite of granitic rocks to the Cape Granite Suite that formed in relation to the Gariiep Orogenesis. Part of this suite also intrudes the Richtersveld Terrane (Frimmel et al. 1996).

In conjunction with the Pan-African Orogenesis, Cambrian-aged sediments formed as a result of the erosion of the mountain chains that had formed. The Vanrhynsdorp Group, which includes the Knersvlakte Subgroup, is such an example. These sediments were formed in a fairly shallow water environment, and towards the south they are covered by the younger Cape Supergroup sedimentary rocks (Gresse & Germs 1993). The rocks of the Vanrhynsdorp Group are also covered in large parts by recent (Quaternary) alluvial deposits of sand and occasional calcretes. These, as well as the recent sediments covering large parts of the west coast, are the result of fluctuations in sea level in the recent past Rogers et al. (1990).

In the southwestern and southern Cape the geology is dominated by the Cape Fold Belt (as discussed in the Chapter on Fynbos Biome in this book). This mountainous area consists of thick packages of fairly monotonous sandstone separated by thinner shale bands that all form part of the Cape Supergroup. These sediments were deposited at a time when Gondwana was moving towards the South Pole. As the supercontinent was situated at these high latitudes, the glacial deposits of the Dwyka Formation were laid down, marking the start of the Karoo Supergroup sedimentation.

Succulent Karoo vegetation occurs predominantly on shale rocks in the southern and western Cape. The Bokkeveld Group of the Cape Supergroup is most dominant, with other rocks of the Supergroup playing a smaller role in certain areas. Examples of this abound: Succulent Karoo of the Western Little Karoo, the Little Karoo near Oudtshoorn as well as the vegetation further east towards Willowmore and Steytlerville occur mostly on these shales of the Cape Supergroup. Shales of the Ecca Group of the Karoo Supergroup also support Succulent Karoo. In the southern Cape they play a role in the northernmost parts such as around Laingsburg and Prince Albert. The Karoo rocks are dominant in the Tanqua Basin as well as on the escarpment and towards the interior. Both Cape and Karoo Supergroups are the underlying rocks of the Succulent Karoo in the Robertson area.

The geology of both the Tanqua Karoo and the surrounds of Laingsburg both feature the lower units of the Karoo Supergroup, with the Dwyka diamictites giving way to deep

marine sediments that include regular occurrences of turbidite deposits. These deposits form in deep water by means of the deposition of material transported in channelised debris-flows that flow down and splay out on the ocean floor. Although the package of sediments in these two areas is similar, there is noticeably more folding in the Laingsburg area as a result of the formation of the Cape Fold Belt over 200 mya. This folding peters out towards the north where the remaining Karoo sediments are almost entirely flat.

The Tanqua Basin is surrounded in the south and west by mountains of the older Cape Supergroup quartzites and shales. Here, in the vicinity of the Tanqua Basin, the Succulent Karoo vegetation can even be found on these Cape Supergroup quartzites, such as those of the Nardouw and the Witteberg. To the east of the Tanqua Basin lies the escarpment built of younger rocks of the Karoo Supergroup, which become younger still towards the interior, with increasing elevation as one travels up through the Karoo Supergroup.

2.3 Soils

Pedogenic diversification is a hallmark of arid environments and is supposedly one of the major driving forces of diversification of flora and vegetation in these climatically extreme ecosystems. In an arid ecosystem such as the Succulent Karoo, the availability of water largely controls the type and functioning of the ecosystem. Since soil is the main body for collecting and storing rainwater or water accumulated from fog, the ways the soil intakes, translocates, stores and eventually loses water are of crucial ecological relevance. The soils of the Succulent Karoo possess special features which modify water infiltration, hydraulic conductivity, subsurface storage and water supply to plants. Unlike in higher-rainfall areas bordering on the Succulent Karoo in the south (Fynbos Biome), where leaching is a regular feature, the soils of the Karoo are generally well supplied with the most important macro- and micronutrients (Ellis 1988). The plethora of habitats encountered in the Succulent Karoo reflects differences in soil chemistry and fertility that play an important role in microscale vegetation patterning.

Information on the Karoo soils is limited to reconnaissance mapping of land types (Land Type Survey Staff 1987), a few unpublished irrigation soil-survey reports and a review paper by Watkeys (1999). The study by Ellis (1988) covered a wide area, and included almost all the areas classified as Succulent Karoo (excluding only the Robertson Karoo). A paper by Francis et al. (2006) serves as an important source of information featuring more recent pedogenic work.

The main broad physiographical (soil-landscape) regions of the Succulent Karoo Biome and surrounding areas are featured in Figure 5.3. The Namaqualand coast (soil-landscape regions A1 and A2) is about 30 km wide, a generally flat plain, consisting of sandy material of aeolian origin. The soils of the coastal area consist of deep, grey, calcareous sands adjacent to the coast, followed by an interrupted zone of yellow sands. The inland part of this region consists of deep, red, sandy (in some places calcareous) soils. Inland of the coastal area and stretching generally northwest-southeast, a hilly mountainous area (soil-landscape regions B1 and B2) is situated, forming part of the Great Escarpment—a region separating a higher and older inland area from a younger low-lying coastal region of southern Africa. On average, it is about 60 km wide and rises from 300 m above sea level to altitudes as high as 1 700 m in places. The dominant rock types are granite and gneiss and the soils are generally shallow, base-rich to calcareous, reddish coloured, with a hardpan (duripan) at shallow depth in the valleys. The escarpment forms a natural separation between

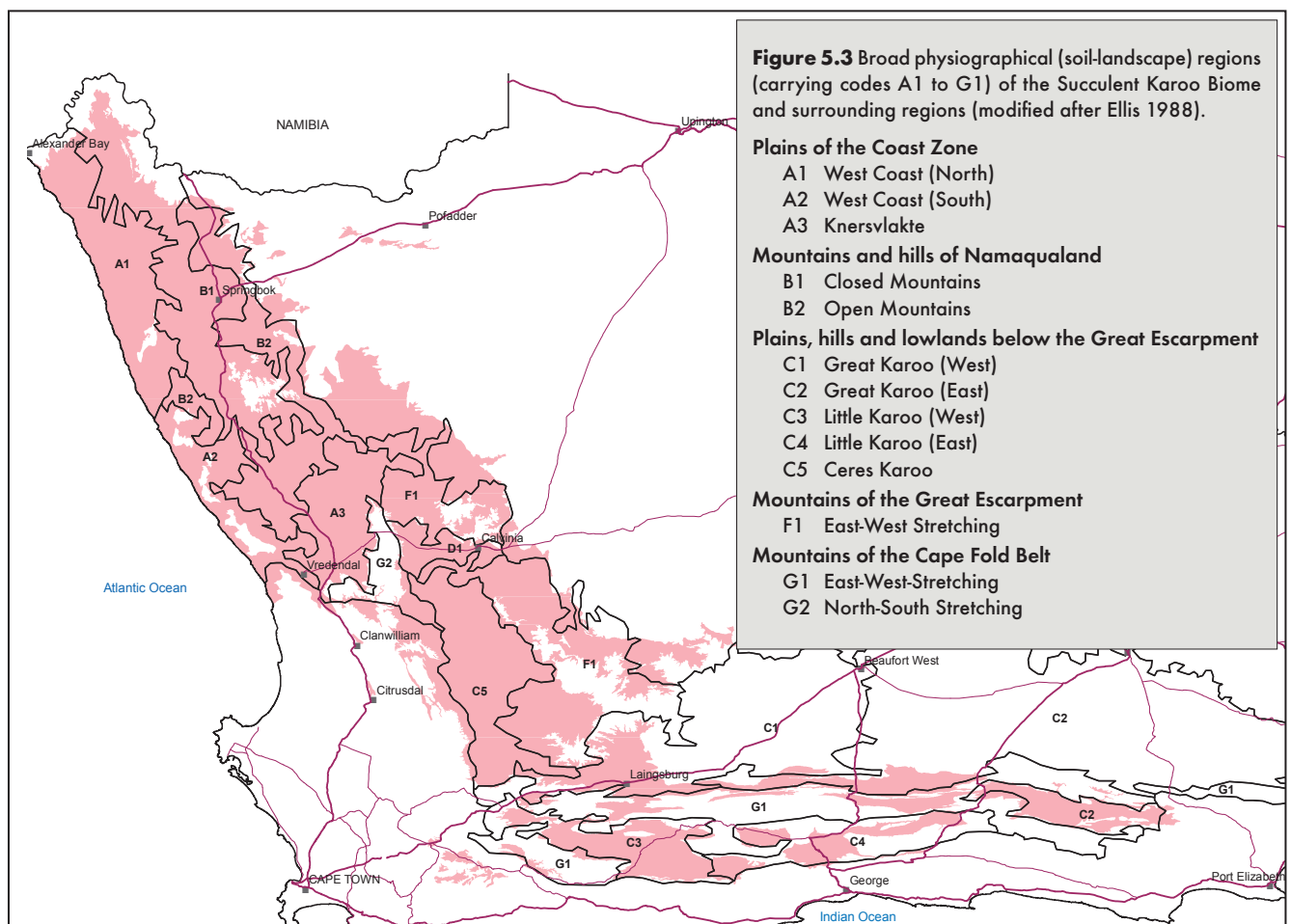
the coastal area and the high-altitude flat inland plateau to the east (soil-landscape regions E2 and E3). The soils of the Knersvlakte are generally shallow, base-rich to calcareous and reddish coloured, with a duripan occurring at a shallow depth from the soil surface. A large area of the soils of the high-altitude plateau to the east consists of shallow to moderately deep, reddish coloured base-rich sands on granite/gneiss parent material (soil-landscape region E2) and shallow calcareous loams with desert pavement on the surface, where shales form the parent material (soil-landscape region E3). Another important feature is the deep pre-weathering, which can be encountered in many places, usually with a silcrete or ferricrete capping still preserved.

From Calvinia to Sutherland, the Great Escarpment (soil-landscape region F1) underlain by shale with shallow, stony lithosols dominant, stretches in a more or less southerly direction, and then (east of Sutherland) changes its direction towards the east. To the south of the Great Escarpment, and running more or less parallel to it, the sandstone and quartzites of the Cape Fold Mountains support stony, shallow, acid, sandy soils. Some of these marginal (very dry) areas (such as Swarttruggens on the eastern rim of the Tanqua Basin and the Doring River Valley) support Succulent Karoo vegetation. The soil-landscape regions C1 to C5 represent plains, hills and lowlands below the Great Escarpment. Irregular plains with parallel hills stretching east-west (mostly built of shales) and lowlands and mountains with moderate relief and shallow lithosols (soil-landscape region C1) occur southwest of the Great Escarpment. The soil-landscape region C2 is a low-relief plain situated immediately to the east of the C1 region. Large areas of deep unconsolidated alluvial and colluvial deposits form the parent material of the soils. To

the south of the Cape Fold Belt mountains (G1), the Little Karoo shows similar physiography to the soil-landscape regions C1 and C2, with C3 (western section) corresponding to C1 and C4 (eastern section, especially around the town of Oudtshoorn) to C2. However, in both cases, occasional silcrete cappings (remnants of the African Surface I; Watkeys 1999), linked to the sandstone mountains, occur with red apedal soils on duripan on the low-lying parts of the landscape and on the plains. These silcrete cappings support very stony, sandy, acid soils. The soil-landscape region C5 is a lowland between the Great Escarpment and the Cape Fold Belt mountains stretching north-south (part of the soil-landscape region G2), with saline alluvial soils along the rivers and lithosols with a very prominent desert pavement on the surface dominant in the remainder of the area.

In terms of the World Reference Base for Soil Resources (FAO 2005), the main soil groups in the Succulent Karoo Biome include both zonal and azonal soil groups such as Leptosols, Fluvisols, Solonchaks, Solonetz, Gypsisols, Durisols, Calcisols and Arenosols. Examples of most of the World Reference Base descriptive soil qualifiers, such as alcalic, arenic, aridic, calcaric, calcic, carbonatic, chloridic, duric, gypsic, hyperochric, hydrophobic, puffic, salic, sodic, takyric and yermic are likely to be found as well. All the special features inherent in this terminology are of ecological significance, some of which are briefly discussed below.

Ellis (1988) defined the bleached orthic A horizon during his survey of the Karoo soils as a surface horizon with a lighter colour than the subsurface horizons. This horizon, very common in most soils of the Karoo, is structurally unstable and is characterised by changes to the thin layer of soil at the interface with the atmosphere (also called 'pedoderm' by Mills &



Fey 2004). Physical soil crusting (or soil sealing) might develop that may negatively influence aeration, germination, seedling emergence and root growth near the surface (Shainberg & Levy 1994). Crust formation promotes water runoff to accumulate in zones where water infiltration can cause deeper penetration, thereby stimulating deeper-rooted plants. On very sandy soils, especially along the Namaqualand coast, the surface soils show temporarily poor wettability, especially after long dry spells. The hydrophobic character is caused by certain organic compounds, such as waxes. Water infiltration is markedly impeded when dry soil is first wetted. This can cause localised ponding of water and subsequent deep infiltration. The water can then be utilised by deep-rooted plants, or more likely, by succulent plants with adapted root systems by upward transport of water vapour (Prinsloo 2005), or accumulate above a limiting layer such as a clay-pan.

The surface of many of the soils as for instance on the Knersvlakte (A3), in the Western Little (Ladismith) Karoo (C3) and Tanqua (Ceres) Karoo (C5) is characterised by formation of desert pavement (surface layer of gravel and stones), in some cases so pronounced that the underlying fine earth material becomes fully covered. Such surfaces function as protective mulch, reducing raindrop impact and thereby preventing crust formation and enhancing water infiltration. Where milky quartz stones dominate, the reflective properties of the white desert pavement (known as quartz patches or quartz fields) influence the surface temperature of the soil, a factor which might have played a role in the structuring of plant communities on the quartz fields (Schmiedel & Jürgens 2004).

Subsurface soil properties that enhance water storage include textural water barriers (involving a very slight change in clay content in sands, influencing downward percolation of infiltrated rain water), cemented horizons such as dorbank (duripan), calcrete (petrocalcic) or sepiocrete (sepiolite-cemented hardpan) or clay pans, which directly influence downward movement of water. If over-saturation occurs in the layers above the hardpan, water may be stored for use by deep-rooted plants or, more likely (especially in the sands along the coast), by plants rooting close to the soil surface through upward transport of water vapour during cooling off of the surface soil layers during the

night. This phenomenon is also known as nocturnal distillation (Prinsloo 2005).

In almost all the areas of the Succulent Karoo, large circular (approximately 30 m diameter), often slightly elevated (up to 1 m high) mounds are abundant. They are easily recognisable from a distance due to different coloration (resulting from different vegetation) against the surrounding background (Figure 5.4). These mounds are called 'heuweltjies' and their origin is ascribed to former activity of harvester termites (*Microhodotermes viator*). Although the conclusive evidence is still pending, heuweltjies are assumed to be ancient abandoned termitaria. Their abundance and presumed importance in ecological processes within the Succulent Karoo landscapes have generated much scientific interest (e.g. Lovegrove & Siegfried 1986, 1989, Midgley & Musil 1990, Esler & Cowling 1995, Laurie 2002, Ellis 2004). Most of the heuweltjies are characterised by a central petrocalcic (calcrete) to petroduric (duripan or dorbank) hardpan, with a petroduric horizon on a petrocalcic horizon towards the outer edge and occasionally also in the surrounding intermound areas. The mounds are virtually absent on base-poor parent material (e.g. sandstone). In a study by Ellis (2004) the pedoderm (0–10 mm surface horizon) of 18 representative heuweltjies was sampled from Springbok in the north to Oudtshoorn in the east. Soils on the heuweltjies are more fertile (average P content for topsoil horizons = 50 mg/kg) than between heuweltjies (P = 2 mg/kg). Most of the soil located near the centre of the heuweltjies tested positive for free lime and had a higher pH than the soil on the periphery of the heuweltjies. The combination of a higher fertility and differences in soil physical properties and of relief on a micro scale (influencing available water), is seen as the reason for the strong differences in biodiversity that occur on and between heuweltjies. Heuweltjies are also common in especially Namaqualand where they cover as much as 25% of the landscape in places.

3. Biogeography and Diversity Patterns

This desert shrubland largely comprises the winter-rainfall arid zone of southern Africa and is classified by phytogeographers as the Succulent Karoo Floristic Region (Jürgens 1991). This relatively new phytochorion formed a part of the broadly conceived Karoo-Namib (Floristic) Region of Werger (1978, 1986) called Karoo-Namib Regional Centre of Endemism (White 1983) until recently.

Jürgens (1991) has subdivided the Succulent Karoo Region into two domains. The Namaqualand-Namib Domain, broadly coinciding with the magisterial district of Namaqualand, is situated in the strongly winter-rainfall region of the Cape West Coast and Namibia. Here, fog and dew supplement the mean annual rainfall of 150 mm, which varies 20-fold across the domain from approximately 20 mm in the northwest to 400 mm in the central granite uplands (Desmet & Cowling 1999). Interestingly, some of the highest temperatures in this domain are recorded in winter, when hot, dry föhn-like berg winds descend towards the coast from the central uplands of the subcontinent (Desmet & Cowling 1999). These winds have the potential to influence population dynamics and turnover



K. Phillips

Figure 5.4 SKn 4 Namaqualand Heuweltjieveld: Complex of ancient termitaria (heuweltjies) scattered across lower slopes of granite glacis and supporting succulent dwarf shrubland, near Garies in Namaqualand (Northern Cape).

dramatically, but evidence in this regard is scant. In contrast, the Southern Karoo Domain has rainfall peaks in spring and autumn. Here the mean annual rainfall, ranging from 50 mm to 250 mm, is associated with post-frontal advection of moist air across the warm Indian Ocean. While the temporal patterns of rainfall differ between the two domains, rainfall predictability is a common feature, and one that sets the Succulent Karoo apart from other deserts (Esler et al. 1999a). At a biome scale, the length and temperature of the growing season demarcates the Succulent Karoo (short and cool) from adjacent Fynbos (long and cool) and Nama-Karoo (short and warm) (Ellery et al. 1991). In addition, geology and soils play some role in distinguishing biome boundaries. For example, Succulent Karoo soils are largely fine-grained, less leached (due to aridity) and have a higher pH (>7) and cation exchange capacity than fynbos soils (Ellis & Lambrechts 1986).

Mole rats, lizards, tortoises and a variety of invertebrates, including monkey beetles, scorpions, bee flies, bees and masarid and vespid wasps (Vernon 1999), all have concentrations of diversity and endemism in the Succulent Karoo Biome. Botanically, it is compositionally fascinating (Cowling et al. 1994) and singularly rich (Cowling et al. 1998), being home to 6 356 species of vascular plants in 1 002 genera and 168 families (Driver et al. 2003). Some 26% (1 630) of the species are strict endemics and 14% (905) are near endemics that have the centre of their distribution in this biome (Driver et al. 2003); 17% (Driver et al. 2003) are listed as Red Data species (International Union for Conservation of Nature 1994). Most of the 80 genera endemic to the biome are either succulents or geophytes (Driver & Maze 2002, Driver et al. 2003).

The high diversity of dwarf leaf-succulent shrubs (1 700 species; Driver et al. 2003) is the biome's most distinctive character (Figure 5.5). The 'vygies' or members of the family Aizoaceae (Bittrich & Hartmann 1988; formerly Mesembryanthemaceae) are particularly prominent among this group, but the 'spurges' or Euphorbiaceae, the 'stone crops' or Crassulaceae and succulent members of the Asteraceae, Iridaceae and Hyacinthaceae also deserve special mention (Hilton-Taylor 1996, Milton et al. 1997, Cowling & Hilton-Taylor 1999). Approximately 16% (1 589 species; Driver et al. 2003) of the world's estimated 10 000 succulent species occur here (Van Jaarsveld 1987). Perennials display high levels of alpha (Cowling et al. 1998), beta and gamma diversity (Cowling et al. 1994). Geophytes are another successful growth form (Figure 5.6), comprising 18% of the flora (Driver et al. 2003). In terms of abundance and diversity, they are as successful in the Succulent Karoo Biome as they are in the Fynbos Biome (Hilton-Taylor 1996, Esler & Rundel 1998, Cowling et al. 1999, Esler et al. 1999b). Finally, while there is nothing unique about diversity of annual plants and their proportional representation in the flora of the Succulent Karoo (390 species; Driver et al. 2003), the relatively predictable and often extravagant mass spring flower displays (Figure 5.7) are worth noting (Struck 1994, Cowling et al. 1999, Van Rooyen 1999).

4. Ecological and Evolutionary Driving Forces

What factors have led to the diversification of such a variety of plant and animal lineages in this biome? Many of the biologically unique features of the Succulent Karoo Biome have been attributed to its climatic conditions (Cowling et al. 1999, Cowling & Pierce 1999). Two key aspects of the climate combine to produce a unique selective regime. First is the highly effective and relatively predictable seasonal rainfall associated with 'cold fronts' and caused by major disturbances in the circumpo-

lar westerly air stream (Desmet & Cowling 1999). Second are the relatively moderate winters and early spring temperatures due to the ameliorating influence of the Atlantic Ocean and a consequence of a 'peninsula' effect of the continent (more typical of the Namaqualand-Namib Domain). The onset of the winter-rainfall regime approximately 5 mya is believed to have triggered the remarkably rapid diversification in at least one key family, the Aizoaceae (Klak et al. 2004).

Some authors suggest that climatic predictability has allowed for plant-pollinator specialisation to occur, since synchronisation in flowering and invertebrate pollinator emergence is virtually guaranteed (Esler 1999, Colville et al. 2002). Others have developed a conceptual model that suggests that the unique selective regime of the Succulent Karoo has had repercussions for pattern and process across different levels of organisation and has ultimately led to species-rich communities (Cowling et al. 1999, Esler et al. 1999a, b). This model highlights the observation that the ratio of functional diversity to species diversity in Succulent Karoo plant communities is generally relatively low (Cowling et al. 1994). While many contemporary models explaining plant structure in desert ecosystems emphasise the role of competition and consequent niche differentiation, this model explicitly plays down competition while emphasising the role of positive interactions (Eccles 2000, Eccles et al. 1999, 2001). Furthermore, the model suggests that the high levels of determinism suggested for other desert ecosystems (e.g. Aguiar & Sala 1999) may have been overshadowed by the structural homogeneity of the species and the rapid population turnover rates. The latter is associated with the fact that succulents, although highly successful in predictable rainfall environments, with their limited storage capacity (Von Willert et al. 1992) and shallow root systems (Esler & Rundel 1999) are also highly sensitive to periodic drought. The suggestion is that stochasticity, both spatial and temporal, as in the case of diverse tropical forests (Hubbell & Foster 1986) may be central to the coexistence of species in this unusually diverse system (even within the broader context of predictable rainfall). Although more research is needed to test and refine the model, several areas of research findings have proved consistent with the model predictions (Cowling et al. 1999).

For certain lineages, speciation may have been fuelled by the combination of life-history characters such as limited gene dispersal, short generation times and nonoverlapping generations as well as periodic droughts that cause high turnover and fragmentation in populations (Cowling et al. 1998, Cowling & Pierce 1999, Colville et al. 2002). For example, these elements all coincide in the Aizoaceae, southern Africa's largest succulent plant family (Smith et al. 1997), which has undergone a remarkable and rapid explosive diversification in the Succulent Karoo (Ihlenfeldt 1994, Klak et al. 2004). This family of mostly obligate out-crossers is pollinated by a variety of insects, including monkey beetles that travel short distances (Colville et al. 2002). Most Aizoaceae have relatively short generation times (5–15 years), as do their pollinators. Seeds are retained in canopy-stored capsules (Esler & Cowling 1995) and are dispersed over short distances during rainfall events (Garside & Lockyer 1930, Lockyer 1932). Finally, Jürgens et al. (1999) reported that the turnover of Aizoaceae over 15 years of monitoring was remarkably high for perennials in an arid system. Disturbance, in the form of short-term, periodic droughts, has a return time in the order of 1–2 decades in this system (Midgley et al. 2001), although prolonged droughts are rare.

Jansson & Dynesius (2002) and Jansson (2003) theorised that limited Pleistocene climatic change in diverse regions of the world, including southwestern South Africa, may have facili-

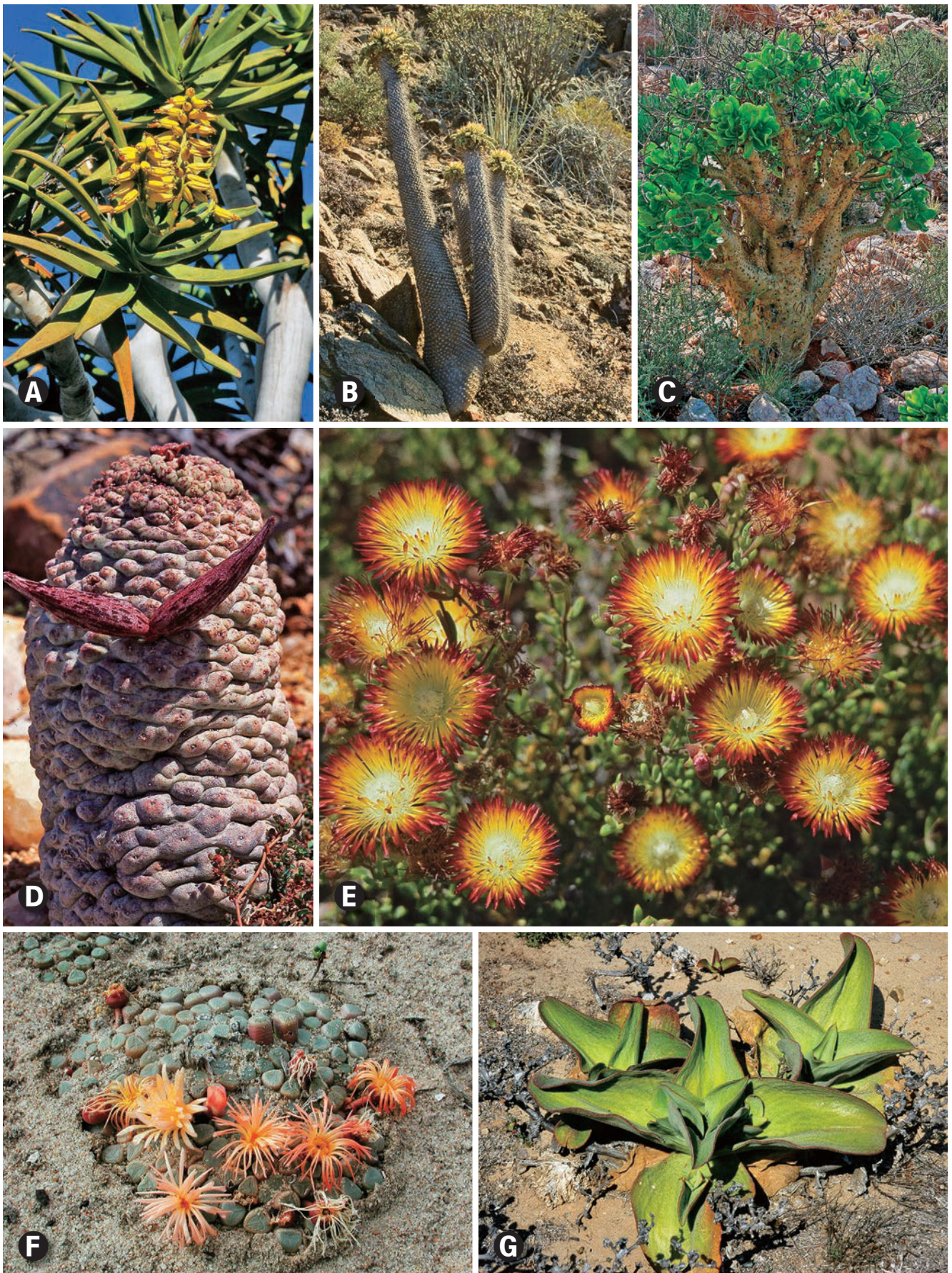


Figure 5.5 Assorted succulent plants from the Succulent Karoo. A: kokerboom—*Aloe dichotoma* var. *dichotoma* (Asphodelaceae); B: halfmens—*Pachypodium namaquanum* (Apocynaceae); C: botterboom—*Tylecodon paniculatus* (Crassulaceae); D: *Larryleachia perlata* (Apocynaceae); E: *Drosanthemum bicolor* (Aizoaceae); F: *Fenestraria rhopalophylla* subsp. *aurantiaca* (Aizoaceae); G: *Mesembryanthemum barklyi* (Aizoaceae). Photographers: L. Mucina (A–C, F–G), K. Phillips (D), J.C. Manning (E).

tated the persistence of lineages through extreme Pleistocene climatic oscillations that caused significant extinctions in many parts of the world. In contrast, Midgley et al. (2001) proposed that climatic oscillations of intermediate amplitudes over the past two million (+) years may have favoured vicariance and allopatric speciation in the Succulent Karoo Biome. They suggest that floral diversity may have arisen by a dynamic pattern of speciation, rather than by a passive accumulation of species in response to smaller climatic oscillations. Centres of endemism, such as the Gariiep CE and the Knersvlakte CE (Van Wyk & Smith 2001), are viewed as landscape-scale glacial refugia (Jürgens 1997, Midgley et al. 2001). Interestingly, climatic oscillations have also been proposed as an explanation for vicariance/population differences among rock-dwelling vertebrates (Matthee & Flemming 2002).

Physical heterogeneity associated with soils may have also played a role in diversification, and has certainly been invoked to explain patterns of diversity at a landscape (Cowling & Hilton-Taylor 1999) and local scale (Schmiedel & Jürgens 1999). The geology and consequently soils of the Succulent Karoo Biome are extremely complex (Meadows & Watkeys 1999, Watkeys 1999). In the northwest, the mountainous Richtersveld region comprises a varied sequence of pre-Gondwanan rocks, extensively intruded by granite and gneiss of the Namaqualand Metamorphic Province. The Richtersveld, with several local endemics, forms the core of the Gariiep CE (Van Wyk & Smith 2001). The height and orientation of the mountains (to intercept moisture) as well as their diverse geology have been invoked to explain the high levels of succulent diversity and endemism in this region (Van Wyk & Smith 2001). Erosion of the Namaqualand metamorphic rocks produced the dramatic 'koppie' landscapes to the south in the escarpment region, known locally as the Hardeveld. Approximately 900–500 mya, sedimentary rocks of the Gariiep, Numees and Nama Formations were laid down in a rift basin coinciding with the west coast region, and forming the floor of the palaeo-Orange River delta. Weathering of quartz veins from these formations resulted in the characteristic quartz patches of the Knersvlakte. In this edaphically variable region of floristic endemism (Knersvlakte Centre; Van Wyk & Smith 2001), differences in soil type can result in sharp species turnover within a few metres (Jürgens 1986). The Knersvlakte supports 52 species adapted to quartz-fields of which 39 are endemic to the region (Schmiedel & Jürgens 1999). Quartz patches (Figure 5.8) also occur in several other regions of the current Succulent Karoo Biome (Schmiedel 2002b, 2004) and contribute notably to increased local species and generic endemism.

Apart from the well-known climatic impact on the coastal biota (see the chapter on Desert in this book), the Benguela Current is also responsible for wind-blown 'sand movement corridors' (Driver et al. 2003) that are of marine origin and consist of an array of sediment types ranging from weathered fine-grained deposits of the late Tertiary to recent white sands along the



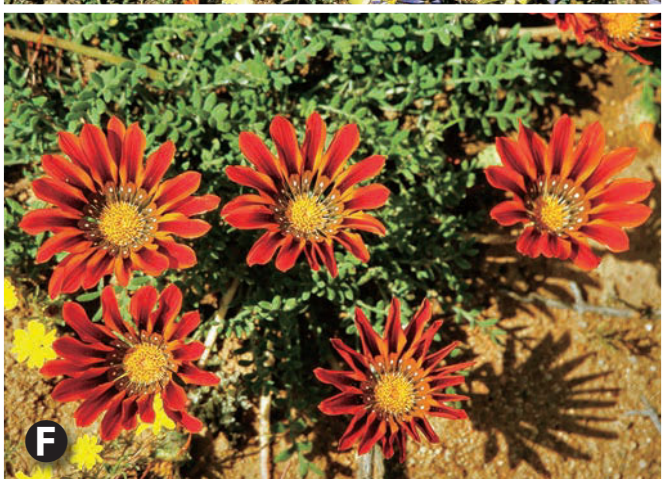
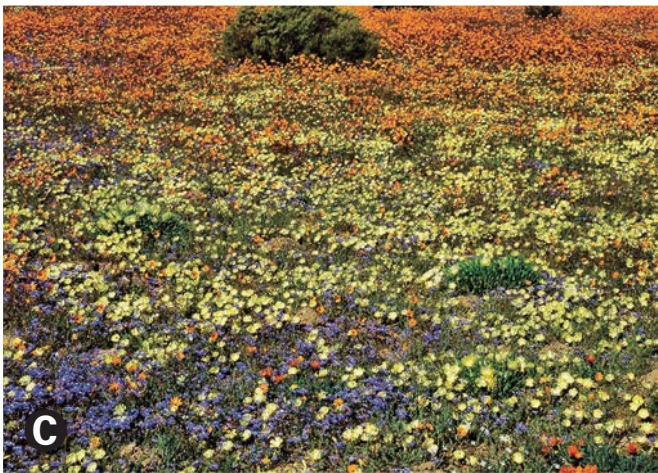
Figure 5.6 Selection of geophytes from the Succulent Karoo. A: *Albuca cooperi* (Hyacinthaceae); B: *Ornithoglossum vulgare* (Colchicaceae); C: *Lachenalia carnosa* (Hyacinthaceae); D: unknown bulbous plant with typical cork-screw leaves. Photographers: L. Mucina (A–C), M. Pfosser (D).

coast. These corridors are dynamic systems that provide a range of key habitats for both flora and fauna (Desmet 1996) and at times act as important barriers to movement of organisms. Rocks in the Southern Karoo Domain are essentially younger than those of the Namaqualand-Namib Domain. This Domain is largely located on the level plains and gently rolling hills in the valleys between the east-west ranges of the Cape Fold Belt. A mosaic of rock strata comprising sediments of the Cape Supergroup and Karoo Sequence (conglomerates, shales, limestone, mudstones, siltstones and sandstones) is found here (Meadows & Watkeys 1999).

In contrast to edaphic variability, topographic variation does not appear to hold the key to explaining extreme richness in this biome, since although it is topographically diverse, it does not approach the altitudinal range and habitat variability associated with the mountains of the Cape Fold Belt (Cowling et al. 1997).

5. Status

A mere 5.8% or 6 500 km² of the Succulent Karoo Biome is formally protected in statutory and nonstatutory reserves (Driver et al. 2003). This area substantially under-represents the diversity associated with the biome, and a recent conservation planning exercise (Driver et al. 2003) highlighted the fact that the current protected area system does not incorporate key ecological processes and evolutionary biodiversity drivers. These include



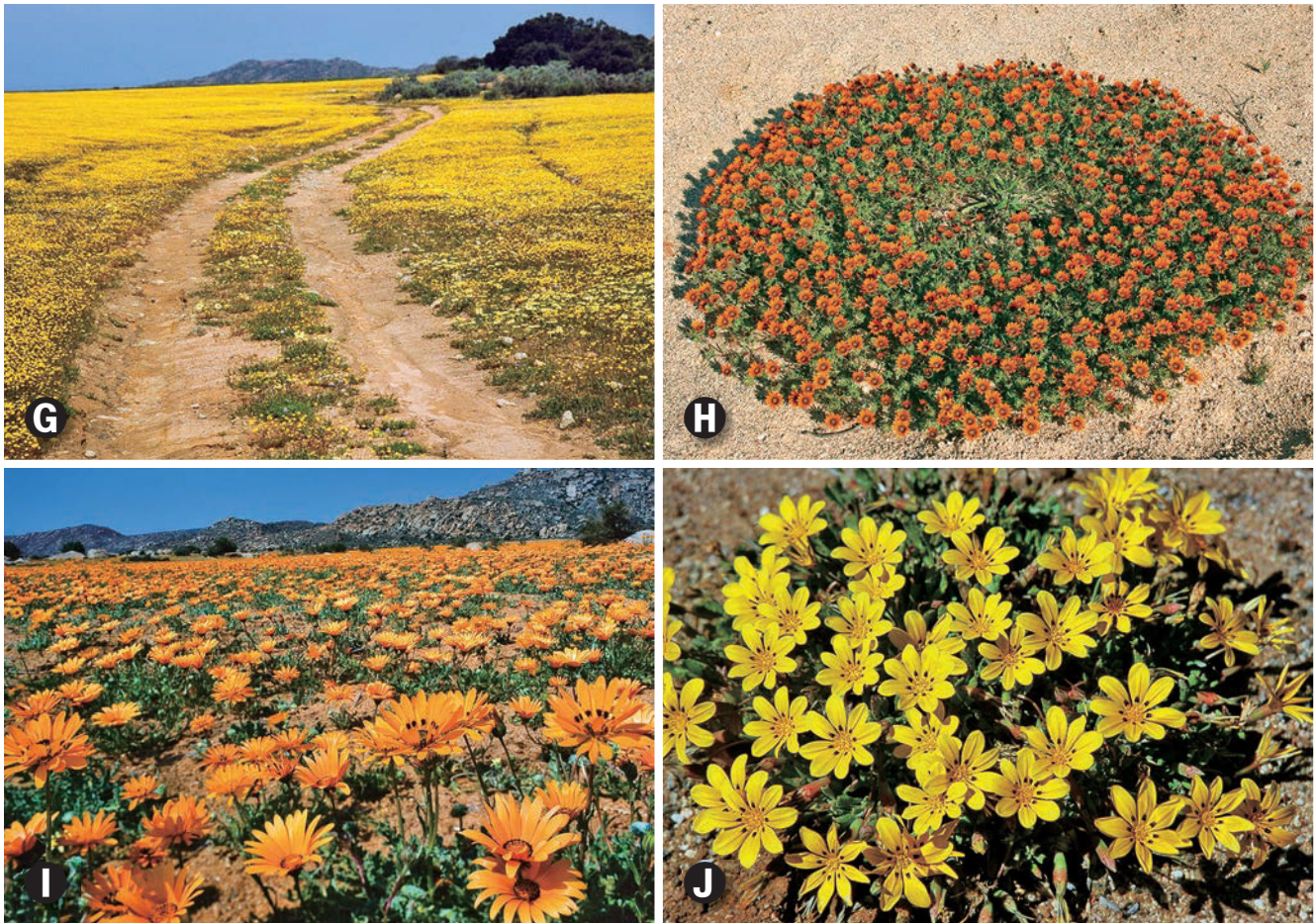


Figure 5.7 Spectacular Namaqualand spring flower displays. A: *Ursinia cakilefolia* (Asteraceae) in the Skilpad Flower Reserve (today part of Namaqua National Park), west of Kamieskroon; B: *Arctotis fastuosa* (Asteraceae) on disturbed shale substrate on the Farm Ezelsfontein in the Spektakelberg Pass (west of Springbok); C: spring flower display of *Grielum humifusum* (yellow), *Felicia namaquana* (blue) and *Arctotis fastuosa* (orange) in an old field in the Goegap Nature Reserve near Springbok; D: a small population of *Felicia* species; E: mass flowering of *Grielum humifusum* (Neuradaceae) on an abandoned pasture; F: *Gazania leiopoda* on the Farm Modderfontein near Kamieskroon; G: *Cotula barbata* and *Arctotheca calendula* (both Asteraceae) on old fields of the Farm Modderfontein east of Kamieskroon; H: a local form of *Gorteria diffusa* (Asteraceae) from the Spektakelberg Pass; I: *Arctotis* species (Asteraceae); J: *Gazania lichtensteinii* (Asteraceae), one of the most common daisies in Namaqualand. Photographers: K. Phillips (A, I), L. Mucina (B–H, J).

riverine and sand movement corridors, quartz patches, edaphic interfaces, climatic and upland-lowland gradients.

Outside formal reserves, land use is primarily focused on agriculture, with livestock grazing as a dominant land use in 90% of the region (Driver et al. 2003). Although grazing is a form of land use that is theoretically compatible with biodiversity conservation, overgrazing has had its consequences (Todd & Hoffman 1999, Archer 2000). Before widespread human settlement by Europeans in the 18th and 19th centuries, indigenous antelope such as springbok (*Antidorcas marsupialis*), gemsbok (*Oryx gazella*), black wildebeest (*Connochaetes gnou*), quagga (*Equus quagga*) and red hartebeest (*Alcelaphus buselaphus*) would have migrated across the landscape in search of grazing (Dean & Milton 1999a), no doubt having an overall positive influence on biodiversity. However, fences, permanent watering points and high stocking densities of domestic livestock and ostriches have almost certainly led to degradation in places (Hoffman et al. 1999). Loss of vegetation cover, seed banks and soil quality may have had dire consequences for biodiversity in general and strategic rehabilitation interventions in local areas may be required.

Mining, although locally devastating, may have ironically protected the Succulent Karoo Biome from massive transforma-

tion due to development and overgrazing. This is because many mines own large buffer areas of land, generally in an excellent condition. For example, in the Alexcor concession, comprising about 800 km² between Port Nolloth and Alexander Bay, only about 10% of the land is affected as a result of open-cast diamond mining (Desmet 1996).

Only about 5% of the geographic area of the Succulent Karoo Biome has been irreversibly transformed (Driver et al. 2003), providing a relatively good situation for conservation planning, since there are still options for meeting conservation targets for most biodiversity features. The unique botanical diversity of the region has been a major advantage, as it has provided solid justification for conservation planning based on plant diversity.

6. Threats

Human population pressures present huge challenges to the future existence of the Succulent Karoo. Climate change has been identified as one of the most significant threats to the environment (Intergovernmental Panel on Climate Change 1996) and global temperatures may have already increased by about 0.5°C over the last century. For sub-Saharan Africa, Global Circulation Models predict an increase of 1–3°C over

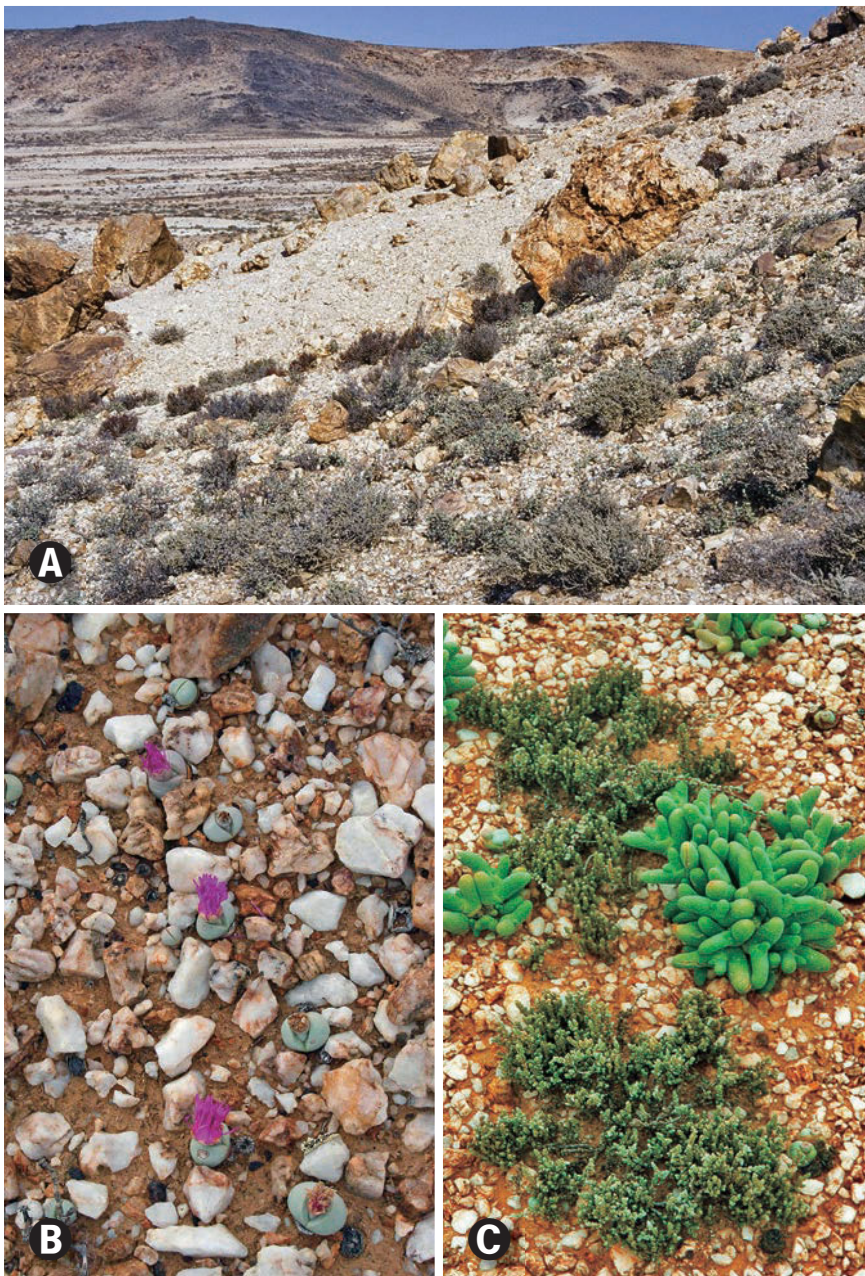


Figure 5.8 A: quartz-dominated slopes of hills bordering on the Knersvlakte (southern Namaqualand, Western Cape). B: quartz patch with flowering *Argyroderma delaetii* (Aizoaceae) near Rooiberg (Knersvlakte). C: dwarf stem succulent *Dactyloopsis digitata* (Aizoaceae) and sprawling individuals of an undescribed species of *Salsola* (Chenopodiaceae) on the Farm Quaggaskop (northwest of Vanrhynsdorp, Western Cape). Photographer: L. Mucina.

the next 50 years (Anonymous 1998) and rainfall is expected to decrease (Ellery et al. 1991, World Wildlife Fund 2001). Predictions for the Succulent Karoo are somewhat uncertain, but shifting climate patterns could result in a change in rainfall seasonality, with a significant portion of the current winter rainfall falling in summer (Bond 1997).

Bioclimatic models at the biome scale have indicated that climate change will be devastating to the Succulent Karoo if the region becomes any drier (World Wildlife Fund 2001). The current bioclimatic envelope could literally 'disappear' from its current range by 2050 (Midgley et al. 2002). Population-level data on species at the edge of their distributions are needed to illustrate the potentially dire consequences of climate change. For example, populations of arborescent succulents are on the decline at the extremes of their distributions in the Succulent

Karoo (Jürgens 1997, Foden 2002), suggesting that climate change may already be having a negative effect.

Early supporting evidence from field experiments (Musil et al. 2005) underscores the lethal impact to endemic quartz-field succulents of warming levels projected for the end of this century. Interestingly, preliminary data from reciprocal transplants of Succulent Karoo Aizoaceae seedlings (Agenbag et al. 2004) show their improved survival and growth under typically cooler and wetter Fynbos-like climatic conditions—suggesting persistence and even greater success of these forms under the cooler and wetter conditions of glacial stages during the Pleistocene. This preliminary result is wholly consistent with the apparent Pleistocene diversification of selected lineages in the Aizoaceae (Klak et al. 2004). Taken together, these findings highlight in an evolutionary context the potentially disastrous effects of warming beyond levels seen at any time during the climatic regime of the Pleistocene.

Changing climate as well as other aspects of global change such as fragmentation, habitat alteration and species invasions may also result in disruptions to pollinator groups, with potentially serious ecological consequences. This is especially so, since many plants with relatively short generation time rely on seedling recruitment for persistence.

Mining, although an important economic driver in the region, still constitutes a significant threat to biodiversity. The primary diamond mining impact is from prospecting through trench excavation, and overburden stripping in larger areas to reach the diamond-bearing gravels. Of key concern is that specialised habitats such as riverine flood plains and coastal terraces are targeted. In many cases, these are the areas considered as key habitats for ecological processes (Driver et al. 2003). New markets and discoveries of metals such as titanium, zinc and copper as well as increased demand for

gypsum, quartz and other industrial minerals continue to transform large areas of limited habitat types (Milton 2001). Mining has already transformed parts of the landscape, but today many mines have reached the end of their lives and thus pose new challenges for restoration (Milton 2001). A formidable task is to provide locally adapted indigenous propagules on the scale required for restoration. This is a prime opportunity for emerging small-scale businesses.

Livestock grazing has been identified as a major threat to biodiversity in the Succulent Karoo. The dramatic decrease in stocking densities by >50% over the past 100 years (Dean & Macdonald 1994) is thought to reflect this degradation, believed to be most critical in communally grazed areas (Cowling & Hilton-Taylor 1994). Livestock exclusion alone is believed to be insufficient to restore degraded areas (Milton et al. 1994a) that may require

more intensive and expensive interventions. Due to changing economic and political climates, there has been a resurgence of interest in game farming for ecotourism and hunting throughout the Karoo. Although heralded as a sustainable alternative to livestock farming, there are nevertheless real threats, such as the introduction of nonnative herbivores that may modify functional relationships among indigenous herbivores, causing resource competition and niche displacement, genetic pollution and even acting as disease vectors (Castley et al. 2001). Of major and immediate concern is the recent boom in the ostrich farming industry. Historically, ostrich would have moved nomadically between rainfall patches, following watercourses and selecting high-quality forage as they moved (Dean & Milton 1999a). For farming purposes, they are now confined to grazing camps at high densities and have a devastating impact on the vegetation (Milton et al. 1994b). Dryland farming is also on the increase, and is often associated with alluvial dry river courses where pumped water is readily available. Rivers are key habitats for many species and are considered of prime importance in conservation planning as they provide migration corridors for a variety of flora and fauna.

Finally, there is a growing threat from unscrupulous collectors of novelty fauna and flora as well as the threat of large-scale, uncontrolled harvesting of flora with medicinal value. Since many species have restricted distributions, illegal removal of populations from the wild can have devastating effects. Although collectors are required to have permits to remove individuals from the wild, cash-strapped authorities battle to enforce policy and legislation. A potential solution is to remove the pressure on wild populations by encouraging propagation by small-scale local nurseries.

7. Action

An overall framework to guide conservation action in the Succulent Karoo has recently been completed by a team of regional experts funded by Conservation International. The Succulent Karoo Ecosystem Plan (SKEP; Driver & Maze 2002) has now moved into implementation phase, and the expected flurry of conservation-related projects places the biome in an overall extremely positive position. The Critical Ecosystem Partnership Fund (CEPF)—a joint initiative of Conservation International, the Global Environment Facility, the Government of Japan, the John D. and Catherine T. MacArthur Foundation and the World Bank—is seen as an opportunity to use innovative mechanisms to catalyse key activities in under-funded geographic priority areas identified by SKEP, the idea being to target biodiversity conservation by involving specific land users such as agriculture, mining and communal authorities. Key areas identified for action by CEPF in the Succulent Karoo include the expansion of protected area corridors; promotion of best practices in key industrial sectors such as the ostrich and mining industries; retention and restoration of critical biodiversity in areas of greatest land use pressure; integration of conservation priorities into land use planning and policy making; increase of awareness of the Succulent Karoo hotspot and finally the creation of capacity to represent biodiversity and conservation concerns into the future (Driver et al. 2003).

8. Further Research

The Terrestrial Ecosystems Programme on the Karoo Biome funded by the Foundation for Research Development (now

NRF) provided a major historical boost to Succulent Karoo research (see Cowling 1986, Cowling & Roux 1987) and the focal study site (Tierberg) attracted significant depth of research attention. Much of this early research is highlighted in Dean & Milton (1999b). CapeNature and SANParks have also stimulated nodes of research and it is hoped that SAEON (South African Environmental Observation Network), initiated in 2002 (see Henschel et al. 2003), will provide a similar impetus. Connections with research initiatives such as the BIOTA Southern Africa Programme (Biodiversity Monitoring Transect Analysis in Southern Africa), with its north-south gradient of observatories have been made and provide promise for understanding biodiversity patterns across land use, landscape and climate gradients within the biome. Clearly there is a need for an understanding of what drives and maintains biodiversity at all scales in the Succulent Karoo Biome, and conservation planning and implementation initiatives such as SKEP (Driver & Maze 2002) have highlighted crucial gaps in our knowledge base (such as poor ecological knowledge of the Hantam-Tanqua-Roggeveld region). There is a very firm place for natural history research to add to our understanding of the interactions between plants, their herbivores, pollinators and dispersal agents, knowledge that is currently far from complete. Species-level information on interactions, coupled with well-dated molecular phylogenies could place us in a better position to understand past evolutionary changes and to predict what may happen under future global change scenarios. This type of information would provide the important background and motivation for conservation actions, but it is currently challenging to obtain financial support for work that is seen to lack immediate management application. Conversely, however, scientifically defensible research, resulting in clear guidelines for management should no longer be seen as add on, simply to justify pure research. The interface between academics and managers has to be strengthened, and books such as Milton & Dean (1996), Dean & Milton (1999b) and more recently Esler et al. (2005) provide practical and scientifically defensible guidelines for sound ecological management of this area. Our research focus should be placed not only on remaining natural areas, but also on the matrix of land uses between protected areas, as these contain a large portion of the biodiversity and may be essential in times of change (e.g. as corridors; allow range shifts to occur). We are in a very fortunate position to be able to produce a vegetation map of the entire biome, an indication that our floristic knowledge is reasonably good, despite some gaps.

9. Descriptions of Vegetation Units

Succulent Karoo Biome encompasses 63 vegetation units, forming six bioregions. Four of these represent traditional regions of Namaqualand (Richtersveld, Namaqualand Hardeveld, Namaqualand Sandveld and Knersvlakte), while the other two regions represent a series of units occupying rainshadow, low-altitude valleys and plains (Rainshadow Valley Karoo) and high-altitude semidesert plains, still characterised by a prevalent winter-rainfall regime (Trans-Escarpment Succulent Karoo). Two of the bioregions (Namaqualand Sandveld and Knersvlakte) are typical lowland units, with overwhelming parts of their respective areas found below 300 m above sea level and show a rather limited altitude span (Figure 5.9). The other bioregions occur at altitudes and span either 200–1 100 m (Richtersveld, Namaqualand Hardeveld and Rainshadow Valley Karoo) or reach as high as 1 550 m (Trans-Escarpment Succulent Karoo). More detail on ecology of these bioregions are found in the Chapter on biomes and bioregions in this book.

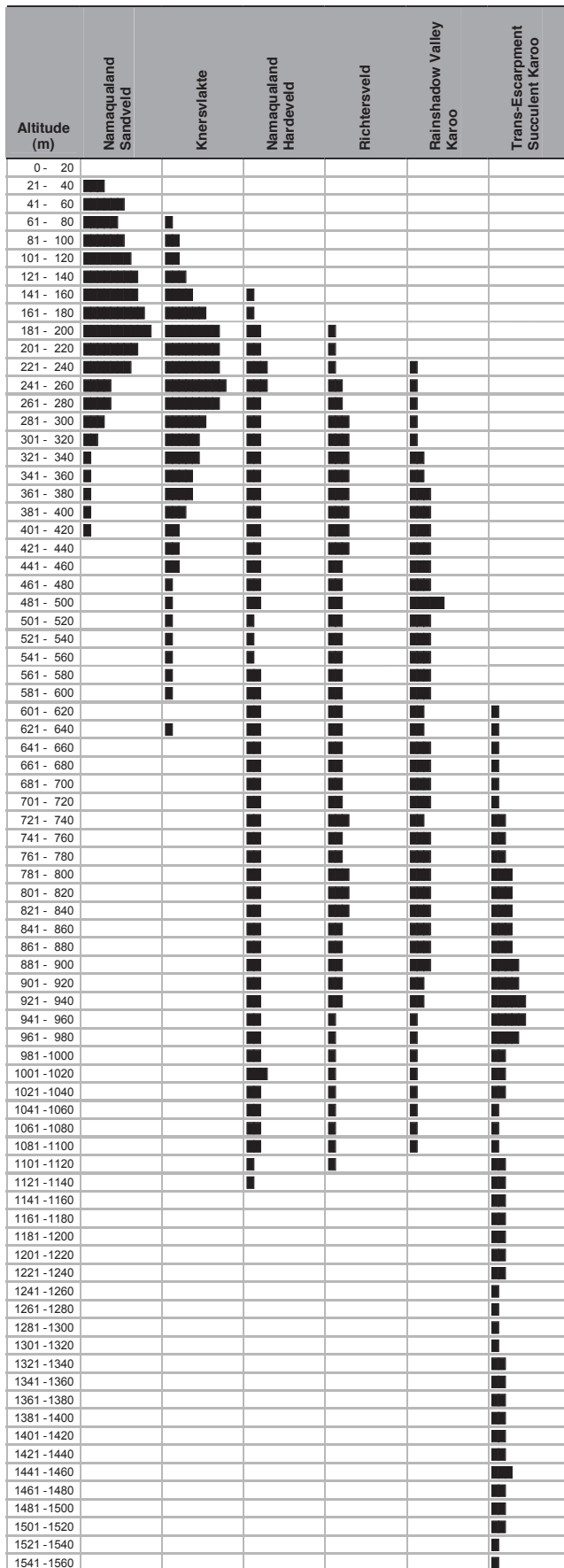


Figure 5.9 Altitudinal profiles of the bioregions of the Succulent Karoo Biome using 20 m classes derived from a digital elevation model (Schulze 1997). The smallest bar represents 1% of the area of the vegetation unit.

Richtersveld

SKr 1 Central Richtersveld Mountain Shrubland

VT 33 Namaqualand Broken Veld (68%) (Acoccks 1953). LR 56 Upland Succulent Karoo (100%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Central regions of the Richtersveld, along the central mountain ridge from Khodas Peak in the north along the Vandersterrberg and Stinkfontein range stretching about 100 km in a north-south direction, but excluding the highest altitudes where it grades into FFq 1 Stinkfonteinberge Quartzite Fynbos. Altitude 240–180 m (most of the area 420–900 m).

Vegetation & Landscape Features Forms the major part of the Richtersveld mountain ranges, including a wide variety of landscapes. Steep and rocky mountains are dominant, with a rolling topography in other parts. Deep canyons, but also wider valleys can be found scattered over most of the area. There is a gradient of increasing density and height of vegetation with increasing altitude and far denser vegetation occurs on the southwestern slopes than on the northeastern slopes (see climate below). The most important types of shrubland are: (a) the sparse dwarf-scrub vegetation of the plains and valley bottoms, with communities dominated by either *Brownanthus pseudoschlichtianus* on loamy or silty soils or *Zygophyllum prismatocarpum* and *Mesembryanthemum pellitum* on calcretes, (b) the chamaephytic to nanophanerophytic shrublands of the low-lying or more arid parts of the mountains, showing high abundance of *Ceraria fruticulosa* and *Euphorbia chersina*, (c) tall (sometimes more than 2 m), dense shrubland at higher altitudes on the mountains with communities similar to the SKn 1 Namaqualand Klipkoppe Shrubland—these communities form a transition towards the high-altitude dry and species-poor forms of quartzite fynbos.

Geology & Soils A spectrum of metavolcanics and meta-sediments, mostly quartzite, of the Stinkfontein Subgroup of the Gariiep Supergroup (Namibian Erathem). Granites of the Mokolian Vioolsdrif Suite are also present. The soils encompass a wide variety of loamy sands, sands and loams. Soils derived from granites may reach a pH between 7 and 8. Land type mainly lc.

Climate Region of mild, winter-rainfall climate. MAP varies from 60–200 mm, but with most of the area less than 90 mm. At higher altitudes, especially on southwestern slopes, the frequent occurrence of fog or cloud results in a significant improvement in water supply for plants. Frost is very rare at lower altitudes, but occurs up to 10 days per year at higher altitudes.

Important Taxa (^AAt higher altitudes) Succulent Shrubs: *Didelta carnosa* var. *carnosa* (d), *Euphorbia gummifera* (d), *E. mauritanica* (d), *Othonna furcata*^A (d), *Psilocaulon sub-nodosum* (d), *Cheiridopsis robusta*, *Cotyledon orbiculata* var. *orbiculata*, *Didelta spinosa*^A, *Euphorbia chersina*, *E. decusata*, *E. ephedroides* var. *ephedroides*, *E. hamata*, *Pelargonium desertorum*, *Senecio sarcoides*, *Tylecodon paniculatus*, *T. viridiflorus*, *Zygophyllum foetidum*^A. Tall Shrub: *Montinia caryophyllacea*^A. Low Shrubs: *Berkheya fruticosa*, *Senecio maydae*, *Tripteris oppositifolia*, *T. sinuata*. Herbs: *Tripteris microcarpa* (d), *Colpias mollis*, *Heliophila variabilis*, *Oncosiphon suffruticosum*. Geophytic Herb: *Trachyandra muricata*. Succulent Herbs: *Mesembryanthemum guerichianum* (d), *Trianthema triquetra* (d), *Stapelia hirsuta*.



Figure 5.10 SKr 1 Central Richtersveld Mountain Shrubland: View of a Richtersveld succulent shrubland with *Aloe pearsonii* (Asphodelaceae) in the foreground (near Die Koei, Richtersveld, Northern Cape)

Biogeographically Important Taxa (^{NQ}Namaqualand endemic, ^GGariep endemic, ^RRichtersveld endemic) Succulent Tree: *Pachypodium namaquanum*^G. Succulent Shrubs: *Aloe dichotoma* var. *ramosissima*^G (d), *Ruschia senaria*^R (d), *Stoeberia frutescens*^{NQ} (d), *Zygophyllum prismatocarpum*^{NQ} (d), *Cephalophyllum goodii*^R, *Ceraria fruticulosa*^G, *Euphorbia dregeana*^G, *Othonna opima*^R, *Phyllobolus deciduus*^G, *P. decurvatus*^{NQ}, *Prenia sladeniana*^R, *Tylecodon buchholzianus* subsp. *buchholzianus*^R, *T. ellaphieae*^R, *T. kritzingeri*^R. Low Shrub: *Galenia dregeana*^R. Herbs: *Gorteria corymbosa*^G (d), *Amellus nanus*^G, *Crotalaria pearsonii*^G. Succulent Herbs: *Brownanthus pseudoschlichianus*^G (d), *Mesembryanthemum peltatum*^G (d), *Crassula grisea*^G.

Endemic Taxa Succulent Shrubs: *Aloe pearsonii* (d), *Astridia speciosa*, *Cheiridopsis pilosula*, *Othonna herrei*. Geophytic Herbs: *Androcymbium exiguum*, *Pseudogaltonia clavata*, *Trachyandra aridimontana*.

Conservation Least threatened. Target 28%. Some 32% statutorily conserved in the Richtersveld National Park. Virtually untransformed, but is subject to strong grazing pressure, mainly by goats. This

vegetation unit is of high biodiversity importance due to high species endemism.

Remarks A similar unit occurs in a restricted area on the northern side of the Orange River in Namibia. Although the unit is characterised by high beta diversity along steep altitudinal gradients, it has a surprisingly wide distribution of communities along the north-south gradient. Endemic taxa shared with some neighbouring vegetation units include *Cephalophyllum goodii*, *Galenia dregeana*, *Pelargonium desertorum*, *Senecio maydae* and *Tylecodon kritzingeri*. Some endemic taxa may also occur in equivalent vegetation types in Namibia.

References Van Jaarsveld (1981), Jürgens (1991, 2001, 2004), Jürgens et al. (1997), Boenigk (1998), Osterloh (2000), Van Wyk & Smith (2001), Gotzmann (2002), Schüttler (2002).

SKr 2 Upper Annisvlakte Succulent Shrubland

VT 31 Succulent Karoo (95%) (Acocks 1953). LR 57 Lowland Succulent Karoo (92%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Southern parts of the Annisvlakte north and northwest of the Goariep Mountain in the northwestern Richtersveld from near Khubus to the region southeast of Arrisdrif. The westernmost section, south-east of Arrisdrif, is virtually separated from the main area by a northwards moving duneveld of red sand (part of the SKs 5 Richtersveld Red Duneveld), which at its northern margin fades out to form a shallow sand sheet, which crosses the main road between Alexander Bay and Khubus and penetrating deeply (not mapped) into the Western Gariep Lowlands Desert. Altitude ranges from 150–500 m.

Vegetation & Landscape Features Landscape is mainly a very wide tilted plain, formed by the huge pediment of the Goariep Mountain towards the Orange River. Some river courses are deeply incised into this plain. On the plains, habitats are controlled by soil salinity and texture and by different states of degradation by overgrazing. The present state is interpreted as a result of strong grazing pressure over the past 100 years. At present,



Figure 5.11 SKr 2 Upper Annisvlakte Succulent Shrubland: Mass germination of *Mesembryanthemum hypertrophicum* (Aizoaceae) on the Annisvlakte near Khubus in the Richtersveld.

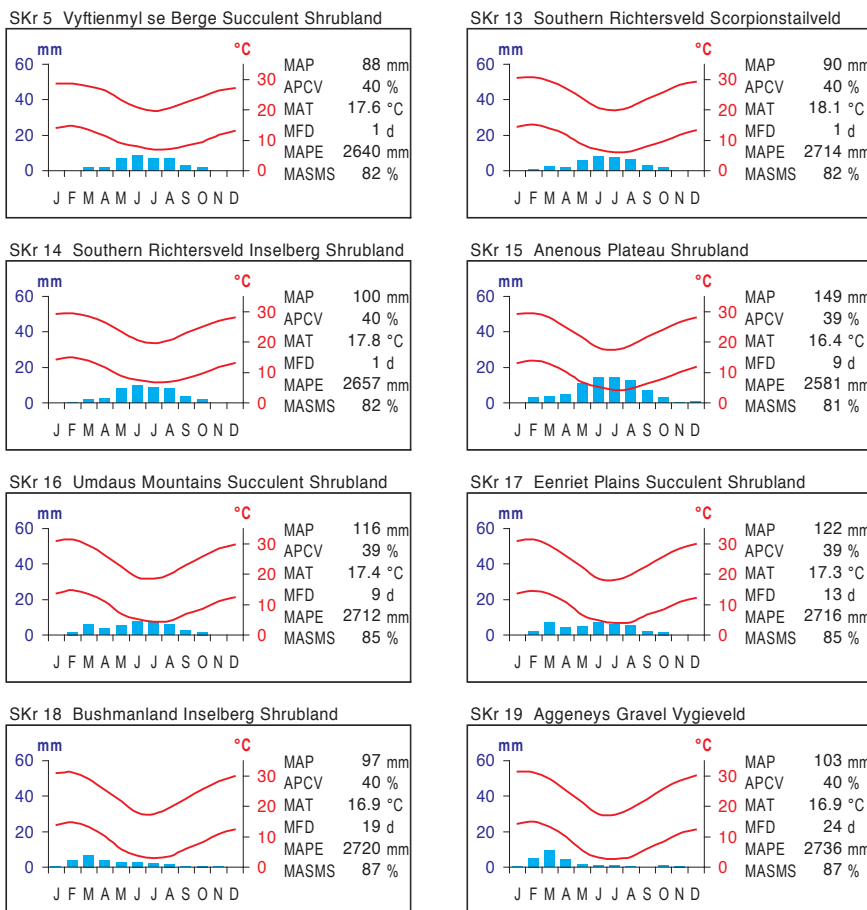


Figure 5.12 Climate diagrams of selected Richtersveld Bioregion units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

very sparse, dwarf vegetation cover is observed, dominated by annuals, geophytes and, only to a lesser extent, by small leaf-succulent chamaephytes. In the past this unit was probably covered by SKr 7 Northern Richtersveld Scorpionstailveld and partly by the *Ruschietum senariae* (Jürgens 2001, 2004).

Geology & Soils The granite of the Kuboos Pluton (of the Cambrian Kuboos, Bremen Suite), largely covered by alluvium and superficial calcrete deposits. Alluvial loamy sandy gravel soils, mainly derived from granite. Ae and Ag land types are almost equally important.

Climate MAP is 55–70 mm. Winter rainfall is predominant. Light frost is a very rare event. This region receives sea fog from a southwesterly direction as well as ‘malmokkie’ fog (see the chapter on Desert in this book). Strong winds to very strong storms occur and cause severe dust and sand storms with consequentially strong erosion of topsoil material and sandblasting.

Important Taxa Succulent Shrubs: *Drosanthemum hispidum* (d), *Euphorbia gummifera* (d), *Psilocalon subnodosum* (d), *Aridaria noctiflora* subsp. *noctiflora*, *Augea capensis*, *Cheiridopsis robusta*, *Didelta carnosa* var. *carnosa*, *Drosanthemum inornatum*, *Euphorbia ephedroides* var. *ephedroides*, *Hypertelis sal-soioides*, *Othonna cylindrica*, *Psilocalon salicornioides*, *Salsola zeyheri*, *Sarcocaulon crassicaule*. Tall Shrub: *Gomphocarpus fruticosus*. Low Shrubs: *Galenia crystallina* (d), *G. fruticosa*

(d), *Asparagus capensis* var. *capensis*, *A. undulatus*, *Hermannia trifurca*, *Lebeckia multiflora*, *Solanum namaquense*. Herbs: *Capnophyllum africanum*, *Gorteria diffusa* subsp. *diffusa*, *Hebenstretia parviflora*, *Heliophila seselifolia* var. *nigellifolia*, *Limeum fenestratum*, *Manulea gariepina*, *Oncosiphon grandiflorum*, *O. piluliferum*, *O. suffruticosum*, *Phyllopodium phyllopodioides*, *Senecio arenarius*, *Tripteris microcarpa*, *Wahlenbergia paniculata*, *Zygophyllum retrofractum*. Geophytic Herbs: *Dipcadi crispum*, *Ferraria divaricata*, *Gethyllis grandiflora*, *Lachenalia undulata*, *Ornithoglossum viride*. Succulent Herbs: *Mesembryanthemum barklyi* (d), *M. guerichianum* (d), *Brownanthus pubescens*, *Psilocalon dinteri*, *Tetragonia echinata*, *Trianthema triquetra*. Graminoids: *Centropodia glauca*, *Ehrharta calycina*, *Schismus barbatus*, *Stipagrostis ciliata*, *S. obtusa*.

Biogeographically Important Taxa (^{NQ}Namaqualand endemic, ^GGariep endemic) Succulent Shrubs: *Dracophilus dealbatus*^G, *Eberlanzia cyathiformis*^G, *E. ebracteata*^G, *Zygophyllum prismatocarpum*^{NQ}. Low Shrub: *Hermbstaedtia glauca*^G. Herb: *Amellus nanus*^G. Geophytic Herbs: *Trachyandra bulbinifolia*^{NQ}, *T. involucrata*^{NQ}. Succulent Herbs: *Mesembryanthemum hypertrophicum*^G (d), *M. barklyi*^{NQ}, *M. pellitum*^G, *Phyllobolus oculatus*^{NQ}.

Conservation Least threatened. Target 28%. None conserved in statutory conservation areas. Very little of the area transformed. Comparison of recent with historical photographs shows that soil and vegetation has been severely altered

since the early 20th century. The main change is degradation from loamy-sandy topsoils to coarser and more saline soils and the replacement of vegetation once dominated by *Brownanthus pseudoschlichtianus* and *Ruschia senaria* to the present dominance of therophytes and geophytes. At present, the degraded and sparse vegetation permits strong and frequent dust and sand storms. These cause further damage due to degradation of seed banks. The export of topsoil material negatively affects neighbouring areas, e.g. the Cornellskop with its population of *Aloe pillansii*. It is emphasised that this unit needs conservation, mainly through reduction of small stock grazing and perhaps rehabilitation measures in some parts.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Van Wyk & Smith (2001), Oguz et al. (2004).

SKr 3 Goariep Mountain Succulent Shrubland

VT 33 Namaqualand Broken Veld (78%) (Acocks 1953). LR 56 Upland Succulent Karoo (51%) (Low & Rebelo 1996).

Distribution Northern Cape Province: The unit is entirely formed by the Goariep Mountain (Ploegberg)—a large granite inselberg located southwest of the village of Khubus and west of the Vandersterrberg-Stinkfonteinberge mountain range in

the northwestern Richtersveld. Altitude ranges from 300–1 214 m.

Vegetation & Landscape Features

The circular geomorphological structure of the Goariep Mountain rises steeply above the surrounding landscape, mostly plains, and culminates in numerous granite domes. The vegetation consists of dense to very dense, tall shrubland with a high frequency of populations of *Aloe dichotoma* var. *ramosissima* and many other shrubs and trees typical of granite rocks and soils. Habitat types differ with regard to texture, nutrient status, aspect and soil moisture levels—the latter being relatively high for a region in close proximity (< 20 km) to the hyper-arid Namib Desert habitats. In the region, the Goariep Mountain Succulent Shrubland has the largest surface area with highest densities of photosynthetically active biomass, as measured by the NDVI index of NOAA or MODIS satellite data in the region.



N. Jürgens

Geology & Soils Built of granite of the Kuboos Pluton (Cambrian). Soils are mostly loamy sands. Ic is almost the exclusive land type.

Figure 5.13 SKr 3 Goariep Mountain Succulent Shrubland: Dense vegetation on west-facing slopes of the Goariep Mountain. *Stoeberia utilis*, *S. beetzii*, *Justicia cuneata* subsp. *latifolia*, *Tylecodon paniculatus*, *Jamesbrittenia ramosissima*, *Sarcostemma viminalis*, *Ceraria fruticulosa* and *Ruschia senaria* are the most important shrubs filling the space between the granite boulders.

Climate Winter-rainfall area with MAP about 70 mm, increasing with altitude and controlled by geomorphology, probably reaching as high as 200 mm at higher altitudes. High moisture levels are generated by orogenic uplift of moist air by the slopes of the large granite massif of the Goariep Mountain—the first high mountain in the pathway of the air stream moving in from the ocean from southern, southwestern or western directions. Consequently, rainfall and fog generate high precipitation along the southern and western slopes of the mountain, especially at higher altitudes. Frequency of frost depends on the altitude, reaching up to about 10 days per year in the summit area.

Important Taxa Succulent Shrubs: *Cheiridopsis robusta*, *Cotyledon orbiculata* var. *orbiculata*, *Didelta carnosus* var. *carnosus*, *D. spinosus*, *Drosanthemum floribundum*, *D. inornatum*, *Euphorbia chersina*, *E. ephedroides* var. *ephedroides*, *Hypertelis salsoloides*, *Lampranthus otzenianus*, *Othonna cylindrica*, *Stoeberia beetzii*, *Tetragonia fruticosa*, *Tylecodon paniculatus*, *Zygophyllum cordifolium*. Tall Shrubs: *Montinia caryophyllacea*, *Rhus populifolia*. Low Shrubs: *Asparagus capensis* var. *capensis*, *Berkheya spinosissima* subsp. *namaensis*, *Blepharis furcata*, *Carissa bispinosa* subsp. *bispinosa*, *Dyerophytum africanum*, *Galenia crystallina*, *Helichrysum obtusum*, *Indigofera pungens*, *Jamesbrittenia ramosissima*, *Lebeckia multiflora*, *Pteronia divaricata*, *Salvia garipensis*, *Zygophyllum retrofractum*. Woody Succulent Climbers: *Dioscorea elephantipes*, *Sarcostemma viminalis*. Herbs: *Arctotis fastuosa* (d), *Codon royenii*, *Colpias mollis*, *Forsskaolea candida*, *Gorteria diffusa* subsp. *diffusa*, *Griellum humifusum*, *Heliophila seselifolia* var. *nigellifolia*, *H. variabilis*, *Manulea androsacea*, *Oncosiphon piluliferum*, *O. suffruticosum*, *Tripteris microcarpa*. Geophytic Herbs: *Boophone haemanthoides*, *Haemanthus coccineus*. Succulent Herbs: *Mesembryanthemum guerichianum*, *Psilocaulon dinteri*, *P. subnodosum*, *Trianthema triquetra*.

Biogeographically Important Taxa (^{NQ}Namaqualand endemic, ^GGariep endemic, ^RRichtersveld endemic) Succulent Shrubs: *Aloe dichotoma* var. *ramosissima*^G (d), *Ceraria fruticulosa*^G,

Eberlanzia cyathiformis^G, *Euphorbia dregeana*^G, *Ruschia senaria*^R, *Stoeberia frutescens*^{NQ}, *Zygophyllum prismatocarpum*^{NQ}. Low Shrubs: *Hermstaedia glauca*^G, *Pelargonium tenuicaule*^R. Geophytic Herbs: *Cyrtanthus herrei*^R, *Trachyandra bulbifolia*^{NQ}. Succulent Herbs: *Brownanthus pseudoschlichtianus*^G, *Crassula grisea*^G, *Mesembryanthemum hypertrophicum*^G.

Conservation Least threatened. Target 28%. None conserved in statutory conservation areas. Due to the close vicinity to the permanent settlement of Khubus and due to the rich resource of exploitable biomass, a long history of strong grazing pressure has degraded the vegetation extensively, especially on the lower slopes of the mountain. Therefore, protection of parts of the higher altitudes, especially in the southwestern region, is recommended.

Remark The name Ploegberg refers to the fact that during the early 20th century ploughed fields were used for the production of cereals in the high-altitude parts of the Goariep Mountain. Its granite flora shows several affinities to that of the Tatasberg (also granite of the same age), for instance by the occurrence of *Jamesbrittenia ramosissima*, *Berkheya spinosissima* and *Crassula grisea*.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Van Wyk & Smith (2001).

SKr 4 Lekkersing Succulent Shrubland

VT 31 Succulent Karoo (80%) (Acocks 1953). LR 57 Lowland Succulent Karoo (80%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Longitudinal band in the southwestern Richtersveld extending north and south of Lekkersing, with an additional extension to the southeast and some scattered patches further north. All these parts are located in the lowlands west and southwest of the central mountain ridge of the Richtersveld. The core area has a north-south extension of some 70 km from near the Goariep Mountain in



L. Mucina

Figure 5.14 SKr 4 Lekkersing Succulent Shrubland: Sharp ridges of dolomite peaks south of the Goariep Mountain, housing a rich assemblage of species of *Zygophyllum* (including *Z. prismatocarpum*) and a diverse yellow daisy flora (*Osteospermum*, *Foveolina* and *Pentzia*).

the north to the vicinity of Oograbies in the south. Altitude ranges from about 150–550 m.

Vegetation & Landscape Features Mosaic of hills, flat or slightly rolling plains, with embedded quartz fields and ridges, some sand sheets and dunes, rocky gorges and including some rocky mountains. Quartz and quartzitic rocks are the most important. A wide spectrum of habitat types occurs, ranging from rocky outcrops to dunes. However, most of the area is hilly with shallow loam or sand cover with gravel above bedrock. These areas are covered by leaf-succulent dwarf shrublands, similar to those at low altitudes of the central mountains of the Richtersveld, but showing lower densities. Coastal elements such as *Stoeberia beetzii* can be dominant while *Zygophyllum prismatocarpum* becomes more important in the disturbed areas. *Enarganthe octonaria* has the highest cover on quartzitic rock and *Brownanthus arenosus* or *Cladoraphis spinosus* on the dunes.

Geology & Soils Mainly quartzite, sometimes schist, dolomite of the Precambrian Gariep Complex supporting sandy, skeletal soils. Half of the area is classified as Ag land type, followed by Fc, Ae, Ic.

Climate MAP is 60–120 mm. Winter rainfall is clearly predominant. Coastal fog is not as frequent as along the coast, but more important than in the Richtersveld mountains. Frost is very rare.

Important Taxa Small Tree: *Rhus undulata*. Succulent Shrubs: *Cephalophyllum regale* (d), *C. rigidum* (d), *Adromischus alstonii*, *Aridaria noctiflora* subsp. *noctiflora*, *Cheiridopsis robusta*, *Drosanthemum inornatum*, *Euphorbia chersina*, *E. decussata*, *E. ephedroides* var. *ephedroides*, *E. tuberculata* var. *tuberculata*, *Hypertelis salsoloides*, *Kleinia longiflora*, *Lampranthus otzenianus*, *Octopoma connatum*, *Othonna arbuscula*, *O. cylindrica*, *O. protecta*, *O. sedifolia*, *Pelargonium crithmifolium*, *P. echinatum*, *Ruschia leucosperma*, *Salsola zeyheri*, *Sarcocaulon crassaule*, *Senecio aloides*, *Tetragonia verrucosa*, *Tylecodon reticulatus*, *Zygophyllum cordifolium*. Low Shrubs: *Zygophyllum*

microphyllum (d), *Asparagus capensis* var. *capensis*, *Galenia crystallina*, *G. fruticosa*, *Helichrysum hebelepis*, *H. obtusum*, *Hermannia paucifolia*, *Hirpicium alienatum*, *Pteronia ciliata*, *P. glabrata*, *Tripteris oppositifolia*, *Z. retrofractum*. Herbaceous Climber: *Cysticapnos vesicaria*. Herbs: *Aizoon canariense*, *Atriplex semibaccata* var. *appendiculata*, *Gorteria diffusa* subsp. *diffusa*, *Grielum humifusum*, *Limeum fenestratum*, *Lotononis falcata*, *Lyperia tristis*, *Manulea androsacea*, *Oncosiphon piluliferum*, *Tripteris hyoseroides*, *T. microcarpa*, *Ursinia caki-leafolia*. Geophytic Herbs: *Babiana tritonioides*, *Bulbine sedifolia*, *Cheilanthes hastata*. Succulent Herbs: *Avonia albissima*, *Conophytum gratum*, *C. hians*, *Crassula columnaris* subsp. *prolifera*, *C. corallina* subsp. *corallina*, *C. deceptor*, *C. hemisphaerica*, *C. muscosa*, *Lithops meyeri*, *Mesembryanthemum guerichianum*, *Phyllobolus nitidus*, *Psilocaulon dinteri*. Graminoids: *Aristida adscensionis*, *Cladoraphis spinosa*, *Stipagrostis obtusa*.

Biogeographically Important Taxa (^{NQ}Namaqualand endemic, ^GGariep endemic, ^RRichtersveld endemic)

Succulent Shrubs: *Aspazoma amplexens*^{NQ} (d), *Cheiridopsis pil-lansii*^G, *Eberlanzia ebracteata*^G, *E. sedoides*^G, *Enarganthe octon-aria*^R, *Meyerophytum meyeri*^{NQ}, *Othonna opima*^R, *Phyllobolus deciduus*^G, *P. decurvatus*^{NQ}, *Schlechteranthus maximilianii*^R, *Stoeberia frutescens*^{NQ}, *Tylecodon racemosus*^{NQ}, *Zygophyllum prismatocarpum*^{NQ}. Herbs: *Adenoglossa decurrens*^{NQ}, *Crotalaria pearsonii*^G. Geophytic Herbs: *Cyrtanthus herrei*^R, *Trachyandra bulbiniifolia*^{NQ}. Succulent Herbs: *Brownanthus pseudoschlich-tianus*^G, *Mesembryanthemum pellitum*^G, *Phyllobolus oculatus*^{NQ}, *Stapeliopsis neronis*^R.

Endemic Taxa Succulent Shrubs: *Cheiridopsis purpurea*, *Nelia schlechteri*, *Tylecodon longipes*, *T. torulosus*.

Conservation Least threatened. Target 28%. None conserved in statutory conservation areas. In places vegetation is highly degraded by overgrazing, especially in a radius of approximately 6 km around Lekkersing. Protection of a substantial area of the quartz fields near Vlakmyn and of the quartzitic rocks south of Lekkersing, including the Karachabpoort, is recommended.

Remark 1 The placement of small granite inselbergs such as Grootberg and Springklipberg (in the northernmost patches) is problematic. They are included in Lekkersing Succulent Shrubland, based on the occurrence of more arid floristic elements. They are, however, geologically closer to the Goariep Mountain.

Remark 2 Certain quartzitic gorges like the Karachabpoort (south of Lekkersing) are very rich in species, including *Cyrtanthus herrei*, *Cheilanthes hastata*, *Helichrysum hebelepis*, *Rhus undulata*, *Cysticapnos vesicaria*, *Pelargonium echinatum* and *Crotalaria pearsonii* as well as endemics such as *Tylecodon torulosus* and *T. longipes*. Quartz fields, e.g. at Herre's famous Vlakmyn area, house endemic or locally rare species like *Nelia pillansii* and *Lithops meyeri*.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Van Wyk & Smith (2001).

SKr 5 Vyftienmyl se Berge Succulent Shrubland

VT 31 Succulent Karoo (100%) (Acocks 1953).
LR 57 Lowland Succulent Karoo (100%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Southwestern Richtersveld—a north-south trending longitudinal series of inselbergs (making up the Vyftienmyl se Berge) some 20 km inland east of Port Nolloth. Altitude ranges from 200–485 m.

Vegetation & Landscape Features

Steep, wall-like, linear series of inselbergs—a prominent geomorphological structure when viewed from the coastal plains near Port Nolloth. The habitat conditions are governed by altitude, rockiness and aspect. Impact of winds and of fog precipitation on the western slopes and much drier conditions on the eastern slopes are reflected in a wide range of vegetation types. High shrublands can be found in sheltered places which receive runoff water from higher rock areas, while exposed rocks support vegetation with very small succulents (*Conophytum*, *Tylecodon*) and lichens. Slopes with gravel or loam support the woody leaf succulent chamaephytes (e.g. *Enarganthe octonaria*, *Ruschia senaria*) typical of the Succulent Karoo.

Geology & Soils Mainly quartzite and some other metasediments of the Stinkfontein Subgroup (Gariep Supergroup). Wide range of soil types, mostly weakly developed (Mispah and Glenrosa form, partly Dorbank). The region is classified as lc land type.

Climate MAP is estimated to range from 60–120 mm. Winter rainfall with strong differences between different slopes. Due to its geomorphological structure and due to the location in the sandveld plains close to the coast, the mountains receive considerable amounts of fog water, especially on the western slopes. Fog frequency is estimated at ca. 60 to 80 days per year. Besides the Boegoe Twins near Alexander Bay, the mountains at Vyftienmyl se Berge are the best example of a 'fog oasis' on the northern Namaqualand coastal plain. Frost is rare. See also climate diagram for SKr 5 Vyftienmyl se Berge Succulent Shrubland (Figure 5.12).

Important Taxa Succulent Shrubs: *Adromischus montium-klinghardtii*, *A. roaneanus*, *Cotyledon orbiculata* var. *orbiculata*, *Euphorbia hamata*, *Mitrophyllum grande*, *Othonna arbuscula*, *Tylecodon buchholzianus*, *T. paniculatus*, *T. reticulatus*, *T. rubrovenosus*, *T. wallichii* subsp. *wallichii*. Low Shrubs: *Blepharis mitrata*, *Euryops dregeanus*, *Justicia cuneata* subsp. *cuneata*, *Pteronia ciliata*, *Senecio maydae*. Herbs: *Gorteria diffusa* subsp. *diffusa*, *Hebenstretia parviflora*, *Lyperia tristis*. Geophytic Herbs: *Gethyllis lanuginosa*, *Gladiolus arcuatus*. Succulent Herbs: *Crassula barklyi*, *C. columella*, *C. columnaris* subsp. *prolifera*, *C. pseudohemisphaerica*, *Gasteria pillansii* var. *ernesti-ruschii*.

Biogeographically Important Taxa (^{NQ}Namaqualand endemic, ^GGariep endemic, ^RRichtersveld endemic) Succulent Shrubs: *Aspazoma amplexens*^{NQ} (d), *Ruschia senaria*^R (d), *Cheiridopsis speciosa*^R, *Enarganthe octonaria*^R, *Hallianthus planus*^{NQ}, *Meyerophytum meyeri*^{NQ}, *Mitrophyllum clivorum*^{NQ},



Figure 5.15 SKr 5 Vyftienmyl se Berge Succulent Shrubland: Vyftienmyl se Berge form a barrier for the sea fog and moist oceanic air moving inland from the coastline (15–20 km away), and support a fairly dense cover of leaf-succulent shrubs (e.g. *Enarganthe octonaria*, *Aspazoma amplexens*, *Ruschia senaria*), while small succulents and lichens are abundant on rock surfaces.

Schlechteranthus maximiliani^R, *Tylecodon racemosus*^{NQ}, *T. similis*^{NQ}. Woody Climber: *Microloma calycinum*^{NQ}. Succulent Herbs: *Conophytum obscurum* subsp. *obscurum*^R, *Crassula grisea*^G.

Endemic Taxa (^QQuartz substrates) Succulent Shrubs: *Mitrophyllum abbreviatum*^Q, *Tylecodon bodleyi*. Geophytic Herbs: *Bulbine lavrani*, *B. torsiva*, *B. vitrea*. Succulent Herbs: *Anacampseros scopata*, *Conophytum bolusiae* subsp. *bolusiae*^Q, *C. francoiseae*, *C. jucundum* subsp. *marlothii*^Q, *C. stephanii* subsp. *stephanii*.

Conservation Target 28%. None conserved in statutory conservation areas. Threatened by farming actions and by illegal plant collecting from the nearby roads. The unit carries numerous succulent species that have been described as endemics or near-endemics, although some of them have unclear taxonomic status. The unit also forms an extraordinary 'fog oasis' with peculiar dwarf succulent formations. Due to these properties the unit has a high conservation value and should be well protected.

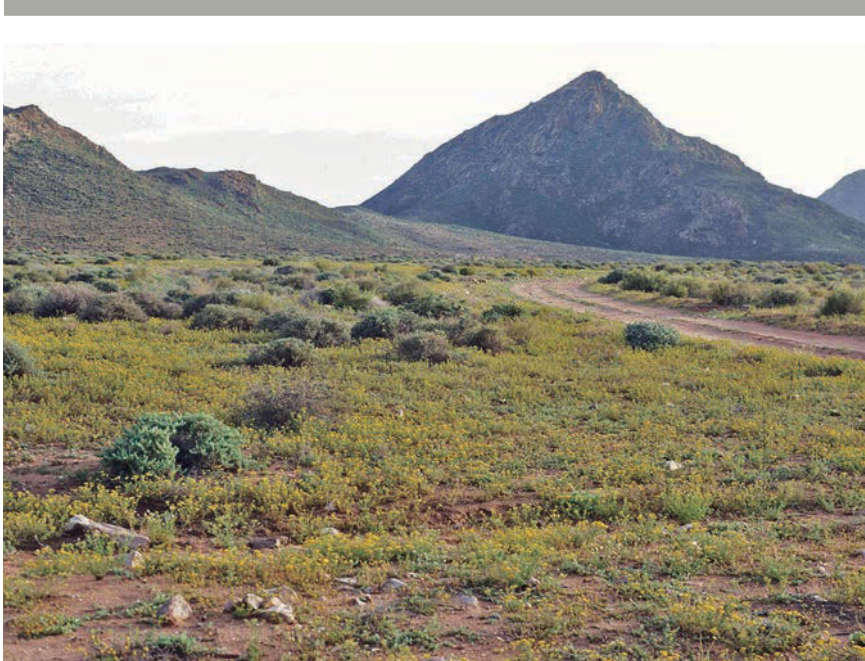
References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Van Wyk & Smith (2001).

SKr 6 Stinkfonteinberge Eastern Apron Shrubland

VT 28 Western Mountain Karoo (66%) (Acocks 1953). LR 56 Upland Succulent Karoo (100%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Narrow belt immediately east of the Stinkfonteinberge range in the southeastern Richtersveld. It has a north-south-trending longitudinal extension of about 35 km from just south of the Rosyntjieberge to immediately north of Eksteenfontein. Altitude ranges from 500–800 m.

Vegetation & Landscape Features Lower flat slopes and the subsequent pediment at the foot of the Stinkfonteinberge range. Also includes a number of small mountains. Mainly flat



N. Jürgens

Figure 5.16 SKr 6 Stinkfonteinberge Eastern Apron Shrubland: Slopes and plains near Jenkinskop east of the Stinkfonteinberge are strongly degraded by over-grazing and erosion. Disturbance indicator species, such as *Manochlamys albicans*, *Hermbstaedtia glauca* and *Oncosiphon suffruticosum*, are dominant.

to rolling landscape at the foot of the higher mountains, characterised by deeper sandy or silty loams similar to soils of the SKr 7 Northern Richtersveld Scorpionstailveld. Distinguished from the latter by more variable topography, much lower vegetation density, and high incidence of indicators of degradation.

Geology & Soils Granites of the Mokolian Vioolsdrif Suite predominate, with Stinkfontein Subgroup Quartzites (Namibian Erathem) along western fringes. Soils are composed of silt or loam with calcretes and show extreme erosion in places. Ag land type is dominant in the region, while Ic is of lesser importance.

Climate Predominantly winter rainfall, with MAP estimated from 50–120 mm. Lies within a gradient of orogenic rains, rapidly decreasing from west to east. Fog is an infrequent phenomenon. Incidence of fog is low.

Important Taxa Succulent Shrubs: *Aridaria noctiflora* subsp. *noctiflora*, *Crassula macowaniana*, *Didelta carnosa* var. *carnosa*, *Euphorbia decussata*, *E. ephedroides* var. *ephedroides*, *E. mauritanica*, *Hypertelis salsoloides*, *Lampranthus otzenianus*, *L. watermeyeri*, *Leipoldtia schultzei*, *Manochlamys albicans*, *Othonna furcata*, *Pelargonium crithmifolium*, *P. echinatum*, *Psilocaulon subnodosum*, *Sarcocaulon salmoniflorum*, *Tetragonia reduplicata*, *T. spicata*, *Tylecodon paniculatus*, *Zygophyllum foetidum*. Low Shrubs: *Atriplex vestita* var. *appendiculata*, *Chrysocoma ciliata*, *Eriocephalus ericoides*, *E. scariosus*, *Galenia africana*, *G. crystallina*, *Hermannia amoena*, *H. cuneifolia*, *H. stricta*, *Lebeckia cinerea*, *Lessertia fruticosa*, *Osteospermum armatum*, *Pteronia ciliata*, *P. glabrata*, *Stachys lamarckii*, *Tripteris sinuata*, *Zygophyllum retrofractum*. Woody Succulent Climber: *Sarcostemma viminale*. Woody Climber: *Asparagus retrofractus*. Semiparasitic Epiphytic Shrub: *Tapinanthus oleifolius*. Herbs: *Arctotis fastuosa* (d), *Amellus microglossus*, *Atriplex semibaccata* var. *appendiculata*, *Dimorphotheca sinuata*, *Felicia minima*, *Forsskaolea candida*, *Foveolina dichotoma*, *Gorteria diffusa* subsp. *diffusa*, *Helichrysum micropoides*, *Heliophila variabilis*, *Lotononis falcata*, *Nemesia anisocarpa*, *Oncosiphon piluliferum*, *O. suffruticosum*, *Plantago cafra*, *Senecio piptocoma*, *S. sisymbriifolius*. Geophytic Herbs: *Albuca maxima*, *Gladiolus saccatus*, *Oxalis pes-caprae*. Succulent Herbs: *Crassula mus-*

cosa, *Mesembryanthemum cryptanthum*, *Psilocaulon dinteri*. Graminoids: *Ehrharta delicatula*, *Fingerhuthia africana*.

Biogeographically Important Taxa (^{NQ}Namaqualand endemic, ^GGariep endemic, ^RRichtersveld endemic) Small Tree: *Ozoroa concolor*^{NQ}. Succulent Shrubs: *Ceraria fruticulosa*^G, *Prenia sladeniana*^R, *Ruschia senaria*^R, *Zygophyllum prismatocarpum*^{NQ}. Low Shrubs: *Berkheya canescens*^G, *Hermbstaedtia glauca*^G, *Pelargonium tenuicaule*^R. Herb: *Amellus nanus*^G. Geophytic Herbs: *Ornithogalum pruinosum*^{NQ}, *Trachyandra bulbifolia*^{NQ}. Succulent Herbs: *Brownanthus pseudoschlichtianus*^G (d), *Mesembryanthemum barklyi*^{NQ}, *M. hypertrophicum*^G, *M. pellitum*^G.

Conservation Least threatened. Target 28%. About 2% statutorily conserved in the Richtersveld National Park. High disturbance and degradation of vegetation and soils are indicated by abundant *Hermbstaedtia glauca*, *Galenia africana*, *Fingerhuthia africana* and *Mesembryanthemum cryptanthum*. The

unit shows extreme forms of gully erosion and sheet erosion compared to other parts of the Richtersveld. It is postulated that it has been a dense Scorpionstailveld with *Ruschia senaria* populations before, in which over-exploitation triggered extreme erosion of the deep loamy soils. Many fence lines subdivided formerly communal land into 'economic units', resulting in land use change from nomadic pressures to localised over-exploitation. The area urgently needs protection or management, particularly in terms of erosion control.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Van Wyk & Smith (2001).

SKr 7 Northern Richtersveld Scorpionstailveld

VT 31 Succulent Karoo (64%) (Acocks 1953). LR 57 Lowland Succulent Karoo (51%) (Low & Rebelo 1996).

Distribution Northern Cape Province: A series of plains or valley floors scattered in the northern Richtersveld, including the large Goariepvlakte, Koeroegabvlakte, some plains between Abiequarivier and Gannakourieprivier and at the western entrance to the Springbokvlakte. Altitude ranges from 260–760 m.

Vegetation & Landscape Features Typically fragmented, and showing a landscape of flat, though often tilted, or very slightly undulating topography. Often the whole large plain is covered by the unit, while in other cases it is restricted to specific geomorphological forms such as pediments west of the main mountains and to locations along the river beds protected against deflation by strong winds (Numees area). *Brownanthus pseudoschlichtianus* is typically dominant, with some other plants regularly associated (such as the geophyte *Trachyandra muricata*). Most of the SKr 7 Northern Richtersveld Scorpionstailveld is covered by a regular pattern of heuweltjies, which mostly support populations of *Mesembryanthemum hypertrophicum*, *M. pellitum*, *M. squamulosum* and *Psilocaulon subnodosum*.

Geology & Soils The small northeastern part of this area is underlain by granites of the Vioolsdrif Suite; the rest occurs on Cenozoic alluvium, aeolian sand and calcrete. Loamy or silty soils formed by aeolian deposition. Calcrete layers or other calcium carbonate accumulations occur not deeper than 40 cm below the surface. Often the soils also show high salinity. The silt component is subject to local aeolian erosion and sedimentation, resulting in erosion in the bare areas between the bushes and silt deposition underneath the bushes—these biogenic mounds regularly attract ants and termites. Almost 70% of the unit is classified as Ae land type, while the Ag and Ah land types are only of marginal importance.

Climate Due to the wide range of the unit, a wide spectrum of climatic conditions can be found. MAP may vary greatly (50–100 mm) and falls mainly in winter. Fog can be important, but not east of the Vandersterrberge. Temperatures can follow a wide spectrum. However, in the northeastern Richtersveld a well-developed Scorpionstailveld is seldom found in the hotter areas below an altitude of 330 m. Some days of frost per year can occur at higher altitudes, e.g. on the Koeroegabvlakte.

Important Taxa Succulent Shrubs: *Aridaria noctiflora* subsp. *noctiflora*, *A. serotina*, *Cheiridopsis robusta*, *Drosanthemum inornatum*, *Hypertelis salsoloides*, *Lampranthus otzenianus*, *Psilocaulon subnodosum*. Low Shrubs: *Lebeckia multiflora*, *Zygophyllum retrofractum*. Herbs: *Oncosiphon piluliferum*, *Senecio piptocoma*. Geophytic Herb: *Trachyandra muricata*. Succulent Herbs: *Psilocaulon salicornioides*, *Tetragonia echinata*.

Biogeographically Important Taxa (^{NQ}Namaqualand endemic, ^GGariep endemic) Succulent Shrubs: *Eberlanzia ebracteata*^G, *Euphorbia dregeana*^G, *Phyllobolus deciduus*^G, *P. decurvatus*^{NQ}. Low Shrub: *Anticharis scoparia*^G. Geophytic Herb: *Trachyandra bulbiniifolia*^{NQ}. Succulent Herbs: *Brownanthus pseudoschlichtianus*^G (d), *Mesembryanthemum barklyi*^{NQ}, *M. hypertrophicum*^G, *M. pellitum*^G, *Phyllobolus oculus*^{NQ}.

Conservation Least threatened. Target 28%. More than 20% statutorily conserved in the Richtersveld National Park. Overgrazing and trampling of the Scorpionstailveld has led to erosion of the silty-sandy to loamy topsoil. Over long periods of time this process has resulted in the replacement of topsoil and vegetation by less productive vegetation dominated by short-lived vygies such as *Mesembryanthemum hypertrophicum*, *M. squamulosum*, *M. pellitum* and *Psilocaulon subnodosum*, and by nonsucculent annuals. Even its protection status does not necessarily prevent degradation (as in the Richtersveld National Park). A certain density of small stock farming by the northern Richtersveld community is permitted. At present, the highest density of stock posts within the Richtersveld National Park has been found in the Koeroegabvlakte (H. Hendricks, personal communication), which forms one of the largest patches of the SKr 7 Northern Richtersveld Scorpionstailveld. Conservation management of these vegetation units is strongly recommended.



Figure 5.17 SKr 7 Northern Richtersveld Scorpionstailveld: Loamy-sandy plains south of the Goariep Mountain on the road to Lekkersing with *Brownanthus pseudoschlichtianus* and *Mesembryanthemum barklyi* dominant and species of *Ursinia* (orange) and *Hypertelis salsoloides* (pink) in between.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Boenigk (1998), Oguz (2000), Osterloh (2000), Van Wyk & Smith (2001), Gembler (2002), Gotzmann (2002), Nußbaum (2003), Oguz et al. (2004), Veste et al. (2004).

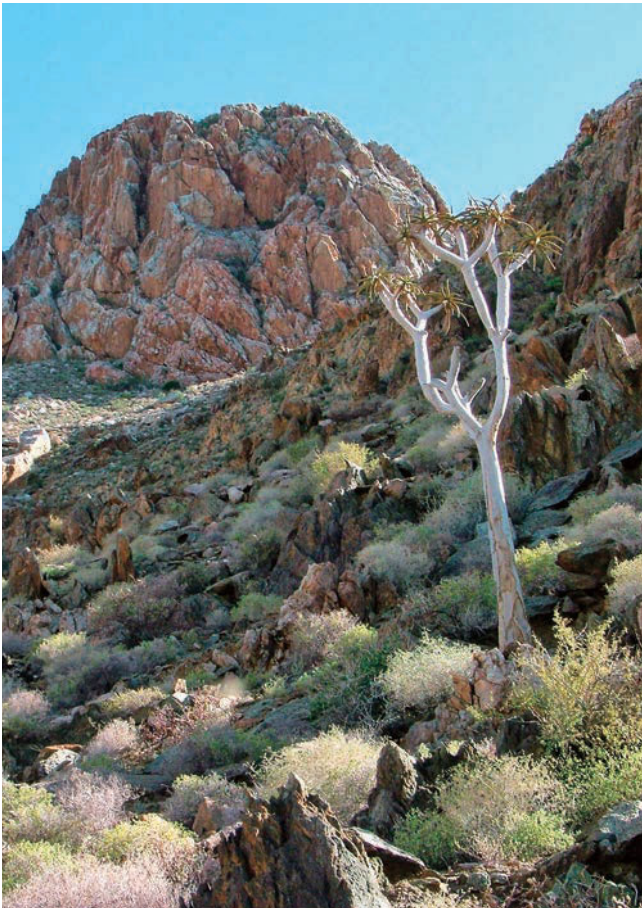
SKr 8 Rosyntjieberg Succulent Shrubland

VT 28 Western Mountain Karoo (62%) (Acocks 1953). LR 56 Upland Succulent Karoo (100%) (Low & Rebelo 1996).

Distribution Northern Cape Province: High mountain range (including Rosyntjieberg and Mount Terror) at latitude of Khubus in the northeastern Richtersveld, extending at right angles from the central Vandersterrberg-Stinkfonteinberge mountain range eastwards to just short of the Orange River. Altitude ranges from about 550–1 329 m at the mountain summit.

Vegetation & Landscape Features The Rosyntjieberg landscape differs from the Vandersterrberge by the predominance of exposed rock and very steep slopes. Some of the mountains have nearly vertical escarpments with strong rock weathering, thereby limiting access to some parts of the unit. Due to the high aridity and relatively higher temperatures (compared to the more western mountains, which are more often exposed to cooling air from the Atlantic Ocean) and the rockiness, a very harsh spectrum of habitat conditions limits plant growth in most parts of the unit. More favoured habitats, with somewhat better soil development, show sparse dwarf shrubland similar to that of the SKr 1 Central Richtersveld Mountain Shrubland (e.g. *Ruschia senaria*, *Euphorbia dregeana*, *Ceraria fruticulosa*), while in other parts of the unit Succulent Karoo species are mixed with Nama-Karoo elements (e.g. *Aloe dichotoma*, *Ceraria namaquensis*, *Tylecodon hallii*, *Wellstedia dinteri*).

Geology & Soils Mainly quartzite of the Rosyntjieberg Formation (Orange River Group), but also granite of the Vioolsdrif Suite (both Mokolian). The shallow soils are mostly of loamy to sandy texture. The exclusive land type is Ic.



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Figure 5.18 SKr 8 Rosyntjieberg Succulent Shrubland: Succulent shrubland on southern middle slopes of the Rosyntjieberg with *Aloe dichotoma* var. *dichotoma* and shrubs such as *Galenia* and *Lycium*.

Climate Mainly, especially at higher altitude, clear predominance of winter rainfall, while in the lowlands, especially in the more eastern part, rare summer rainfall events may be more important. The region lies in the rainshadow of the Vandersterrberge, with MAP of only 50–90 mm (all these estimates derived from correlations with plant cover). Frequency of frost is estimated at a few to 10 days per year. Fog plays no role.

Important Taxa Succulent Tree: *Aloe dichotoma* var. *dichotoma*. Succulent Shrubs: *Euphorbia chersina* (d), *E. guerichiana*, *Kleinia cephalophora*, *Lycium horridum*, *Pelargonium dasyphyllum*, *P. desertorum*, *Sarcocaulon crassicaule*, *Tylecodon hallii*. Tall Shrubs: *Commiphora capensis*, *Diospyros ramulosa*, *Montinia caryophyllacea*, *Polemanniopsis marlothii*, *Pteronia lucilioides*. Low Shrubs: *Wellstedtia dinteri* (d), *Antherothamnus pearsonii*, *Fagonia capensis*, *Heliophila cornuta* var. *squamata*, *Hermannia disermifolia*, *H. minutiflora*, *H. stricta*, *Nolletia gariepina*, *Pharnaceum albens*, *Polygala leptophylla*, *Pteronia divaricata*, *Salvia gariepensis*, *Selago beaniana*, *Senecio maydae*, *Zygophyllum microphyllum*. Woody Succulent Climber: *Dioscorea elephantipes*. Herbaceous Climber: *Cyphia crenata*. Herbs: *Acanthopsis disperma*, *Arctotis fastuosa*, *Chascanum garipense*, *Cleome foliosa* var. *lutea*, *Colpias mollis*, *Geigeria vigintiquamea*, *Hebenstretia namaquensis*, *Heliophila cornellsbergia*, *H. deserticola*, *Leysera tenella*, *Lotononis rabenaviana*, *Manulea gariepina*, *Polycarena tenella*, *Wahlenbergia androsacea*, *W. meyeri*. Geophytic Herbs: *Albuca viscosa*, *Melasphaerula ramosa*, *Pterygodium schelpei*. Succulent Herbs: *Crassula umbella*, *Gasteria pillansii* var. *pillansii*, *Lithops geyeri*. Graminoids: *Aristida adscensionis*, *Ehrharta calycina*, *E. delicatula*, *Enneapogon scaber*, *Tribolium utriculosum*.

Biogeographically Important Taxa (^{NQ}Namaqualand endemic, ^GGariep endemic, ^RRichtersveld endemic) Succulent Shrubs: *Euphorbia dregeana*^G (d), *Ruschia senaria*^R (d), *Ceraria fruticulosa*^G, *C. namaquensis*^G, *Tylecodon ellaphieae*^R, *T. kritzinger*^R. Tall Shrubs: *Calliandra redacta*^G, *Gymnosporia gariepensis*^R. Low Shrubs: *Monechma mollissimum*^G, *Pelargonium spinosum*^G. Geophytic Herb: *Whiteheadia bifolia*^{NQ}.

Endemic Taxa Succulent Shrub: *Aloe meyeri*. Succulent Herbs: *Conophytum taylorianum* subsp. *rosynense*, *Larryleachia cactiformis* var. *felina*.

Conservation Least threatened. Target 28%. The entire unit is statutorily conserved in the Richtersveld National Park. Untransformed, yet based on a contract with the northern Richtersveld community, there is continued small stock grazing in the Park. A number of local endemics underline the importance of the unit, which has no parallel in nearby Namibia.

Remark An altitudinal coenocline, reflected in transition from Succulent Karoo (dominant at higher altitudes) to vegetation with a stronger admixture of Nama-Karoo elements at lower altitudes can be observed within this vegetation unit.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Van Wyk & Smith (2001).

SKr 9 Tatasberg Mountain Succulent Shrubland

VT 33 Namaqualand Broken Veld (100%) (Acocks 1953). LR 56 Upland Succulent Karoo (100%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Tatasberg—a prominent granitic inselberg massif north of the Springbokvlakte in the northeastern Richtersveld. The southern slope forms an important part of the vegetation unit. Altitude ranges from about 560–1 026 m at the summit.

Vegetation & Landscape Features Huge granitic domes separated by fields of large boulders. The impression is a mosaic of rocky habitats with sparse shrubby vegetation in places. At the base of large granite domes dense low woodland sometimes occurs. On the rocks, mostly restricted to smaller fissures, succulent chamaephytes dominate.

Geology & Soils Acid and intermediate metavolcanics and metasediments of the Orange River Group (Mokolian) as well as granite and syenite of the Tatasberg Complex (Cambrian Kuboos, Bremen Suite). Soils are very shallow and only very patchy. Deeper and more developed soils are formed in cracks and crevices in places that receive larger amounts of rainfall runoff. Ic land type is dominant.

Climate MAP estimated at 50–120 mm and appears to be less in the rainshadow of the Vandersterrberge than on the Rosyntjieberg. Due to the higher altitude, the Tatasberg catches more rainfall and less water evaporates, in strong contrast to the surrounding (mostly desert) areas. Rainfall seasonality has transitional features between winter and summer rainfall, and is poorly predictable. High temperatures in summer are common. Very few frost days per year. Fog does not play an important role.

Important Taxa Succulent Tree: *Aloe dichotoma* var. *dichotoma*. Small Tree: *Ficus ilicina*. Succulent Shrubs: *Euphorbia decussata*, *Pelargonium alternans*, *P. dasyphyllum*, *P. desertorum*, *Phyllobolus gariepensis*, *Zygophyllum dregeanum*. Tall Shrubs: *Commiphora capensis*, *Diospyros ramulosa*, *Montinia caryophyllacea*, *Nymanina capensis*, *Pentatrichia petrosa*, *Rhynchosia*

schlechteri. Low Shrubs: *Antherothamnus pearsonii*, *Aptosimum indivisum*, *Berkheya spinosissima* subsp. *namaensis*, *Blepharis furcata*, *Carissa bispinosa* subsp. *bispinosa*, *Dyerophytum africanum*, *Eriocephalus scariosus*, *Galenia pruinosa*, *Hermannia minutiflora*, *Indigofera adenocarpa*, *I. pungens*, *Jamesbrittenia ramosissima*, *J. sessilifolia*, *Lophiocarpus polystachyus*, *Monechma spartioides*, *Nolletia gariepina*, *Pegolettia oxyodonta*, *Petalidium parvifolium*, *Pteronia divaricata*, *Rhynchosia emarginata*, *Salvia garipensis*, *Selago angustibractea*, *Solanum burchellii*, *Stachys rugosa*. Semiparasitic Epiphytic Shrubs: *Septulina glauca*, *Tapinanthus oleifolius*, *Viscum capense*, *V. rotundifolium*. Herbs: *Aizoon canariense*, *Amellus epaleaceus*, *Cucumis rigidus*, *Felicia namaquana*, *Helichrysum gariepinum*, *H. herniarioides*, *Hypertelis spergulacea*, *Indigastrium argyroides*, *Indigofera hololeuca*, *Lyperia tristis*, *Manulea crassifolia*, *M. robusta*, *Mollugo tenella*, *Monsonia luederitziana*, *Myxopappus acutilobus*, *Senecio eenii*, *Tephrosia dregeana* var. *dregeana*, *Tripteris pinnatilobata*, *Troglophyton parvulum*, *Wahlenbergia patula*, *Zaluzianskya diandra*. Geophytic Herbs: *Asplenium cordatum*, *Cheilanthes deltoidea*, *C. rawsonii*, *Lachenalia polyopodantha*, *Lapeirousia plicata* subsp. *plicata*. Succulent Herbs: *Trianthema triquetra* (d), *Anacampseros karasmontana*, *Crassula tenuipedicellata*. Graminoids: *Enneapogon scaber*, *Pentaschistis airoides*, *Stipagrostis anomala*, *S. obtusa*.

Biogeographically Important Taxa (^{NQ}Namaqualand endemic, ^GGariep endemic, ^RRichtersveld endemic) Succulent Shrubs: *Ceraria namaquensis*^G (d), *Eberlanzia ebracteata*^G, *Lycium grandicalyx*^G, *Schwantesia herrei*. Tall Shrub: *Gymnosporia gariepensis*^R. Low Shrubs: *Anticharis scoparia*^G, *Gaillonia crocylis*^G, *Galenia dregeana*^R, *Melianthus pectinatus*^{NQ}, *Monechma mollissimum*^G, *Pelargonium spinosum*^G. Herb: *Gorteria corymbosa*^G. Geophytic Herbs: *Ornithogalum geniculatum*^{NQ}, *Oxalis copiosa*^{NQ}, *Tritonia marlothii* subsp. *marlothii*^R. Succulent Herbs: *Brownanthus nucifer*^G, *Crassula grisea*^G, *Mesembryanthemum gariusanum*^G.

Conservation Least threatened. Target 34%. The entire unit is statutorily conserved in the Richtersveld National Park. No transformation observed.

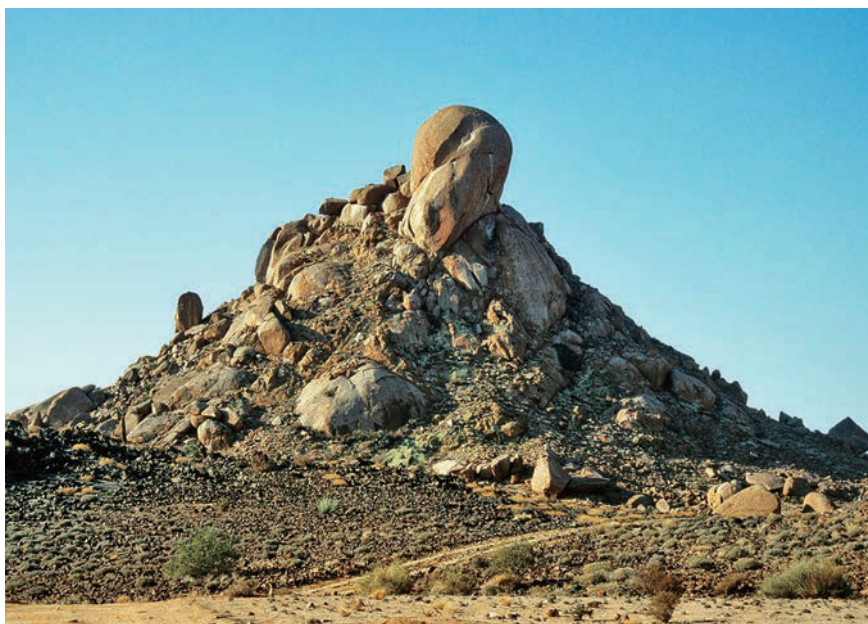


Figure 5.19 SKr 9 Tatasberg Mountain Succulent Shrubland: Solitary, disintegrating granite dome of the Tatasberg (1 028 m) north of the Springbokvlakte in the Richtersveld National Park, supporting succulent shrubland. Viewed from the foot covered by desert vegetation of the unit Dg 3 Richtersveld Sheet Wash Desert.

Remark The flora of this unit, due to similarities in geology, shows affinities to the Ploegberg (SKr 3 Goariëp Mountain Succulent Shrubland).

SKr 10 Die Plate Succulent Shrubland

VT 33 Namaqualand Broken Veld (69%) (Acocks 1953). LR 56 Upland Succulent Karoo (91%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Plateau east of Lekkersing and south of Eksteenfontein in southern Richtersveld. Altitude ranges from 300–800 m.

Vegetation & Landscape Features A plateau with a series of open flat steps descending from north to south with isolated embedded hills. Habitat types show little differences within the flats. The regular pattern of large heuweltjies is a remarkable feature of the region. Vegetation is a dwarf shrubland, probably strongly shaped by intensive grazing and the vegetation shows clear signs of degradation. Consequently, degradation indicators, such as *Drosanthemum floribundum*, *D. inornatum* and *Galenia sarcophylla*, are dominant elements in the vegetation.

Geology & Soils Mainly quartzite rocks of the Stinkfontein Formation of the Precambrian Gariep Complex. Soils are mainly shallow and with loamy-sandy texture. Ag is the almost exclusive land type of this unit.

Climate MAP is estimated at 80–120 mm, with winter-rainfall pattern clearly predominant. Frost is a very rare event and fog is of little importance.

Important Taxa Succulent Shrubs: *Drosanthemum floribundum* (d), *D. inornatum* (d), *Galenia sarcophylla* (d), *Aridaria noctiflora* subsp. *noctiflora*, *Crassula macowaniana*, *Didelta carnosa* var. *carnosa*, *Euphorbia ephedroides* var. *ephedroides*, *Lampranthus otzenianus*, *Manochlamys albicans*, *Ruschia hexamera*, *Senecio aloides*, *Tetragonia verrucosa*, *Tylecodon paniculatus*, *Zygophyllum cordifolium*. Low Shrubs: *Galenia africana*, *G. crystallina*, *Helichrysum asperum* var. *albidulum*, *Pteronia glabrata*, *Tripteris oppositifolia*. Semiparasitic Shrub: *Thesium lineatum*. Herbs: *Atriplex semibaccata* var. *appendiculata*, *Gazania leiopoda*, *Gorteria diffusa* subsp. *diffusa*, *Lessertia diffusa*, *Oncosiphon piluliferum*, *O. suffruticosum*, *Rhynchosidium pumilum*, *Senecio arenarius*, *Tripteris clandestina*, *T. hyoseroides*, *Ursinia cakilefolia*. Geophytic Herbs: *Albuca cooperi*, *A. maxima*, *Bulbine namaensis*, *B. succulenta*, *Cyanella ramosissima*, *Gladiolus orchidiflorus*, *Lachenalia verticillata*, *Ornithogalum glandulosum*. Succulent Herbs: *Crassula pseudohemisphaerica*, *Haworthia arachnoidea*, *Orbea namaquensis*. Graminoids: *Chaetobromus involucratus* subsp. *dregeanus*, *Ehrharta calycina*.

Biogeographically Important Taxa (^{NQ}Namaqualand endemic, ^GGariep endemic, ^RRichtersveld endemic) Succulent Shrubs: *Aspazoma amplexens*^{NQ}, *Mitrophyllum clivorum*^{NQ}, *Phyllobolus deciduus*^G, *P. decurvatus*^{NQ}, *Ruschia senaria*^R, *Tylecodon buchholzianus* subsp. *buchholzianus*^R, *T.*



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Figure 5.20 SKr 10 Die Plate Succulent Shrubland: Open succulent shrubland with prominent *Aloe pillansii* and *Boscia foetida* (low shrub).

racemosus^{NQ}. Woody Climber: *Microlooma calycinum*^{NQ}. Herb: *Amellus nanus*^G. Geophytic Herbs: *Bulbine mesembryanthoides* subsp. *namaquensis*^R, *Ornithogalum pruinatum*^{NQ}. Succulent Herb: *Mesembryanthemum pellitum*^G.

Conservation Least threatened. Target 28%. None conserved in statutory conservation areas. The area is severely degraded by overgrazing, to such an extent that the original plant communities cannot be recognised anymore; the conservation value of the unit is low.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Van Wyk & Smith (2001).

gummifera, are dominant on rocky outcrops. Large plains of silty or loamy soils are dominated by *Brownanthus pseudoschlichtianus* or by *Zygophyllum prismatocarpum*.

Geology & Soils Metavolcanics and quartzitic metasediments of the De Hoop Subgroup of the Orange River Group account for half the area, with most of the remainder being granite of the Vioolsdrif Suite (both are early Mokolian). Patches of quartzite with a diameter of some metres to several hundred metres embedded within grey granite-gneiss of the Precambrian. Saline loamy soils often underlie the quartz-rich top layers. The almost exclusive land type is Ag.

Climate MAP is 70–120 mm, with winter rainfall predominant. Very few frost days per year and fog plays no important role.

Important Taxa Succulent Shrubs: *Cephalophyllum regale* (d), *Euphorbia gummifera* (d), *Ruschia leucosperma* (d), *Cephalophyllum rigidum*, *Pelargonium crithmifolium*, *Ruschia goodiae*. Low

Shrubs: *Fagonia capensis*, *Justicia cuneata* subsp. *latifolia*, *Lessertia falciformis*, *Monechma spartioides*, *Pteronia glabrata*. Herb: *Dischisma spicatum*. Geophytic Herbs: *Babiana striata* var. *planifolia*, *Crossyne flava*, *Lapeirousia dolomitica* subsp. *dolomitica*, *L. spinosa*, *Ornithogalum nanodes*. Succulent Herbs: *Anacampseros papyracea*, *Crassula columnaris* subsp. *prolifera*, *C. deceptor*.

Biogeographically Important Taxa (^{NQ}Namaqualand endemic, ^GGariep endemic, ^RRichtersveld endemic) Succulent Shrubs: *Aspazoma amplexans*^{NQ} (d), *Ruschia paucipetala*^{NQ} (d), *Schlechteranthus hallii*^R (d), *Arenifera pillansii*^R, *Cephalophyllum*

SKr 11 Rooiberg Quartz Vygieveld

VT 33 Namaqualand Broken Veld (100%) (Acocks 1953). LR 56 Upland Succulent Karoo (100%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Richtersveld, region east of Eksteenfontein, south of the Rooiberg and west of the Helskloof Canyon. Altitude ranges from 500–750 m.

Vegetation & Landscape Features Plateau with slightly undulating flats and hills, mosaic of rocky surfaces, loamy and silty-sandy plains and hills covered with quartz layers. Leaf-succulent chamaephytes like *Aspazoma amplexans*, *Cephalophyllum regale*, *Ruschia leucosperma* and *Schlechteranthus hallii* are dominant on quartz fields, together with highly contracted growth forms such as *Crassula deceptor*, *C. columnaris*, *Cheiridopsis speciosa* and *Euphorbia*



L. Mucina

Figure 5.21 SKr 11 Rooiberg Quartz Vygieveld: Even plains covered by quartz close to the Rooiberg Mountain (visible in the background) near Eksteenfontein (Northern Cape) rich in rare and endemic flora.

goodii^R, *Cheiridopsis herrei*^R, *C. speciosa*^R, *Euphorbia dregeana*^G, *Hoodia alstonii*^G, *Tylecodon bayeri*^R, *Zygophyllum prismatocarpum*^{NQ}. Low Shrub: *Berkheya canescens*^G. Geophytic Herbs: *Adenoglossa decurrens*^{NQ}, *Tritonia marlothii* subsp. *marlothii*^R. Succulent Herbs: *Brownanthus pseudoschlichtianus*^G (d), *Conophytum herreanthus* subsp. *rex*^R.

Endemic Taxa Geophytic Herb: *Tritonia marlothii* subsp. *delpierrei*. Succulent Herb: *Conophytum jucundum* subsp. *fragile*.

Conservation Target 28%. None conserved in statutory conservation areas. Grazing impact and illegal plant collecting due to the easy access are major threats. A number of endemic species, especially within the quartz fields, increase the conservation value of this unit.

Remark Endemic taxa shared with some neighbouring vegetation units include *Arenifera pillansii*, *Cheiridopsis herrei*, *Conophytum herreanthus* subsp. *rex* and *Tylecodon bayeri*.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Schmiedel (1994, 2002a, b, 2004), Jürgens et al. (1997), Schmiedel & Jürgens (1999, 2002, 2004), Van Wyk & Smith (2001).

SKr 12 Kosiesberg Succulent Shrubland

VT 33 Namaqualand Broken Veld (79%) (Acocks 1953). LR 56 Upland Succulent Karoo (99%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Southwestern Richtersveld—a major part of the mountain ranges and escarpment region stretching 55 km from Eksteenfontein in the north over the slopes of the Kosiesberg to the Anenous Pass in the southeast. Altitude varies from about 500–1 100 m.

Vegetation & Landscape Features Escarpment that includes the steep slope between the high plateau in the east and the lower plateau in the west as well as several ranges of mountains and hills at the upper and lower level. Due to the incision of deep valley systems, the area is deeply dissected into a number of thinly connected fragments. A number of the plant communities found in the SKr 1 Central Richtersveld Mountain Shrubland, also occur here (Jürgens 2004).

Geology & Soils Granite and gneiss of the Mokolian Hoogoor and Voolsdrif Suites are most significant, but a large area in the west is underlain by Namaqua System alkali-granite of the Korridor Suite. These rocks support mostly loamy soils. Ib land type is dominant, followed by Ic land type.

Climate MAP is estimated at 100–200 mm (and possibly slightly higher). Winter rainfall is clearly predominant. Orographic cloud formation and fog are frequently observed in winter. At higher altitudes up to 10 frost days per year can be expected.

Important Taxa (^AAt higher altitudes) Succulent Shrubs: *Didelta spinosa*^A (d), *Euphorbia mauritanica* (d), *Othonna furcata*^A (d), *Tylecodon paniculatus* (d), *Cheiridopsis namaquensis*, *Cotyledon orbiculata* var. *orbiculata*, *Euphorbia gummifera*, *E. hamata*, *Zygophyllum foetidum*^A. Tall Shrubs: *Montinia caryophyllacea*^A (d), *Rhus populifolia* (d), *R. incisa*. Low Shrubs: *Elytropappus rhinocerotis*^A (d), *Euryops tenuissimus*^A (d), *Galenia africana* (d), *Senecio haworthii*^A. Semiparasitic Epiphytic Shrub: *Moquiniella rubra*. Geophytic Herbs: *Babiana truncata*, *Haemanthus crispus*, *H. namaquensis*, *Hesperantha pauciflora*, *Hessea breviflora*, *Lachenalia bolusii*, *L. violacea*, *Moraea tortilis*, *Strumaria truncata*, *S. villosa*, *Syringodea longituba*, *Tulbaghia dregeana*.

Biogeographically Important Taxa (^{NQ}Namaqualand endemic, ^GGariep endemic, ^RRichtersveld endemic) Succulent

Shrubs: *Ruschia senaria*^R (d), *Zygophyllum prismatocarpum*^{NQ} (d), *Aloe dichotoma* var. *ramosissima*^G, *Ceraria fruticulosa*^G, *Cheiridopsis denticulata*^{NQ}, *C. herrei*^R, *C. speciosa*^R, *Phyllobolus deciduus*^G, *Tylecodon bayeri*^R, *Zygophyllum leptopetalum*^{NQ}. Geophytic Herbs: *Geissorhiza namaquensis*^{NQ}, *Haemanthus unifolius*^{NQ}, *Lachenalia carnosa*^{NQ}, *Moraea herrei*^{NQ}. Succulent Herbs: *Brownanthus pseudoschlichtianus*^G (d), *Conophytum herreanthus* subsp. *rex*^R, *Crassula grisea*^G.

Endemic Taxon Succulent Shrub: *Mitrophyllum dissitum*.

Conservation Least threatened. Target 28%. None conserved in statutory conservation areas. Not transformed, but the major threat is the expansion of small stock farming, especially at the northern and southern ends of the unit. A major part is relatively protected due to the steep and inaccessible landscape. The unit is not well studied and includes a large number of species, including rare and endemic ones. Therefore, parts of the unit, including at least a part of the escarpment slopes, should be conserved.

Remark 1 The unit is characterised by high beta diversity due to steep altitudinal gradients and mountainous topography. *Conophytum herreanthus* subsp. *herreanthus* occurs at Klipbok (within the unit) but also within SKr 16 Umdaus Mountains Succulent Shrubland. *Cheiridopsis speciosa* and *Tylecodon bayeri* are also found towards SKr 11 Rooiberg Quartz Vygieveld. Although the summit of Kosiesberg is mapped just outside this unit, its main escarpment represents this unit.

Remark 2 Due to the lower temperatures and possibly higher rainfall, this shrubland shows some important differences from the SKr 1 Central Richtersveld Mountain Shrubland. Generally, it has a higher proportion of tall and dense shrublands (partly higher than 2 m), with communities quite similar to the dominant vegetation of the SKn 1 Namaqualand Klipkoppe Shrubland, with a group of communities dominated by *Didelta spinosa* and associated with *Tylecodon paniculatus*, *Montinia caryophyllacea*, *Othonna furcata* and *Galenia africana*. A large number of species that do not occur (or are only rarely seen) in the SKr 1 Central Richtersveld Mountain Shrubland occur here; these include especially geophytes of the genera *Babiana*, *Haemanthus*, *Hesperantha*, *Hessea*, *Lachenalia*, *Strumaria*, *Syringodea* and *Tulbaghia*.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Van Wyk & Smith (2001).

SKr 13 Southern Richtersveld Scorpionstailveld

VT 31 Succulent Karoo (70%) (Acocks 1953). LR 57 Lowland Succulent Karoo (62%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Southern Richtersveld—large portion of the plains west of the Anenous Pass, stretching over some 55 km to Oograbies in the west and from Skimmelberg in the north to just south of the road connecting Steinkopf and Port Nolloth. Altitude is mainly 200–600 m.

Vegetation & Landscape Features Flat basin landscape with a number of inselbergs embedded (mapped as SKr 14 Southern Richtersveld Inselberg Shrubland). Generally the low vegetation is dominated by the flat cushions of *Brownanthus pseudoschlichtianus*. Towards the west, a strong admixture of grasses, or mosaic elements of grassland, accompany the (flat) transition to SKs 6 Oograbies Plains Sandy Grassland. Towards the escarpment, increasing rainfall and grazing pressure result in increasing importance of *Zygophyllum retrofractum*. In degraded



Figure 5.22 SKr 13 Southern Richtersveld Scorpionstailveld: Succulent shrublands with *Brownanthus pseudoschlichtianus* west of Steinkopf on the road to Port Nolloth (Northern Cape).

areas *Lebeckia multiflora* and/or *Euphorbia ephedroides* are important.

Geology & Soils Silts and loamy sands of partly aeolian origin above migmatite and gneiss of the Namaqualand Metamorphic Complex (Precambrian age). Ae land type is dominant, followed by Ag land type.

Climate MAP is estimated at 80–140 mm, with winter rainfall clearly predominant. Frost is very rare. Fog and high air humidity often occur. Southerly winds are stronger in the west of the unit. See also climate diagram for SKr 13 Southern Richtersveld Scorpionstailveld (Figure 5.12).

Important Taxa Succulent Shrubs: *Euphorbia ephedroides* var. *ephedroides* (d), *Aridaria serotina*, *Cheiridopsis robusta*, *Drosanthemum inornatum*, *Eberlanzia dichotoma*, *Hypertelis sal-soioides*, *Lampranthus otzenianus*, *Leipoldtia laxa*, *L. schultzei*, *L. uniflora*, *Psilocaulon subnodosum*, *Ruschia goodiae*. Low Shrub: *Lebeckia multiflora* (d). Herbs: *Grielum humifusum*, *Leysera tenella*, *Plantago cafra*. Geophytic Herbs: *Ophioglossum polyphyllum*, *Trachyandra muricata*. Succulent Herb: *Conicosia pugioniformis* subsp. *alborosea*.

Biogeographically Important Taxa (^{NQ}Namaqualand endemic, ^GGariep endemic) Succulent Shrubs: *Eberlanzia cyathiformis*^G, *Phyllobolus deciduus*^G. Geophytic Herb: *Oxalis copiosa*^{NQ}. Succulent Herb: *Brownanthus pseudoschlichtianus*^G (d).

Conservation Least threatened but in reality susceptible. Target 28%. None conserved in statutory conservation areas. Evidence of overgrazing and trampling leading to erosion and to disturbance of topsoil occurs. High cover of *Lebeckia multiflora* and *Euphorbia ephedroides* in many parts of this unit might be indicative of a shift towards a higher proportion of weeds, when heavily grazed.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997).

SKr 14 Southern Richtersveld Inselberg Shrubland

VT 31 Succulent Karoo (72%) (Acocks 1953). LR 57 Lowland Succulent Karoo (70%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Southern Richtersveld—inselbergs scattered over the plains between Anenus Pass and Port Nolloth, partly surrounded by patches of SKr 13 Southern Richtersveld Scorpionstailveld. Includes Klaarkop, Kabies se Berg, Rooidam se Koppe, Steenbok se Berge and Beesvlei se Berg (but excludes the unique Vyftienmyl se Berge inselbergs). Altitude varies from about 100–600 m.

Vegetation & Landscape Features The inselbergs differ markedly in size, altitude, steepness, rockiness and spatial aggregation. Habitats vary depending on exposure, altitude and soil type. Smaller inselbergs are considerably more arid than higher ones, with lower parts covered by sparse chamaephyte vegetation, often dominated by the nanophanerophyte *Zygophyllum prismatocarpum*. At higher altitudes, especially on southwest-facing slopes, dense vegetation of dwarf leaf-succulents and lichens occurs.

Geology & Soils Granite, gneiss and schist mostly of the Gladkop and Hoogoor Suites (Mokolian) that were affected by the Namaqualand metamorphic event. Shallow soils of mostly loamy sand. Almost 75% of the area is Ag land type, followed by lb.

Climate MAP estimated at 80–150 mm, with winter rainfall clearly predominant. The importance of fog is high in the west and decreases towards the east. Frost is very rare. See also climate diagram for SKr 14 Southern Richtersveld Inselberg Shrubland (Figure 5.12).



Figure 5.23 SKr 14 Southern Richtersveld Inselberg Shrubland: Shrubland dominated by *Stoeberia frutescens* (Aizoaceae) on the slopes of an inselberg on the Farm Aardvark (east of Port Nolloth, Northern Cape).

Important Taxa Succulent Shrubs: *Drosanthemum floribundum* (d), *D. inornatum* (d), *Stoeberia frutescens* (d), *Adromischus mammillaris*, *A. marianiae* var. *immaculatus*, *Cheiridopsis robusta*, *Cotyledon orbiculata* var. *orbiculata*, *Eberlanzia gravis*, *Euphorbia decussata*, *E. hamata*, *E. mauritanica*, *Hypertelis salsoloides*, *Kleinia longiflora*, *Octopoma connatum*, *Pelargonium crithmifolium*, *Psilocaulon subnodosum*, *Ruschia intricata*, *Salsola namibica*, *S. zeyheri*, *Sarcocaulon l'heritieri*, *Senecio sarcoides*, *Tetragonia fruticosa*, *Tylecodon paniculatus*. Tall Shrubs: *Montinia caryophyllacea*, *Rhus populifolia*. Low Shrubs: *Dyerophytum africanum*, *Galenia fruticosa*, *Helichrysum asperum* var. *albidulum*, *Lebeckia sericea*, *Pteronia glomerata*, *Tripteris oppositifolia*. Succulent Herbs: *Conophytum chrisocruxum*, *C. meyeri*, *Crassula columnaris* subsp. *prolifera*, *C. muscosa*, *Mesembryanthemum guerichianum*, *Senecio cicatricosus*, *Tromotriche aperta*. Graminoids: *Enneapogon scaber* (d), *Fingerhuthia africana*, *Stipagrostis zeyheri* subsp. *macropus*.

Biogeographically Important Taxa (^{NQ}Namaqualand endemic, ^GGariep endemic, ^RRichtersveld endemic, ^NNorthern distribution limit, ^WWestern distribution limit) Succulent Shrubs: *Stoeberia frutescens*^{NQ} (d), *Zygophyllum prismatocarpum*^{NQ} (d), *Euphorbia dregeana*^G, *Hallianthus planus*^{NQ}, *Schlechteranthus maximilianii*^R, *Tetragonia robusta* var. *psiloptera*^N. Low Shrub: *Hermstaedtia glauca*^G. Herb: *Gorteria corymbosa*^G. Succulent Herbs: *Conophytum obscurum* subsp. *obscurum*^R, *Crassula grisea*^G, *Huernia namaquensis*^{NQ}, *Larryleachia cactiformis* var. *cactiformis*^W.

Endemic Taxa Succulent Shrubs: *Euphorbia ephedroides* var. *debilis*, *Namaquanthus vanheerdi*, *Polymita steenbokensis*, *Tylecodon cordiformis*. Succulent Herb: *Crassula alstonii*.

Conservation Least threatened. Target 28%. None conserved in statutory conservation areas. The inselbergs house a number of endemic species and should receive protection status. Besides small stock grazing there is no specific threat.

Remark Compared to the SKr 5 Vyftienmyl se Berge Succulent Shrubland, these few major inselbergs or ridges at similar altitude lie further inland and are, therefore, less exposed to the coastal fog.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Van Wyk & Smith (2001).

SKr 15 Anenous Plateau Shrubland

VT 33 Namaqualand Broken Veld (97%) (Acocks 1953). LR 56 Upland Succulent Karoo (91%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Anenous Plateau (west of the Steinkopf Plateau) in the southeastern Richtersveld, and parts of the adjacent escarpment, extending some 15 km to the north and to the south of the Anenous Pass. Region includes mountains such as Narraberg and Klipfonteinberg. Altitude ranges from 500–1 100 m with most of the unit 700–1 000 m.

Vegetation & Landscape Features High plateau with some rolling hills and larger mountains. The original dense

shrubland is now fragmented and confined to mountains and to rocky areas. On the plains, the former shrubland is found only as dense bush patches around rocky outcrops. Flat rocky areas also support vegetation dominated by leaf-succulent dwarf shrubs. On deeper soils on the plains, old fields and heavily grazed areas show a dominance of annual herbs and geophytes.

Geology & Soils Gneiss and schist of the Precambrian Namaqualand Metamorphic Complex. Soils are mostly loamy sands and loams. Almost the entire area falls within Fb land type.

Climate Mild to cool winter-rainfall climate. MAP ranges in most of the area from 120–160 mm. Most of the area experiences up to 10 frost days per year. See also climate diagram for SKr 15 Anenous Plateau Shrubland (Figure 5.12).

Important Taxa Succulent Tree: *Aloe dichotoma* var. *dichotoma*. Succulent Shrubs: *Didelta spinosa* (d), *Othonna furcata* (d), *Tylecodon paniculatus* (d), *Aloe microstigma*, *Drosanthemum hispidum*, *Euphorbia mauritanica*, *Lampranthus otzenianus*, *L. watermeyeri*, *Manochlamys albicans*, *Psilocaulon subnodosum*, *Zygophyllum foetidum*. Tall Shrubs: *Rhus incisa* (d), *R. populifolia*. Low Shrubs: *Euryops tenuissimus* (d), *Galenia africana* (d), *Elytropappus rhinocerotis*, *Pteronia divaricata*, *Senecio haworthii*. Semiparasitic Shrub: *Thesium lineatum*. Herbs: *Arctotis fastuosa* (d), *Dimorphotheca sinuata* (d), *Grielum humifusum*, *Leysera tenella*. Geophytic Herbs: *Albuca maxima*, *Brunsvigia herrei*, *Gethyllis britteniana* subsp. *britteniana*, *Haemanthus crispus*, *Lachenalia violacea*, *Moraea breviflora*, *M. rivulicola*, *Strumaria truncata*, *Trachyandra muricata*. Succulent Herb: *Conicosia pugioniformis* subsp. *alborosea*.

Biogeographically Important Taxa (^{NQ}Namaqualand endemic, ^GGariep endemic) Succulent Shrubs: *Cheiridopsis denticulata*^{NQ}, *Eberlanzia cyathiformis*^G, *Hallianthus planus*^{NQ}, *Prenia pallens* subsp. *namaquensis*^{NQ}, *Zygophyllum leptopetalum*^{NQ}. Geophytic Herb: *Lachenalia carnosus*^{NQ}. Succulent Herb: *Cleretum papulosum* subsp. *schlechteri*^{NQ}.

Conservation Least threatened. Target 28%. None conserved in statutory conservation areas. Apparently little transformed



Figure 5.24 SKr 15 Anenous Plateau Shrubland: Species-rich succulent shrublands on the Anenous Pass (west of Steinkopf).

judging from land-cover satellite information. However, field evidence shows that strong grazing pressure has dramatically changed the face of this landscape. Most of the landscape forms open grazing ground for stock and ploughed land is frequently seen. This suggests endangered status combined with a moderate risk of erosion (more than 90% classified as moderate erosion). The target conservation percentage of the unit should include part of the mountains and the escarpment.

Remark This unit includes some of the wettest flat areas in the Richtersveld due to mild temperatures and orogenic rains caused by the escarpment. The unit is not well studied and the boundaries (especially the inclusion of parts of the escarpment) are based on a limited number of observations.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Van Wyk & Smith (2001).

SKr 16 Umdaus Mountains Succulent Shrubland

VT 33 Namaqualand Broken Veld (70%) (Acocks 1953). LR 56 Upland Succulent Karoo (75%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Area between the Steinkopf Plateau and the Nababeep Mountains in the south-eastern Richtersveld including the wide basins of the Wyeport and Aribes Rivers. The eastern margin is not well defined and is mapped just short of Geelberg. Altitude ranges from about 500–1 000 m.

Vegetation & Landscape Features Mountainous terrain along the southern and western edges and sheet wash plains with roundish or steep rocky hills. While most of the unit is characterised by various Succulent Karoo plant communities, towards the northern and eastern margin Nama-Karoo elements are increasingly important. Mainly exposure and soil type define the habitat types with a variety of vegetation units, including rocky outcrops with *Aloe dichotoma*, *Euphorbia dregeana*, *Pachypodium namaquanum* and *Sarcostemma viminalis*, loamy plains with *Brownanthus pseudoschlichtianus*, calcrete plains with *Stomatium alboroseum* and quartz patches with *Polymita albiflora*.



Figure 5.25 SKr 16 Umdaus Mountains Succulent Shrubland: Sparse succulent shrubland on granite sheet outcrops north of Steinkopf. Shrublands belonging to the vegetation unit SKr 17 Eenriet Plains Succulent Shrubland are visible in the background.

Geology & Soils Mainly Mokolian granites, gneisses and schists supporting shallow soils of loamy or sandy texture. lb land type dominates the landscapes.

Climate Mainly winter rainfall with slight transition to summer rainfall in the east. Estimated MAP 100–200 mm. Up to 10 frost days per year. Fog not important. See also climate diagram for SKr 16 Umdaus Mountains Succulent Shrubland (Figure 5.12).

Important Taxa Succulent Tree: *Aloe dichotoma* var. *dichotoma*. Succulent Shrubs: *Ruschia robusta* (d), *Tetragonia arbuscula* (d), *Arenifera stylosa*, *Cephalophyllum rigidum*, *Cheiridopsis namaquensis*, *Euphorbia mauritanica*, *Hoodia gordonii*, *Leipoldtia schultzei*, *Pelargonium crithmifolium*, *Salsola namibica*, *Zygophyllum dregeanum*, *Z. lichtensteinianum*. Tall Shrubs: *Cadaba aphylla*, *Nymanina capensis*, *Rhus populifolia*. Low Shrubs: *Galenia fruticosa* (d), *Aptosimum spinescens*, *Berkheya fruticosa*, *Dyerophytum africanum*, *Hermannia stricta*, *Limeum aethiopicum*, *Microlooma incanum*, *Monechma spartioides*, *Osteospermum karrooicum*, *Petalidium parvifolium*, *Pharnaceum dichotomum*, *Polygala leptophylla*, *Pteronia ambrariifolia*, *Sericocoma avolans*, *Zygophyllum retrofractum*. Semiparasitic Shrubs: *Thesium hystrix*, *T. lineatum*. Woody Succulent Climber: *Sarcostemma viminalis*. Herbs: *Chascanum garipense* (d), *Codon royenii*, *Dianthus namaensis* var. *dinteri*, *Osteospermum pinnatum*. Geophytic Herbs: *Brunsvigia namaquana*, *B. radula*, *Hessea breviflora*, *Moraesa saxicola*. Succulent Herbs: *Conophytum herreanthus* subsp. *herreanthus*, *Crassula deceptor*, *C. muscosa*, *Haworthia venosa* subsp. *tesselata*. Parasitic Herb: *Hyobanche glabrata*. Graminoids: *Aristida adscensionis* (d), *Stipagrostis obtusa* (d), *Enneapogon desvauxii*, *E. scaber*, *Stipagrostis brevifolia*.

Biogeographically Important Taxa (^{NQ}Namaqualand endemic, ^GGariep endemic, ^RRichtersveld endemic) Succulent Tree: *Pachypodium namaquanum*^G. Small Tree: *Ozoroa concolor*^{NQ}. Succulent Shrubs: *Ceraria namaquensis*^G (d), *Cheiridopsis denticulata*^{NQ} (d), *Polymita albiflora*^{NQ} (d), *Cheiridopsis herrei*^R, *C. schlechteri*^G, *Euphorbia dregeana*^G, *Hoodia alstonii*^G, *Ruschia paucipetala*^{NQ}, *Stoeberia frutescens*^{NQ}, *Stomatium alboroseum*^{NQ}. Tall Shrub: *Calliandra redacta*^G. Low Shrubs: *Hermbstaedtia glauca*^G, *Pelargonium spinosum*^G. Succulent Herbs: *Brownanthus pseudoschlichtianus*^G (d), *Larryleachia perlata*^R.

Endemic Taxa Succulent Shrub: *Tylecodon pusillus*. Succulent Herb: *Anacampseros pisina*.

Conservation Least threatened. Target 28%. None conserved in statutory conservation areas. A number of rare, interesting and a few endemic species point to a relatively high conservation value. The expansion of small stock farming from the south and southwest and a few mining activities in the eastern region of the unit are viewed as main threats.

Remark This vegetation unit is of special interest as it forms an overlap of climate and floristic elements of East Gariep and Succulent Karoo. It includes the southernmost populations of the East Gariep element *Pachypodium namaquanum*.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Van Wyk & Smith (2001).

SKr 17 Eenriet Plains Succulent Shrubland

VT 33 Namaqualand Broken Veld (57%) (Acocks 1953). LR 49 Bushmanland Nama Karoo (41%), LR 56 Upland Succulent Karoo (30%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Plains northwest of Kabinaberg and south of the Koubank River, extending west and east of the main road between Steinkopf and Vioolsdrif, in the southeastern Richtersveld, partly forming the transition to Bushmanland. Altitude varies from ca. 650 m in the north to 950 m in the south.

Vegetation & Landscape Features Wide plains tilting towards the north, with few inselbergs. The extensive plains often resemble sheet wash plains. The deep loamy-sandy soils support mostly dense shrubby vegetation dominated by *Ruschia paucipetala*, *Prenia tetragona* or *Brownanthus pseudoschlichtianus*. *Stomatium alboroseum* and *Polymita albiflora* are found on calcrete or quartz patches. On the inselberg rocky outcrops numerous isolated populations of some Crassulaceae (e.g. *Crassula macowaniana* and *Tylecodon racemosus*) are found.

Geology & Soils Fine-structured deep loamy sands over gneiss of the Precambrian Namaqualand Metamorphic Complex. Ag land type dominates.

Climate Winter-rainfall regime, but with some summer rainfall also occurring (mainly March), especially towards the eastern boundaries of the unit. MAP was estimated at 100–160 mm. Some 10 to 20 frost days occur per year. See also climate diagram for SKr 17 Eenriet Plains Succulent Shrubland (Figure 5.12).

Important Taxa Succulent Shrubs: *Ruschia leucosperma* (d), *Drosanthemum floribundum*, *Euphorbia ephedroides* var. *ephedroides*, *E. friedrichiae*, *Lampranthus otzenianus*, *Leipoldtia schultzei*, *Odontophorus nanus*, *Pelargonium echinatum*, *Prenia tetragona*, *Sarcocaulon herrei*. Geophytic Herbs: *Hessea pilosula*, *Lachenalia violacea*. Succulent Herb: *Piранthus cornutus*. Graminoids: *Stipagrostis ciliata*, *S. obtusa*.

Biogeographically Important Taxa (^{NQ}Namaqualand endemic, ^GGariep endemic, ^RRichtersveld endemic) Succulent

Shrubs: *Ruschia paucipetala*^{NQ} (d), *Cheiridopsis herrei*^R, *C. schlechteri*^G, *Polymita albiflora*^{NQ}, *Stomatium alboroseum*^{NQ}, *Tylecodon pearsonii*^{NQ}, *T. racemosus*^{NQ}. Herb: *Gorteria corymbosa*^G. Succulent Herbs: *Brownanthus pseudoschlichtianus*^G (d), *Mesembryanthemum barklyi*^{NQ}.

Endemic Taxon Geophytic Herb: *Ornithogalum unifoliatum*.

Conservation Least threatened. Target 28%. None conserved in statutory conservation areas. No obvious major threats. Small stock grazing is of low intensity. An analysis of the biodiversity of the inselbergs is recommended.

Remark This unit has characters that are intermediate between Succulent Karoo and Nama-Karoo with respect to biogeographical patterns and to growth form composition.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Van Wyk & Smith (2001).

SKr 18 Bushmanland Inselberg Shrubland

VT 29 Arid Karoo and Desert False Grassveld (49%), VT 33 Namaqualand Broken Veld (33%) (Acocks 1953). LR 49 Bushmanland Nama Karoo (70%) (Low & Rebelo 1996).

Distribution Northern Cape Province: A group of prominent solitary mountains (inselbergs) and smaller koppies towering over surrounding flat plains in northern Bushmanland in the Aggeneys and Pofadder regions. The most important inselbergs include Achab se Berg, Aggeneys se Berg, Ghaamsberg, Goob se Berg, Naib se Berg and Namiesberge. Altitude ranges from 600–1 180 m (most of the area 700–1 120 m).

Vegetation & Landscape Features Shrubland with both succulent (Aizoaceae, Asphodelaceae, Crassulaceae, Didiereaceae, Euphorbiaceae, Zygophyllaceae) as well as nonsucculent (mainly Asteraceae) elements and with sparse grassy undergrowth (*Aristida*, *Eragrostis*, *Stipagrostis*) on steep slopes of the inselbergs.

Geology & Soils Inselbergs of high-grade metamorphic rocks on a broad alluvial plain consist of clastic sediments, volcanics and intrusive rocks of Mokolian age that were metamorphosed during the Namaqualand Metamorphic Event. lb and lc land types are dominant in the area.

Climate Erratic, very low rainfall (MAP below 100 mm, range 70–120 mm) occurring mainly in the form of thunderstorms in late summer from February to April. Around 20 days of frost per year (range 10–30 days). Mean maximum and minimum mean monthly temperatures for Aggeneys are 38°C and –3°C for February and July, respectively. See also climate diagram for SKr 18 Bushmanland Inselberg Shrubland (Figure 5.12).

Important Taxa Succulent Shrubs: *Adromischus diabolicus* (d), *Euphorbia gregaria* (d), *Ihlenfeldtia vanzylii* (d), *Ruschia divaricata* (d), *Schwantesia pilansii* (d), *Tylecodon sulphureus* (d), *Euphorbia gariepina*, *Kleinia longiflora*, *Othonna euphorbioides*, *Psilocaulon subnodosum*, *Tetragonia reduplicata*, *Tylecodon rubrovenosus*. Tall Shrub:



Figure 5.26 SKr 17 Eenriet Plains Succulent Shrubland: Succulent shrublands with *Ruschia pauciflora* (in the foreground) and *Sisymbrium spartea* (in the background).

N. Jürgens



Figure 5.27 SKr 18 Bushmanland Inselberg Shrubland: South-facing slopes of Naip se Berg inselberg in northern Bushmanland with *Euphorbia gregaria* and *Cotyledon orbiculare*. Note the sparse vegetation on hot north-facing slopes in the background.

Boscia foetida. Low Shrubs: *Eriocephalus pauperrimus* (d), *Pteronia unguiculata*. Woody Succulent Climber: *Sarcostemma viminale* (d). Herb: *Acanthopsis hoffmannseggiana*. Succulent Herbs: *Anacampseros baeseckeii* (d), *A. karasmontana* (d), *Avonia ruschii* (d), *Conophytum fulleri* (d), *Avonia quinaria* subsp. *alstonii*, *Conophytum marginatum* var. *haramoepense*. Graminoids: *Aristida adscensionis* (d), *Eragrostis annulata*, *Stipagrostis obtusa*.

Biogeographically Important Taxa (NQNamaqualand endemic, GGariep endemic) Succulent Shrubs: (d), *Ceraria fruticulosa*^G, *Cheiridopsis pillansii*^G. Geophytic Herb: *Whiteheadia bifolia*^{NQ}. Succulent Shrub: *Hoodia alstonii*^G.

Endemic Taxon Succulent Herb: *Huernia barbata* subsp. *ingae*.

Conservation Threatened (although not immediately) by potential mining interests around Aggeneys. Target 34%. None conserved in statutory conservation areas—a fact needing quick remedy. Erosion is very low.

Remark The vegetation of this unit is of extrazonal nature—a unit of Succulent Karoo embedded within a region with transitional winter/summer-rainfall regime of the surrounding NKb 3 Bushmanland Arid Grassland. The major motivation for the classification of the Bushmanland Inselberg Shrubland (as well as the associated SKr 19 Aggeneys Gravel Vygieveld, see below) is based on special substrate-generating conditions for domi-

nance of (dwarf) succulent flora. There is also a very tight topographic link to the Desert Biome: while the Succulent Karoo unit occurs on the climatically more favourable southern aspect, the northern slopes of the same inselbergs host the Dg 9 East Gariep Rocky Desert vegetation. The inselbergs support a high number of local endemics, especially succulents of the families Aizoaceae, Apocynaceae, Crassulaceae as well as some interesting Portulacaceae (*Avonia*, *Anacampseros*) and closely related Didiereaceae (*Ceraria*).

References Anderson & Van Heerden (2000), Desmet (2000a, b), Fick (2000), Hammer (2002).

SKr 19 Aggeneys Gravel Vygieveld

VT 33 Namaqualand Broken Veld (92%) (Acocks 1953). LR 51 Orange River Nama Karoo (83%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Plains at foothills or on peneplains of inselbergs in northern Bushmanland scattered between Pofadder and Aggeneys and further westwards to the edges of the Namaqualand granite hill ridges. Altitude: mainly 840–1 060 m.

Vegetation & Landscape Features Flat or slightly sloping plains (appearing as distinctly white surface quartz layers against the background of red sand or reddish soil) and supporting sparse, low-growing vegetation dominated by small to dwarf leaf-succulents of the families Aizoaceae, Crassulaceae, Euphorbiaceae, Portulacaceae and Zygophyllaceae, with some perennial component. The resurrection grass *Eragrostis nindensis* is the dominant perennial graminoid.

Geology & Soils Gneiss of the Little Namaqualand and Hoogoor Suites, and quartzite of the Bushmanland and Geelvloer Groups dominate. The occurrence of these two broad geological groups is the primary determinant of the location of the different types of gravel patches usually found at the foothills or on peneplains associated with the base of inselbergs or low ridges amongst the gently undulating plains. In places rare feldspar patches occur, always associated with the pink gneiss of the Hoogoor Suite. Four types of gravel patches are encountered in the area: (1) fine-grained quartz patches with a uniform covering of small diameter (<1 cm) quartz pebbles occur on the summits and foothills of some inselbergs (e.g. Gamsberg and Achab), (2) quartz gravel patches with more variable size-class distribution occurring more widely, but generally associated with the foothills of the quartzite inselbergs of the region, (3) feldspar gravel patches associated with open plains with underlying gneiss geology, and (4) calcrete gravel patches occurring on open plains, where the topsoil and dorbank of the colluvial soils have been eroded, exposing the underlying calcrete layer. The soils are very shallow, skeletal and loamy-sandy. Ag land type covers half of the area, followed by Ic and Af land types.

Climate Overall climatic characters are largely identical (or very similar) to those listed for the topographically neighbouring SKr 18 Bushmanland Inselberg Shrubland. See also climate diagram for SKr 19 Aggeneys Gravel Vygieveld (Figure 5.12).

Important Taxa Small Tree: *Boscia albitrunca*. Succulent Shrubs: *Ruschia divaricata* (d), *Euphorbia gariepina*, *E. gregaria*, *E. mauritanica*, *Hypertelis salsoloides*, *Kleinia longiflora*, *Lycium cinereum*, *Psilocaulon subnodosum*, *Sarcocaulon crassicaule*, *Senecio sarcoides*, *Titanopsis hugo-schlechteri*. Low Shrubs: *Pegolettia retrofracta* (d), *Aptosimum spinescens*, *Eriocephalus ambiguus*, *Euphorbia spinea*, *Fagonia capensis*, *Galenia fruticosa*, *Helichrysum pumilio* subsp. *pumilio*, *Hermannia spinosa*, *Microloma incanum*, *Monechma spartioides*. Succulent Herbs:

Crassula corallina subsp. *macrorrhiza*, *C. deltoidea*. Graminoid: *Stipagrostis ciliata*.

Biogeographically Important Taxa (^{NQ}Namaqualand endemic, ^GGariep endemic) Succulent Shrubs: *Antimima vanzylii*^G (d), *Ceraria fruticulosa*^G, *C. namaquensis*^G, *Stomatium alboroseum*^{NQ}. Low Shrub: *Berkheya canescens*^G. Succulent Herbs: *Anacampseros filamentosa* subsp. *namaquensis*^{NQ}, *Avonia papyracea* subsp. *namaensis*^G, *A. papyracea* subsp. *papyracea*^G, *Crassula sericea* var. *sericea*^G, *Mesembryanthemum inachabense*^G, *Phyllobolus latipetalus*^G. Herb: *Adenoglossa decurrens*^{NQ}.

Endemic Taxa Succulent Shrubs: *Adromischus nanus*, *Dinteranthus puberulus*, *D. vanzylii*, *Lapidaria margaretae*. Succulent Herbs: *Anacampseros bayeriana*, *Conophytum achabense*, *C. angelicae* subsp. *angelicae*, *C. burgeri*, *C. calculus* subsp. *vanzylii*, *C. friedrichiae*, *C. limpidum*, *C. lydiae*, *C. maughanii*, *C. praesectum*, *C. ratum*, *Lithops dorotheae*, *L. julii* subsp. *fulleri*.

Conservation The unit features as least threatened and none is conserved in statutory conservation areas. The conservation target was set at 18%. Due to low vegetation cover, the gravel patches are not targeted for grazing. No serious alien-plant incursions have been observed since the soil surface does not suffer disturbance injuries—consequently erosion is very low.

Remark 1 The gravel patches of northern Bushmanland are not as well defined in the landscape as those in other parts of the Succulent Karoo Biome. There are probably more gravel patches of considerable extent in the region of Pofadder and Aggeneys than what we are featuring on our vegetation map. The unit also occurs in southern Namibia in the Warmbad region. The low precipitation regime of the northern Bushmanland explains why the biomass of plants occurring on the gravel patches is very low in comparison to the floristically related and more mesic gravel patches of the Little Karoo or Knersvlakte. Floristically and structurally the Aggeneys Gravel Vygieveld can be considered a true Succulent Karoo vegetation type and thus, in conjunction with that found on the steep southern slopes of the larger inselbergs, forms the easternmost extent of the Succulent Karoo Biome in Bushmanland. Except for a small

pocket of this vegetation on the Naip se Berg inselberg (half-way between Springbok and Aggeneys), this enclave of the Succulent Karoo vegetation is isolated from the main body of this vegetation in Namaqualand (that finds its limits in the area of Smorenskadu and Kangnas) by the sandy plains covered with NKb 3 Bushmanland Arid Grassland.

Remark 2 Two endemic genera, *Dinteranthus* and *Lapidaria* (both Aizoaceae), occur in the Warmbad-Aggeneys gravel patches. *Schwantesia* (also Aizoaceae) has a distinct centre of diversification in this unit.

References Desmet (2000a, b), Fick (2000), Hammer (2002), Schmiedel (2002a, b).

Namaqualand Hardeveld

SKn 1 Namaqualand Klipkoppe Shrubland

VT 33 Namaqualand Broken Veld (65%) (Acocks 1953). LR 56 Upland Succulent Karoo (73%) (Low & Rebelo 1996).

Distribution Northern and Western Cape Provinces: Central and north-central regions of Namaqualand spanning Steinkopf in the north and Nuwerus in the south. Altitude 120–1 260 m.

Vegetation & Landscape Features Dramatic landscape of huge granite and gneiss domes, smooth glacis and disintegrating boulder koppies supporting open shrubland up to 1 m tall, dominated by shrubs of dwarf to medium stature and with ericoid or succulent leaves. A few scattered pachycaul kokerboom trees (*Aloe dichotoma* var. *dichotoma*) are found mostly on north-facing slopes. Flat or gently sloping rock sheets (the dominant feature of this unit) support dwarf or prostrate succulents in shallow pockets with soil or in cracks. Fringe vegetation at the bottom of steep rock sheets (collecting run-off water) consists of 1–3 m tall shrubs with nonsucculent leaves and canopy cover reaching 40–100%.

Geology & Soils A number of Mokolian granites and gneisses (most widespread is the Kamieskroon Gneiss) form gentle to moderate rocky slopes, rock sizes varying from medium to large with flat to gentle rock sheets as well as rock domes, yellow-brown to brown loamy sand, 0.15–0.6 m deep. Ag and Ib land types (35% each), followed by Fb and Fc (10% each).

Climate Seasonal winter rainfall (May to September). MAP about 160 mm, with epizodic drought periods (well below 100 mm per year) of one or two years in succession. Dew is present throughout the winter. MAT 16.6°C. Hot summers, with mean maximum and minimum daily temperatures 30°C and 5°C for January and July, respectively. Frost occurs about 8 days per year, but can vary widely from year to year. See also climate diagram for SKn 1 Namaqualand Klipkoppe Shrubland (Figure 5.29).

Important Taxa Succulent Tree: *Aloe dichotoma* var. *dichotoma* (d). Small Trees: *Ficus ilicina*, *Pappea capensis*. Succulent Shrubs: *Didelta spinosa* (d), *Euphorbia decussata* (d), *E. mauritanica* (d), *Leipoldtia schultzei* (d), *Adromischus marianiae* var. *immaculatus*, *Antimima*



P.G. Desmet

Figure 5.28 SKr 19 Aggeneys Gravel Vygieveld: A calcrete patch on the Farm Koeries (north-west of Aggeneys, northern Bushmanland). This patch is unusual in having a dense cover of both calcrete and quartzite pebbles. The dominant shrubby species is *Fagonia capensis* and the grass is *Stipagrostis obtusa*. A local endemic *Lithops julii* var. *julii* is restricted to this habitat.

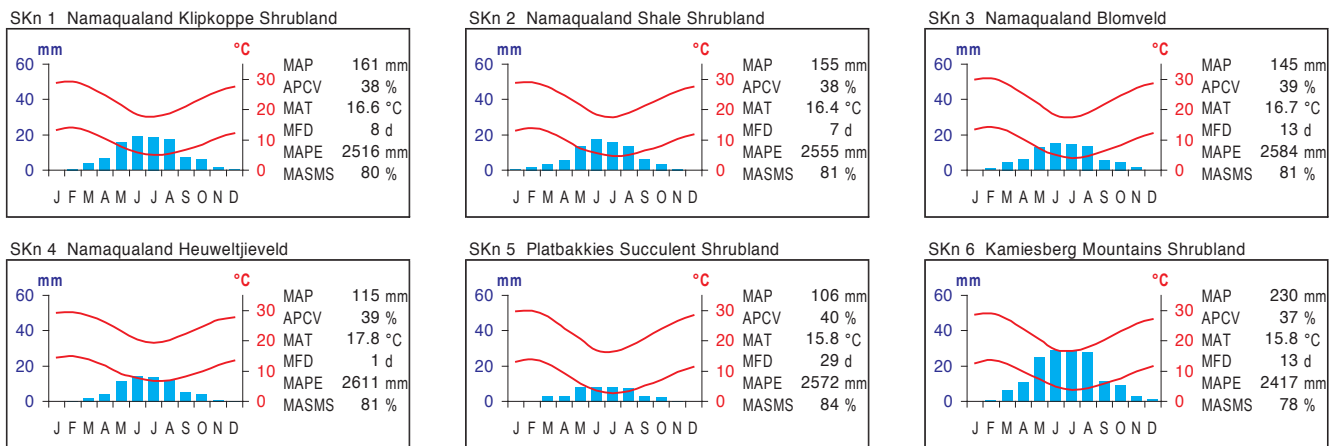


Figure 5.29 Climate diagrams of Namaqualand Hardeveld Bioregion units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

mesklipensis, *Cotyledon cuneata*, *C. orbiculata* var. *orbiculata*, *Crassula atropurpurea* var. *watermeyerii*, *C. tetragona* subsp. *robusta*, *Manochlamys albicans*, *Othonna cylindrica*, *O. floribunda*, *O. furcata*, *Pelargonium crithmifolium*, *Phyllobolus roseus*, *Ruschia goodiae*, *R. viridifolia*, *Sarcocaulon crassicaule*, *S.*

l'heritieri, *Senecio junceus*, *Stoeberia utilis*, *Tetragonia fruticosa*, *Tylecodon paniculatus*, *T. striatus*, *T. wallichii* subsp. *wallichii*, *Zygophyllum foetidum*, *Z. morgsana*. Tall Shrubs: *Dodonaea viscosa* var. *angustifolia*, *Euclea tomentosa*, *Montinia caryophyllacea*, *Putterlickia pyracantha*, *Rhus undulata*. Low Shrubs:



Figure 5.30 SKn 1 Namaqualand Klipkoppe Shrubland: Kokerboom (*Aloe dichotoma* var. *dichotoma*) stand on granodiorite slopes in the Goegap Nature Reserve (Namaqualand, Northern Cape).

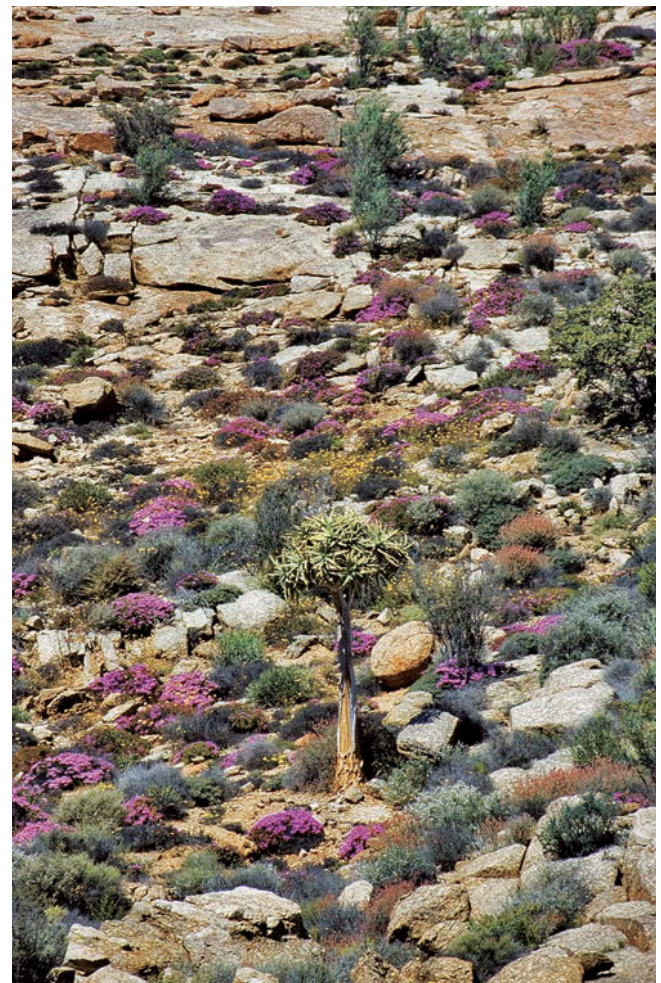


Figure 5.31 SKn 1 Namaqualand Klipkoppe Shrubland: Rocky granodiorite slope with succulent shrubland (*Ruschia*, *Leipoldtia*, *Eriocephalus*, *Othonna*) and scattered populations of kokerboom (*Aloe dichotoma*) in the Goegap Nature Reserve (Namaqualand, Northern Cape).

Berkheya fruticosa (d), *Eriocephalus microphyllus* var. *pubescens* (d), *Galenia africana* (d), *Hermannia disermifolia* (d), *Lebeckia sericea* (d), *Acanthopsis spathularis*, *Antizoma miersiana*, *Asparagus capensis* var. *capensis*, *Athanasia flexuosa*, *Ballota africana*, *Berkheya ferox*, *Eriocephalus brevifolius*, *Galenia fruticosa*, *Gnidia meyeri*, *Helichrysum scabrum*, *H. tricostatum*, *Indigofera nigromontana*, *Maytenus oleoides*, *Passerina galpinii*, *Pelargonium grandicalcaratum*, *P. praemorsum*, *Pharnaceum albens*, *Phylla montana*, *P. oleaefolia*, *Pteronia divaricata*, *P. incana*, *Selago divaricata*, *S. glutinosa*, *Senecio cinerascens*, *Solanum burchellii*, *S. giftbergense*, *Tripteris oppositifolia*, *T. sinuata*. Semiparasitic Shrubs: *Thesium lineatum*, *T. patulum*, *T. polycephalum*, *T. spinosum*. Woody Succulent Climber: *Sarcostemma viminale*. Woody Climbers: *Asparagus retrofractus*, *Astephanus triflorus*, *Microloma sagittatum*. Herbaceous Climber: *Cysticapnos grandiflora*. Semiparasitic Epiphytic Shrub: *Viscum capense*. Herbs: *Tripteris amplexens* (d), *T. hyoseroides* (d), *Adenogramma glomerata*, *Aizoon canariense*, *Arctotis revoluta*, *Diascia diffusa*, *Felicia bergeriana*, *Galium tomentosum*, *Heliophila amplexicaulis*, *H. thunbergii*, *H. variabilis*, *Hemimeris racemosa*, *Hermannia althaeifolia*, *Oncosiphon suffruticosum*, *Plantago cafra*, *Senecio glabrifolius*, *Trichogyne paronychioides*, *Tripteris microcarpa*, *Ursinia cakilefolia*, *Wahlenbergia oxyphylla*. Geophytic Herbs: *Ornithogalum multifolium*, *O. rupestre*, *Oxalis ambigua*, *O. obtusa*, *O. pes-caprae*, *Trachyandra falcata*. Succulent Herbs: *Conophytum breve*, *C. depressum*, *Crassula muscosa*, *C. tomentosa*, *Tetragonia microptera*. Graminoids: *Ehrharta calycina* (d), *Chaetobromus involucreatus* subsp. *dregeanus*, *Ehrharta barbinodis*, *E. delicatula*, *Fingerhuthia africana*, *Tribolium echinatum*.

Biogeographically Important Taxa (^{NQ}Namaqualand endemic, ^NNorthern distribution limit, ^SSouthern distribution limit) Small Trees: *Ozoroa concolor*^{NQ}, *O. dispar*^{NQ}. Succulent Shrubs: *Polymita albiflora*^{NQ} (d), *Aloe striata* subsp. *komaggasensis*^{NQ}, *Cheiridopsis denticulata*^{NQ}, *Crassula brevifolia* subsp. *brevifolia*^{NQ}, *Euphorbia oxystegia*^{NQ}, *Othonna euphorbioides*^{NQ}, *Psilocaulon foliolosum*^{NQ}, *Stoebria frutescens*^{NQ}, *Tylecodon similis*^{NQ}, *T. wallichii* subsp. *ecklonianus*^S. Tall Shrub: *Otholobium striatum*^N. Low Shrubs: *Acanthopsis horrida*^{NQ}, *Asparagus alopecurus*^{NQ}, *Athanasia linifolia*^N, *Chrysocoma oblongifolia*^N, *Dischisma clandestinum*^{NQ}, *Euryops brevipapposus*^N, *Felicia brevifolia*^S, *Oedera sedifolia*^N, *Pelargonium abrotanifolium*^N, *P. sericifolium*^{NQ}, *Pteronia leptospermoides*^{NQ}, *P. ovalifolia*^N, *Salvia dentata*^{NQ}, *S. lanceolata*^N, *Selago speciosa*^N, *Senecio parvifolius*^N. Woody Succulent Climber: *Crassula rudolfii*^{NQ}. Woody Climbers: *Asparagus multituberosus*^N, *Indigofera amoena*^N, *Microloma calycinum*^{NQ}. Herbaceous Succulent Climber: *Crassula rogeveldii*^N. Herbs: *Adenogramma mollugo*^N, *Annesorhiza nuda*^N, *Gorteria diffusa* subsp. *calendulacea*^{NQ}, *Hermannia stipitata*^{NQ}, *Jamesbrittenia pedunculosa*^{NQ}, *Manulea altissima* subsp. *glabri-caulis*^{NQ}, *Mollugo namaquensis*^{NQ}, *Phyllopodium anomalum*^N, *Polycarena capensis*^N, *Sonderina tenuis*^N, *Wahlenbergia cernua*^N. Geophytic Herbs: *Babiana curviscapa*^{NQ}, *B. dregei*^{NQ}, *B. stenomera*^{NQ}, *Gladiolus equitans*^{NQ}, *Lapeirousia pyramidalis*^N, *L. silenoides*^{NQ}, *Oxalis comosa*^{NQ}, *O. furcillata* var. *furcillata*^{NQ}, *O. namaquana*^{NQ}, *Pelargonium bubonifolium*^{NQ}, *Romulea citrina*^{NQ}, *R. namaquensis*^{NQ}, *Tenicroa multifolia*^{NQ}, *Trachyandra involucreata*^{NQ}, *Whiteheadia bifolia*^{NQ}. Succulent Herbs: *Cleretum papulosum* subsp. *schlechteri*^{NQ}, *Conophytum bilobum*^{NQ}, *Crassula dichotoma*^N, *C. hirsuta*^{NQ}, *Othonna macrophylla*^{NQ}, *Quaqua cincta*^{NQ}. Graminoids: *Aristida dasydesmis*^{NQ}, *Ehrharta erecta*^N, *Pentaschistis patula*^N.

Endemic Taxa Succulent Shrubs: *Ottosonderia monticola*, *Tylecodon nigricaulis*. Low Shrubs: *Lotononis benthamiana*, *L. longiflora*, *L. quinata*, *Wiborgia incurvata*. Herbs: *Tripteris spathulata*, *Zaluzianskya collina*. Geophytic Herbs: *Ornithogalum leeu-*

poortense, *Oxalis clavifolia*, *O. louisae*, *Xysmalobium pearsonii*. Succulent Herbs: *Quaqua bayeriana*, *Q. pallens*, *Stapeliopsis khamiesbergensis*.

Conservation Least threatened. Some 6% statutorily conserved in Namaqua National Park (incl. former WWF Skilpad Wild Flower Reserve), Goegab Nature Reserve with spectacular granite-koppie landscapes, and a small portion in the Moedverloren Nature Reserve. Target 28%. Largely without any alien invaders and hardly any transformation due to agriculture (steep rocky habitats), but old mine spoils (mainly copper) are a disturbing view in some localities. Erosion is moderate (35%), very low (35%) or low (30%).

Remark Spring flower displays, beautiful rock formations and a wealth of succulents make this a very popular tourist area, both nationally and internationally. One of the local botanical celebrities is the famous kokerboom (*Aloe dichotoma*). Historically these trees were also found on the flats between the rocky hills, but they were heavily utilised by the local inhabitants for making coolers to keep food fresh and also for building houses. In Namaqualand, *Tylecodon paniculatus* is found only on steep, south-facing slopes, while in the moister Succulent Karoo further south (e.g. in Robertson Karoo) this species is usually found on north-facing slopes or on heuweltjies.

References Le Roux (1984), Rösch (2001), L. Mucina (unpublished data).

SKn 2 Namaqualand Shale Shrubland

VT 33 Namaqualand Broken Veld (79%) (Acocks 1953). LR 56 Upland Succulent Karoo (55%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Area some 10 km to the north and to the southwest of Steinkopf in southeastern Richtersveld. Reaching as far south as Spektakelberg west of Springbok. Most of the area situated at altitudes between 500–1 100 m.

Vegetation & Landscape Features Smooth hilly country supporting mostly dense shrubland (due to high local rainfall and mild temperatures), often with strong abundance of *Galenia africana* and *Eriocephalus* spp. and locally dominant *Elytropappus rhinocerotis*. Rocky habitats support abundant dwarf succulents.

Geology & Soils Shales of Schwarzrand Subgroup accompanied by quartzites of the Kuibis Subgroup and of the Cambrian Nama Group supporting shallow soils over quartzite and deep-profile soils over shales. Almost 90% of the area falls within Fb land type, while the rest is largely classified as Ib land type.

Climate Seasonal, frontal winter rainfall peaking between May and August. Occasional late summer thunderstorms occur between February and April. MAP ranges from about 120 mm at low elevations to about 200 mm at higher elevations (overall MAP 155 mm). It is possible that areas along the edge of the escarpment such as Naries and Nigramoep would receive as much as 350 mm due to a regional precipitation effect. Mean maximum and minimum monthly temperatures in Nigramoep are 32°C and –5°C for February and July, respectively. The overall MAT lies between 16°C and 17°C. Incidence of frost averages 10 days per year, ranging from fewer than 5 days to more than 30 days per year. See also climate diagram for SKn 2 Namaqualand Shale Shrubland (Figure 5.29).

Important Taxa Succulent Shrubs: *Euphorbia mauritanica* (d), *Cheiridopsis namaquensis*, *Crassula tetragona* subsp. *robusta*, *Didelta spinosa*, *Lampranthus otzenianus*, *L. watermeyerii*, *Manochlamys albicans*, *Monilaria obconica*, *Pelargonium*



Figure 5.32 SKn 2 Namaqualand Shale Shrubland: Undulating landscape built of Nama shales and supporting endemic-rich succulent shrubland in northern Namaqualand (Spektakelberg, west of Springbok).

crithmifolium, *P. echinatum*, *P. karoocicum*, *Ruschia extensa*, *Tetragonia glauca*, *Tylecodon paniculatus*, *T. wallichii* subsp. *wallichii*, *Zygophyllum foetidum*. Tall Shrubs: *Dodonaea viscosa* var. *angustifolia* (d), *Rhus populifolia*. Low Shrubs: *Elytropappus rhinocerotis* (d), *Asparagus capensis* var. *capensis*, *Athanasia flexuosa*, *Berkheya fruticosa*, *Blepharis mitrata*, *Chrysocoma longifolia*, *Eriocephalus brevifolius*, *E. microphyllus* var. *pubescens*, *Euryops dregeanus*, *Galenia africana*, *Gnidia meyeri*, *Helichrysum hebelepis*, *H. oxybelium*, *H. tricoctatum*, *Indigofera nigromontana*, *Lebeckia sericea*, *Phyllica oleaefolia*, *Pteronia glabrata*, *P. incana*, *Selago glutinosa*, *Wahlenbergia tenella*, *Zygophyllum spinosum*. Semiparasitic Shrubs: *Thesium namaquense*, *T. patulum*, *T. polycephalum*. Woody Climbers: *Asparagus fasciculatus*, *A. multituberosus*, *Astephanus triflorus*, *Microloma sagittatum*. Herbaceous Succulent Climber: *Crassula roggeveldii*. Herbaceous Climbers: *Convolvulus capensis*, *Cysticapnos grandiflora*. Herbs: *Aizoon canariense* (d), *Cotula laxa* (d), *Heliophila crithmifolia* (d), *Leysera tenella* (d), *Plantago cafra* (d), *Diascia diffusa*, *Felicia bergeriana*, *F. tenella* subsp. *longifolia*, *Helichrysum leontonyx*, *Heliophila amplexicaulis*, *H. thunbergii*, *Hemimeris racemosa*, *Polygala refracta*, *Senecio glabrifolius*, *S. glutinariis*, *Silene burchellii* var. *angustifolia*, *Tripteris microcarpa*, *Ursinia anthemoides* subsp. *anthemoides*, *U. anthemoides* subsp. *versicolor*, *U. nana*, *U. speciosa*. Geophytic Herbs: *Bulbine disimilis*, *B. sedifolia*, *Bulbinella gracilis*, *Cheilanthes hirta*, *Chlorophytum undulatum*, *Drimia intricata*, *Hesperantha bachmannii*, *Lachenalia undulata*, *Melaspheerula ramosa*, *Moraea miniata*, *Ornithogalum hispidum*, *O. rupestre*, *Oxalis obtusa*, *O. purpurea*, *Spiloxene scullyi*, *Xenoscapa fistulosa*. Succulent Herbs: *Crassula tenuipedicellata*, *C. tomentosa*, *Tetragonia microptera*. Graminoids: *Cynodon dactylon* (d), *Ehrharta calycina*, *E. delicatula*, *E. longiflora*, *Merxmüllera stricta*.

Biogeographically Important Taxa (^{NQ}Namaqualand endemic, ^NNorthern distribution limit) Succulent Shrubs: *Adromischus phillipsiae*^N, *Antimima dasyphylla*^N, *Cheiridopsis denticulata*^{NQ}, *C. meyeri*^{NQ}, *C. rostrata*^N, *Euphorbia oxystegia*^{NQ}, *Othonna pteronioides*^N. Tall Shrubs: *Cliffortia amplexistipula*^N, *C. rus-cifolia* var. *purpurea*^N. Low Shrubs: *Agathosma serpyllacea*^N, *Aspalathus cymbiformis*^N, *A. hispida* subsp. *albiflora*^N, *Asparagus*

alopecurus^{NQ}, *Diosma ramosissima*^N, *Dischisma clandestinum*^{NQ}, *Eriocephalus macroglossus*^{NQ}, *Euryops namaquensis*^N, *Lobostemon glaucophyllus*^N, *Lotononis densa* subsp. *gracilis*^N, *Microdon polygaloides*^N, *Oedera genistifolia*^N, *Oftia revoluta*^{NQ}, *Otholobium hirtum*^N, *Passerina galpinii*^N, *Pelargonium sericifolium*^{NQ}, *Pharnaceum incanum*^N, *Pteronia leptospermoides*^{NQ}, *Selago acocksi*^N, *S. triquetra*^N, *Stachys flavescens*^{NQ}, *Struthiola leptantha*^N, *Tetragonia namaquensis*^{NQ}, *Wiborgia fusca* subsp. *fusca*^N. Woody Succulent Climber: *Crassula rudolfii*^{NQ}. Woody Climbers: *Asparagus aethiopicus*^N, *Microloma namaquense*^{NQ}. Herbs: *Annesorhiza altiscapa*^N, *Chamarea capensis*^N, *Cotula bipinnata*^N, *Dimorphotheca acutifolia*^N, *Gorteria diffusa* subsp. *calendulacea*^{NQ}, *Heliophila gariepina*^{NQ}, *H. laciniata*^{NQ}, *Hermannia althaeifolia*^N, *Manulea cheiranthus*^N, *Osteospermum acanthospermum*^N, *Polycarena pubescens*^N, *Wahlenbergia acaulis*^N. Geophytic Herbs: *Androcymbium dregei*^N, *A. scabromarginatum*^{NQ}, *A. volutare*^N, *Babiana*

curviscapa^{NQ}, *B. stenomera*^{NQ}, *Bulbinella divaginata*^N, *Empodium plicatum*^N, *Geissorhiza namaquensis*^{NQ}, *Gladiolus arcuatus*^{NQ}, *Haemanthus unifolius*^{NQ}, *Holothrix aspera*^N, *H. filicornis*^{NQ}, *Lachenalia carnosus*^{NQ}, *L. unifolia* var. *schlechteri*^N, *Moraea galaxia*^N, *M. herrei*^{NQ}, *M. unguiculata*^N, *Ornithogalum concordianum*^N, *O. geniculatum*^{NQ}, *O. pruinatum*^{NQ}, *Oxalis dregei*^N, *O. eckloniana* var. *hopefieldiana*^N, *O. furcillata* var. *furcillata*^{NQ}, *O. grammopetala*^N, *O. melanosticta* var. *melanosticta*^N, *O. namaquana*^{NQ}, *Pelargonium bubonifolium*^{NQ}, *P. incrassatum*^{NQ}, *Romulea citrina*^{NQ}, *R. namaquensis*^{NQ}, *Satyrium erectum*^N, *Trachyandra involucreta*^{NQ}. Succulent Herbs: *Aloe melanacantha*^{NQ}, *Conophytum bilobum*^{NQ}, *Crassula capensis* var. *capensis*^N, *C. glomerata*^N, *Othonna incisa*^{NQ}, *O. macrophylla*^{NQ}, *O. obtusiloba*^{NQ}, *O. retrorsa*^{NQ}, *Phyllobolus oculatus*^{NQ}. Graminoids: *Ficinia argyropa*^N, *F. deusta*^N, *Tribolium echinatum*^N, *T. hispidum*^N.

Endemic Taxa Succulent Shrubs: *Cheiridopsis aspera*, *C. delphinoides*, *C. peculiaris*, *C. umdausensis*, *Odontophorus marlothii*, *Tylecodon atropurpureus*, *T. hirtifolius*, *T. tribblei*, *T. tuberosus*. Low Shrub: *Phyllica pearsonii*. Geophytic Herbs: *Lachenalia namaquensis*, *Lapeirousia verecunda*, *Moraea margaretae*, *M. namaquana*, *Pelargonium aridicola*, *Strumaria merxmülleriana*. Succulent Herb: *Brownanthus lignescens*.

Conservation Least threatened and none conserved in statutory conservation areas. Some protection is warranted on private game farms. Target 24%. Only very small part transformed, but this might change due to overall better suited deep-soil habitats found within the area. No obvious invasions of alien plants. Erosion is mostly moderate.

Remark 1 Namaqualand Shale Shrubland is phytogeographically one of the most intriguing vegetation units. It is supported by a peculiar combination of high altitude experiencing slightly higher local rainfall as well as occasional mist and of substrate—Nama shales weathering into clay-rich, heavy soils able to retain water in a more efficient way than the dominant granite-derived sandy soils of northern and central Namaqualand. These unique pedo-hydrological (and geological) conditions create habitat islands supporting a number of apparently relictual (Midgley et al. 2001) Cape elements of the genera *Aspalathus*, *Cliffortia*, *Diosma*, *Elytropappus*, *Gladiolus*, *Holothrix*, *Metalasia*,

Moraea, *Oedera*, *Oxalis*, *Romulea*, *Satyrion* and *Phyllica*—represented by taxa reaching their northern distribution limits here. A number of taxa, such as *Cliffortia ruscifolia* var. *purpurea*, occurring all the way along the high altitudes of South African meseta (along the Escarpment) from as far as Limpopo Province and Mpumalanga also reach their northwestern limits of distribution here. The local endemism, counting 26 taxa so far (some still pending formal description) is also remarkable.

Remark 2 Low & Rebelo (1996) mapped a small portion of this unit (Spektakelberg area) as part of North-western Mountain Renosterveld. There are indeed some patches of vegetation reminiscent of shrubby renosterveld (with *Elytropappus rhinocerotis* dominant—see for example Van Jaarsveld & Koutnik 2004: 54, Figure 59) on the Farm Eselsfontein. Future research will possibly bring more clarity on the extent and identity of these patches and the renosterveld on the escarpment west of Springbok can become recognised again.

Reference P.G. Desmet (unpublished data).

SKn 3 Namaqualand Blomveld

VT 33 Namaqualand Broken Veld (61%) (Acocks 1953). LR 56 Upland Succulent Karoo (62%) (Low & Rebelo 1996).

Distribution Northern Cape Province and to a small extent also Western Cape Province: Valleys and flat areas (piedmonts, vlaktes) between granitic rocky hills of the Namaqualand Escarpment, from Steinkopf southwards to Bitterfontein. Most of the area at altitudes 460–1 080 m.

Vegetation & Landscape Features Level to slightly undulating sedimentary surfaces between rocky granitic hills and mountains, such as wide plains and broad valleys with dry channels of intermittent water courses. Sparse dwarf shrubs with succulent or ericoid leaves dominate these shrublands. Geophytes and ephemeral herbs and in places also low, spreading, leaf-succulents show spectacular flower displays (hence the name of the unit) in wet years.

Geology & Soils Underlain by granite-gneisses and metasediments of Mokolian age, affected by the Namaqualand Metamorphic Event. Supporting relatively deep, yellow-brown, fine to coarse loamy sand derived through weathering of the granite rocks. Ag and Ae land types make up almost 80% of the area, followed by Fc land type accounting for a further 15%.

Climate Seasonal winter rainfall (May to September) with sporadic drought periods (well below 100 mm per year) of one or two years in succession. Dew is present throughout the winter. MAP 145 mm. An average of 13 days of frost per year, but varying greatly from year to year. Mean maximum and minimum daily temperatures from January to February and June to August span 29–32°C and 3–5°C, respectively. See also climate diagram for SKn 3 Namaqualand Blomveld (Figure 5.29).

Important Taxa Succulent Shrubs: *Drosanthemum hispidum* (d), *Euphorbia mauritanica* (d), *Galenia sarcophylla*

(d), *Hypertelis salsoloides* (d), *Leipoldtia schultzei* (d), *Ruschia robusta* (d), *Aridaria noctiflora* subsp. *noctiflora*, *Euphorbia decussata*, *Lycium cinereum*, *Ruschia brevibracteata*, *Tetragonia fruticosa*, *T. robusta* var. *psiloptera*, *Tylecodon wallichii* subsp. *wallichii*. Low Shrubs: *Eriocephalus microphyllus* var. *pubescens* (d), *Galenia africana* (d), *Aptosimum indivisum*, *A. spinescens*, *Asparagus capensis* var. *capensis*, *Berkheya fruticosa*, *Hermannia disermifolia*, *H. trifurca*, *Peliostomum virgatum*, *Pentzia incana*, *Pteronia divaricata*, *Tripteris sinuata*, *Zygophyllum retrofractum*. Semiparasitic Shrub: *Thesium lineatum*. Woody Climbers: *Astephanus triflorus*, *Microlooma sagittatum*. Herbaceous Climber: *Cysticapnos grandiflora*. Herbs: *Aizoon canariense* (d), *Arctotheca calendula* (d), *Arctotis fastuosa* (d), *Dimorphotheca sinuata* (d), *Felicia merxmülleri* (d), *Foveolina dichotoma* (d), *Gazania lichtensteinii* (d), *Gorteria diffusa* subsp. *diffusa* (d), *Grielum humifusum* (d), *Heliophila coronopifolia* (d), *H. variabilis* (d), *Leysera gnaphalodes* (d), *L. tenella* (d), *Oncosiphon grandiflorum* (d), *O. suffruticosum* (d), *Plantago cafra* (d), *Senecio arenarius* (d), *S. cardaminifolius* (d), *Ursinia cakilefolia* (d), *U. nana*, *Adenogramma glomerata*, *Felicia bergeriana*, *F. namaquana*, *F. tenella* subsp. *cotuloides*, *Gazania leiopoda*, *Heliophila seselifolia* var. *nigellifolia*, *Hermannia althaeifolia*, *Jamesbrittenia racemosa*, *Lessertia diffusa*, *Lotononis falcata*, *Nemesia affinis*, *Pelargonium redactum*, *Trichogyne paronychioides*, *Zaluzianskya benthamiana*. Geophytic Herbs: *Massonia depressa* (d), *Oxalis obtusa* (d), *Eriospermum paradoxum*, *Hesperantha pauciflora*, *Lachenalia violacea*, *Moraea serpentina*, *Ornithogalum hispidum*, *Oxalis inconspicua*, *Pelargonium triste*, *Tulbaghia dregeana*. Succulent Herbs: *Crassula thunbergiana* (d), *Conicosia elongata*, *Crassula muscosa*, *Tetragonia microptera*. Graminoids: *Karoochloa schismoides* (d), *Chaetobromus involucreatus* subsp. *dregeanus*, *Ehrharta barbinodis*, *E. calycina*, *E. longiflora*, *Schismus barbatus*.

Biogeographically Important Taxa (^{NQ}Namaqualand endemic, ^NNorthern distribution limit) Succulent Shrubs: *Cheiridopsis denticulata*^{NQ}, *Othonna abrotanifolia*^{NQ}, *Prenia palensis* subsp. *namaquensis*^{NQ}. Low Shrubs: *Dischisma clandestinum*^{NQ}, *Indigofera dillwynioides*^N, *Salvia dentata*^{NQ}. Herbaceous



Figure 5.33 SKn 3 Namaqualand Blomveld: Spring display of veygies (*Ruschia* species, pink) and Asteraceae including *Arctotis fastuosa* (deep orange), *Foveolina dichotoma* (small yellow-flowered plant in the foreground) and *Tripteris sinuata* (yellow-flowered shrubs in the background) in the Goegap Nature Reserve (Springbok, Northern Cape).



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Figure 5.34 SKn 3 Namaqualand Blomveld: Spring flower display of *Heliophila seselifolia* (white), *Senecio cardaminifolius* (yellow) and *Arctotis fastuosa* (orange) in an old field in the Goegap Nature Reserve near Springbok (Namaqualand, Northern Cape).

Climber: *Cyphia angustifolia*^N. Herbs: *Hebenstretia hamulosa*^{NQ}, *Heliophila laciniata*^{NQ}, *Jamesbrittenia pedunculosa*^{NQ}, *Lotononis rostrata* subsp. *namaquensis*^{NQ}, *L. stenophylla*^N, *Manulea decipiens*^{NQ}, *Mollugo namaquensis*^{NQ}, *Monopsis debilis* var. *gracilis*^{NQ}, *Polycarena rariflora*^N, *Wahlenbergia prostrata*^{NQ}. Geophytic Herbs: *Babiana curviscapa*^{NQ}, *B. dregei*^{NQ}, *Gladiolus arcuatus*^{NQ}, *Lachenalia carnosus*^{NQ}, *L. hirta*^N, *Lapeirousia silenoides*^{NQ}, *Moraea collina*^N, *Pelargonium incrassatum*^{NQ}, *Romulea citrina*^{NQ}, *Wurmbea capensis*^N.

Endemic Taxa Herbs: *Lessertia capitata*, *Lotononis arenicola*. Succulent Herbs: *Dorotheanthus bellidiformis* subsp. *hestermalensis*, *D. rourkei*.

Conservation Target 28%. Small areas (1.5%) statutorily conserved in Goegap Nature Reserve and Namaqua National Park. Some protection is warranted on private game farms. Only about 6% of the total area is transformed, mainly by grain cultivation and some planting of salt-bush (*Atriplex nummularia*). Overgrazing is found almost throughout this unit. The most serious invasive plants are American *Amsinckia retrorsa*, Eurasian *Erodium* and *Bromus*, and Australian *Atriplex lindleyi* subsp. *inflata*. All alien infestations are only of local extent. Erosion is low (40%), very low (30%) or moderate (30%).

Remark 1 The vegetation on abandoned (formerly ploughed) fields is the result of continued disturbance, first by ploughing and then the vegetation is kept from recovery by heavy grazing of the annuals and palatable perennial seedlings. In areas with loamy soils *Drosanthemum hispidum*, *Galenia sarcophylla* and *Hypertelis salsoloides* are sometimes dominant, while elsewhere



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Figure 5.35 SKn 4 Namaqualand Heuweltjieveld: Undulating granite landscape south of Garies dotted by numerous heuweltjies with *Drosanthemum hispidum* (Aizoaceae) and *Arctotis fastuosa* (Asteraceae) dominant.

the only perennial species sometimes is *Galenia africana*. In lightly grazed areas many of the palatable perennial species can also be present. In disturbed areas on the eastern side of the Namaqualand Escarpment, this unit can be dominated by *Ruschia robusta*.

Remark 2 The sandy flats among the granite and granodiorite koppies of Namaqualand have been the subject of intensive research into population and vegetation dynamics, especially including aspects such as annual phenology of the short-lived plant communities, competitive relations and seed ecology (Van Rooyen et al. 1979a, b, Van Rooyen & Grobbelaar 1982, Le Roux 1984, Theron et al. 1993, Steyn et al. 1996, Van Rooyen et al. 1996, Rösch et al. 1997a, b, c; see also Van Rheede van Oudtshoorn & Van Rooyen 1999 for further references).

References Van Rooyen et al. (1979a, b, 1996), Van Rooyen & Grobbelaar (1982), Le Roux (1984), Theron et al. (1993), Steyn et al. (1996), Rösch et al. (1997a, b, c).

SKn 4 Namaqualand Heuweltjieveld

VT 31 Succulent Karoo (88%) (Acocks 1953). LR 57 Lowland Succulent Karoo (79%) (Low & Rebelo 1996).

Distribution Northern Cape Province: At the western foothills of the Namaqualand Escarpment from west of Steinkopf southwards to Soebatsfontein and to Kotzesrust. Altitude ranging from 100–540 m (most of the area).

Vegetation & Landscape Features Undulating plains leading up to the Escarpment with a mosaic of communities on heuweltjies (slightly raised, rounded termite mounds up to 10

m in diameter) and in between the heuweltjies. Low shrubland (canopy cover 20–45%) dominated by leaf-succulent shrubs.

Geology & Soils Deep red loamy soils on granites and gneisses of Mokolian age (most significantly the Kamieskroon Gneiss and Gladkop Suite). Ag land type dominates the area (58%), while Ae land type makes up most of the remainder of the area.

Climate Winter-rainfall climate with irregular rain events occurring mostly from May to August and almost always no rain between November and February. MAP of 115 mm. Dew is experienced throughout the winter. MAT is quite high (17.8°C) and frosts hardly occur. In the coldest months of the year (May to August) temperatures below 10°C are often recorded. The highest temperatures are reached from December to January (may well exceed 30°C). See also climate diagram for SKn 4 Namaqualand Heuweltjieveld (Figure 5.29).

Important Taxa Succulent Shrubs: *Drosanthemum hispidum* (d), *Euphorbia ephedroides* var. *ephedroides* (d), *Jordaniella cuprea* (d), *Lampranthus otzenianus* (d), *Ruschia leucosperma* (d), *R. robusta* (d), *Salsola namibica* (d), *Antimima compacta*, *Aridaria noctiflora* subsp. *noctiflora*, *Didelta carnosa* var. *carnosa*, *Eberlanzia parvibracteata*, *Lycium cinereum*, *Manochlamys albicans*, *Salsola aellenii*, *S. aphylla*, *Sarcocaulon flavescens*, *Tetragonia fruticosa*, *T. spicata*. Low Shrubs: *Galenia fruticosa* (d), *Lebeckia halenbergensis* (d), *Anthospermum aethiopicum*, *Berkheya fruticosa*, *Galenia africana*, *Hermannia trifurca*, *Hirpicium alienatum*, *Limeum africanum*, *Pelargonium praemorsum*, *Pentzia globosa*, *Pteronia glabrata*, *Tripteris oppositifolia*, *Zygophyllum retrofractum*. Herbs: *Arctotis fastuosa* (d), *Dimorphotheca sinuata* (d), *Leysera tenella* (d), *Oncosiphon suffruticosum* (d), *Osteospermum pinnatum* (d), *Tripteris microcarpa* (d), *Amellus microglossus*, *A. strigosus* subsp. *pseudoscabridus*, *Emex australis*, *Felicia bergeriana*, *F. tenella* subsp. *longifolia*, *Pharnaceum croceum*, *Plantago cafra*, *Rhynchosidium pumilum*, *Ursinia cakilefolia*, *Zaluzianskya villosa*. Geophytic Herb: *Oxalis annae* (d). Succulent Herbs: *Mesembryanthemum guerichianum* (d), *Psilocaulon junceum* (d), *Tetragonia microptera* (d). Graminoids: *Ehrharta calycina* (d), *E. longiflora* (d), *E. pusilla*, *Pentaschistis airoides*, *Tribolium echinatum*, *T. utriculosum*.

Biogeographically Important Taxa (all Namaqualand endemics) Succulent Shrubs: *Psilocaulon foliosum* (d), *Stoeberia frutescens* (d). Low Shrub: *Tetragonia namaquensis*.

Conservation Not under immediate threat except for local intensive grazing pressure responsible for veld degradation. Target 28%. Some 11% of the area of the unit statutorily conserved in Namaqua National Park. Scattered *Acacia cyclops* can be seen as an infestation problem on about 5% of the area in this unit. About 3–4% of the area is transformed by cultivation. Erosion remains at very low to low levels.

Remark Heuweltjies are often dominated by *Lampranthus otzenianus* and *Psilocaulon foliosum*. In other places the heuweltjies are turned into bare circles by overgrazing, often with *Oncosiphon suffruticosum* as the only species occurring here. The heuweltjies are often the home of burrowing animals like



Figure 5.36 SKn 4 Namaqualand Heuweltjieveld: Ancient termitaria (heuweltjies) east of Wallekraal in Namaqualand (Northern Cape).

erdvark or antbear (*Orycteropus afer*), porcupine (*Hystrix africae-australis*) and Brants' whistling rat (*Parotomys brantsii*). Species turnover is considerable within this vegetation unit due to its large north-south extent. Some of the patches are floristically related to the SKr 13 Southern Richtersveld Scorpionstailveld.

SKn 5 Platbakkies Succulent Shrubland

VT 33 Namaqualand Broken Veld (61%) (Acocks 1953). LR 49 Bushmanland Nama Karoo (56%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Western piedmonts at boundaries between Namaqualand Hardeveld and Bushmanland between Gamoep in the north and Banke in the south. Altitude 820–1 140 m (most of the area 920–1 120 m).

Vegetation & Landscape Features Mainly plains, but also low koppies and hills dominated by shrubland vegetation (especially on koppies), low succulent shrub-dominated (e.g. *Ruschia robusta*) vegetation on loamy colluvial and rocky soil, and grass-dominated (e.g. *Stipagrostis brevifolia*) vegetation on sandy soil accumulations in valleys. Within this matrix are gravel plains of various types supporting vegetation characterised by the dominance of dwarf leaf-succulents (Aizoaceae and Crassulaceae) generally restricted to these types of habitats. The shrub component of the vegetation is phenologically adjusted to a winter-rainfall growth pattern, but the C₄ grass component of the vegetation responds well to the late summer-rainfall events.

Geology & Soils Gneiss of the Little Namaqualand Suite, and Bushmanland Group metasediments and metavolcanics with shallow unstructured soils predominate in the west. In the east the landscape is covered by sandy Bushmanland soils overlying calcrete. A unique feature in this vegetation type is the presence of silcrete caps (Bitterfontein Formation) along the edge of the erosion front between the Bushmanland surface and the underlying metamorphic rocks—these are associated with deeply weathered underlying gneiss giving rise to quartz pebble-covered gravel plains. In the east and north, another type of gravel plain is formed by the presence of palaeo-river terraces characterised by the presence of rounded rocks and

boulders and calcrete nodules. Northwest and west of Gamoep, and in the south around Banke, the gravel plains comprise quartz pebble lags over kaolinised gneiss, often associated with eroding silcrete outcrops. The dominant land type is Ag (78%), while the rest of the area is classified as Ae land type.

Climate Seasonal winter-rainfall climate with shallow peak from May to August. About a third of the annual rainfall (MAP slightly above 100 mm, range 80–120 mm) arrives as late summer thunderstorms. Overall MAT is about 16°C, mean maximum and minimum monthly temperatures in Platbakkies are 37°C and –3°C for January and July, respectively. Incidence of frost is between 20 and 40 days per year. See also climate diagram for SKn 5 Platbakkies Succulent Shrubland (Figure 5.29).

Important Taxon (Gravel patches) Succulent Shrubs: *Aloinopsis luehmannii*, *Euphorbia gentilis* subsp. *gentilis*, *Ihlenfeldtia excavata*, *Ruschia divaricata*, *Tylecodon reticulatus*. Low Shrub: *Wahlenbergia oxyphylla*. Geophytic Herb: *Ornithogalum gethyloides*. Succulent Herbs: *Brownanthus vaginatus*, *Conophytum pellucidum* subsp. *cupreatum*, *Crassula columnaris* subsp. *prolifera*, *Lithops villetii* subsp. *villetii*.

Biogeographically Important Taxon (Namaqualand endemic) Succulent Shrub: *Cheiridopsis meyeri*.

Endemic Taxa (Gravel patches) Succulent Shrub: *Vanheerdea primosii*. Low Shrub: *Nenax namaquensis*. Succulent Herbs: *Conophytum arturolofago*, *C. caroli*, *C. jarmilae*, *C. pubicalyx*, *C. reconditum* subsp. *reconditum*, *C. tomasi*, *Lithops naureniae*.

Conservation Target 28%. Overgrazing on communal land is a serious threat to this vegetation of which none is conserved in statutory conservation areas so far. Scattered alien *Prosopis* (on about 2–3% of the area) might also be seen as a conservation challenge. Erosion is low (70%) and very low (30%).

Remark The matrix vegetation on rocky and colluvial substrates reminds one of the SKn 1 Namaqualand Klipkoppe Shrubland, and that on sandy substrates is similar to NKb 3 Bushmanland Arid Grassland. The unique component of the vegetation occurs in special habitats comprising the quartz, palaeo-river terrace or gneiss grit-pan gravel patches and silcrete outcrops. The vegetation of these edaphically arid habitats is structurally typical of such habitats in the Succulent Karoo being dominated by low succulent plants. The recent discovery of several new species of *Conophytum* in this area indicates that there is still much to be discovered here. The delimitation of this vegetation type is primarily to draw attention to the presence of the gravel patches. These are generally too small and scattered throughout the landscape to map as a single discrete vegetation unit.

References Petersen (2003), P.G. Desmet (unpublished data).

SKn 6 Kamiesberg Mountains Shrubland

VT 33 Namaqualand Broken Veld (39%), VT 43 Mountain Renosterbosveld (29%) (Acocks 1953). LR 56 Upland Succulent Karoo (36%), LR 59 North-western Mountain Renosterveld (29%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Kamiesberg Mountains (central Nama-

qualand) from about 30 km north of Kamieskroon southwards almost to Kliprand as well as on western slopes of the northern Bokkeveld Escarpment in the Vanrhynsdorp-Nieuwoudtville area. Most of the area at altitudes of 800–1 160 m.

Vegetation & Landscape Features Steep, mainly south- to east-facing upper (high-altitude) slopes of large granite domes exposed to increased topographic precipitation as well as in deep gullies in the Hardeveld, supporting tall shrubland (canopy cover 45–65%) dominated by a mixture of nonsucculent (*Eriocephalus*, *Euclea*, *Euryops*, *Dodonaea*, *Hermannia*, *Lebeckia*, *Melianthus*, *Pteronia*, *Rhus*, *Salvia*, *Wiborgia*) and succulent (*Didelta*, *Euphorbia*, *Othonna*, *Ruschia*, *Tylecodon*, *Zygophyllum*) shrubs.

Geology & Soils Bitterfontein quartzites of the Bushmanland Group and the Kamieskroon gneiss occur in the north, giving rise to moderate to steep rocky slopes. Rock sizes vary from medium to large, with flat to gentle rock sheets as well as rock domes. In the south, the clastic sediments of the Knersvlakte Subgroup of the Vanrhynsdorp Group predominate. Most of the soils are yellow-brown to brown, loamy and sandy. Ib land type dominates the area (70%), while the rest is characterised by Ic land type.

Climate Winter-rainfall area with MAP of 230 mm. Almost all the rainfall occurs from May to August, while rain is very rare between December and February. Dew is experienced throughout the winter. Frost occurs for about 13 days of the year and the lowest temperatures in the winter are 5–10°C. The highest temperatures in summer are around 30°C. See also climate diagram for SKn 6 Kamiesberg Mountains Shrubland (Figure 5.29).

Important Taxa Small Tree: *Ficus cordata*. Tall Shrubs: *Dodonaea viscosa* var. *angustifolia* (d), *Euclea tomentosa* (d), *Montinia caryophyllacea* (d), *Olea europaea* subsp. *africana* (d), *Rhus undulata* (d), *Anisodontea triloba*, *Erythrophysa alata*, *Nylandtia spinosa*, *Rhus incisa*. Succulent Shrubs: *Didelta spinosa* (d), *Tylecodon paniculatus* (d), *Crassula dejecta*, *Euphorbia decussata*, *Leipoldtia schultzei*, *Othonna cylindrica*, *O. furcata*, *Ruschia multiflora*, *R. viridifolia*, *Senecio junceus*, *Tetragonia fruticosa*, *Zygophyllum foetidum*, *Z. morgsana*. Low Shrubs: *Berkheya fruticosa* (d), *Lebeckia sericea* (d), *Anthospermum*



Figure 5.37 SKn 6 Kamiesberg Mountains Shrubland: *Didelta spinosa*-dominated shrubland with *Ursinia cakilefolia* fields in the background in the former Skilpad Flower Reserve, today part of the Namaqua National Park (near Kamieskroon, Northern Cape).

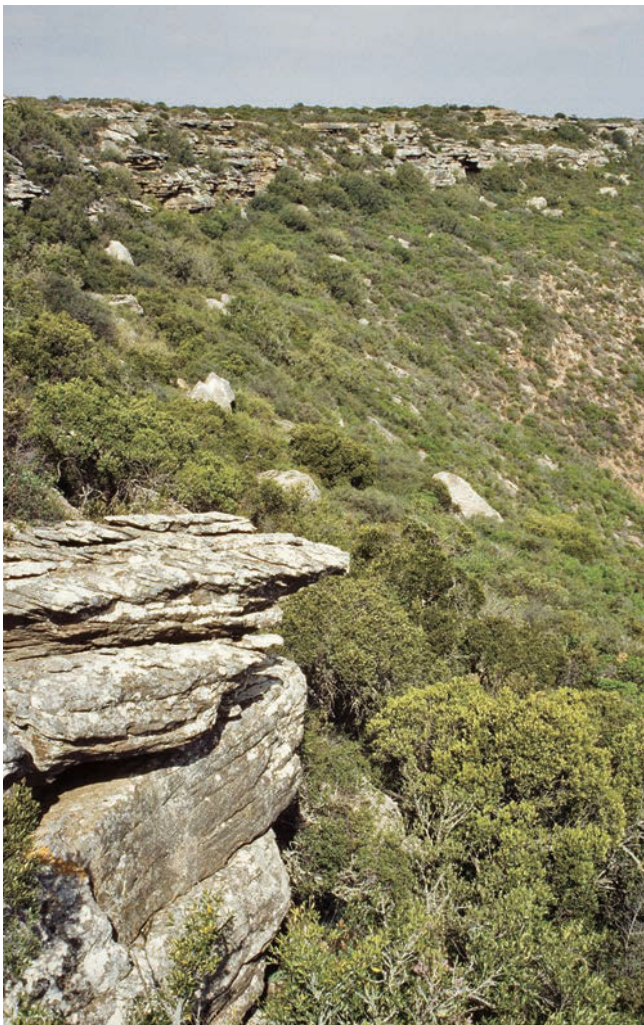


Figure 5.38 SKn 6 Kamiesberg Mountains Shrubland: Southern variation of the mesic (tall) shrubland with *Euclea*, *Diospyros* and *Rhus* dominant on the subescarpment rim of the Noord Bokkeveld on the Farm Perdekraal, north of Nieuwoudtville (border of the Northern Cape and Western Cape Provinces).

aethiopicum, *Asparagus capensis* var. *capensis*, *Ballota africana*, *Chrysocoma ciliata*, *Clutia imbricata*, *Eriocephalus brevifolius*, *E. microcephalus*, *Euryops tenuissimus*, *Helichrysum scabrum*, *Hermannia cuneifolia*, *H. disermifolia*, *Indigofera pungens*, *Maytenus oleoides*, *Pegolettia retrofracta*, *Pelargonium antidysentericum*, *P. praemorsum*, *Pentzia incana*, *Pharnaceum albens*, *Rhus horrida*, *Selago divaricata*, *Senecio cotyledonis*, *Wahlenbergia thunbergiana*, *Wiborgia mucronata*. Woody Succulent Climber: *Sarcostemma viminale*. Woody Climber: *Microloma sagittatum*. Herbaceous Parasitic Climber: *Cassytha ciliolata*. Herbs: *Ursinia cakilefolia* (d), *Amellus alternifolius*, *Anchusa capensis*, *Galium tomentosum*, *Heliophila crithmifolia*, *Hemimeris racemosa*, *Jamesbrittenia glutinosa*, *Nemesia affinis*, *Plantago cafra*, *Rhynchopsidium pumilum*, *Senecio sisymbriifolius*, *Silene undulata*, *Sutera foetida*, *Trichogyne paronychioides*, *Ursinia anthemoides* subsp. *anthemoides*. Geophytic Herbs: *Asplenium cordatum*, *Cyanella hyacinthoides*, *Oxalis obtusa*, *Spiloxene scullyi*. Succulent Herb: *Crassula muscosa*. Graminoids: *Chaetobromus involucreatus* subsp. *dregeanus*, *Cymbopogon pospischilii*, *Ehrharta barbinodis*, *E. calycina*, *E. longiflora*, *Ficinia nigrescens*, *Fingerhuthia africana*, *Schismus inermis*.

Biogeographically Important Taxa (^{NQ}Namaqualand endemic, ^KKamiesberg endemic, ^NNorthern distribution limit, ^FFynbos ele-

ment) Low Shrubs: *Antithrixia flavicoma*^K, *Diosma acmaeophylla*^F, *Elytropappus rhinocerotis*^F, *Felicia diffusa* subsp. *khamiesbergensis*^K, *Lobostemon argenteus*^F, *L. glaucophyllum*^F, *Melianthus pectinatus*^{NQ}, *Muraltia rigida*^K, *Oftia revoluta*^{NQ}, *Pteronia leptospermoides*^{NQ}, *Salvia dentata*^{NQ}, *Stachys flavescens*^{NQ}. Herbs: *Gorteria diffusa* subsp. *calendulacea*^{NQ}, *Lotononis acutiflora*^K. *Nemesia gracilis*^N. Geophytic Herbs: *Babiana dregei*^{NQ}, *Disa macrostachya*^K. Succulent Herb: *Cleretum papulosum* subsp. *schlechteri*^{NQ}. Graminoids: *Aristida dasydesmis*^{NQ}, *Ischyrolepis gaudichaudiana*^F, *Pentaschistis patula*^F, *Tribolium echinatum*^F.

Endemic Taxon Low Shrub: *Muraltia namaquensis*.

Conservation Least threatened and only about 2% statutorily conserved in Namaqua National Park and small patches also in Goegap and Oorlogskloof Nature Reserves. Target 28%. Transformation by cultivation is of no importance due to poor accessibility or overall unsuitability of the habitats to agriculture. Erosion is moderate (50%), low (30%) and high in places (20%), mainly due to steep terrain.

Remark The southernmost part of this vegetation is a narrow subkrantz strip on west-facing (fog-catching) slopes of the northern Bokkeveld Escarpment (between the Farms Perdekraal north of Nieuwoudtville and Waterval east of Vanrhynsdorp). Unlike in the central Namaqualand, where the major patches of SKn 6 Kamiesberg Mountains Shrubland occur on granite and gneiss, the Noord Bokkeveld patch is limited to boulder fields and scree built of hard Nardouw sandstones. *Rhus undulata*, *Didelta spinosa*, *Euclea tomentosa* and other tall shrubs dominate this shrubland, squeezed between renosterveld (on the upper boundary) and low Succulent Karoo shrublands (on the lower boundary). Despite some structural characteristics, floristic composition as well as its position in vegetation complexes, there are a number of idiosyncrasies suggesting that the Noord Bokkeveld patch of the SKn 6 Kamiesberg Mountains Shrubland is a vegetation unit in its own right.

References Le Roux (1984), Theron et al. (1993), Van Rooyen (2002).

Namaqualand Sandveld

SKs 1 Richtersveld Coastal Duneveld

VT 34 Strandveld of West Coast (99%) (Acocks 1953). LR 55 Strandveld Succulent Karoo (85%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Broad belt of 1–12 km along Atlantic Ocean coast from a point between the Boegoe Twins and Alexander Bay to about halfway between Port Nolloth and Kleinsee. The north-south extension is 104 km. Altitude 0–200 m.

Vegetation & Landscape Features Generally flat with some large, gently rolling hills. Only the Boegoe Twins south of Alexander Bay form steeper rocky slopes. Relatively homogeneous vegetation covers fairly stable sand sheets. Depth of sand and soil crust define character of habitat types. On the active dunes, depending on the aspects of the slopes and on the phase of deflation and sedimentation, different plant communities occur. *Stoeberia utilis* often grows on the dune crests, while *S. beetzii* is found more on stabilised sand sheets. *Lampranthus hoerleinianus* and *Cladoraphis cyperoides* are pioneers settling in habitats created by recent sand deflation.

Geology & Soils Wind-blown white sands of coastal origin overlying rocks belonging to the Holgat and Grootderm Formations of the Gariep Supergroup. Especially around Port

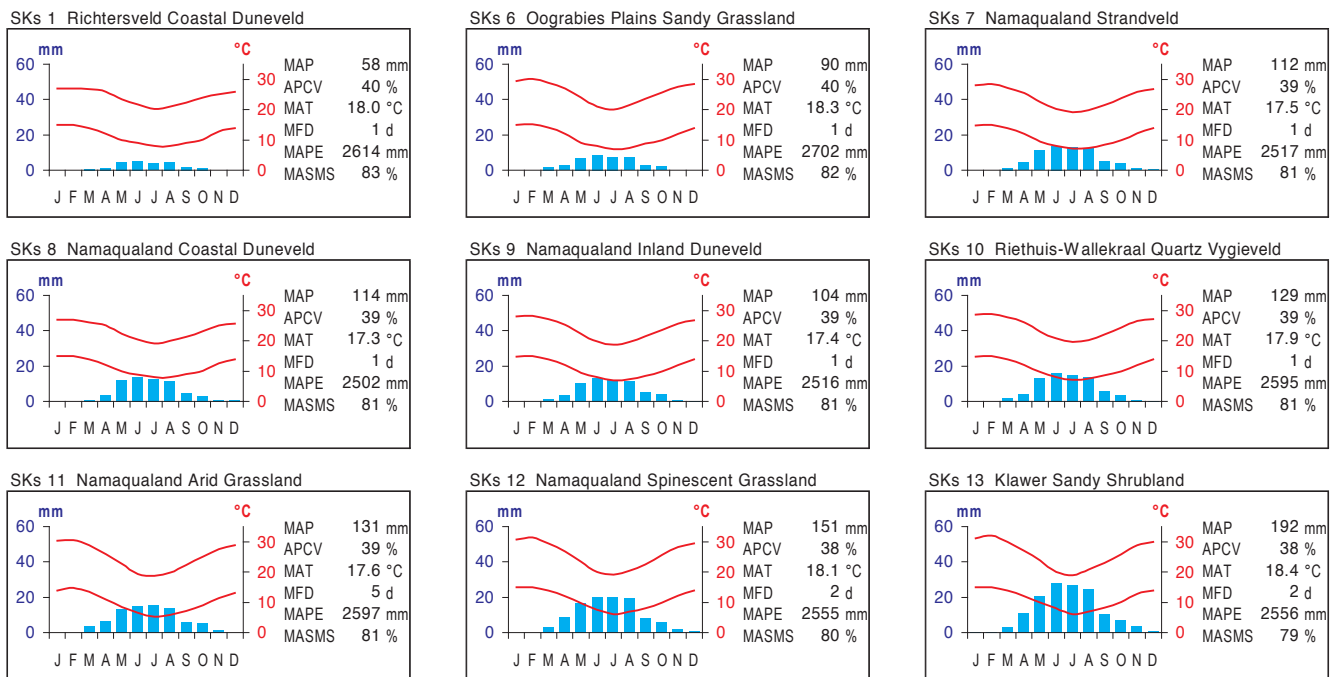


Figure 5.39 Climate diagrams of selected Namaqualand Sandveld Bioregion units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).



Figure 5.40 SKs 1 Richtersveld Coastal Duneveld: *Othonna sedifolia* community on deep white sand dunes (near Holgat River on the road between Port Nolloth and Alexander Bay).

Nolloth and north of the Holgat River mouth active dune fields can be found. The dominant land type is Ha.

Climate Extreme wind speeds and sand blasting from the south. High storm frequency. MAP is 50–80 mm, with winter rains clearly predominant. Medium to high frequency of sea fog. No incidence of frost. See also climate diagram for SKs 1 Richtersveld Coastal Duneveld (Figure 5.39).

Important Taxa Succulent Shrubs: *Cephalophyllum ebracteatum* (d), *Euphorbia mauritanica* (d), *Othonna sedifolia* (d), *Salsola nollothensis* (d), *Zygophyllum morgsana* (d), *Aloe microstigma*, *Amphibolia rupis-arcuatae*, *Didelta carnosa* var. *tomentosa*, *Drosanthemum luederitzii*, *Euphorbia burmannii*, *E. tuberculata* var. *macowani*, *Hypertelis angrae-pequenae*, *Jordaniella cuprea*, *J. spongiosa*, *Lampranthus hoerleinianus*, *Lycium tetrandrum*, *Manochlamys albicans*, *Salsola tuberculata*, *Senecio radicans*, *Stoeberia utilis*, *Tylecodon schaeferianus*, *Zygophyllum clavatum*, *Z. cordifolium*. Low Shrubs: *Asparagus capensis* var. *litoralis* (d), *Atriplex vestita* var. *appendiculata*, *Heliophila carnosa*, *Jamesbrittenia fruticosa*, *Pteronia glabrata*, *P. onobromoides*. Woody Succulent Climber: *Pelargonium fulgidum*. Herb: *Grielum grandiflorum*. Geophytic Herb: *Babiana thunbergii*. Succulent Herbs: *Aloe arenicola*, *Fenestraria rhopalophylla*, *Psilocaulon dinteri*. Parasitic Herb: *Harveya squamosa*. Graminoids: *Cladoraphis cyperoides* (d), *Chaetobromus involu-cratus* subsp. *dregeanus*, *Stipagrostis ciliata*.

Biogeographically Important Taxa (^{NQ}Namaqualand endemic, ^RRichtersveld endemic) Succulent Shrubs: *Stoeberia beetzii*^{NQ} (d), *Amphibolia succulenta*^R, *Arctotis scullyi*^{NQ}.

Endemic Taxa Succulent Shrub: *Crassula brevifolia* subsp. *psammophila*. Low Shrub: *Bassia dinteri*.

Conservation Least threatened. Target 26%. None conserved in statutory conservation areas. Almost 10% transformed mainly by diamond mining.

Remark *Acanthosicyos horridus*, a typical Namib Desert element, occurs only on the mobile dunes northeast of Port Nolloth. The two rocky outcrops of the Boegoe Twins form two fog oases within the vegetation unit housing *Tylecodon schaeferianus*, *Senecio phonolithicus*, *Jordaaniella spongiosa* and *Cephalophyllum ebracteatum*. *Aloe framesii*, *Jordaaniella cuprea* and *J. spongiosa* are regional endemics shared with the neighbouring coastal units.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Van Wyk & Smith (2001).

SKs 2 Northern Richtersveld Yellow Duneveld

VT 31 Succulent Karoo (74%) (Acocks 1953). LR 57 Lowland Succulent Karoo (92%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Richtersveld, band some 5–25 km wide east of the coastline, stretching over 45 km from south of Brandkaros in the north to the Holgat River in the south. The altitude of the unit varies from about 50–300 m.

Vegetation & Landscape Features Most of the area is covered by flat sand shields, often interrupted by dunes, which normally form flat whale-backs. Steep dune crests and dune valleys form only rarely—here the vegetation mirrors different topographic units: the dune tops are covered with *Stoeberia utilis*, while the interdune valleys are dominated by *Brownanthus pseudoschlichtianus*, *B. arenosus*, *Cheiridopsis robusta* and *Cephalophyllum ebracteatum*.

Geology & Soils Mainly yellow, wind-blown sands of coastal origin, older than the white dune sands found further west—an ancient mobile dune field, which became stabilised as a consequence of improving climate conditions and increase of vegetation cover after the last glaciation. The structure of south-north-oriented dune ridges and accompanying valley systems is still visible, but the local processes of erosion and sedimentation have resulted in formation of relatively saline valleys with silty or

loamy soil. Currently wind erosion is active only to a very limited extent. Ah is the dominant land type, while Ai land type is of subordinate importance.

Climate MAP is 50–70 mm with mainly winter rainfall. High frequency of coastal fog. Extreme wind speeds and sand blasting from the south. Storms occur frequently. Frost is very rare.

Important Taxa Succulent Shrubs: *Euphorbia burmannii* (d), *E. chersina* (d), *E. mauritanica* (d), *Othonna cylindrica* (d), *Aridaria serotina*, *Cephalophyllum ebracteatum*, *Cheiridopsis robusta*, *Didelta carnosus* var. *tomentosa*, *Hypertelis salsoloides*, *Jordaaniella cuprea*, *Lampranthus hoerleianus*, *Salsola tuberculata*, *Zygophyllum morgsana*. Low Shrubs: *Asparagus capensis* var. *capensis*, *Lebeckia cinerea*, *L. multiflora*. Herbs: *Grielum humifusum*, *Oncosiphon piluliferum*. Geophytic Herb: *Trachyandra falcata*. Succulent Herb: *Brownanthus arenosus* (d). Graminoid: *Cladoraphis cyperoides* (d).

Biogeographically Important Taxa (^{NQ}Namaqualand endemic, ^GGariep endemic, ^RRichtersveld endemic) Succulent Shrubs: *Amphibolia succulenta*^R, *Eberlanzia sedoides*^G, *Phyllobolus decurvatus*^{NQ}. Succulent Herbs: *Brownanthus pseudoschlichtianus*^G, *Mesembryanthemum pellitum*^G.

Conservation Least threatened. Target 26%. None conserved in statutory conservation areas. Slightly transformed by mining. At present no major threat to the unit has been identified.

Remark The unit is characterised by high beta diversity due to dune structures, especially high differences between mobile and fixed sand areas (the latter are partly covered by heuweltjies). *Jordaaniella cuprea* and *J. spongiosa* are regional endemics shared with the neighbouring coastal units.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Oguz (2000), Stöcker (2000), Van Wyk & Smith (2001), Nußbaum (2003), Oguz et al. (2004).

SKs 3 Southern Richtersveld Yellow Duneveld

VT 34 Strandveld of West Coast (84%) (Acocks 1953). LR 57 Lowland Succulent Karoo (53%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Richtersveld—a strip running parallel to, and roughly 5–12 km from, the coastline from the Holgat River in the north to almost level with Port Nolloth in the south. A small isolated patch also found east of Vyftienmyl se Berge. The altitude varies from 50–300 m.

Vegetation & Landscape Features Flat to undulating sand shields, in places also with dunes forming flat whale-backs. The appearance of vegetation in this unit is similar to that of the SKs 2 Northern Richtersveld Yellow Duneveld, but the southern unit is much denser due to higher moisture levels, and it is also more species-rich.

Geology & Soils Yellow wind-blown sands, mainly of marine origin. Soils vary as to the soil depth covering various duricrusts, mainly calcrete. Ah is the dominant land type, while Ha land type is also present.



N. Jürgens

Figure 5.41 SKs 2 Northern Richtersveld Yellow Duneveld: Richtersveld Sandveld with *Brownanthus pseudoschlichtianus* and *Cladoraphis cyperoides*.



L. Mucina

Figure 5.42 SKs 3 Southern Richtersveld Yellow Duneveld: Succulent-rich strandveld vegetation on stabilised dunes northwest of Port Nolloth (Richtersveld).

Climate MAP is 55–80 mm of winter rainfall. Low to medium average maximum temperatures. Wind and sand blasting from the south. Coastal fog also occurs. No incidence of frost.

Important Taxa Succulent Shrubs: *Euphorbia burmannii* (d), *E. chersina* (d), *E. mauritanica* (d), *Othonna cylindrica* (d), *Zygophyllum morgsana* (d), *Aloe microstigma*, *Aridaria serotina*, *Cheiridopsis robusta*, *Didelta carnosus* var. *tomentosa*, *Euphorbia decussata*, *E. ephedroides* var. *ephedroides*, *Jordaaniella cuprea*, *J. spongiosa*, *Manochlamys albicans*, *Salsola tuberculata*, *Tylecodon paniculatus*. Low Shrubs: *Tripteris oppositifolia* (d), *Asparagus capensis* var. *capensis*, *Atriplex vestita* var. *appendiculata*, *Pteronia glabrata*, *P. onobromoides*. Herbs: *Capnophyllum africanum*, *Grielum humifusum*. Geophytic Herb: *Trachyandra falcata*. Succulent Herbs: *Aloe arenicola*, *Psilocaulon dinteri*. Graminoids: *Chaetobromus involucreatus* subsp. *dregeanus* (d), *Cladoraphis cyperoides* (d), *Stipagrostis ciliata* (d).

Biogeographically Important Taxa (^{NQ}Namaqualand endemic, ^GGariep endemic, ^RRichtersveld endemic) Succulent Shrubs: *Stoeberia beetzii*^{NQ} (d), *Amphibolia succulenta*^R, *Arctotis scullyi*^{NQ}. Succulent Herb: *Mesembryanthemum pellitum*^G.

Conservation Least threatened. Target 26%. None conserved in statutory conservation areas. More than 3% transformed mostly by mining, especially in the southern and western parts.

Remark *Jordaaniella cuprea* and *J. spongiosa* are regional endemics shared with the neighbouring coastal units.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Van Wyk & Smith (2001), Nußbaum (2003).

SKs 4 Richtersveld Sandy Coastal Scorpionstailveld

VT 31 Succulent Karoo (100%) (Acocks 1953). LR 57 Lowland Succulent Karoo (100%) (Low & Rebelo 1996).

Distribution Northern Cape Province: A fragmented band running parallel to the coast 8 to 28 km inland, from a northern boundary at the southwestern corner of the Annisvlakte

to the Holgat River, and then for some 30 km southwards. Further this unit is found from just north of the road between Alexander Bay and Oograbies in a southern direction halfway between Port Nolloth and Kleinsee. The unit covers 103 km along the north-south axis. Altitude ranging from 100–400 m.

Vegetation & Landscape Features

Slightly flatter compared to the SKr 7 Northern Richtersveld Scorpionstailveld. The boundaries of this unit are clearly visible on satellite and aerial images, characterised by a darker colour, which is created by the intense biological soil surface crusts. Within this unit, habitat variability is mainly controlled by soil types and age of vegetation, which again are controlled by the proportion of wind-blown sands, and partly also by grazing and mining. The matrix of the unit is formed by more loamy sands with old and stable vegetation, often dominated by *Brownanthus pseudoschlichtianus* and mixed with co-dominant species like *Stoeberia beetzii*, *Othonna cylindrica*,

Lebeckia multiflora, *Cephalophyllum ebracteatum* and *Phyllobolus decurvatus*.

Geology & Soils Sandy loams, partly covered by yellow and red wind-blown sands, probably of coastal origin. This unit clearly shows an increase in the silt texture class (ca. 20%), which is linked to an increase in pH, compared to the neighbouring units. Within this unit, the surface cover of biological soil crusts at the soil surface reaches maximum values for the Richtersveld coastal plain (80–90%). The hypothesis is proposed that this unit is controlled by maximum silt deposition (desert margin loess) and minimum disturbance, compared to the neighbouring units of the coastal plain. Ah land type is absolutely dominant.

Climate MAP 60–100 mm, with mainly winter rainfall. Coastal fog also occurs. High wind speeds occur, but are less frequent and weaker than in the SKs 2 Northern Richtersveld Yellow Duneveld. Frost is very rare.

Important Taxa Succulent Shrubs: *Cephalophyllum ebracteatum* (d), *Othonna cylindrica* (d), *Aridaria serotina*, *Cheiridopsis robusta*, *Euphorbia burmannii*, *E. chersina*, *E. mauritanica*, *Hypertelis salsoloides*, *Zygophyllum morgsana*. Low Shrubs: *Lebeckia multiflora* (d), *Asparagus capensis* var. *capensis*. Herb: *Oncosiphon piluliferum*. Geophytic Herb: *Trachyandra falcata*. Graminoid: *Cladoraphis cyperoides* (d).

Biogeographically Important Taxa (^{NQ}Namaqualand endemic, ^GGariep endemic) Succulent Shrubs: *Phyllobolus decurvatus*^{NQ} (d), *Stoeberia beetzii*^{NQ} (d), *Eberlanzia ebracteata*^G. Succulent Herbs: *Brownanthus pseudoschlichtianus*^G (d), *Mesembryanthemum pellitum*^{NQ}.

Conservation Least threatened. Target 26%. None conserved in statutory conservation areas. Very little of the area has been transformed. There is no information available allowing for an estimation of the past and present role of small stock grazing.

Remark Where sand layers occur, larger islands of the *Othonna cylindrica* are found (Jürgens 2004).

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Oguz (2000), Van Wyk & Smith (2001), Nußbaum (2003), Oguz et al. (2004).

SKs 5 Richtersveld Red Duneveld

VT 31 Succulent Karoo (96%) (Acocks 1953). LR 57 Lowland Succulent Karoo (85%) (Low & Rebelo 1996).

Distribution Northern Cape Province: A band running parallel to the coastline, east of the SKs 4 Richtersveld Sandy Coastal Scorpionstailveld, and forming the eastern margin of the Richtersveld Sandveld, running from the Annisvlakte in the north southwards and reaching its southern limit north-west of the Oograbies Mountains (east of Port Nolloth). Usually not closer than 12–26 km from the coast. Altitude varies from 200–500 m.

Vegetation & Landscape Features High dune aggregates (oriented in a north-south direction), which again carry smaller dunes (mainly west-east-orientated). Habitat variability is mainly controlled by exposure and by dynamics of sand movement as well as by age of subsequent succession phases of vegetation. Large parts of the red dunes are dominated by tall grasses and vegetation of tall shrubs with dense *Lebeckia cinerea*-dominated thickets over some large areas. Otherwise *Cladoraphis spinosa*, *Brownanthus arenosus*, *Asparagus capensis* and *Stipagrostis ciliata* are dominant and are associated with the relatively high water input caused by orogenic rains of the nearby mountain ranges in conjunction with the coarse soil texture that supports effective water storage. In disturbed places, there is often a high cover of *Conicosia pugioniformis*, *Arctotis fastuosa* and *Foveolina dichotoma*. The slopes exposed to the west show a strong admixture of taxa of the SKs 2 Northern Richtersveld Yellow Duneveld (e.g. *Stoeberia beetzii* and *S. utilis*), and in some parts *Stipagrostis lutescens* is an important element.

Geology & Soils Dark red sands with their thick iron coating are interpreted as old sands, which have experienced a longer period without major mechanical or chemical disturbance. The red dunes show the lowest admixture of silt and clay, compared to the other dune types in the Richtersveld. The pH is around 6.5 as compared to the average of 8.0 to 8.5 found in the neighbouring units. Salt content and electrical conductivity are the lowest (10 μ S), hence 10 to 100 times lower than elsewhere in the region. The land types Af and Ah are almost equally important, while Ae is less important.



Figure 5.43 SKs 5 Richtersveld Red Duneveld: The northernmost reaches of the red duneveld with *Euphorbia gummifera*. The grass in the foreground is *Stipagrostis capensis*, while the larger tufts further back belong to *S. lutescens*.

Climate Winter-rainfall with estimated MAP 50–100 mm. Maximum temperatures are lower than further inland. Coastal fog also occurs, and frost is very rare.

Important Taxa Succulent Shrubs: *Euphorbia ephedroides* var. *ephedroides* (d), *Othonna cylindrica* (d), *Salsola tuberculata*. Low Shrubs: *Asparagus capensis* var. *capensis* (d), *Lebeckia multiflora* (d), *Galenia crystallina*, *Lebeckia cinerea*. Herbs: *Arctotis fastuosa*, *Foveolina dichotoma*. Succulent Herbs: *Brownanthus arenosus* (d), *Conicosia elongata*, *C. pugioniformis* subsp. *alborosea*. Graminoids: *Cladoraphis spinosa* (d), *Stipagrostis ciliata* (d), *S. lutescens*.

Biogeographically Important Taxa (^{NQ}Namaqualand endemic, ^GGariep endemic) Succulent Shrubs: *Euphorbia dregeana*^G, *Stoeberia beetzii*^{NQ}.

Conservation Least threatened. Target 26%. None conserved in statutory conservation areas. There is no information available on which to base an estimation of the past and present role of small stock grazing.

Remark An important difference from all other units of the coastal Sandveld (e.g. SKs 1 Richtersveld Coastal Duneveld and SKs 2 Northern Richtersveld Yellow Duneveld) is its low salinity.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Oguz (2000), Stöcker (2000), Oguz et al. (2004).

SKs 6 Oograbies Plains Sandy Grassland

VT 31 Succulent Karoo (100%) (Acocks 1953). LR 57 Lowland Succulent Karoo (100%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Richtersveld—central and lower portion of the large plains east of Vyftienmyl se Berge, starting at about ca. 25 km east of Port Nolloth and continuing northeastwards for another 25 km. At relatively narrow range of altitudes from 180–300 m.

Vegetation & Landscape Features Flat or slightly undulating landscape with some dune ridges. Main habitats are dune formations and flat sand sheets. The main vegetation feature is the relatively homogeneous grassy shrubland or shrubby spinescent grassland dominated by *Cladoraphis spinosa* and *Stipagrostis ciliata*. In different seasons and years (probably as a consequence of rainfall availability) the biomass of this unit can vary and show dominance of either grasses or leaf-succulent chamaephytes and annuals.

Geology & Soils Stabilised, deep, red, aeolian sands forming fossil dunes and overlying gneiss of the Namaqualand Metamorphic Complex forming active dunes in places. Ai is the dominant land type, with Ae land type playing a minor role.

Climate MAP estimated to range from 80–120 mm, with winter rainfall clearly dominant. Frequent fog occurrence. Incidence of frost is very rare. See also climate diagram for SKs 6 Oograbies Plains Sandy Grassland (Figure 5.39).

Important Taxa Succulent Shrubs: *Othonna cylindrica* (d), *Zygophyllum morganii*. Low Shrubs: *Hermannia paucifolia*, *Lebeckia cinerea*, *L. mul-*

N. Jürgens



M. Ploosier

Figure 5.44 SKs 6 Oograbies Plains Sandy Grassland: *Cladoraphis spinosa* with *Salsola* shrubs and fragrant *Bulbine frutescens* in spring on the Oograbies Plains, east of Port Nolloth (southern Richtersveld, Northern Cape).

tiflora, *Psilocaulon subnodosum*. Herbs: *Coelanthum grandiflorum*, *Lyperia tristis*. Geophytic Herbs: *Bulbine frutescens* (d), *Gethyllis lanuginosa*, *Massonia depressa*, *Trachyandra falcata*. Graminoids: *Cladoraphis spinosa* (d), *Stipagrostis ciliata* (d).

Biogeographically Important Taxon (Namaqualand endemic)
Herb: *Trichogyne lerouxiae*.

Conservation Least threatened. Target 26%. None conserved in statutory conservation areas and little transformed. Based on the available data, no special conservation status is proposed from a botanical point of view.

Remark In places, large mobile dunes with higher water storage capacity support larger shrubs and relict populations of the tree *Parkinsonia africana*. The northernmost populations of a number of species typical of the dune fields of the West Coast are found in this unit.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997).

SKs 7 Namaqualand Strandveld

VT 31 Succulent Karoo (67%) (Acocks 1953).
LR 57 Lowland Succulent Karoo (70%) (Low & Rebelo 1996).

Distribution Northern and Western Cape Provinces: Namaqualand Strandveld—from Gemboksvlei (at southern foothills of the Vyftienmyl se Berge in southern Richtersveld as far south as Donkins Bay (south of Doringbaai). Especially in the northern region (plains north and south of Buffels River) this unit penetrates deeply inland (40 km in places). Most of the area is situated deep inland (isolated from the coast by a belt of SKs 8 Namaqualand Coastal Duneveld) and approaching the



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Figure 5.45 SKs 7 Namaqualand Strandveld: Isolated granite outcrops in the Molyneux Reserve at Kleinzee (Namaqualand coast) with sparse succulent shrubland (with prominent *Aloe framesii*) housing a number of local endemics and species still pending description.

coast only near the river mouths of the Buffels River, Swartlintjies River, Spoeg River, Bitter River and Groen River. South of Abraham Villiersbaai (south of Groen River mouth) Namaqualand Strandveld descends to the coast and continues as an unequally broad band as far south as Donkins Bay (north of Lamberts Bay). In the south it also reaches deeply inland along the Groen and Swartdoorn Rivers as well as along the lower stretches of the Olifants River. Altitude 20–380 m.

Vegetation & Landscape Features

Flat to slightly undulating landscape of coastal penneplain. Vegetation is low species-rich shrubland dominated by a plethora of erect and creeping succulent shrubs (*Cephalophyllum*, *Didelta*, *Othonna*, *Ruschia*, *Tetragonia*, *Tripteris*, *Zygophyllum*) as well as nonsucculent shrubs (*Eriocephalus*, *Lebeckia*, *Pteronia*, *Salvia*). Annual mixed with perennial flora can present spectacular displays in wet years.

Geology & Soils Quaternary stabilised aeolian, deep, red or yellowish red, stable dunes and deep sand overlying marine sediments and granite gneisses. Sometimes weakly defined scattered heuweltjies are found further away from the sea. Unstable white sand dune plumes originate from the river mouths and extend north- and northeastwards up to 25 km inland. Dunes become slightly more stable north of Kleinzee. The area is a combination of Ah, Ae, Af, Ai and Ag land types.

Climate Arid, winter-rainfall area with MAP of 112 mm. Almost all the rainfall occurs from May to August and almost always no rainfall in December and February. Frost is a rare event. Lowest temperatures in winter are 8–10°C and the highest temperatures in the summer just below 30°C. See also climate diagram for SKs 7 Namaqualand Strandveld (Figure 5.39).



Figure 5.46 SKs 7 Namaqualand Strandveld: Well-developed coastal shrubland south of Doringbaai (southern Namaqualand), with bushes of an undescribed species of *Afromilon* (Plumbaginaceae).

Important Taxa Succulent Shrubs: *Didelta carnos* var. *carnos* (d), *Euphorbia burmannii* (d), *Othonna cylindrica* (d), *Ruschia brevibracteata* (d), *Salsola nollothensis* (d), *Tetragonia fruticosa* (d), *T. spicata* (d), *Zygophyllum morgsana* (d), *Adromischus mammillaris*, *Aridaria noctiflora* subsp. *noctiflora*, *Euphorbia tuberculata* var. *macowani*, *Exomis microphylla* var. *axyrioides*, *Manochlamys albicans*, *Othonna sedifolia*, *Salsola namibica*, *Sarcocaulon flavescens*, *Senecio sarcoides*, *Stoerberia utilis*, *Tylecodon paniculatus*, *T. reticulatus*, *T. wallichii* subsp. *wallichii*. Tall Shrubs: *Nylandtia spinosa*, *Putterlickia pyracantha*. Low Shrubs: *Galenia fruticosa* (d), *Pteronia onobromoides* (d), *Tripteris oppositifolia* (d), *Zygophyllum spinosum* (d), *Asparagus capensis* var. *capensis*, *Berkheya fruticosa*, *Chrysocoma longifolia*, *Galenia secunda*, *Helichrysum cylindriflorum*, *H. hebelepis*, *Hermannia cuneifolia*, *H. multiflora*, *H. trifurca*, *Hirpicium alienatum*, *Justicia cuneata* subsp. *latifolia*, *Lebeckia halenbergensis*, *L. spinescens*, *Limeum africanum*, *Nenax arenicola*, *Pelargonium praemorsum*, *Pharnaceum aurantium*, *P. confertum*, *Pteronia divaricata*, *Salvia lanceolata*, *Tripteris sinuata*, *Wiborgia fusca* subsp. *fusca*. Semiparasitic Shrub: *Thesium spinosum*. Woody Climbers: *Asparagus fasciculatus*, *A. retrofractus*, *Microloma sagittatum*. Herbs: *Oncosiphon suffruticosum* (d), *Amellus microglossus*, *Arctotheca calendula*, *Gazania jurineifolia* subsp. *scabra*, *Heliophila coronopifolia*, *Hermannia althaeifolia*, *Leidesia procumbens*, *Nemesia ligulata*, *Osteospermum pinatum*, *Rhynchosidium pumilum*. Geophytic Herbs: *Bulbine frutescens*, *Oxalis annae*, *O. pes-caprae*, *O. purpurea*. Succulent Herbs: *Aloe arenicola*, *Conicosia pugioniformis* subsp. *pugioniformis*, *Psilocalon dinteri*. Graminoids: *Ehrharta calycina* (d), *Schismus barbatus* (d), *Stipagrostis zeyheri* subsp. *macropus* (d), *Chaetobromus involucreatus* subsp. *dregeanus*, *Cladoraphis cyperoides*, *Ehrharta barbinodis*, *E. delicatula*, *E. triandra*, *Pentaschistis airoides*, *Willdenowia incurvata*.

Biogeographically Important Taxa (^{NQ}Namaqualand endemic, ^NNorthern distribution limit) Succulent Shrubs: *Othonna arborescens*^N, *Vanzijlia annulata*^{NQ}. Tall Shrubs: *Euclaea racemosa*^N, *Rhus glauca*^N. Low Shrubs: *Aspalathus spinescens* subsp. *lepida*^N, *Dischisma struthioloides*^{NQ}, *Lebeckia grandiflora*^N, *Leucoptera nodosa*^{NQ}, *Lobostemon pearsonii*^N, *Pelargonium crassipes*^{NQ},

Pteronia fastigiata^N, *Salvia africana-lutea*^N. Semiparasitic Shrub: *Thesium elatius*^N. Herbaceous Climber: *Indigofera procumbens*^N. Herbs: *Zaluzianskya villosa*^N (d), *Diascia nana*^N, *Indigastrum costatum* subsp. *macrum*^N, *Kedrostis psammophylla*^{NQ}, *Manulea altissima* subsp. *longifolia*^{NQ}, *Nemesia versicolor*^N, *Trichogyne lerouxiae*^{NQ}. Geophytic Herbs: *Ferraria foliosa*^N (shared with FS 1 Lambert's Bay Strandveld), *Gethyllis polyanthera*^N, *Holothrix grandiflora*^N, *Lachenalia bulbifera*^N, *Oxalis compressa*^N, *O. flava*^N, *O. pulchella* var. *glauca*^{NQ}. Succulent Herb: *Othonna gymnodiscus*^N, *Tetragonia pilansii*^{NQ}. Graminoids: *Ehrharta ramosa* subsp. *aphylla*^N, *E. villosa* var. *maxima*^N, *Thamnochortus lucens*^N.

L. Mucina

Endemic Taxa Succulent Shrubs: *Lampranthus suavissimus*, *Tylecodon decipiens*, *T. fragilis*. Low Shrubs: *Afromilon* sp. nov. (*Mucina* 210103/1 STEU), *Gorteria* sp. nov. (*Le Roux, Karis & Mucina* 050905/2 STEU), *Sutera multiramosa*. Geophytic Herbs: *Lachenalia valeriae*, *Romulea sinispinosensis*.

Conservation The threats to the vegetation are coastal mining for heavy metals currently at the Brand-se-Baai area east of Lutzville, and this mining is extending at an alarming rate. Target 26%. None of the area is conserved in a statutory conservation area, but some small private reserves (Bojaanskop, Donkins Bay, Doorspring, Molyneux, Zeven Puts) protect some of its vegetation. About 10% of the area has been transformed. This vegetation is generally subject to extensive grazing. Alien *Acacia* species may become a problem, especially in the southern part of the area. Erosion is very low.

Remark The considerable geographic extent of this unit (spanning 2° 36' of latitude) suggests that a more detailed floristic-biogeographical and vegetation-ecological analysis of data (much still to be collected) would result in splitting SKs 7 Namaqualand Strandveld into at least new northern and southern vegetation units in their own right.

References Boucher & Le Roux (1989, 1993), De Villiers et al. (1994, 1999, 2001, 2003), De Villiers (2000), Eccles (2000), Eccles et al. (1999, 2001).

SKs 8 Namaqualand Coastal Duneveld

VT 34 Strandveld of West Coast (77%) (Acocks 1953). LR 55 Strandveld Succulent Karoo (63%) (Low & Rebelo 1996).

Distribution Northern and Western Cape Provinces: Namaqualand Sandveld, coastal plains on or very near the sea, from Deurloopbaai (south of Port Nolloth) to Abraham Villiersbaai (south of the Groen River mouth). Altitude range 10–260 m.

Vegetation & Landscape Features Coastal peneplain with semimobile sand plains to highly mobile, sharp, angular dune plumes usually north of the estuaries. Vegetation is dwarf shrubland dominated by erect succulent shrubs (*Didelta*, *Othonna*, *Ruschia*, *Tetragonia*, *Tripteris*, *Zygophyllum*) as well as nonsucculent shrubs (*Eriocephalus*, *Lebeckia*, *Pteronia*, *Salvia*). Spiny grasses (*Cladoraphis*) are a common sight on wind-blown semistable dunes, with 1–2 m erect to spreading shrubs mostly with malacophyllous leaves protected from the wind between dunes.



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Figure 5.47 SKs 8 Namaqualand Coastal Duneveld: Coastal succulent shrubland with low hemispheric shrubs such as *Othonna cylindrica* (Asteraceae) and *Manochlamys albicans* (Chenopodiaceae) at the road between Kleinzee and Koingnaas on the Namaqualand diamond-bearing coast.

Annual flora can present spectacular displays in wet years, but unlike the usual well-known displays of Namaqualand annual flowers, this display is produced mostly by perennial species.

Geology & Soils Quaternary, aeolian, yellowish or grey to white, up to 1.5 m deep fine sands forming mobile as well as stabilised coastal dune fields and overlying Tertiary sediments of marine origin. Ai land type covers about two thirds of the area and it is followed by Ha land type.

Climate Arid, winter-rainfall area with MAP only 114 mm and almost all rain events occurring from May to August. Winter dew occurs throughout and often with fog rolling in from the sea in the mornings, sometimes fog also occurs in summer. The lowest temperatures in winter are around 10°C (but hardly any frost), and the highest temperatures in summer just above 25°C. See also climate diagram for SKs 8 Namaqualand Coastal Duneveld (Figure 5.39).

Important Taxa Succulent Shrubs: *Didelta carnosus* var. *tomentosa* (d), *Jordaaniella dubia* (d), *Manochlamys albicans* (d), *Othonna cylindrica* (d), *O. sedifolia* (d), *Tetragonia fruticosa* (d), *T. spicata* (d), *Zygophyllum cordifolium* (d), *Crassula subaphylla*, *Euphorbia brachiata*, *E. burmannii*, *Jordaaniella spongiosa*, *Salsola nollothensis*, *Stoeberia utilis*, *Tylecodon paniculatus*, *Zygophyllum morgsana*. Tall Shrubs: *Euclea racemosa* (d), *Chrysanthemoides monilifera* subsp. *pisifera*, *Ehretia rigida*, *Melianthus elongatus*, *Putterlickia pyracantha*. Low Shrubs: *Chrysanthemoides incana* (d), *Galenia fruticosa* (d), *Lebeckia halenbergensis* (d), *Nenax arenicola* (d), *Pteronia divaricata* (d), *Zygophyllum spinosum* (d), *Asparagus capensis* var. *litoralis*, *A. lignosus*, *Atriplex vestita* var. *appendiculata*, *Berkheya fruticosa*, *Capparis hereroensis*, *Chrysocoma ciliata*, *Eriocephalus racemosus* var. *affinis*, *Helichrysum hebelepis*, *Hermannia heterophylla*, *H. trifurca*, *Lebeckia cinerea*, *L. mucronata*, *Limeum africanum*, *Pteronia onobromoides*, *P. paniculata*, *Salvia lanceolata*, *Tripteris oppositifolia*. Woody Succulent Climber: *Pelargonium gibbosum*. Woody Climbers: *Asparagus fasciculatus*, *A. racemosus*, *Cissampelos capensis*, *Microloma sagittatum*. Semiparasitic Epiphytic Shrub: *Viscum capense*. Herbs: *Amellus alternifolius*, *Oncosiphon suffruticosum*. Succulent Herbs: *Conicosia pugioniformis* subsp. *alborosea*, *Psilocaulon dinteri*. Graminoids:

Cladoraphis cyperoides (d), *Stipagrostis zeyheri* subsp. *macrospus*.

Biogeographically Important Taxa (^{NQ}Namaqualand endemic, ^SSouthern distribution limit) Succulent Shrubs: *Amphibolia rupis-arcuatae*^S (d), *Arctotis scullyi*^{NQ}, *Stoeberia beetzi*^{NQ}, *Vanzijlia annulata*^{NQ}. Low Shrub: *Leucoptera nodosa*^{NQ}. Succulent Herbs: *Crassula elegans* subsp. *elegans*^{NQ}, *Mesembryanthemum barklyi*^{NQ}. Graminoid: *Eragrostis sabulosa*^{NQ} (d).

Endemic Taxa Succulent Shrub: *Wooleya farinosa* (d). Herb: *Gazania* sp. nov. (*Mucina & Santos 7237/4* STEU).

Conservation Target 26%. None of the unit is conserved in statutory conservation areas, but an area between the Spoeg and Groen Rivers has been earmarked for a national park. Large areas were affected by diamond mining (about 8% of the area transformed) and prospecting. Kelp collection and vehicle tracks to the beach are also a disturbing factor in accessible places (much of the

area is still out of limits due to occurrence of diamonds). *Acacia cyclops* locally invades the dunes. Erosion is generally very low.

Remark *Capparis hereroensis* has enormous old underground tubers, making it possible to survive moving dunes that periodically cover and uncover the plants. This species is known only from a few plants (< 20) between the Bitter and Swartlinterjies Rivers and then they only occur in the Namib Desert in Namibia.

References Boucher & Le Roux (1993), A. le Roux (unpublished data).

SKs 9 Namaqualand Inland Duneveld

VT 31 Succulent Karoo (96%) (Acocks 1953). LR 57 Lowland Succulent Karoo (69%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Namaqualand Sandveld, where it occurs in two patches—one between Kotzesrus northwards to Groen River while another is located between Wallekraal and Hondeklipbaai. Altitude 60–280 m.

Vegetation & Landscape Features Coastal peneplain with mobile dunes. Vegetation is tall shrubland dominated by non-succulent shrubs (*Berkheya*, *Eriocephalus*, *Euclea*, *Gloveria*, *Lycium*, *Rhus*, *Tetragonia*, *Tripteris*, *Zygophyllum*) as well as some grasses (*Ehrharta*) and restioids (*Willdenowia*).

Geology & Soils Quaternary aeolian, deep, loose, red to yellowish sand, forming medium (1–3 m) to high (3–6 m) dunes. Ah land type covers almost two thirds of the area, while the rest is classified as Ai land type.

Climate Arid, winter-rainfall area with MAP only 104 mm, with almost all the rainfall from May to August. Dew occurs throughout the winter. Lowest temperatures in winter just below 10°C. Hardly any incidence of frost. The highest temperatures in summer 25–30°C. See also climate diagram for SKs 9 Namaqualand Inland Duneveld (Figure 5.39).

Important Taxa Succulent Shrubs: *Othonna cylindrica* (d), *Tetragonia fruticosa*, *Zygophyllum morgsana*. Tall Shrubs: *Diospyros ramulosa*, *Euclea racemosa*, *Nylantia spinosa*, *Rhus longispina*, *R. undulata*. Low Shrubs: *Eriocephalus racemosus*



Figure 5.48 SKs 9 Namaqualand Inland Duneveld: Succulent shrubland on deep sandy soils near Wallekraal in Namaqualand (Northern Cape).

var. *affinis* (d), *Helichrysum hebelepis* (d), *Berkheya fruticosa*, *Gloveria integrifolia*, *Hermannia trifurca*, *Lebeckia sericea*, *Monechma spartioides*, *Pharpaceum incanum*, *Pteronia paniculata*, *Salvia lanceolata*, *Selago pinguicula*, *Tripteris ambigua*, *Tripteris oppositifolia*. Graminoids: *Willdenowia incurvata* (d), *Ehrharta barbinodis*, *E. calycina*, *Ficinia argyropha*.

Conservation Least threatened and none conserved in statutory conservation areas. Target 26%. No obvious transformation observed, although overgrazing and (animal) trampling can result in destabilising of the sandy substrate (on the whole erosion is still very low). Some areas are invaded by *Acacia cyclops*.

Reference A. le Roux (unpublished data).

SKs 10 Riethuis-Wallekraal Quartz Vygieveld

VT 31 Succulent Karoo (100%) (Acocks 1953).
LR 57 Lowland Succulent Karoo (98%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Namaqualand, surrounds of Riethuis, Wallekraal and Soebatsfontein. Altitude 60–240 m.

Vegetation & Landscape Features Slightly undulating plains covered by

white patches of quartz pavement covered with open-canopy dwarf-succulent shrubland with dominant local endemic species of *Jacobsenia*, *Monilaria* and *Dicrocaulon*.

Geology & Soils Shallow silty and skeletal soils, saline in part. In between with small-scale mosaics of level or sloping quartz patches. The underlying geology is gneiss of the Stalhoek Complex and Kamieskroon Gneiss. Ag land type is dominant, while Ae land type is only of subordinate importance.

Climate Winter-rainfall climate. MAP of 129 mm, with almost all the rainfall between May and August. The lowest temperatures in winter are 5–10°C. Frost occurs in winter, but it is very rare. The highest temperatures in the summer are 25–30°C. Frequent occurrence of fog (mainly in winter and spring) and dew representing an important source of water supply. See also climate diagram for SKs 10 Riethuis-Wallekraal Quartz Vygieveld (Figure 5.39).

Important Taxa ^(O)Outside quartz patches) Succulent Shrubs: *Antimima watermeyeri* (d), *Cephalophyllum inaequale*^(O) (d), *Drosanthemum pulverulentum*^(O) (d), *Euphorbia hamata*, *Ruschia leucosperma*, *Salsola zeyheri*, *Senecio aloides*, *Tetragonia verrucosa*, *Zygophyllum cordifolium*. Low Shrubs: *Asparagus capensis* var. *capensis*, *Hirpicium alienatum*, *Pharpaceum elongatum*, *Pteronia ciliata*, *P. glabrata*, *Tripteris oppositifolia*^(O). Geophytic Herbs: *Bulbine sedifolia*, *Chlorophytum crassinerve*. Succulent Herbs: *Crassula columnaris* subsp. *prolifera*, *C. deceptor*, *Phyllobolus spinuliferus*, *Psilocaulon dinteri*. Graminoids: *Ehrharta barbinodis*^(O), *Stipagrostis ciliata*^(O), *S. obtusa*^(O).

Biogeographically Important Taxa ^(NQ)Namaqualand endemic, ^(R)Richtersveld endemic) Succulent Shrubs: *Aspazoma amplexens*^(NQ) (d), *Meyerophytum meyeri*^(NQ) (d), *Monilaria scutata* subsp. *obovata*^(NQ) (d). Geophytic Herb: *Bulbine mesembryanthoides* subsp. *namaquensis*^(R). Succulent Herb: *Brownanthus corallinus*^(NQ).

Endemic Taxa Succulent Shrubs: *Dicrocaulon ramulosum* (d), *D. spissum* (d), *Monilaria scutata* subsp. *scutata* (d), *Jacobsenia vaginata*, *Meyerophytum globosum*. Low Shrub: *Afrolimon namaquanum*. Succulent Herbs: *Conophytum auriflorum*, *C. concavum*, *C. obscurum* subsp. *vitreopapillum*, *Crassula susannae*.



Figure 5.49 SKs 10 Riethuis-Wallekraal Quartz Vygieveld: Succulent shrubland dominated by *Meyerophytum meyeri* (Aizoaceae) in a quartz patch near Wallekraal (near Hondeklipbaai, Northern Cape).

Conservation Target 28%. About 25% of the unit is statutorily conserved in Namaqua National Park. Due to low suitability for grazing or other agricultural uses, the vegetation of this unique quartz vygieveld has not been transformed or disturbed to allow invasion of alien plants. Trampling and browsing caused severe damages to the vulnerable quartz-field vegetation. Erosion is very low.

References Schmiedel (2002a, b).

SKs 11 Namaqualand Arid Grassland

VT 31 Succulent Karoo (89%) (Acocks 1953). LR 57 Lowland Succulent Karoo (77%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Namaqualand, north-west of Soebatsfontein and patches south of Kliprand. Smaller patches also scattered within the Namaqualand Blomveld (these were not mapped due to small extent). Altitude 80–840 m.

Vegetation & Landscape Features Flat to slightly undulating plains covered with short grasslands dominated by *Stipagrostis ciliata* and *S. obtusa* and accompanied by few scattered dwarf shrubs. When overgrazed, the physiognomy of this grassland changes into open-canopy, dwarf shrubland.

Geology & Soils Quaternary aeolian, deep, coarse, loose, red sands overlying granitic-gneiss of the Stalhoek Complex as well as clastic sediments of the Knersvlakte Subgroup of the Vanrhynsdorp Group. Ag land type dominates the landscape and Ah and Ae land types make a small contribution.

Climate Winter-rainfall area with MAP of 131 mm, with almost all the rainfall between May and August. Due to the inland position of the unit, some frost days per year can be recorded. The lowest temperatures in winter range from 5–10°C, while the highest temperatures in summer are between 25°C and just higher than 30°C. See also climate diagram for SKs 11 Namaqualand Arid Grassland (Figure 5.39).

Important Taxa Succulent Shrubs: *Euphorbia decussata*, *Galenia sarcophylla*, *Hypertelis salsoloides*, *Lycium cinereum*, *Salsola zeyheri*, *Tetragonia fruticosa*, *Zygophyllum morgsana*. Low Shrubs: *Asparagus capensis* var. *capensis*, *Galenia fruti-*



Figure 5.50 SKs 11 Namaqualand Arid Grassland: *Stipagrostis ciliata* grassland with an undescribed species of *Arctotis* (orange daisy), *Zaluzianskya affinis* (small white flowers) and *Dimorphotheca pluvialis* (white daisy) on deep red sands of ancient inland dunes near Soebatsfontein (Namaqua National Park, Northern Cape).

cosa, *G. mezziana*, *Hermannia trifurca*, *Lebeckia halenbergen-sis*, *Limeum africanum*, *Tripteris sinuata*, *Zygophyllum microphyllum*, *Z. retrofractum*. Herb: *Gazania pectinata*. Geophytic Herb: *Drimia intricata*. Succulent Herb: *Conicosia pugioniformis* subsp. *alborosea*. Graminoids: *Stipagrostis ciliata* (d), *S. obtusa* (d), *Chaetobromus involucreatus* subsp. *dregeanus*, *Cladoraphis spinosa*, *Ehrharta pusilla*, *Stipagrostis brevifolia*, *S. zeyheri* subsp. *macropus*.

Biogeographically Important Taxon (Namaqualand endemic) Herb: *Kedrostis psammophylla*.

Conservation Target 26%. About 20% is statutorily conserved in Namaqua National Park, but none of the patches along the northeastern edges of the Knersvlakte enjoy any form of conservation. About 5% has been transformed by overgrazing. Erosion varies between low (50%), very low (30%) and moderate (20%).

Remark This grassland is structurally (and partly also floristically) related to the NKb 3 Bushmanland Arid Grassland, with the same dominant *Stipagrostis* species in deep red sands, although the grassland in Bushmanland receives summer rainfall. The occurrence of C₄-dominated grasslands within winter-rainfall regions remains unexplained, but the azonal character of the deep sandy soils (and possibly some features of their nutrient status) is a logical suspect.

Reference A. le Roux and L. Mucina (unpublished data).

SKs 12 Namaqualand Spinescent Grassland

VT 31 Succulent Karoo (67%) (Acocks 1953). LR 57 Lowland Succulent Karoo (72%) (Low & Rebelo 1996). BHU 77 Knersvlakte Vygieveld (72%) (Cowling & Hejnis 2001).

Distribution Western Cape Province: Namaqualand, a strip in the Knersvlakte from Lutzville and Koekenaap eastwards to north of Vanrhynsdorp. Altitude 60–340 m.

Vegetation & Landscape Features Level landscape covered with vegetation dominated by spinifex-like grass (*Cladoraphis spinosa*) and a few scattered emergent taller shrubs. The shrubs are both succulent (*Euphorbia*, *Ruschia*, *Othonna*, *Salsola*, *Zygophyllum*) and nonsucculent (*Hermannia*, *Justicia*, *Lebeckia*, *Lycium*, *Wiborgia*). Geophytes and annuals (especially obvious in wet years) occur in the shrub-grass matrix.

Geology & Soils Cenozoic aeolian, deep, coarse, unstructured, red, sandy soils with very low stone content, more or less neutral soil pH, low salinity and with no or very low carbonate content. Sand originated from the mouth of the palaeo-Orange River formerly located about east of the sand strip and it has been transported inland by the westerly winds. This ancient alluvium sediments are overlying Gariep Supergroup metapelites (mostly schist and phyllite) and some clastic sediments and metavolcanics (Namibian Erathem). Ae land type dominates and Ag land type plays only a subordinate role.

Climate Winter-rainfall climate with MAP of 151 mm, with almost all the rainfall between May and August. The lowest temperatures in winter are 5–10°C. Frost

L. Mucina



Figure 5.51 SKs 12 Namaqualand Spinescent Grassland: Mixed shrubland-grassland vegetation dominated by the spinifex-like grass *Cladoraphis spinosa*, with *Grielum humifusum* (bright yellow-flowered Neuradaceae) and various annual herbs (*Manulea*, *Wahlenbergia*, *Osteospermum*, *Zaluzianskya*) on deep red sands near the Varsch River, north of Vanrhynsdorp (Western Cape).

occurs in winter, but it is rare. The highest temperatures in summer are between 25°C and just higher than 30°C. See also climate diagram for SKs 12 Namaqualand Spinescent Grassland (Figure 5.39).

Important Taxa Succulent Shrubs: *Euphorbia burmannii* (d), *E. mauritanica* (d), *Zygophyllum morgsana* (d), *Antimima excedens*, *Aridaria noctiflora* subsp. *noctiflora*, *Augea capensis*, *Didelta spinosa*, *Othonna cylindrica*, *Prenia pallens* subsp. *lutea*, *Ruschia bipapillata*, *R. brevibracteata*, *Salsola namibica*, *S. zeyheri*, *Tetragonia fruticosa*, *T. spicata*. Tall Shrub: *Wiborgia obcordata*. Low Shrubs: *Lebeckia halenbergensis* (d), *Asparagus capensis* var. *capensis*, *Eriocephalus brevifolius*, *Galenia africana*, *Hermannia amoena*, *H. scordifolia*, *H. trifurca*, *Justicia cuneata* subsp. *latifolia*, *J. orchioides* subsp. *glabrata*, *Limeum africanum*, *Pteronia divaricata*, *Tripteris oppositifolia*, *Wiborgia sericea*. Woody Climbers: *Asparagus fasciculatus*, *A. retrofractus*, *Cissampelos capensis*, *Microloma sagittatum*. Herbaceous Climber: *Kedrostis capensis*. Herbs: *Dimorphotheca pluvialis* (d), *Foveolina tenella* (d), *Arctotheca calendula*, *Emex australis*, *Grielum grandiflorum*, *G. humifusum*, *Hebenstretia repens*, *Helichrysum micropoides*, *Heliophila arenaria*, *Indigofera alternans*, *Lyperia tristis*, *Nestlera biennis*, *Oncosiphon piluliferum*, *Osteospermum pinnatum*, *Phyllopodium phyllopodoides*, *Rumex cordatus*, *Silene clandestina*, *Sonderina tenuis*, *Wahlenbergia annularis*. Geophytic Herbs: *Boophone haemanthoides*, *Drimia altissima*, *Ornithoglossum viride*, *Oxalis flava*, *Trachyandra falcata*. Succulent Herb: *Apatesia helianthoides*. Graminoids: *Cladoraphis spinosa* (d), *Ehrharta brevifolia* (d), *Willdenowia incurvata* (d), *Chaetobromus involucratus* subsp. *dregeanus*, *Ehrharta calycina*, *Schismus barbatus*, *Stipagrostis ciliata*.

Biogeographically Important Taxa (^{NQ}Namaqualand endemic, ^KKners-

vlakte endemic, ^NNorthern distribution limit, ^SSouthern distribution limit) Succulent Shrub: *Othonna sparsiflora*^S. Low Shrubs: *Aspalathus cuspidata*^{NQ}, *Nenax hirta* subsp. *calciphila*^N, *Otholobium incanum*^N. Herbs: *Lebeckia sepriaria*^N, *Manulea altissima* subsp. *longifolia*^{NQ}, *Nemesia azurea*^S. Geophytic Herb: *Lapeirousia simulans*^K. Succulent Herb: *Crassula elegans* subsp. *elegans*^{NQ}. Graminoid: *Ficinia bulbosa*^N.

Endemic Taxa Geophytic Herb: *Ornithogalum autumnulmum*. Succulent Herbs: *Quaqua pulchra*, *Tridentea peculiaris*.

Conservation Least threatened. Target 26%. Only 4% statutorily conserved in Lutzville and Moedverloren Nature Reserves. The same percentage has been transformed and scattered *Acacia saligna* and *A. cyclops* might be a cause for concern in some areas. Erosion is very low (80%) and low (20%).

Remark This unit has some similarities to the SKs 13 Klawer Sandy Shrubland, but this grassland is most likely a more arid version of the tall shrubland, with shrubs becoming more prominent with increased rainfall.

References Schmiedel (2002a, b), Boucher (2003).

SKs 13 Klawer Sandy Shrubland

VT 31 Succulent Karoo (92%) (Acocks 1953). LR 57 Lowland Succulent Karoo (100%) (Low & Rebelo 1996). BHU 76 Klawer Vygieveld (100%) (Cowling & Hejnis 2001).

Distribution Western Cape Province: Lower Olifants River Valley in close surrounds of Klawer. Altitude 40–320 m.



Figure 5.52 SKs 13 Klawer Sandy Shrubland: Deep white sands with sparse, tall shrubland dominated by *Montinia caryophyllacea* (Montiniaceae) and spinifex-like *Cladoraphis spinosa* (Poaceae) in the undergrowth accompanied by a species-rich spring display of annual and geophytic flora including various species of *Dimorphotheca*, *Oncosiphon*, *Osteospermum*, *Senecio*, *Ursinia*, *Zaluzianskya*, *Albuca* and *Lachenalia*.

Vegetation & Landscape Features Slightly undulating landscape and foothills covered with medium dense, tall shrubland with *Montinia caryophyllacea* and understorey with prominent sand-loving spinifex-like grass *Cladoraphis spinosa*.

Geology & Soils Well-drained, moderately deep to deep, yellow to red sands overlying Gariap Supergroup schists and phylites as well as lesser sandstones, carbonates and metavolcanics. Some Table Mountain Group quartzites are also present. Occasionally heuweltjies occur as well. Ag land type is dominant, while the importance of Ae, Db and Fc land types is secondary.

Climate Winter-rainfall regime, with obvious peak from June to August. MAP reaches almost 200 mm (semidesert), but an additional contribution from regional precipitation (fog condensing on Gifberg escarpment) cannot be excluded. MAT 18–19°C and only 2 days of frost per year on average. See also climate diagram for SKs 13 Klawer Sandy Shrubland (Figure 5.39).

Important Taxa Succulent Shrubs: *Othonna cylindrica* (d), *Antimima dasyphylla*, *Delosperma crassum*, *Euphorbia mauritanica*, *E. tuberculata* var. *macowani*, *Manochlamys albicans*, *Prenia pallens* subsp. *lutea*, *Tetragonia fruticosa*, *Tylecodon paniculatus*, *T. wallichii* subsp. *wallichii*, *Zygophyllum morgsana*. Tall Shrubs: *Montinia caryophyllacea* (d), *Wiborgia obcordata*. Low Shrubs: *Lebeckia halenbergensis* (d), *Aizoon paniculatum*, *Aspalathus biflora* subsp. *biflora*, *Asparagus juniperoides*, *Eriocephalus brevifolius*, *Euryops namaquensis*, *Galenia africana*, *Hermannia cuneifolia*, *H. procumbens*, *Hoplophyllum spinosum*, *Justicia cuneata* subsp. *cuneata*, *J. orchoides* subsp. *glabrata*, *Limeum africanum*, *Pharnaceum incanum*, *Pteronia divaricata*, *P. glabrata*, *P. paniculata*, *Tripteris oppositifolia*, *Wiborgia fusca* subsp. *fusca*, *W. sericea*. Herbs: *Dimorphotheca pluvialis* (d), *Oncosiphon grandiflorum* (d), *Adenogramma glomerata*, *Amellus strigosus* subsp. *pseudoscabridus*, *Cotula microglossa*, *Dischisma spicatum*, *Emex australis*, *Felicia bergeriana*, *Foveolina tenella*, *Grielum humifusum*, *Helichrysum moesianum*, *H. tinctum*, *Hemimeris racemosa*, *Leysera gnaphalodes*, *Nemesia bicornis*, *N. ligulata*, *Phyllopodium caespitosum*, *P. cephalophorum*, *Plantago cafra*, *Silene clandestina*, *Tripteris clandestina*, *Ursinia anthemoides* subsp. *versicolor*, *Wahlenbergia annularis*, *W. asperifolia*, *Zaluzianskya benthamiana*, *Z. villosa*. Geophytic Herbs: *Moraea collina* (d), *Ammocharis longifolia*, *Brunsvigia orientalis*, *Chlorophytum undulatum*, *Drimia intricata*, *Lachenalia ventricosa*, *Lapeirousia jacquinii*, *Moraea fugax*, *Ornithogalum maculatum*, *Oxalis annae*, *O. pes-caprae*, *O. purpurea*, *Trachyandra jacquiniana*, *T. scabra*, *Walleria gracilis*. Succulent Herbs: *Apatesia sabulosa*, *Conicosia pugioniformis* subsp. *pugioniformis*, *Tetragonia micropetra*. Graminoids: *Cladoraphis spinosa* (d), *Stipa capensis* (d), *Chaetobromus involucreatus* subsp. *dregeanus*, *Cynodon dactylon*, *Ehrharta barbinodis*, *E. brevi-*

folia, *E. calycina*, *Ficinia argyropa*, *Karoochloa schismoides*, *Pentastichis capillaris*, *Tribolium pusillum*.

Biogeographically Important Taxa (^{NQ}Namaqualand endemic, ^KKnersvlakte endemic, ^SSouthern distribution limit, ^WWestern distribution limit) Herbs: *Crotalaria effusa*^S, *Helichrysum marmarolepis*^{NQ}, *Steirodiscus capillaceus*^W. Geophytic Herbs: *Ornithogalum pruinosum*^{NQ}, *Trachyandra zebrina*^S.

Endemic Taxa Herb: *Vellereophyton pulvinatum*. Geophytic Herb: *Haemanthus pubescens* subsp. *leipoldtii*.

Conservation Least threatened and none conserved in statutory conservation areas. Target 29%. About 6% transformed for cultivation or by road building. Erosion is moderate (65%) or very low (35%).

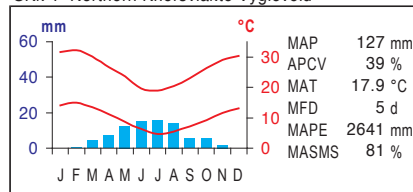
References Milton (1978), Boucher (2003).

Knersvlakte

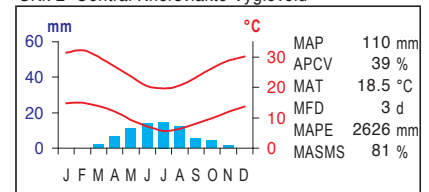
SKk 1 Northern Knersvlakte Vygieveld

VT 31 Succulent Karoo (94%) (Acocks 1953). LR 57 Lowland Succulent Karoo (92%) (Low & Rebelo 1996).

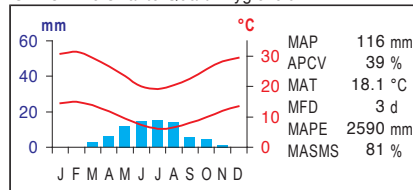
SKk 1 Northern Knersvlakte Vygieveld



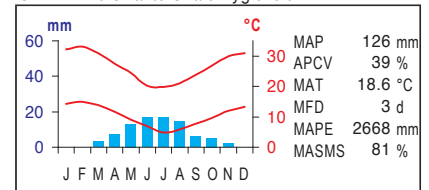
SKk 2 Central Knersvlakte Vygieveld



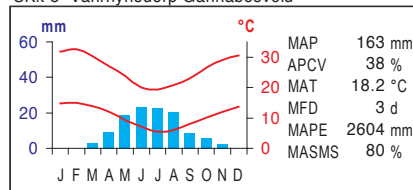
SKk 3 Knersvlakte Quartz Vygieveld



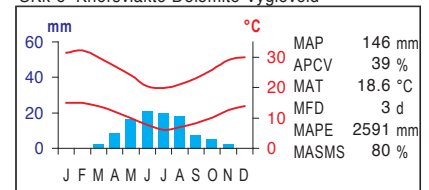
SKk 4 Knersvlakte Shale Vygieveld



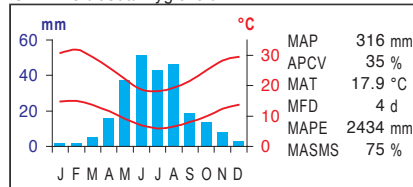
SKk 5 Vanrhynsdorp Gannabosveld



SKk 6 Knersvlakte Dolomite Vygieveld



SKk 7 Citrusdal Vygieveld



SKk 8 Piketberg Quartz Succulent Shrubland

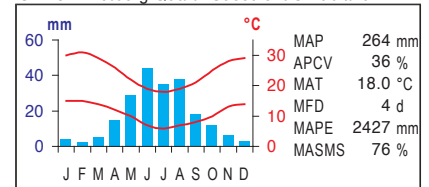


Figure 5.53 Climate diagrams of Knersvlakte Bioregion units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

Distribution Western and Northern Cape Provinces: Knersvlakte (southern part of Namaqualand), situated roughly between Nuwerus and the escarpment in the east and the Sout River in the north. Only a small portion of this unit is found in the Northern Cape (in the upper valleys of the Kamdanie River and Krom River, west of Loeriesfontein). Altitude 200–800 m.

Vegetation & Landscape Features Slightly undulating landscape covered with open-canopy (10–30%) succulent shrubland. Heuweltjies occur in places and these are dominated by *Stoeberia frutescens* or *Lampranthus uniflorus*. Annuals and geophytes can determine the appearance of the vegetation in spring after good winter rains.

Geology & Soils Mostly Cenozoic alluvium and calcrete that overlies the mudstone, siltstone and sandstone of the Knersvlakte Subgroup (Vanrhynsdorp Group, Namibian Erathem) as well as gneiss of the Stalhoek Complex (Mokolian). Low stone content, soils acid to neutral, shallow to deep, where shallow bedrock or duripan crusts underly. Heuweltjies occur in places. Some 80% of the area falls within Ag land type, while Fc land type is the second most important one.

Climate Winter-rainfall climate with dry, hot summers and mild, rainy winters. MAP estimated to be 127 mm. The lowest temperatures in winter are 5–10°C, while the highest temperatures in summer are 30–35°C. Winters are mild, with rare occurrence of frost (on average 5 days per year). See also climate diagram for SKk 1 Northern Knersvlakte Vygieveld (Figure 5.53).

Important Taxa Succulent Shrubs: *Cephalophyllum framesii*, *C. parvibracteatum* (d), *Drosanthemum curtrophyllum* (d), *D. pulverulentum* (d), *Leipoldtia calandra* (d), *Ruschia subsphaerica* (d), *Salsola zeyheri* (d), *Antimima watermeyeri*, *Augea capensis*, *Didelta carnosia* var. *carnosia*, *Galenia sarcophylla*, *Lampranthus uniflorus*, *Phyllobolus trichotomus*, *Ruschia lisabeliae*, *R. robusta*, *Salsola namibica*, *S. tuberculata*, *Tetragonia fruticosa*, *T. robusta* var. *psiloptera*, *Zygophyllum cordifolium*. Low Shrubs: *Asparagus capensis* var. *capensis*, *Galenia fruticosa*, *G. secunda*, *Lessertia depressa*, *Melolobium adenodes*, *Pteronia glabrata*, *P. intermedia*, *P. villosa*. Woody Climber: *Asparagus kraussianus*. Herbs: *Gazania lichtensteinii* (d), *Adenogramma glomerata*, *Amellus microglossus*, *Cotula microglossa*, *Diascia pachyceras*, *Felicia bergeriana*, *Heliophila variabilis*, *Lotononis parviflora*, *Lyperia tristis*, *Manulea cheiranthus*, *M. gariepina*, *Oncosiphon suffruticosum*, *Pelargonium minimum*, *Pharnaceum croceum*, *Rhynchosidium pumilum*, *Tripteris brevibradiata*, *Ursinia nana*, *Zaluzianskya benthamiana*, *Z. villosa*. Geophytic Herbs: *Cyanella hyacinthoides*, *Drimia intricata*, *Eriospermum paradoxum*, *Freesia viridis*, *Moraea ciliata*, *M. pallida*, *Ornithoglossum viride*, *Oxalis annae*, *O. obtusa*, *O. purpurea*, *Trachyandra jacquiniana*. Succulent Herbs: *Brownanthus vaginatus*, *Notechidnopsis tessellata*, *Phyllobolus nitidus*, *P. spinuliferus*, *Psilocaulon junceum*, *Quaqua acutiloba*.

Biogeographically Important Taxa (^{NQ}Namaqualand endemic, ^KKnersvlakte endemic) Succulent Shrubs: *Drosanthemum schoenlandianum*^K, *Hallianthus planus*^{NQ}, *Malephora purpureo-crocea*^{NQ}, *Stoeberia frutescens*^{NQ}. Succulent Herb: *Tromotriche revoluta*^K.

Endemic Taxon Geophytic Herb: *Lachenalia framesii*.

Conservation Least threatened. Target 28%. None conserved in statutory conservation areas. Largely nontransformed, but stretches can be severely disturbed by the alien *Atriplex lindleyi* subsp. *inflata*, in places dominating the vegetation cover. Erosion is mainly low (78%) or very low (11%).

References Schmiedel (2002a, b).

SKk 2 Central Knersvlakte Vygieveld

VT 31 Succulent Karoo (100%) (Acocks 1953). LR 57 Lowland Succulent Karoo (90%) (Low & Rebelo 1996). BHU 77 Knersvlakte Vygieveld (83%) (Cowling & Hejnis 2001).

Distribution Western Cape Province: Knersvlakte (southern part of Namaqualand), along the upper courses of the Salt River and the Groot-Graafwater River north of Vanrhynsdorp. About half of the area is found at altitudes of 100–200 m and most of the rest at 200–300 m.

Vegetation & Landscape Features Slightly undulating landscape covered with low succulent shrubland with low canopy cover (5–30%). The dominant shrub genera include *Ruschia*, *Drosanthemum* and *Leipoldtia*.

Geology & Soils Underlain by the clastic sediments of the Vanrhynsdorp Group (particularly by the Knersvlakte Subgroup, Namibian Erathem) and partly covered by Cenozoic superficial deposits and some Gariiep Supergroup schists. Soils are shallow to moderately deep, with low salinity and sometimes deep, coarse and unstructured red, aeolian, sandy soils with very low skeletal content. Half of the area is classified as Fc land type, while Ia and Ah land types cover about one quarter of the area each.

Climate Winter-rainfall climate with dry, hot summers and mild, rainy winters. MAP of 110 mm, fog and dew occasionally sup-



Figure 5.54 SKk 2 Central Knersvlakte Vygieveld: *Drosanthemum pulverulentum* dominant in dwarf succulent shrubland on shale-derived soils of the central Knersvlakte near Vanrhynsdorp (Western Cape).

plementing the water supply. Lowest temperatures in winter 5–10°C. The highest temperatures in summer 30–35°C. Winters are mild, with rare occurrence of frost (on average 3 days per year). See also climate diagram for SKk 2 Central Knersvlakte Vygiveld (Figure 5.53).

Important Taxa Succulent Shrubs: *Drosanthemum pulverulentum* (d), *Leipoldtia schultzei* (d), *Ruschia robusta* (d), *Aridaria brevicarpa*, *Augea capensis*, *Drosanthemum curtophyllum*, *Euphorbia burmannii*, *Salsola zeyheri*. Low Shrubs: *Asparagus capensis* var. *capensis*, *Galenia africana*, *G. fruticosa*, *Zygophyllum retrofractum*. Woody Climber: *Asparagus kraussianus*. Herb: *Galenia papulosa*. Geophytic Herb: *Drimia altissima*. Succulent Herbs: *Conicosia pugioniformis* subsp. *alborosea*, *Phyllobolus nitidus*, *P. spinuliferus*. Graminoids: *Hordeum capense*, *Pentaschistis airoides*.

Biogeographically Important Taxon (Knersvlakte endemic) Succulent Shrub: *Drosanthemum schoenlandianum*.

Endemic Taxon Succulent Shrub: *Tylecodon nolteei*.

Conservation Least threatened. Target 28%. None conserved in statutory conservation areas. Mainly not transformed, but some areas are severely disturbed by the alien *Atriplex lindleyi* subsp. *inflata*. Erosion is low (74%) or moderate (15%).

Remark In contrast to the SKk 1 Northern Knersvlakte Vygiveld, this unit is characterised by alluvial sandy soils, increased abundance of graminoid species and taller (*Aridaria brevicarpa*, *Ruschia robusta*) as well as cushion-forming leaf-succulents (*Ruschia versicolor*).

References Schmedel (2002a, b).

SKk 3 Knersvlakte Quartz Vygiveld

VT 31 Succulent Karoo (95%) (Acocks 1953). LR 57 Lowland Succulent Karoo (97%) (Low & Rebelo 1996). BHU 77 Knersvlakte Vygiveld (62%) (Cowling & Heijns 2001).

Distribution Western Cape Province: Knersvlakte (southern part of Namaqualand), from Bitterfontein southwards to just south of Klaver, with the main centre north and northwest of Vanrhynsdorp. Altitude 40–460 m (with most of the area 100–280 m).

Vegetation & Landscape Features Slightly undulating landscape with slopes and broad ridges covered by prominent though very patchy white layer of quartzite. The succulent shrublands supported by this relatively young (Tertiary) plain are mostly dwarf, with a high proportion of compact and subterranean vygies (Aizoaceae), often imitating their surroundings. This is probably the most extensive area of 'living stones' in the world. The mosaic of floristically and ecologically distinct quartz vygieveld communities and the matrix of low succulent shrublands, with *Ruschia* and *Drosanthemum* as the most prominent structure-determining genera, are very intricate and small-scale in places. Spectacular flower displays of both perennial and annual species flowering *en masse* and simultaneously are a common sight after good winter rain. The increased occurrence of indigenous *Caulipsolon rapaceum*, *Drosanthemum hispidum*, *Malephora purpureo-crocea*, *Mesembryanthemum guerichianum* as well as of the alien *Atriplex lindleyi* subsp. *inflata* is a good indicator of local veld disturbance.

Geology & Soils Clastic sediments of the Vanrhynsdorp Group and some Gariiep Supergroup schists supporting loamy-sandy shallow to moderately deep, slightly alkaline soils, low to high stone (especially quartz) content. Fc and Fb are land types of

equal importance (both covering about a third of the area), followed by Ag land type.

Climate Winter-rainfall climate with dry, hot summers and mild, rainy winters. MAP 116 mm. Fog and dew occasionally supplementing the water supply. The lowest temperatures in winter 5–10°C. The highest temperatures in summer 30–35°C. Winters are mild, with rare occurrence of frost (on average 3 days per year). See also climate diagram for SKk 3 Knersvlakte Quartz Vygiveld (Figure 5.53).

Important Taxa Succulent Shrubs: *Didelta carnosa* var. *carnosa* (d), *Drosanthemum diversifolium* (d), *Ruschia burtoniae* (d), *Antimima watermeyerii*, *Euphorbia mauritanica*, *E. muricata*, *Galenia sarcophylla*, *Pelargonium crithmifolium*, *Prenia tetragona*, *Ruschia cymosa*, *R. leucosperma*, *R. patulifolia*, *Salsola aphylla*, *S. namibica*, *Senecio aloides*, *Tetragonia verucosa*, *Tylecodon reticulatus*, *T. ventricosus*, *Zygophyllum cordifolium*. Low Shrubs: *Berkheya fruticosa*, *Galenia fruticosa*, *Hirpicium alienatum*, *Pteronia ciliata*, *P. heterocarpa*, *Tripteris sinuata*, *Zygophyllum retrofractum*. Semiparasitic Shrub: *Thesium lineatum*. Herbs: *Amellus microglossus* (d), *Dimorphotheca sinuata* (d), *Oncosiphon suffruticosum* (d), *Lasiopogon glomerulatus*, *Nemesia anisocarpa*, *Oncosiphon piluliferum*, *Osteospermum pinnatum*, *Rhynchopsidium pumilum*. Geophytic Herbs: *Drimia intricata* (d), *Oxalis annae* (d), *O. obtusa*, *O. pes-caprae*, *O. purpurea*. Succulent Herbs: *Tetragonia echi-*



Figure 5.55 SKk 3 Knersvlakte Quartz Vygiveld: Dwarf succulent shrubland dominated by endemic *Dactyloopsis digitata* (Aizoaceae) on the Farm Quaggaskop near Salt River, northwest of Vanrhynsdorp (Western Cape).

nata (d), *Aloe variegata*, *Crassula columnaris* subsp. *prolifera*, *C. deceptor*, *C. expansa* subsp. *expansa*, *C. muscosa*, *C. subaphylla*, *Mesembryanthemum fastigiatum*, *M. nodiflorum*, *Psilocaulon dinteri*. Graminoids: *Ehrharta delicatula* (d), *Karoochloa tenella*, *Schismus barbatus*.

Biogeographically Important Taxa

^(N^Q)Namaqualand endemic, ^(K)Knersvlakte endemic Succulent Shrubs: *Malephora purpureo-crocea*^{N^Q} (d), *Euphorbia schoenlandii*^K, *Tylecodon pearsonii*^{N^Q}. Succulent Herbs: *Brownanthus corallinus*^{N^Q} (d), *Crassula elegans* subsp. *elegans*^{N^Q}, *C. expansa* subsp. *pyrifolia*^{N^Q}.

Endemic Taxa Succulent Shrubs:

Argyroderma crateriforme (d), *A. delatetii* (d), *A. fissum* (d), *A. patens* (d), *A. pearsonii* (d), *Cephalophyllum spissum* (d), *Dactyloopsis digitata* (d), *Dicrocaulon brevifolium* (d), *D. nodosum* (d), *Dicrocaulon* sp. nov. ('longifolium') (d), *Dicrocaulon* sp. nov. ('pseudonodosum') (d), *Monilaria chrysoleuca* (d), *M. moniliformis* (d), *M. pisiformis* (d), *Oophytum nanum* (d), *O. oviforme* (d), *Afrolimon teretifolium*, *Antimima dualis*, *Argyroderma congregatum*, *A. framesii* subsp. *framesii*, *A. framesii* subsp. *hallii*, *A. ringens*, *A. subalbum*, *A. testicularis*, *Cephalophyllum staminodosum*, *Dactyloopsis littlewoodii*, *Dicrocaulon grandiflorum*, *D. humile*, *D. microstigma*, *Dicrocaulon* sp. nov. ('nanum'), *D.* sp. nov. ('neglectum'), *Dicrocaulon* sp. nov. ('prostratum'), *Diplosoma luckhoffii*, *Ruschia firma*, *Salsola* sp. nov. ('quartzicola') (Schmiedel 93110 HBG, *Mucina* 160601/9 STEU), *Sarcocornia xerophila*, *Tylecodon occultans*, *T. peculiaris*, *T. pygmaeus*, *Zygophyllum teretifolium*. Low Shrub: *Pentzia peduncularis*. Geophytic Herbs: *Bulbine wiesei*, *Lachenalia barkeriana*, *Moraea deserticola*, *Ornithogalum knersvlaktense*, *Pelargonium caroli-henrici*, *P. quarcitcola*, *Romulea maculata*. Succulent Herbs: *Conophytum acutum*, *C. calculus* subsp. *calculus*, *C. minutum* var. *minutum*, *C. minutum* var. *pearsonii*, *C. subfenestratum*, *Othonna intermedia*, *Phyllobolus abbreviatus*.

Conservation Least threatened, although in places still utilised for grazing by goats. Target 28%. About 5% is statutorily conserved in Moedverloren Nature Reserve. The area is disturbed by prospecting for diamonds (ceased) in the past and gypsum mining, leaving behind mine spoil heaps in places. Alien plants are not a big problem, although *Atriplex lindleyi* subsp. *inflata* is invading where saline quartz fields have been disturbed by trampling or off-road driving. Erosion is low (75%) or very low (20%).

Remark 1 The white quartz debris originates from weathered quartz veins which are embedded within the bedrock matrix. The quartz veins weather and are spread downhill by alluvial transport. Quartz fields in the arid regions of southern Africa represent edaphically defined special habitats, which house distinct vegetation units. In different regions, the quartz fields are inhabited by similar plant growth forms of distantly related lineages (compare SKv 10 Little Karoo Quartz Vygieveld and SKs 10 Riethuis-Wallekraal Quartz Vygieveld).

Remark 2 This vegetation unit carries one of the largest local densities of endemic plants, counting more than 60 species and three genera (*Argyroderma*, *Dactyloopsis* and *Oophytum*: all Aizoaceae). The genera *Dicrocaulon*, *Monilaria* (Aizoaceae) and *Tylecodon* (Crassulaceae) score high numbers of endemic



Figure 5.56 SKk 3 Knersvlakte Quartz Vygieveld: Spring flower aspect dominated by *Malephora purpureo-caerulea* (Aizoaceae) and the yellow daisies *Didelta carnosa* var. *carnosa* and *Rhynchosidium pumilum*, south of Bitterfontein (Western Cape).

species here—a phenomenon shared with other Namaqualand quartz vylgievelds.

References Van Jaarsveld (1998b), Schmiedel & Jürgens (1999), Schmiedel (2002a, b), Ellis et al. (2006).

SKk 4 Knersvlakte Shale Vygieveld

VT 31 Succulent Karoo (93%) (Acocks 1953). LR 57 Lowland Succulent Karoo (96%) (Low & Rebelo 1996). BHU 77 Knersvlakte Vygieveld (93%) (Cowling & Heijnis 2001).

Distribution Western Cape Province: Knersvlakte (southern part of Namaqualand), at the western foot of the Bokkeveld Escarpment near Vanrhynsdorp. Altitude 160–540 m.

Vegetation & Landscape Features Low (10–20% of canopy cover) shrubland formed by mat-forming and cushion-forming shrubs, mainly with succulent leaves and high incidence of spinescence. *Ruschia* and *Salsola* are the major dominants.

Geology & Soils Shale bands of the Knersvlakte Subgroup (Vanrhynsdorp Group, Namibian Erathem), on level plains or hilltops and moderate to steep slopes covered by shallow soils, moderately acid to slightly alkaline, high stone content. Almost the entire area is classified as Fc land type.

Climate Winter-rainfall climate with dry, hot summers and mild, rainy winters. MAP 126 mm, with almost all the rainfall between May and August. The lowest temperatures in winter 5–10°C, highest temperatures in summer 30–35°C. Winters are mild, with rare occurrence of frost (on average 3 days per year). See also climate diagram for SKk 4 Knersvlakte Shale Vygieveld (Figure 5.53).

Important Taxa Succulent Shrubs: *Arenifera stylosa* (d), *Caulopsilon rapaceum* (d), *Ruschia spinosa* (d), *Salsola zeyheri* (d), *Augea capensis*, *Cheiridopsis namaquensis*, *Lampranthus uniflorus*, *Salsola aphylla*, *S. namibica*, *Tetragonia fruticosa*, *Tylecodon wallichii* subsp. *wallichii*, *Zygophyllum foetidum*. Low Shrubs: *Asparagus capensis* var. *capensis*, *Atriplex vestita* var. *appendiculata*, *Eriocephalus ericoides*, *Galenia fruticosa*, *Hirpicium alienatum*, *Pteronia ciliata*, *Tripteris sinuata*. Woody Climber: *Asparagus kraussianus*. Herbs: *Dimorphotheca sinuata* (d), *Gorteria diffusa* subsp. *diffusa* (d), *Oncosiphon suffrutico-*

sum (d), *Osteospermum pinnatum* (d), *Amellus microglossus*, *Emex australis*, *Jamesbrittenia glutinosa*, *Lasiopogon glomerulatus*, *Lepidium africanum*, *Sisymbrium capense*. Geophytic Herbs: *Drimia intricata*, *Gethyllis lata* subsp. *lata*, *G. linearis*, *Oxalis pes-caprae*. Succulent Herbs: *Brownanthus vaginatus* (d), *Phyllobolus nitidus*, *Psilocalaon dinteri*, *P. junceum*, *Tetragonia microptera*. Graminoids: *Ehrharta delicatula*, *E. longiflora*, *Karoochloa tenella*.

Biogeographically Important Taxa (^{NQ}Namaqualand endemic, ^KKnersvlakte endemic) Succulent Shrub: *Malephora purpureo-crocea*^{NQ}. Herb: *Lasiopogon debilis*^K. Succulent Herb: *Tromotriche revoluta*^K.

Endemic Taxon Succulent Shrub: *Tylecodon suffultus*.

Conservation Target 28%. None of the unit is conserved in statutory conservation areas. Local overgrazing and high erosion pressure (90%) can be seen as threats in some places, otherwise no visible signs of transformation. *Atriplex lindleyi* subsp. *inflata* is the most common invasive alien.

Remark This unit houses a number of Karoo elements typical of the summer-rainfall region and shows traits of transition between the summer-rainfall and winter-rainfall regions.

References Schmiedel (2002a, b).

SKk 5 Vanrhynsdorp Gannabosveld

VT 31 Succulent Karoo (92%) (Acocks 1953). LR 57 Lowland Succulent Karoo (95%) (Low & Rebelo 1996). BHU 77 Knersvlakte Vygieveld (79%) (Cowling & Hejnis 2001).

Distribution Western Cape Province: Namaqualand, southern Knersvlakte between Vredendal and Vanrhynsdorp at the foot of the Matsikamma and Gifberg Mountains as well as northeast of Vanrhynsdorp. About half of the area lies at 100–200 m and most of the rest at 200–300 m.

Vegetation & Landscape Features Mainly flat or only slightly undulating landscape supporting succulent shrubland dominated by *Salsola* (over large stretches), *Drosanthemum*, *Ruschia* and some disturbance indicators such as (mainly) short-lived Aizoaceae, including representatives of the genera *Galenia*, *Psilocalaon*, *Caulipsolon* and *Mesembryanthemum*. In the south, the shale plains can acquire a grassland appearance through seasonal dominance of *Bromus pectinatus* and *Stipa capensis*. Spectacular annual and geophyte flora can appear in spring after good winter rains.

Geology & Soils The greater part of this area is underlain by schists, phyllite and sandstones of the Gariiep Supergroup, which outcrop when they are not covered by recent superficial deposits of alluvium and duripan crusts (calcrete). Soils are sandy-loamy, moderately deep, slightly acid to alkaline, with high skeletal content. More than half of the area is classified as Ag land type, followed by Fc land type, with Db and Ae land types only of minor importance.

Climate Winter-rainfall climate with dry, hot summers and mild, rainy winters. MAP of 163 mm is considerably higher than in the other parts of the Knersvlakte due to the orographic effects of the neighbouring Matsikamma and Gifberg Mountains and the Escarpment. Almost all the rainfall occurs between April and August. The lowest temperatures in winter 5–10°C; the highest temperatures in summer 30–35°C. Winters are mild, with rare occurrence of frost (on average 3 days per year). See also climate diagram for SKk 5 Vanrhynsdorp Gannabosveld (Figure 5.53).

Important Taxa Succulent Shrubs: *Caulipsolon rapaceum* (d), *Drosanthemum deciduum* (d), *D. hispidum* (d), *Euphorbia mauritanica* (d), *Salsola namibica* (d), *S. zeyheri* (d), *Adromischus sphenophyllus*, *Antimima dasyphylla*, *Aridaria brevicarpa*, *A. noctiflora* subsp. *noctiflora*, *Delosperma crassum*, *Drosanthemum latipetalum*, *Euphorbia aspericaulis*, *Lampranthus uniflorus*, *Manochlamys albicans*, *Ruschia fugitans*, *Tetragonia hirsuta*, *T. sarcophylla*, *Tylecodon reticulatus*, *T. ventricosus*, *Zygophyllum cordifolium*. Low Shrubs: *Galenia fruticosa* (d), *Asparagus capensis* var. *capensis*, *A. suaveolens*, *Chrysocoma longifolia*, *Eriocephalus microphyllus* var. *pubescens*, *Galenia africana*, *Hermannia cuneifolia*, *Pteronia paniculata*, *Selago albida*, *Tripteris sinuata*. Herbs: *Gazania lichtensteinii* (d), *Foveolina dichotoma* (d), *Oncosiphon suffruticosum* (d), *Tribulus terrestris* (d), *Adenogramma glomerata*, *Amellus microglossus*, *Arctotis hirsuta*, *Cotula microglossa*, *Cromidon corrigioloides*, *Dimorphotheca sinuata*, *Felicia namaquana*, *F. tenella*, *Gazania krebsiana* subsp. *arctotoides*, *Gorteria diffusa* subsp. *diffusa*, *Griellum humifusum*, *Heliophila pendula*, *Nestlera biennis*, *Osteospermum pinnatum*, *Plantago cafra*, *Rhynchopsidium pumilum*, *Tripteris microcarpa*. Geophytic Herbs: *Babiana minuta*, *B. sambucina* var. *longibracteata*, *Cyanella orchidiformis*, *Dipcadi crispum*, *Lapeirusia exilis*, *Massonia echinata*, *Moraea galaxia*, *M. miniata*, *Oxalis annae*, *O. compressa*, *O. pes-caprae*, *O. purpurea*, *Sparaxis galeata*, *Strumaria unguiculata*, *Trachyandra falcata*, *T. jacquiniana*, *T. scabra*. Succulent Herbs: *Psilocalaon junceum* (d), *Apatesia helianthoides*, *A. sabulosa*, *Phyllobolus nitidus*, *Psilocalaon leptarthron*. Graminoids: *Stipa capensis* (d), *Bromus pectinatus*, *Ehrharta ramosa* subsp.



Figure 5.57 SKk 5 Vanrhynsdorp Gannabosveld: Flower-rich spring aspect on shaly soils of the Knersvlakte south of Vanrhynsdorp (Western Cape). The dominant plants include *Osteospermum pinnatum* (pink), local endemic vygie *Caulipsolon rapaceum* (white) and *Foveolina dichotoma* (yellow daisy).

aphylla, *Enneapogon desvauxii*, *Ficinia argyropa*, *Karoochloa tenella*, *Pentaschistis patula*, *Stipagrostis ciliata*, *S. zeyheri* subsp. *macropus*, *Tribolium pusillum*.

Biogeographically Important Taxa (^{NQ}Namaqualand endemic, ^KKnersvlakte endemic) Succulent Shrubs: *Drosanthemum schoenlandianum*^K, *Malephora purpureo-crocea*^{NQ}. Herbs: *Manulea altissima* subsp. *longifolia*^{NQ}, *Ursinia pygmaea*^K. Geophytic Herbs: *Babiana salteri*^K, *Lapeirousia simulans*^K, *Oxalis copiosa*^{NQ}.

Endemic Taxa Succulent Shrub: *Euphorbia fasciculata*. Geophytic Herbs: *Eriospermum eriophorum*, *Ornithogalum diluculum*. Succulent Herb: *Brownanthus glareicola*. Herb: *Cotula pedunculata*.

Conservation Vulnerable region due to transformation pressure. None of the unit is conserved in statutory conservation areas. Target 28%. So far 20% transformed into cultivated land and open-cast gypsum mining. Rehabilitation after open-cast mining remains minimal due to lack of little viable topsoil to cover the rehabilitated fields. Aliens (*Atriplex*, *Bromus*) have invaded large patches of vegetation. Increased cover of *Stipa capensis* (despite the name still unclear whether of indigenous or alien origin) diminishes grazing potential for sheep (due to damage to wool by caryopses). Erosion is moderate (71%) to high (18%).

References Greeff (1987), Steinschen et al. (1996), Schmiedel (2002a, b), Boucher (2003).

SKk 6 Knersvlakte Dolomite Vygieveld

VT 31 Succulent Karoo (100%) (Acocks 1953). LR 57 Lowland Succulent Karoo (100%) (Low & Rebelo 1996). BHU 76 Klaver Vygieveld (98%) (Cowling & Hejnis 2001).

Distribution Western Cape Province: Namaqualand, Knersvlakte between Vanrhynsdorp and the Farm Aties along the Troe-Troe River. Altitude 40–180 m

Vegetation & Landscape Features Sparse, succulent shrubland (canopy cover 10–30%) dominated by erect shrubs lower than 0.3 m with succulent leaves. In overgrazed habitats annual weeds and spiny, nonsucculent dwarf shrubs can become dominant.

Geology & Soils Metasediments of the Namibian Gariep Supergroup, in particular, on the dolomite-rich units. Soils are moderately deep, with high content of soil skeleton, typically slightly alkaline with high carbonate content. Entire area is classified as Ag land type.

Climate Winter-rainfall climate with dry, hot summers and mild, rainy winters. MAP of 164 mm is considerably higher than in the other parts of the Knersvlakte due to the orographic effects of the adjacent escarpment. Almost all the rainfall occurs between April and August. The lowest temperatures in winter 5–10°C, highest temperatures in summer 30–35°C. Winters are mild, with rare occurrence of frost (on average 3 days per year). See also climate diagram for SKk 6 Knersvlakte Dolomite Vygieveld (Figure 5.53).

Important Taxa Succulent Shrubs: *Drosanthemum pulverulentum* (d), *Salsola*

zeyheri (d), *Zygophyllum divaricatum*. Low Shrubs: *Hermannia cuneifolia* (d), *Melolobium candicans* (d), *Asparagus capensis* var. *capensis*, *Galenia fruticosa*. Geophytic Herb: *Sparaxis galeata*. Graminoids: *Stipa capensis* (d), *Tribolium echinatum*.

Biogeographically Important Taxon (Knersvlakte endemic) Succulent Shrub: *Euphorbia schoenlandii*.

Conservation Least threatened. Target 28%. None of the unit is conserved in statutory conservation areas. Local invasion of aliens (*Atriplex lindleyi* subsp. *inflata*) can diminish the utilisation potential in overgrazed areas. Erosion is moderate.

References Schmiedel (2002a, b).

SKk 7 Citrusdal Vygieveld

VT 69 Macchia (Fynbos) (60%) (Acocks 1953). Mosaic of Dry Mountain Fynbos & Karroid Shrublands (35%), Mesic Mountain Fynbos (16%) (Moll & Bossi 1984). LR 64 Mountain Fynbos (93%) (Low & Rebelo 1996). BHU 47 Cederberg Mountain Fynbos Complex (56%) (Cowling & Hejnis 2001).

Distribution Western Cape Province: The unit encompasses several patches situated on the broad bottom of the Olifants River valley spanning surrounds of Citrusdal in the south, Clanwilliam, and Klaver in the north. Due to floristic and geologic reasons we incorporate into this unit also narrow shale bands crossing the low and mid-slopes of the valley. Altitude 180–700 m.

Vegetation & Landscape Features Broad, slightly sloping mountain flanks as well as ridges of low hillocks emerging from the bottom of the broad valley between mountain ranges. Covered with mainly succulent shrublands, medium to tall in height (often dominated by *Euphorbia mauritanica* and vygies) and with spectacular displays (in precipitation-rich years) of spring annual and geophyte flora. Vegetation of low-lying shale bands embedded within the hard sandstones of the Nardouw series of the Olifants River Valley supports this vegetation type as well.

Geology & Soils Dominated by shale and quartzite of the Cape Supergroup (most important being the Ceres Subgroup of the Bokkeveld Group and the Nardouw and Peninsula Subgroups of the Table Mountain Group) supporting sandy and sandy-loamy,



Figure 5.58 SKk 7 Citrusdal Vygieveld: Succulent shrubland with dominant *Euphorbia mauritanica* (in foreground) and numerous heuweltjies dotting the shale slopes near Clanwilliam (Western Cape).

moderately deep soils. The area is a mosaic of five almost equally important land types: Fc, lb, Fb, Db and Ia.

Climate Winter-rainfall climate—the modelled MAP of 316 mm is the highest among the Knersvlakte vegetation units, but one can accept real values to be lower, apparently due to pronounced rainshadow effect. The mountains of the Olifants River in the south and Swartberg and Uitkomsberge in the north catch the scanty precipitation brought in by northwesterly winds and prevent penetration of the ocean-borne fog into the Olifants River Valley. MAT is around 18°C. Winters are mild, while summers are relatively hot. The incidence of frost is within the Knersvlakte norm (3–5 days per year). See also climate diagram for SKk 7 Citrusdal Vygieveld (Figure 5.53).

Important Taxa Succulent Shrubs: *Euphorbia mauritanica* (d), *Aloe comosa*, *Cotyledon paniculata*, *Euphorbia burmannii*, *Ruschia decurvans*. Tall Shrubs: *Didelta spinosa* (d), *Montinia caryophyllacea* (d), *Berkheya fruticosa*, *Nylandtia spinosa*, *Rhus undulata*. Low Shrubs: *Galenia africana* (d), *Diosma passerinoides*, *Elytropappus rhinocerotis*, *Tetragonia hirsuta*. Herbs: *Dimorphotheca pluvialis* (d), *Ursinia anthemoides* subsp. *versicolor* (d), *U cakilefolia* (d), *Heliophila coronopifolia*, *Leysera tenella*, *Senecio elegans*, *Tetragonia rosea*. Geophytic Herbs: *Albuca maxima* (d), *Massonia depressa* (d), *Bulbinella graminifolia*, *Cyanella alba*, *C. hyacinthoides*, *C. lutea*, *Gladiolus recurvus*, *Haemanthus amarylloides* subsp. *amarylloides*, *Melaspheerula ramosa*, *Moraea villosa*, *Oxalis obtusa*, *O. purpurea*, *Trachyandra dissecta*, *Valtheimia capensis*. Succulent Herbs: *Dorotheanthus bellidiformis* subsp. *bellidiformis*, *Huernia guttata* subsp. *reticulata*, *Quaqua parviflora* subsp. *dependens*. Graminoid: *Stipa capensis*.

Biogeographically Important Taxon (Knersvlakte endemic) Succulent Herb: *Tromotriche revoluta*.

Endemic Taxa Succulent Shrubs: *Drosanthemum prostratum*, *Lampranthus plenus*. Geophytic Herbs: *Sparaxis roxburghii*, *S. variegata*. Succulent Herb: *Stapelia glanduliflora*.

Conservation Vulnerable, especially due to insular character and surrounding high-intensity agricultural land. The fragmented character and limited extent of this vegetation unit suggest that some localities in the Olifants River valley previously inhabited by this Karoo vegetation have been turned into cultivated land (vineyards, orchards, grain fields). The local-authority Ramskop Nature Reserve (near Clanwilliam) protects some small (albeit already transformed) patches of this vegetation unit. Erosion is very low.

Remark 1 Citrusdal Vygieveld can be seen as the southern continuation of the SKk 5 Vanrhynsdorp Gannabosveld (at least in its northern reaches) due to a number of shared floristic elements and similarities in vegetation structure. While the northern patches of the shale bands support succulent shrublands, increase of renosterveld and Cape thicket elements can be observed along a north-west geographic gradient. The identity of the southernmost patches remains contentious and eventually only more detailed survey research in the area might bring more clarity about the delimitation of the Citrusdal Vygieveld.

Remark 2 A patch of this intravalley Succulent Karoo vegetation was errone-

ously mapped by Low & Rebelo (1996) as belonging to the Nama-Karoo Biome.

References Milton (1978), Knight et al. (1989), Boucher (1990, 1991, 2003), L. Mucina (unpublished data).

SKk 8 Piketberg Quartz Succulent Shrubland

VT 34 Strandveld of West Coast (100%) (Acocks 1953). LR 62 West Coast Renosterveld (100%) (Low & Rebelo 1996). BHU 31 Swartland Coast Renosterveld (100%) (Cowling & Hejnis 2001).

Distribution Western Cape Province: Piketberg area, larger patch on the Farm Draaihoek between Piketberg and Eendekuil (at eastern foothills of the Piketberg Mountains), in the vicinity of Het Kruis and Redelingshuys (north of Piketberg Mountains) as well as near Sauer at the southwestern foot of the Piketberg Mountains. Altitude 120–160 m.

Vegetation & Landscape Features Low shrubland dominated by sturdy, succulent *Sarcocornia* from the *S. mossiana* complex, and accompanied by leaf-succulent, contracted vygies, especially in shallow trenches and depressions. Elevated sites (hummocks) with deeper soils support dense shrubland.

Geology & Soils This small area is entirely situated on the Porterville Formation (Boland Subgroup) of the Malmesbury Group (Namibian Erathem). Weathering of softer shales left behind hard quartzitic veins which, after disintegration, form an almost continuous quartzite rubble layer. The area is exclusively classified as Db land type.

Climate Low, winter-rainfall precipitation regime (most of the rain falls between May and August, with small peaks in June and August). The area is largely in the local rainshadow of the Piketberg Mountains and located within the already generally dry West Coast region—MAP is only about 270 mm and potential evaporation is very high. The local climate is mild (only 4 frost days per year on average) and MAT (18°C) clearly suggests the classification of the unit as warm-temperate. See also climate diagram for SKk 8 Piketberg Quartz Succulent Shrubland (Figure 5.53).

Important Taxa Succulent Shrubs: *Drosanthemum asperulum* (d), *Galenia sarcophylla* (d), *Sarcocornia* sp. nov. (*Mucina*



Figure 5.59 SKk 8 Piketberg Quartz Succulent Shrubland: Quartz patch on the Farm Draaihoek near Eendekuil (West Coast lowlands) with an undescribed species of *Sarcocornia* dominant.

200103/8 STEU) (d). Low Shrub: *Athanasia trifurca* (d). Geophytic Herbs: *Albuca longipes*, *Oxalis copiosa*. Succulent Herb: *Psilocaulon parviflorum* (d).

Endemic Taxa Succulent Shrubs: *Drosanthemum zygophylloides* (d), *Diplosoma retroversum*. Herb: *Limonium* sp. nov. (*Mucina* 200103/8 STEU) (d). Geophytic Herb: *Drimia barkerae*.

Conservation None of it is conserved in statutory conservation areas, but the major patches of this unit occur on only a few commercial farms, especially on the Farm Draaihoek, where the farm owner (Mr Pierre Rossouw) has so far refrained from utilising the site and effectively pursues its preservation in its original state. Official conservation target 26%. Erosion is low (60%) to very low (40%).

Remark This is an extraordinary vegetation unit physiognomically and ecologically closely linked to Knersvlakte, being effectively separated from Citrusdal Vygiveld only by a ridge of the mountains of the Olifants River a few kilometres broad. There is an interesting evolutionary link between the Knersvlakte Quartz Vygiveld and quartz patches of the Piketberg area in sharing the Knersvlakte endemic genus *Diplosoma* (Aizoaceae), which comprises two species—each endemic to the respective vegetation unit.

References Van Jaarsveld (1998a), Klak (2003), Manning & Goldblatt (2003), L. Mucina (unpublished data).

Trans-Escarpment Succulent Karoo

SKt 1 Western Bushmanland Klipveld

VT 39 False Succulent Karoo (88%) (Acocks 1953). LR 49 Bushmanland Nama Karoo (92%) (Low & Rebelo 1996).

Distribution Northern Cape Province: Northwestern plains of Bushmanland east of Namaqualand Klipkoppe, north and northeast of Kliprand and west of Stofvlei. Altitude 650–1 040 m, with most of the area at 800–1 000 m.

Vegetation & Landscape Features Very sparsely populated plains with a desert appearance (rocky pavements built of rounded, dark-coloured rocks and boulders) supporting succulent dwarf shrubs (*Aridaria*, *Drosanthemum*, *Eberlanzia*, *Phyllobolus*, *Psilocaulon*, *Ruschia*), with microphyllous non-succulent shrubs (*Aptosimum*, *Pentzia*) and drought-tolerant grasses. Occasional mass display of annual spring flora.

Geology & Soils Hutton and Mispah soils over Karoo Sequence sediments (mostly Dwyka diamictite and Ecce shale). The rocky pavements of rounded boulders, which characterise this area,

are palaeo-river terraces of the palaeo-Orange River, which is presumed to have flowed south through this area (approximately 22 mya). Fc land type covers the entire region.

Climate Very dry region with MAP only 90 mm (range 70–100 mm), and erratic (almost desert-like) rainfall. Slight peak in precipitation in winter, hardly any in December and January, consistent with the classification of this unit in winter-rainfall Succulent Karoo Biome. Potential evaporation exceeds 2 660 mm. Overall MAT 16–17°C, with clear maxima in December to January. Mean maximum and minimum monthly temperatures in Kliprand are 36°C and –2°C for January and July, respectively. Incidence of frost is relatively high (25 days, range 20–40 days) due to its land-locked position and high altitude generating effect of thermal continentality. See also climate diagram for SKt 1 Western Bushmanland Klipveld (Figure 5.60).

Important Taxa Succulent Shrubs: *Antimima pumila* (d), *Arenifera stylosa* (d), *Augea capensis* (d), *Euphorbia decussata* (d), *Ruschia muricata* (d), *R. robusta* (d), *Salsola glabrescens* (d), *S. tuberculata* (d), *S. zeyheri* (d), *Aridaria noctiflora* subsp. *noctiflora*, *A. noctiflora* subsp. *straminea*, *Galenia sarcophylla*, *Prenia tetragona*, *Sarcocaulon patersonii*, *Tetragonia arbuscula*, *Titanopsis schwantesii*, *Zygophyllum flexuosum*, *Z. lichtensteinianum*. Tall Shrub: *Xerocladia viridiramis*. Low Shrubs: *Eriocephalus spinescens* (d), *Hermannia paucifolia* (d), *Zygophyllum retrofractum* (d), *Aptosimum depressum*, *A. spinescens*, *Asparagus capensis* var. *capensis*, *Eriocephalus ericoides*, *E. microphyllum* var. *pubescens*, *Galenia africana*, *G. fruticosa*, *Lebeckia spinescens*, *Melolobium candicans*, *Oncosiphon piluliferum*, *Osteospermum armatum*, *O. spinescens*, *Pegolettia retrofracta*, *Pentzia spinescens*, *Pteronia glauca*, *P. leucoclada*, *P. mucronata*, *P. sordida*, *Selago albida*, *Solanum capense*, *Tripteris sinuata*, *Zygophyllum microphyllum*. Semiparasitic Shrub: *Thesium lineatum*. Woody Climber: *Asparagus africanus*. Herbs: *Foveolina dichotoma* (d), *Gazania lichtensteinii* (d), *Leysera tenella* (d), *Tribulus terrestris* (d), *Amellus strigosus* subsp. *pseudoscabridus*, *Dicoma capensis*, *Dimorphotheca polyptera*, *Forsskaolea candida*, *Galenia papulosa*, *Helichrysum herniarioides*, *Heliophila variabilis*, *Limeum argute-carinatum* var. *argute-carinatum*, *Osteospermum pinnatum*, *Sesamum capense*. Geophytic Herb: *Drimia intricata*. Succulent Herbs: *Brownanthus vaginatus* (d), *Mesembryanthemum guerichianum*, *M. stenandrum*. Graminoids: *Enneapogon scaber* (d), *Stipagrostis anomala* (d), *S. brevifolia* (d), *S. ciliata* (d), *S. obtusa* (d), *Centropodia glauca*, *Enneapogon desvauxii*, *Schismus barbatus*.

Biogeographically Important Taxon (Western distribution limit) Succulent Shrub: *Euphorbia fusca*.

Endemic Taxa Succulent Shrub: *Salsola henriciae*. Low Shrubs: *Lessertia perennans* var. *polystachya*, *Senecio aquifoliaceus*,

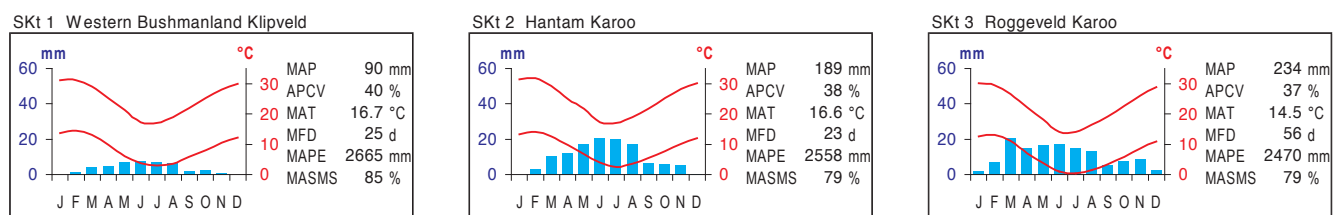


Figure 5.60 Climate diagrams of Trans-Escarpment Succulent Karoo Bioregion units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

Stachys zeyheri. Herb: *Wahlenbergia albicaulis*. Geophytic Herbs: *Lachenalia glaucophylla*, *Strumaria aestivalis*. Succulent Herb: *Conophytum concordans*.

Conservation Least threatened. Target 18%. None conserved in statutory conservation areas. No signs of serious large-scale transformation or invasion of alien plants. Erosion is high (70%) and moderate (12%).

Remark This unit shows climatic and vegetation characters indicative of a transition between the Succulent and Nama-Karoo Biomes.

References Acocks (1953, 1988), Lloyd (1985, 1989a, b).

SKt 2 Hantam Karoo

VT 28 Western Mountain Karoo (81%) (Acocks 1953). LR 56 Upland Succulent Karoo (88%) (Low & Rebelo 1996).

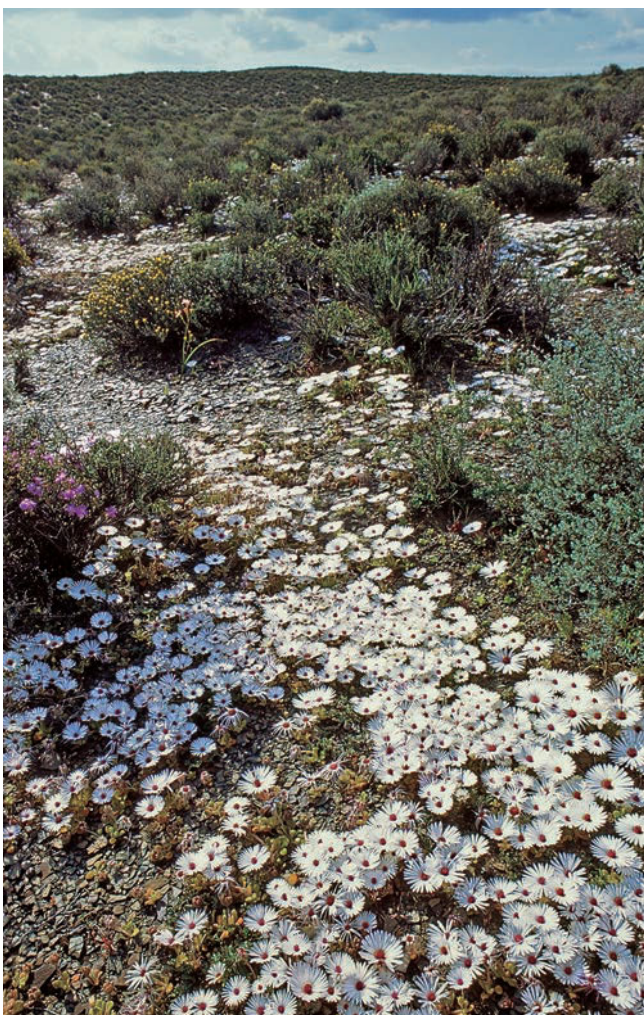
Distribution Northern (and to a smaller extent also Western) Cape Province: Greater part of the Onder-Bokkeveld and Hantam region between Nieuwoudtville and Calvinia. The unit also encompasses the lower slopes of the Hantamsberg (but not the mountain itself). A small patch of the unit is found north of the Langberg (west of Loeriesfontein)—where, in places, it also moves into the Western Cape Province. Altitude 400 m (in the western part of the unit) to 1 280 m in the east and southeast.

Vegetation & Landscape Features Dwarf Karoo shrubland with nearly equal proportions of succulent elements (*Aloe*, *Antimima*, *Euphorbia*, *Ruschia*) and low microphyllous karroid shrubs, particularly of the family Asteraceae (*Eriocephalus*, *Pentzia*, *Pteronia*). Rich displays of spring annuals and geophytes. Vegetation supported by Ag soils shows transitional features towards Nama-Karoo.

Geology & Soils Sediments of the Karoo Sequence (predominantly Ecca Group shales and Dwyka tillites), both significantly intruded by dykes and sills of the Jurassic Karoo Dolerite Suite. About half of the region is classified as Fc land type, followed by Fb, Ag and Da.

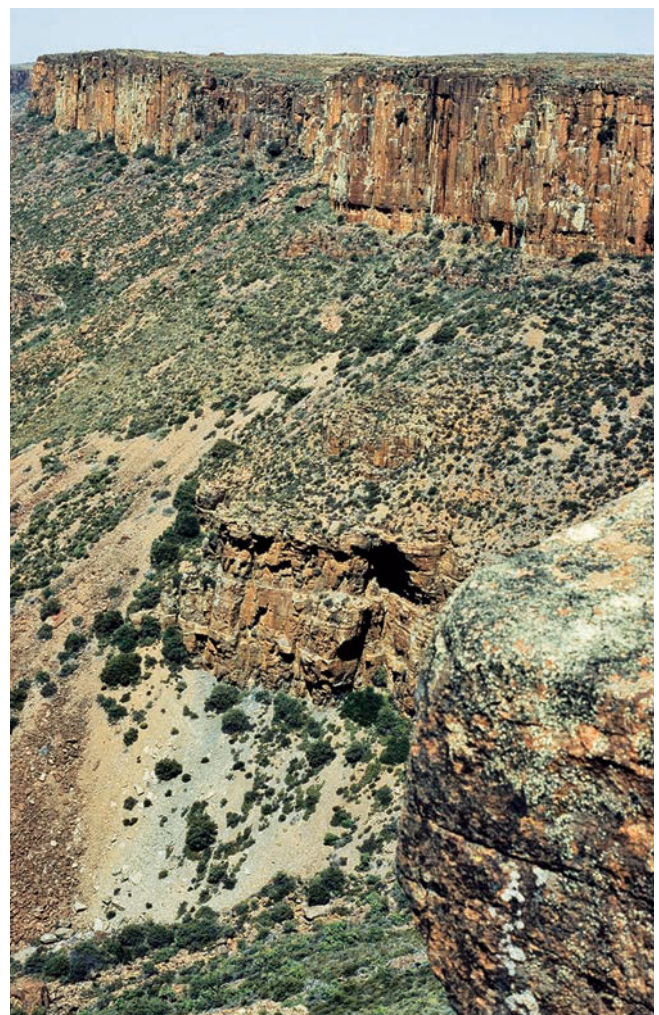
Climate Arid area (MAP around 190 mm and MAPE more than 2 550 mm), with clear peak in June to July and hardly any notable precipitation in December and January—characters typical of winter-rainfall regime. MAT 16–17°C and incidence of frost high (for the same reasons as with SKt 1 Western Bushmanland Klipveld). See also climate diagram for SKt 2 Hantam Karoo (Figure 5.60).

Important Taxa Succulent Shrubs: *Antimima hallii*, *A. hantamensis*, *Aridaria noctiflora* subsp. *straminea*, *Drosanthemum framesii*, *Lampranthus watermeyerii*, *Lycium cinereum*, *Manochlamys albicans*, *Pelargonium crithmifolium*, *Ruschia fugitans*, *Salsola aphylla*, *S. namibica*, *Stomatium mustellinum*, *Tetragonia robusta* var. *psiloptera*, *Tylecodon wallichii* subsp. *wallichii*, *Zygophyllum flexuosum*. Low Shrubs: *Eriocephalus*



J.C. Manning

Figure 5.61 SKt 2 Hantam Karoo: Endemic *Dorotheanthus maughanii* in succulent karoo shrubland near Calvinia (Northern Cape) in spring.



L.W. Powrie

Figure 5.62 SKt 2 Hantam Karoo: Top of Akkerendam Nature Reserve near Calvinia as viewed from the top of the Hantamsberg.

purpureus (d), *Hermannia cuneifolia* (d), *Hirpicium alienatum* (d), *Pentzia incana* (d), *Pteronia incana* (d), *Asparagus capensis* var. *capensis*, *Chrysocoma ciliata*, *Eriocephalus ericoides*, *E. pauperrimus*, *E. spinescens*, *Galenia africana*, *G. fruticosa*, *Hermannia multiflora*, *Pteronia erythrochaeta*, *P. glauca*, *P. glomerata*, *P. intermedia*, *P. oblanceolata*, *Tripteris sinuata*, *Zygophyllum microphyllum*. Semiparasitic Shrub: *Thesium lineatum*. Woody Climbers: *Asparagus fasciculatus*, *A. multituberosus*, *Microloma sagittatum*. Herbs: *Amellus tridactylus*, *Cotula microglossa*, *Dimorphotheca tragus*, *Gazania rigida*, *Leysera tenella*, *Pelargonium minimum*, *P. nervifolium*, *Plantago cafra*, *Ursinia nana*. Geophytic Herbs: *Drimia intricata*, *Gethyllis linearis*, *Moraea ciliata*, *Oxalis pes-caprae*, *Wurmbea variabilis*. Succulent Herbs: *Aloe variegata*, *Brownanthus vaginatus*, *Conophytum roodiae* subsp. *roodiae*, *Crassula muscosa*, *Duvalia caespitosa* subsp. *caespitosa*, *Hoodia flava*, *Mesembryanthemum guerichianum*, *Notechidnopsis tessellata*, *Orbea ciliata*, *Piранthus geminatus* subsp. *decorus*, *P. punctatus*, *Psilocaulon junceum*, *Quaqua acutiloba*, *Q. arida*, *Q. incarnata* subsp. *tentaculata*, *Q. multiflora*, *Stapeliopsis exasperata*, *S. saxatilis*, *Tetragonia microptera*, *Tromotriche pedunculata* subsp. *pedunculata*. Graminoids: *Dregeochloa calviniensis*, *Ehrharta calycina*, *Karroochloa tenella*.

Biogeographically Important Taxa (RH Roggeveld-Hantam endemic, N Northern distribution limit, W Western distribution limit, E Eastern distribution limit) Succulent Shrubs: *Antimima androsacea*^{RH}, *A. prolongata*^{RH}, *Euphorbia aequoris*^W, *E. cylindrica*^W, *E. pillansii*^W, *Hertia ciliata*^W. Low Shrubs: *Felicia whitehillensis*^N, *Hermannia grandiflora*^W, *H. johanssenii*^{RH}, *Pteronia adenocarpa*^W, *Rosenia glandulosa*^W, *Stachys aurea*^{RH}. Herbs: *Alyssum minutum*^{RH}, *Cromidon austerum*^{RH}, *C. plantaginis*^{RH}, *C. varicalyx*^{RH}, *Diascia cardiosepala*^{RH}, *D. macrophylla*^{RH}, *Galeomma oculus-cati*^{RH}, *Hemimeris centrodies*^{RH}, *Hermannia erodioides*^W, *Jamesbrittenia thunbergii*^{RH}, *Lotononis lenticula*^W, *Nemesia leipoldtii*^{RH}, *Zaluzianskya cohabitans*^{RH}, *Z. inflata*^{RH}, *Z. minima*^{RH}, *Z. violacea*^{RH}. Geophytic Herbs: *Androcymbium hantamense*^{RH}, *Babiana spathacea*^{RH}, *Bulbinella elegans*^{RH}, *Geissorhiza corrugata*^{RH}, *Haemanthus barkerae*^{RH}, *Ixia curvata*^{RH}, *Moraea bifida*^{RH}, *M. marlothii*^{RH}, *M. pritzeliana*^{RH}, *Pelargonium articulatum*^{RH}, *Romulea atrandra*^N, *Strumaria truncata*^E. Succulent Herbs: *Quaqua aurea*^{RH}, *Pectinaria articulata* subsp. *articulata*^{RH}, *P. longipes* subsp. *longipes*^{RH}, *Stapelia resurrecta*^{RH}, *Tromotriche thudichumii*^{RH}.

Endemic Taxa Succulent Shrubs: *Aloinopsis malherbei*, *Antimima distans*, *A. gracillima*, *A. stayneri*, *Cephalophyllum halii*, *Drosanthemum glabrescens*, *Ruschia punctulata*. Geophytic Herbs: *Androcymbium crispum*, *Lachenalia dasybotrya*, *Moraea hesperantha*, *M. pseudospicata*, *Ornithogalum rotatum*, *Oxalis pulvinata*, *Polyxena maughanii*. Succulent Herbs: *Dorotheanthus maughanii* (d), *Pectinaria longipes* subsp. *villetii*, *P. maughanii*, *Quaqua parviflora* subsp. *swanepoelii*, *Stapelia villetiae*.

Conservation Least threatened. Target 18%. Only a small patch is statutorily conserved in Akkerendam Nature Reserve near Calvinia. Transformation rate is low and invasions of alien plants have not been identified as a problem yet. Erosion is moderate (73%) and high (18%).

Remark 1 Hantam Karoo (including this unit as well as FRd 1 Nieuwoudtville-Roggeveld Dolerite Renosterveld and FRd 2 Hantam Plateau Dolerite Renosterveld), the neighbouring Roggeveld (see Van Wyk & Smith 2001), to which we would also add the marginal regions surrounding the Tanqua Basin from the west, and possibly also the SKv 6 Koedoesberge-Moordenaars Karoo, forms an important centre of endemism. Remarkable is the concentration of endemic Scrophulariaceae (many of them

short-lived), including *Alonsoa*, *Cromidon*, *Diascia*, *Hemimeris*, *Zaluzianskya* as well as bulbous and cormous geophytes of the Hyacinthaceae, Iridaceae and Amaryllidaceae.

Remark 2 This vegetation unit borders on Tanqua Karoo in the south and differs from it by a higher vegetation cover of microphyllous shrubs and a greater diversity of species, especially geophytes. The spring displays of annual Asteraceae and Scrophulariaceae are striking in years of good rainfall.

References Snijman & Perry (1987), Manning & Goldblatt (1997), Van Wyk & Smith (2001), L. Mucina (unpublished data).

SKt 3 Roggeveld Karoo

VT 28 Western Mountain Karoo (69%) (Acocks 1953). LR 56 Upland Succulent Karoo (69%) (Low & Rebelo 1996).

Distribution Northern (and to a very small extent also Western) Cape Province: Keiskiesberg and Kappgat se Berge southeast of Calvinia, surrounds of Sutherland and Hondefontein as far west as Teekloof Pass in the Nuweveld Mountains southeast of Fraserburg: the area constitutes a gradually sloping plateau situated inland of the Roggeveld Escarpment towards the Bushmanland Basin. Only negligible patches of this vegetation type move into Western Cape Province in the Besemgoedberge area (Nuweveld Mountains region). Altitude 1 040–1 680 m.

Vegetation & Landscape Features Diverse landscape including vast stretches of slightly undulating hills, steeper mountain slopes as well as extensive slightly sloping plateaus. The dominant image of the vegetation is sparse dwarf shrubland with high proportions of both succulent and nonsucculent (low microphyllous shrubs). The dominant shrubby genera include *Antimima*, *Eriocephalus*, *Pentzia*, *Pteronia* and *Salsola*. The occurrence and structural appearance of grasses (*Aristida*, *Stipagrostis*, but also *Ehrharta*) is notable and probably one of the most striking features within Succulent Karoo units—all these characters indicate the transitional position of Roggeveld Karoo between the Succulent Karoo and Nama-Karoo Biomes.

Geology & Soils The area is dominated by Adelaide Subgroup mudrock and subordinate sandstone (Beaufort Group, Karoo Sequence), with Ecca Group shale and sandstone found in the northeast (Waterford and Volksrust Formations). Karoo dolerites are found throughout the area. Fc land type dominates the region, while Da land type is also present.

Climate Roggeveld is climatically one of the most peculiar regions of southern Africa due to the unusual combination of high altitude, a land-locked continental position and a transitional position between two major climatic systems responsible for winter- and summer-rainfall regimes. It is a semidesert region under slight influence of a rainshadow (the area slopes landwards, away from the elevated Escarpment), with MAP reaching around 230 mm. Pronounced precipitation peaks are in March and June, and the overall precipitation in December to January is markedly lower than during the rest of the year. MAT 14–15°C, but the high frequency of low temperatures in autumn and winter resulting in an average of 56 frost days per year, has won the region (the town of Sutherland in particular) the reputation as the coldest place in South Africa. Clear skies (low cloudiness due to overall dry climate and high altitude as well as remoteness from major settlements and especially sources of air pollution) put Sutherland on the world map of astronomy through its famous telescope centre built near the town. See also climate diagram for SKt 3 Roggeveld Karoo (Figure 5.60).

Important Taxa Succulent Shrubs: *Lycium cinereum* (d), *Antimima pumila*, *A. subtruncata*, *Aridaria noctiflora* subsp. *straminea*, *Euphorbia stolonifera*, *Exomis microphylla* var. *axyrioides*, *Galenia sarcophylla*, *Salsola glabrescens*, *S. tuberculata*, *Tetragonia arbuscula*, *Zygophyllum flexuosum*. Low Shrubs: *Chrysocoma ciliata* (d), *Eriocephalus ericoides* (d), *E. spinescens* (d), *Felicia muricata* (d), *Helichrysum lucilioides* (d), *Pentzia spinescens* (d), *Pteronia glauca* (d), *P. glomerata* (d), *Amphiglossa triflora*, *Aptosimum elongatum*, *Asparagus capensis* var. *capensis*, *Chrysocoma coma-aurea*, *Eriocephalus decussatus*, *E. pauperimus*, *Euryops imbricatus*, *E. lateriflorus*, *E. multifidus*, *Felicia macrorrhiza*, *F. ovata*, *Galenia africana*, *Hermannia multiflora*, *Limeum aethiopicum*, *Melolobium candicans*, *Osteospermum leptolobum*, *O. spinescens*, *Pentzia globosa*, *Plinthus karoocicus*, *Pteronia adenocarpa*, *P. oblanceolata*, *P. tricephala*, *Rosenia glandulosa*, *R. humilis*, *R. oppositifolia*, *Senecio angustifolius*, *Stachys cuneata*, *Zygophyllum microphyllum*. Semiparasitic Shrub: *Thesium lineatum*. Woody Climber: *Asparagus multiberosus*. Herbs: *Leysera tenella* (d), *Alonsoa unilabiata*, *Amellus strigosus* subsp. *pseudoscabridus*, *Arctotheca calendula*, *Gazania jurineifolia* subsp. *scabra*, *Lepidium desertorum*, *Osteospermum acanthospermum*, *Pelargonium minimum*, *Ursinia nana*. Geophytic Herbs: *Drimia intricata* (d), *Androcymbium ciliolatum*, *Bulbine asphodeloides*, *Drimia physodes*, *Empodium plicatum*, *Geissorhiza spiralis*, *Ixia marginifolia*, *Moraea pallida*, *Oxalis densa*, *O. obtusa*, *Strumaria karoocica*. Succulent Herbs: *Deilanthus thudichumii*, *Mesembryanthemum guerichianum*, *M. stenandrum*, *Othonna auriculifolia*, *O. rechingeri*, *Tripteris aghilana* var. *integrifolia*. Graminoids: *Aristida diffusa* (d), *Ehrharta calycina* (d), *Stipagrostis ciliata* (d), *S. obtusa* (d), *Chaetobromus involucreatus* subsp. *dregeanus*, *Ehrharta capensis*, *E. pusilla*, *Karoochloa tenella*.

Biogeographically Important Taxa (RH Roggeveld-Hantam endemic, W Western distribution limit) Succulent Shrubs: *Antimima androsacea*^{RH}, *A. prolongata*^{RH}. Low Shrubs: *Pentzia punctata*^W, *Pteronia aspalatha*^{RH}, *Selago articulata*^{RH}. Herbs: *Alyssum minutum*^{RH}, *Corycium deflexum*^{RH}, *Cromidon austurum*^{RH}, *C. decumbens*^{RH}, *C. hamulosum*^{RH}, *C. plantaginis*^{RH}, *Diascia macrophylla*^{RH}, *Galeomma oculus-cati*^{RH}, *Gazania othonnites*^{RH}, *Heliophila pubescens*^{RH}, *Hemimeris centrodes*^{RH}, *Lotononis maximiliani*^{RH}, *Polycarena aurea*^{RH}, *Zaluzianskya cohabitans*^{RH}, *Z. minima*^{RH}, *Z. violacea*^{RH}. Geophytic Herbs: *Androcymbium hantamense*^{RH}, *Bulbinella elegans*^{RH}, *Eriospermum marginatum*^{RH}, *Gladiolus pritzelii*^{RH}, *G. uysiae*^{RH}, *Hesperantha ciliolata*^{RH}, *H. cucullata*^{RH}, *H. luticola*^{RH}, *H. marlothii*^{RH}, *H. pseudopilosa*^{RH}, *H. teretifolia*^{RH}, *Ixia curvata*^{RH}, *Lapeirousia montana*^{RH}, *Moraea bifida*^{RH}, *M. marlothii*^{RH}, *M. pritzeliana*^{RH}, *R. membranacea*^{RH}, *R. monadelpha*^{RH}, *R. syringodeoflora*^{RH}, *R. tetragona* var. *tetragona*^{RH}, *R. unifolia*^{RH}, *Syringodea unifolia*^{RH}. Succulent Herb: *Pectinaria articulata* subsp. *articulata*^{RH}. Graminoids: *Helictotrichon namaquense*^{RH}, *Pentaschistis aristifolia*^{RH}, *Secale strictum* subsp. *africanum*^{RH}.

Endemic Taxa Succulent Shrubs: *Drosanthemum eburneum* (d), *Aloinopsis spathulata*, *Antimima emarcescens*, *Hammeria gracilis*. Low Shrub: *Polhillia involucreta*. Herb: *Reyemia nemeioides*. Geophytic Herbs: *Babiana virginea*, *Moraea contorta*, *M. fistulosa*, *Romulea albiflora*. Succulent Herbs: *Dorotheanthus boosensii*, *Phyllobolus amabilis*.

Conservation Least threatened and none of the area is conserved in statutory conservation areas. Target 18%. Transformed only to a very small extent (about 2%) and hardly suffering invasions of alien plants. Erosion is moderate (71%) and low (29%).

Remarks Roggeveld Karoo is a botanically poorly researched vegetation type and this despite its intriguing transitional position between three major biomes (Fynbos, Succulent Karoo

and Nama-Karoo) and high level of local endemism (see SKt 2 Hantam Karoo for more details). The classification of the unit itself into a biome still remains a contentious issue demanding research into vegetation and phytogeography patterns (and history) of the SKt 3 Roggeveld Karoo as well as the spatially and floristically associated units such as FRd 1 Nieuwoudtville-Roggeveld Dolerite Renosterveld, FRs 3 Roggeveld Shale Renosterveld and SKv 4 Tanqua Escarpment Shrubland.

Reference Van Wyk & Smith (2001).

Rainshadow Valley Karoo

SKv 1 Doringrivier Quartzite Karoo

VT 31 Succulent Karoo (68%) (Acocks 1953). Dry Mountain Fynbos (77%) (Moll & Bossi 1984). LR 64 Mountain Fynbos (78%) (Low & Rebelo 1996). BHU 46 Gifberg Mountain Fynbos Complex (77%) (Cowling & Hejnis 2001).

Distribution Western Cape Province: Valley of the Doring River (from Doringbos and the bottom of the Botterkloof) to the confluence of the Doring and Olifants Rivers. It also includes the broader surrounds of Knolvlei (north of Pakhuis Pass, north of Clanwilliam) and a small patch of the Karoo east of Trawal and southwest of Klaver. Altitude 60–500 m.

Vegetation & Landscape Features Slopes of low mountains and of deep river canyons as well as table lands supporting shrublands housing a mixture of growth forms including tall

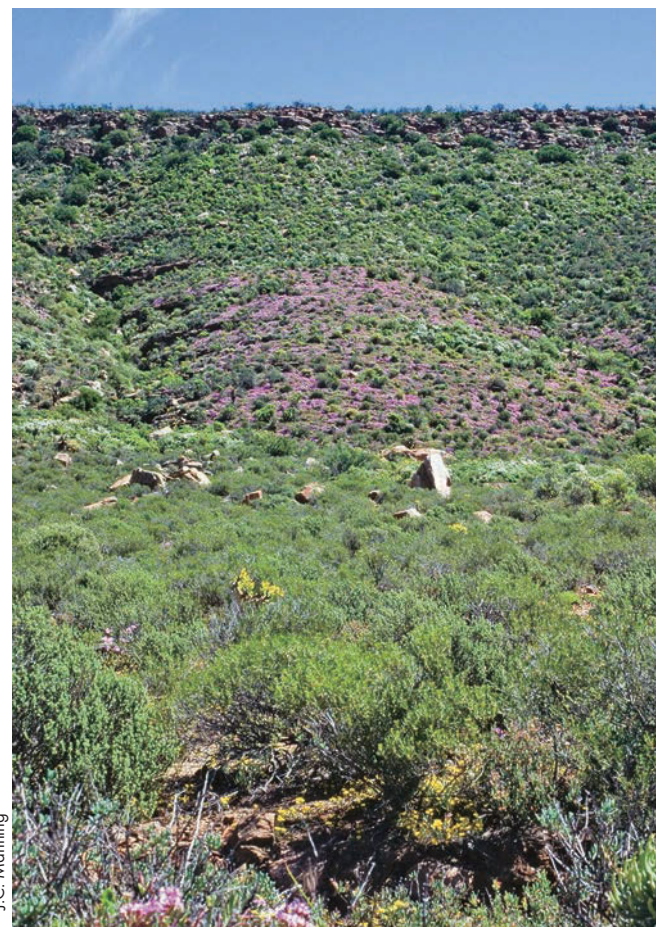


Figure 5.63 SKv 1 Doringrivier Quartzite Karoo: Succulent shrublands in the Botterkloof in the Doring River Valley (Western Cape).

shrubs (*Diospyros ramulosa*, *Montinia caryophyllacea*, *Berkheya fruticosa*) and low succulent shrubs, for example *Ruschia*, *Tylecodon*, *Euphorbia* and *Zygophyllum*.

Geology & Soils Here the Doring River cuts mostly through Table Mountain Group quartzites as well as some Bokkeveld Group (Nardouw Subgroup) sandstone and shale (both of Cape Supergroup). Ia, Ic and Ah land types are equally important.

Climate Semidesert region (obviously accentuated by the rain-shadow of deeply incised valleys) with MAP reaching almost 200 mm and MAPE exceeding 2 500 mm. Pronounced concentration of precipitation in winter (June, July, August). December to February have very low (and erratic) rainfall. Incidence of frost is very low. See also climate diagram for SKv 1 Doringrivier Quartzite Karoo (Figure 5.65).

Important Taxa Succulent Shrubs: *Euphorbia mauritanica* (d), *Ruschia brevibracteata* (d), *Didelta spinosa*, *Euphorbia burmannii*, *Tetragonia arbuscula*, *T. fruticosa*, *T. spicata*, *Tylecodon paniculatus*, *T. wallichii* subsp. *wallichii*. Tall Shrubs: *Diospyros ramulosa* (d), *Montinia caryophyllacea* (d), *Rhus undulata*, *Wiborgia obcordata*. Low Shrubs: *Berkheya fruticosa* (d), *Galenia africana* (d), *Eriocephalus africanus*, *Galenia fruticosa*, *Helichrysum hebelepis*, *Hermannia trifurca*, *Pteronia ovalifolia*, *Triptaris sinuata*. Woody Climber: *Cissampelos capensis*. Herb: *Lessertia pauciflora*. Geophytic Herb: *Chlorophytum lewisiae*. Graminoids: *Ehrharta villosa* var. *villosa* (d), *E. calycina*, *E. thunbergii*, *Pentaschistis airoides*.

Conservation Ranked as least threatened, but some important stretches might be destroyed by plans to build dams in certain rivers. Target 19%. None conserved in statutory conservation areas. About 15% has been transformed for cultivation. Aliens do not play a major role. Erosion is low (52%) especially due to low erodibility of hard sandstone rocks, moderate (25%) and very low (23%).

Remark Intrusion of the Succulent Karoo vegetation onto hard quartzitic sandstones is a relatively rare phenomenon occurring only in climatically marginal (dry) regions such as edges of the Tanqua Basin (SKv 2 Swartruggens Quartzite Karoo) and the adjacent Doring River Valley with the SKv 1 Doringrivier Quartzite Karoo.

Reference Boucher (2003).

SKv 2 Swartruggens Quartzite Karoo

VT 31 Succulent Karoo (91%) (Acocks 1953). LR 57 Lowland Succulent Karoo (96%) (Low & Rebelo 1996). BHU 78 Tanqua Vygieveld (94%) (Cowling & Heijns 2001).

Distribution Western and Northern Cape Provinces: Hottentotsberge and eastern portions of the Swartruggens bordering on the Tanqua Basin—from the canyon of the Doring River (leaving the Tanqua Karoo Basin at Elandsvlei) in the north to the Karoopoort (east of Ceres) in the south. Altitude 300–1 180 m.

Vegetation & Landscape Features Hilly landscape dissected by valleys with steep rocky slopes housing succulent shrublands with *Euphorbia*, *Tylecodon*, *Phiambolia*. Fynbos and renosterveld elements, shared with the neighbouring dry sandstone fynbos units, such as *Willdenowia*, *Dodonaea* and *Elytropappus*, are also important.

Geology & Soils Quartzitic sandstones of the Witteberg Group (Cape Supergroup) supporting shallow, skeletal soils (mainly Mispah soil form). Ib land type is dominant.

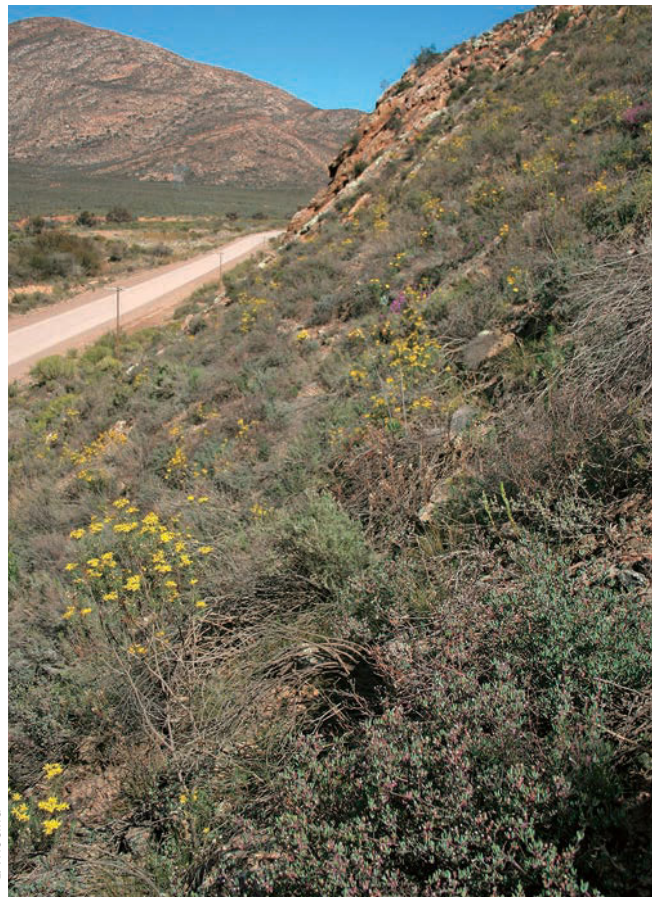


Figure 5.64 SKv 2 Swartruggens Quartzite Karoo: Steep quartzite slopes of Karoopoort (northeast of Ceres) supporting succulent karoo shrubland with *Euphorbia mauritanica* (Euphorbiaceae) and *Euryops tenuissimus* (Asteraceae).

Climate Winter-rainfall regime with clear precipitation optimum from June to August. MAP is around 200 mm (semidesert). MAT 15–16°C. Incidence of frost in midrange in comparison with other units of the Rainshadow Valley category (SKv). See also climate diagram for SKv 2 Swartruggens Quartzite Karoo (Figure 5.65).

Important Taxa (⁵Deep sandy soils) Succulent Shrubs: *Euphorbia decussata*⁵ (d), *E. mauritanica* (d), *Tylecodon wallichii* subsp. *wallichii* (d), *Aloe comosa*, *Euphorbia hamata*, *Tylecodon paniculatus*. Tall Shrubs: *Dodonaea viscosa* var. *angustifolia*, *Rhus undulata*. Low Shrubs: *Euryops tenuissimus* (d), *Gnidia deserticola* (d), *Elytropappus rhinocerotis*, *Eriocephalus africanus*, *Hoplophyllum spinosum*, *Pelargonium magenteum*. Herb: *Gazania lichtensteinii* (d), *Ursinia anthemoides* subsp. *versicolor* (d), *Rhynchosidium pumilum*, *Ursinia nana*. Geophytic Herb: *Xenoscapa fistulosa*. Graminoid: *Willdenowia incurvata*⁵.

Endemic Taxa Succulent Shrubs: *Cephalophyllum alstonii*, *Phiambolia franciscii*, *P. hallii*, *Tylecodon stenocaulis*.

Conservation Least threatened. Target 19%. About 5% statutorily conserved in Matjiesrivier Nature Reserve. Only a very small portion transformed for cultivation. No signs of serious alien plant infestations. Erosion is very low (55%) and low (43%).

Remark This vegetation type is the developmental centre of the recently recognised (Klak 2003) endemic succulent genus *Phiambolia* (Aizoaceae).

References Lechmere-Oertel (1998), Lechmere-Oertel & Cowling (1999, 2001), Klak (2003).

SKv 3 Agter-Sederberg Shrubland

VT 31 Succulent Karoo (37%), VT 69 Macchia (Fynbos) (33%) (Acocks 1953). LR 57 Lowland Succulent Karoo (41%), LR 56 Upland Succulent Karoo (33%) (Low & Rebelo 1996). BHU 78 Tanqua Vygieveld (41%), BHU 75 Western Mountain Vygieveld (33%) (Cowling & Hejnis 2001).

Distribution Western (and to a lesser extent also Northern) Cape Province: Includes Stinkfonteinberge and Boegoeberge (with the botanically famous Botterkloof), Biedouberge and Tra-Traberger near Wuppertal as well as a very narrow (shale) belt extending south of Wuppertal and squeezed between the Skurweberg in the west and Swartruggens in the east. Altitude 220–1 320 m (most of the area at 340–780 m).

Vegetation & Landscape Features

Slopes of low mountains and deeply incised valleys supporting tall shrublands composed of mixture of nonsucculent (*Berkheya*, *Felicia*, *Pteronia*) and succulent (*Crassula*, *Euphorbia*, *Ruschia*, *Tylecodon*) shrubs.

Geology & Soils Dark grey siltstones and shales with intercalated mudstones and sandstones of the Devonian Ceres and Bidouw Subgroups (Bokkeveld Group) and quartzitic sandstones of the Witteberg Group and Nardouw Subgroup (Table Mountain Group). Supporting deep soils over shales and shallow soils over quartzitic sandstone. Most of the area is classified as Fb land type. Fa and Fc land types are of lesser importance.

Climate Typical winter-rainfall regime with most of the rain falling between June and August. MAP is about 250 mm, which is higher than the nearby quartzite Karoo units and especially the neighbouring Tanqua Karoo. MAT reaches almost 17°C and incidence of frost is relatively low. See also climate diagram for SKv 3 Agter-Sederberg Shrubland (Figure 5.65).

Important Taxa Succulent Shrubs: *Aridaria noctiflora* subsp. *noctiflora* (d), *Euphorbia burmannii* (d), *E. mauritanica* (d), *Leipoldtia schultzei* (d), *Tetragonia fruticosa* (d), *Tylecodon wallichii* subsp. *wallichii* (d), *Adromischus mammillaris*, *Cotyledon orbiculata* var. *orbiculata*, *Crassula subaphylla*, *Didelta spinosa*, *Euphorbia caterviflora*, *Exomis microphylla* var. *axyrioides*, *Tetragonia robusta* var. *psiloptera*, *T. verrucosa*, *Tylecodon paniculatus*. Tall Shrubs: *Wiborgia obcordata* (d), *Euclea tomentosa*, *Montinia caryophyllacea*, *Nylandtia spinosa*, *Rhus incisa*, *R. pallens*. Low Shrubs: *Asparagus stipulaceus* (d), *Berkheya fruticosa* (d), *Galenia africana* (d), *Helichrysum cylindriflorum* (d), *Struthiola leptantha*

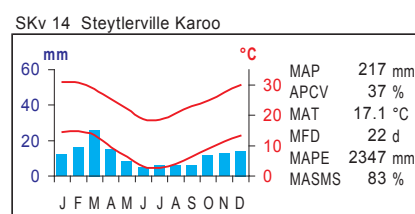
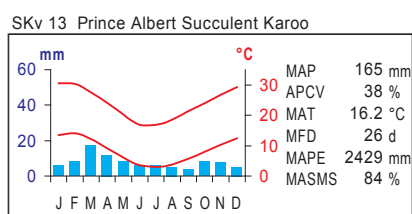
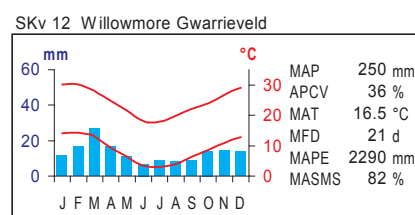
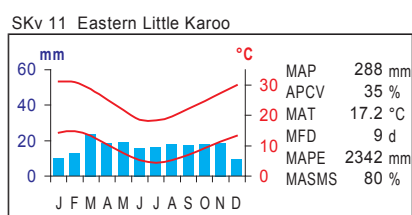
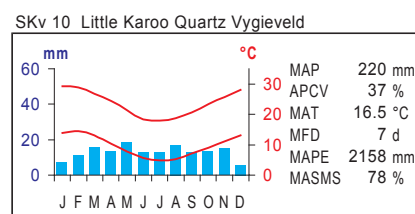
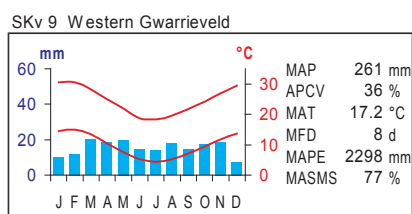
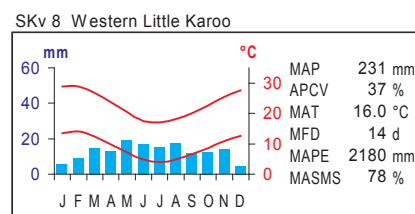
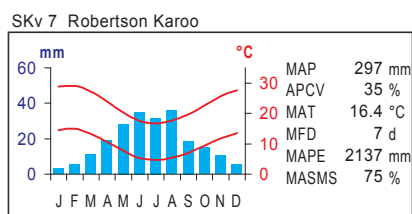
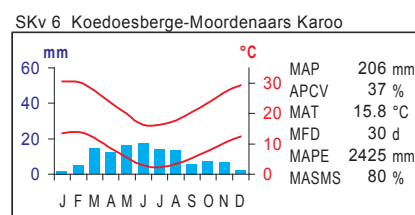
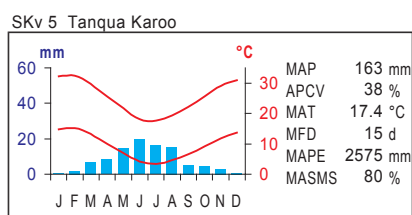
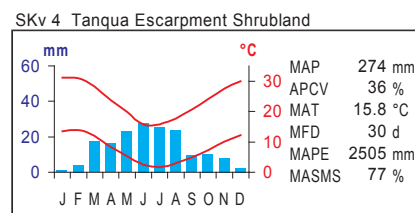
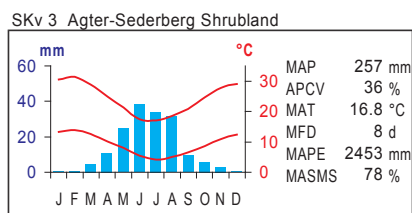
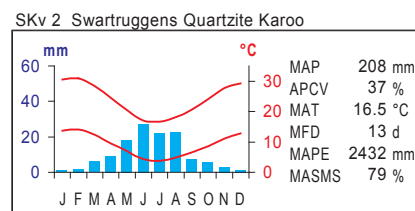
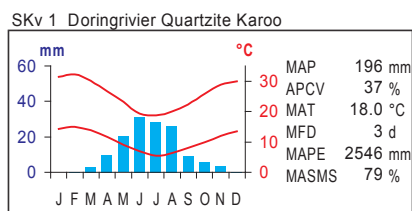


Figure 5.65 Climate diagrams of Rainshadow Valley Karoo Bioregion units. Blue bars show the median monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C); MAPE: Mean Annual Potential Evaporation; MASMS: Mean Annual Soil Moisture Stress (% of days when evaporative demand was more than double the soil moisture supply).

(d), *Asparagus capensis* var. *capensis*, *Elytropappus rhinocerotis*, *Eriocephalus africanus*, *Euryops tenuissimus*, *Galenia fruticosa*, *Helichrysum hebelepis*, *Indigofera heterophylla*, *Prenia pal-*



E. J. van Jaarsveld

Figure 5.66 SKv 3 Agter-Sederberg Shrubland: Shrubland at lower western foothills of Blinkberg near Op-die-Berg in the Koue Bokkeveld.

lens subsp. *lancea*, *Pteronia divaricata*, *P. incana*, *P. paniculata*, *Tripteris sinuata*, *Wiborgia sericea*. Semiparasitic Shrub: *Thesium lineatum*. Woody Climber: *Microlooma sagittatum*. Herbs: *Felicia bergeriana* (d), *Oncosiphon suffruticosum* (d), *Plantago cafra* (d), *Rhynchopsidium pumilum* (d), *Osteospermum pinnatum*, *Sutera caerulea*, *Tripteris brevibradiata*. Succulent Herbs: *Psilocalon junceum* (d), *Crassula alpestris* subsp. *alpestris*, *C. muscosa*, *C. tomentosa*, *Quaqua mammillaris*. Graminoids: *Tribolium pusillum* (d), *Ehrharta calycina*, *E. longiflora*, *Pentstemon patula*, *Tribolium echinatum*.

Biogeographically Important Taxon (Southern distribution limit) Succulent Shrub: *Lampranthus watermeyeri*.

Endemic Taxa Low Shrub: *Aspalathus bidouwensis*. Succulent Shrub: *Euphorbia hallii*. Geophytic Herbs: *Pelargonium punctatum*, *Strumaria watermeyeri* subsp. *botterkloofensis*.

Conservation Least threatened. Target 19%. Only a small patch statutorily conserved in Matjiesrivier Nature Reserve and only about 2–3% transformed for cultivation. No serious alien infestation. Erosion covers all possible categories, from very low (17%), low (11%) and high (10%).

Remark Agter-Sederberg Shrubland is a very poorly studied vegetation type promising new taxonomic surprises.

Reference Klak (2003).

SKv 4 Tanqua Escarpment Shrubland

VT 28 Western Mountain Karoo (68%) (Acocks 1953). LR 56 Upland Succulent Karoo (51%) (Low & Rebelo 1996).

Distribution Western Cape Province: Narrow belt on northwest-facing slopes of the Klein-Roggeveldberge and on

southwest-facing and west-facing slopes of the Roggeveld Escarpment as far north as (and west of) Bloukrans Pass (south of Calvinia). Altitude 620–1 600 m (most of the area between 720–1 220 m).

Vegetation & Landscape Features

Steep flanks below an escarpment overlooking a basin, generally facing southwest supporting succulent shrubland of medium height with *Tylecodon* (botterboom) and *Euphorbia mauritanica* (melkboom) prominent and with undergrowth of both succulent (*Aridaria*, *Crassula*) and nonsucculent (*Asparagus*, *Pteronia*) shrubs.

Geology & Soils Mudrocks of the Adelaide Subgroup (Beaufort Group) and Permian Volksrust Formation (Ecca Group) as well as brown to grey shale, siltstone and sandstone of the Permian Waterford Formation (also Ecca Group), broken by network of intrusive Jurassic Karoo dolerites. The shallow soils form the basis for the classification of most of

the area into lb land type (with Dc land type being of lesser importance).

Climate Less pronounced winter-rainfall regime with most of the rainfall spread between March and August (peaking from June to August). MAT is almost 16°C and the incidence of frost is relatively high (30 days). See also climate diagram for SKv 4 Tanqua Escarpment Shrubland (Figure 5.65).

Important Taxa Succulent Shrubs: *Tylecodon paniculatus* (d), *T. wallichii* subsp. *wallichii* (d), *Aridaria noctiflora* subsp. *straminea*, *Crassula tetragona* subsp. *connivens*, *Drosanthemum lique*, *Euphorbia caterviflora*, *E. mauritanica*, *Lycium cinereum*, *Manocharis albicans*, *Tetragonia robusta* var. *psiloptera*, *Tylecodon ventricosus*. Tall Shrubs: *Diospyros austro-africana*, *Gomphocarpus fruticosus*, *Montinia caryophyllacea*, *Rhus burchellii*, *R. undulata*. Low Shrubs: *Pteronia incana* (d), *Asparagus capensis* var. *capensis*, *A. striatus*, *Berkheya*



L. Mucina

Figure 5.67 SKv 4 Tanqua Escarpment Shrubland: Succulent shrubland with *Tylecodon paniculatus* (Crassulaceae) and *Salvia disermas* (Lamiaceae) on slopes of the Bloukrans Pass linking the Tanqua Karoo with the Hantam Plateau.

cardopatifolia, *Chrysocoma ciliata*, *Eriocephalus africanus*, *E. ericoides*, *E. spinescens*, *Felicia filifolia*, *F. macrorrhiza*, *F. scabrida*, *Galenia africana*, *G. fruticosa*, *Heliophila cornuta* var. *squamata*, *Hermannia multiflora*, *Lessertia fruticosa*, *Limeum aethiopicum*, *Pelargonium grandicalcaratum*, *Pteronia oblanceolata*, *P. sordida*, *Salvia disermas*, *Selago albida*, *S. polycephala*, *Tripteris sinuata*, *Ursinia pilifera*. Semiparasitic Shrub: *Thesium lineatum*. Woody Climbers: *Asparagus fasciculatus*, *A. multituberosus*, *Microlooma sagittatum*. Herbaceous Climber: *Fockea sinuata*. Herbs: *Galium capense* subsp. *garipense*, *Lasiospermum brachyglossum*, *Leysera tenella*, *Pelargonium moniliforme*, *Tripteris microcarpa*. Geophytic Herbs: *Androcymbium volutare*, *Asplenium cordatum*, *Boophone disticha*, *Cyanella hyacinthoides*, *Empodium plicatum*, *Oxalis obtusa*. Succulent Herbs: *Crassula tomentosa*, *C. umbella*, *Tetragonia microptera*. Graminoids: *Ehrharta calycina*, *Fingerhuthia africana*, *Merxmüllera dura*.



Figure 5.68 SKv 5 Tanqua Karoo: Extremely thin vegetation cover of the central Tanqua Karoo (near Jakkalsfontein), some years receiving as little as 40 mm of rainfall.

Biogeographically Important Taxa (RH Roggeveld-Hantam endemic, ^SSouthern distribution limit, ^WWestern distribution limit) Low Shrubs: *Felicia burkei*^S, *Nenax cinerea*^{RH}, *Pelargonium magenteum*^{RH}, *Pteronia aspalatha*^{RH}, *Selago polygala*^{RH}, *Stachys aurea*^{RH}. Herbs: *Cromidon hamulosum*^{RH}, *Diascia macrophylla*^{RH}, *Jamesbrittenia thunbergii*^{RH}, *Lotononis maximilianii*^{RH}, *Nemesia anisocarpa*^S, *Polycarena aurea*^{RH}, *Trigonocarpus lichtensteinii*^{RH}. Succulent Herb: *Crassula dodii*^{RH}. Graminoids: *Ehrharta melicoides*^W, *Secale strictum* subsp. *africanum*^{RH}.

Endemic Taxon Low Shrub: *Indigofera hantamensis*.

Conservation Least threatened. Target 19%. Only a very small portion statutorily conserved in Tankwa Karoo National Park. No visible signs of transformation or invasion of alien plants. Erosion is moderate (59%) and low (41%).

Remark Tanqua Escarpment Shrubland is part of the Hantam-Roggeveld Centre of Endemism (Van Wyk & Smith 2001) and remains one of the least studied vegetation types of the country.

Reference Van Wyk & Smith (2001).

SKv 5 Tanqua Karoo

VT 31 Succulent Karoo (84%) (Acocks 1953). LR 57 Lowland Succulent Karoo (80%) (Low & Rebelo 1996). BHU 78 Tanqua Vygieveld (50%) (Cowling & Hejnis 2001).

Distribution Western and Northern Cape Provinces: Basin encompassing valleys of Tanqua and Doring Rivers located between Cederberg (Swartruggens) in the west, the Roggeveld Escarpment in the east and Klein Roggeveld Mountains in the southeast; towards the north this unit borders on higher elevated plains of the Hantam Karoo. Altitude 240–960 m (most of the area at 300–450 m).

Vegetation & Landscape Features Slightly undulating intramountain basin sheltered by steep slopes of mountain ranges. The plain is interrupted by a series of solitary dolerite butts and elevated ridges, extensive, flat sheet-washes and deeper incised channels of intermittent rivers (these habitats support vegetation of the AZi 7 Tanqua Wash Riviere). The plains are

very sparsely vegetated (low succulent shrubland with *Ruschia*, *Drosanthemum*, *Aridaria*, *Augea*, *Zygophyllum*), in extreme precipitation-poor years appearing barren, while the slopes of the koppies and adjacent mountain piedmonts support well-developed medium-tall succulent *Euphorbia hamata*–*Pteronia incana* shrubland (Rubin 1998). Small quartz patches occur in the southern Tanqua Basin. Annual flora (*Gazania lichtensteinii*, *Euryops annuus*, *Ursinia nana*) becomes conspicuous with sufficient precipitation, while geophytes and grasses play a subordinate role. *Stipagrostis ciliata* and *S. obtusa* can become locally dominant in places.

Geology & Soils Permian Volksrust Formation mudrocks of the Ecca Group, Carboniferous Dwyka Group diamictites and Ceres Subgroup sandstones (Bokkeveld Group) predominate. Intrusive Jurassic Karoo dolerite dykes occur in the northwest. Sandy-loamy soils of various depths. Quartz patches are a rare phenomenon concentrated in the southern portions of the Tanqua Basin. Fc is the dominant land type, with Ag land type playing subordinate role.

Climate Winter-rainfall regime: most of the precipitation falls between May and August, while December and January are virtually precipitation-free. The region has high spatial variability of precipitation, with some rainshadows experiencing as little as 40 mm of rainfall per year (in extremely dry years). MAP varies from a low of 72 mm in the central part of the unit (Elandsvlei on the Tanqua River, 41 years of records) to 112 mm in the north of the unit (Reenen on the Wolf River, 79 years) and to 111 mm in the south of the unit (Spes Bona on the Doring River, 29 years). MAT is slightly above 17°C, but in winter the temperature can often fall below the frost mark (15 days in a year). Mean maximum and minimum monthly temperatures of 35.9°C and 5.64°C occur in January and July, respectively. See also climate diagram for SKv 5 Tanqua Karoo (Figure 5.65).

Important Taxa (^WWestern distribution limit) Succulent Shrubs: *Antimima hantamensis* (d), *Augea capensis* (d), *Gibbaea gibbosum* (d), *Ruschia spinosa* (d), *Antimima wittebergensis*, *Aridaria noctiflora* subsp. *noctiflora*, *A. noctiflora* subsp. *straminea*, *Braunsia apiculata*, *Cephalophyllum curtrophyllum*, *C. framesii*, *Crassula subaphylla*, *C. tetragona* subsp. *connivens*, *Drosanthemum delicatulum*, *D. framesii*, *D. lique*, *Euphorbia decussata*, *E. mauritanica*, *E. multiceps*, *E. rectirama*, *Hoodia gordonii*, *Leipoldtia schultzei*, *Lycium cinereum*, *Othonna*

pteronioides, *Peersia macradenia*, *Pelargonium crithmifolium*, *Phyllobolus grossus*, *P. splendens*, *Ruschia intricata*, *Salsola aphylla*, *S. namibica*, *Sarcocaulon crassicaule*, *Scopelogena bruynsii*, *Tetragonia fruticosa*, *T. robusta* var. *psiloptera*, *Tylecodon reticulatus*, *T. wallichii* subsp. *wallichii*, *Zygophyllum flexuosum*, *Z. microcarpum*. Low Shrubs: *Tripteris sinuata* (d), *Aptosimum indivisum*, *Asparagus capensis* var. *capensis*, *Berkheya spinosa*, *Chrysocoma ciliata*, *Eriocephalus africanus*, *E. ericoides*, *E. pauperimus*, *E. spinescens*, *Euryops cuneatus*, *Galenia africana*, *G. fruticosa*, *Hermannia multiflora*, *Lessertia fruticosa*, *Limeum aethiopicum*, *Monechma spartioides*, *Pelargonium grandicalcaratum*, *Pteronia aspalatha*, *P. ciliata*, *P. erythrochaeta*, *P. glauca*, *P. intermedia*, *P. oblanceolata*, *P. pallens*, *P. scariosa*, *P. sordida*, *Rhynchosia bullata*, *Stachys cuneata*^W, *Zygophyllum microphyllum*. Semiparasitic Shrub: *Thesium lineatum*. Woody Climbers: *Asparagus fasciculatus*, *Microloma sagittatum*.

Herbaceous Climber: *Cyphia comptonii*. Herbs: *Gazania lichtensteinii* (d), *Amellus microglossus*, *A. strigosus* subsp. *pseudocabridus*, *Dicoma capensis*, *Emex australis*, *Euryops annuus*, *Hebenstretia parviflora*, *Helichrysum herniarioides*, *Lepidium africanum*, *L. desertorum*, *Lessertia pauciflora*, *Leysera tenella*, *Lotononis parviflora*, *Lyperia tristis*, *Oncosiphon grandiflorum*, *Osteospermum pinnatum*, *Pelargonium minimum*, *Plantago cafra*, *Radyera urens*, *Ursinia nana*. Geophytic Herbs: *Drimia intricata*, *Lachenalia ameliae*, *Moraea pallida*, *M. speciosa*, *Ornithogalum xanthochlorum*, *Ornithoglossum viride*, *Oxalis pes-caprae*, *Strumaria unguiculata*, *Tritonia florentiae*. Succulent Herbs: *Brownanthus vaginatus*, *Crassula muscosa*, *Duvalia caespitosa* subsp. *caespitosa*, *Mesembryanthemum excavatum*, *M. guerichianum*, *M. stenandrum*, *Psilocaulon articulatum*, *P. junceum*, *Tetragonia microptera*. Graminoids: *Stipagrostis ciliata* (d), *S. obtusa* (d), *Aristida adscensionis*, *Cladoraphis spinosa*, *Ehrharta calycina*, *Enneapogon desvauxii*, *E. scaber*, *Fingerhuthia africana*.

Biogeographically Important Taxa (RH Roggeveld-Hantam endemic, ^SSouthern distribution limit) Low Shrubs: *Nenax cinerea*^{RH}, *Stachys aurea*^{RH}. Herbs: *Alatoseta tenuis*^{RH}, *Dimorphotheca polyptera*^S, *Nemesia karroensis*^{RH}. Geophytic Herbs: *Haemanthus barkeri*^{RH}, *Lapeirousia violacea*^{RH}. Succulent Herbs: *Stapelia surrecta*^{RH}, *Tridentea parvipuncta* subsp. *truncata*^{RH}, *Tromotriche thudichumii*^{RH}.

Endemic Taxa Succulent Shrubs: *Braunsia stayneri*, *Cephalophyllum corniculatum*, *Didymaotus lapidiformis*, *Drosanthemum bellum*, *D. lignosum*, *Euphorbia gentilis* subsp. *tanquana*, *Hammeria meleagris*, *Hereroa nelii*, *H. teretifolia*, *Malephora crassa*, *Ruschia tardissima*, *Tanquana prismatica*. Geophytic Herbs: *Haemanthus tristis*, *Strumaria karooportensis*.

Conservation Least threatened. Target 19%. About 10% statutorily conserved in the Tankwa Karoo National Park and a further 4% in private reserves, including Inverdoorn, Zwartbosch, Jakkalsfontein, Basjansklouf, Groote Kapelsfontein, Uintjieskraal and Vaalkloof. Only a small portion of this area of low agricultural production has been transformed but due to overgrazing in some places, aliens such as *Atriplex lindleyi* subsp. *inflata*



Figure 5.69 SKv 5 Tanqua Karoo: Grass-rich (*Stipagrostis ciliata*) succulent shrubland dominated by *Augea capensis* (Zygophyllaceae) west of Elandsberg in the western part of the Tankwa National Park. This region is a kind of climatic anomaly since it sometimes receives as much as 30% of its annual rainfall in summer.

have invaded. Erosion is moderate (47%), high (36%) as well as very low (14%).

Remark 1 Tanqua (Tankwa) Karoo is one of the driest forms of the Succulent Karoo Biome, and the whole appearance of the landscape resembles desert rather than semidesert during most of the year (in extremely precipitation-poor years in particular). The eastern edge (the foot of the Roggeveld Escarpment) and southern parts of the Tanqua Karoo, are wetter and consequently more densely vegetated. The classification status of the driest parts of the Tanqua Karoo as rainshadow desert rather than semidesert (Succulent Karoo) remains open for the time being. The mapped unit nevertheless lies within the same range of MAP corresponding to some of the Succulent Karoo mapped elsewhere within the winter-rainfall region (Port Nolloth southwards to Wallekraal), but lacks the coastal fog of the latter area. The role of heavy grazing pressure in the 19th and early 20th centuries in the Tanqua Karoo needs to be evaluated in places where it is 'terribly tramped out' according to Acocks (1953).

Remark 2 Tanqua Karoo (including the extensive sheet-wash plains) is an important local centre of endemism housing two endemic genera (*Didymaotus* and *Eurystigma*) and three near-endemic genera (*Braunsia*, *Hammeria* and *Tanquana*)—all of the family Aizoaceae.

References Lane (1977), Jürgens (1986), Acocks (1988), Mackay (1994), Mackay & Zietsman (1996), Milton et al. (1997), Rubin (1998), Schmiedel & Mucina (2006).

SKv 6 Koedoesberge-Moordenaars Karoo

VT 26 Karroid Broken Veld (27%), VT 28 Western Mountain Karoo (27%) (Acocks 1953). LR 56 Upland Succulent Karoo (27%), LR 57 Lowland Succulent Karoo (27%) (Low & Rebelo 1996). BHU 79 Laingsberg Vygieveld (23%), BHU 75 Western Mountain Vygieveld (17%), BHU 40 Roggeveld Inland Renosterveld (15%) (Cowling & Heijnis 2001).

Distribution Western Cape and Northern Cape (smaller portion) Provinces: Koedoesberge and Pienaar se Berg low mountain ranges bordering on southern Tanqua Karoo and separated by the Klein Roggeveld Mountains from the Moordenaars Karoo

in the broad area of Laingsburg and Merweville. The unit also includes the Doesberg region east of Laingsburg and piedmonts of the Elandsberg as far as beyond the Gamkapoort Dam at Excelsior (west of Prince Albert). Altitude 500–1 250 m (most of the area at 680–1 120 m).

Vegetation & Landscape Features Slightly undulating to hilly landscape covered by low succulent scrub and dotted by scattered tall shrubs, patches of 'white' grass visible on plains, the most conspicuous dominants being dwarf shrubs of *Pteronia*, *Drosanthemum* and *Galenia*.

Geology & Soils Mudstone (mainly), shale and sandstone of the Adelaide Subgroup (Beaufort Group), accompanied by sandstone, shale and mudstone of the Permian Waterford Formation (Ecca Group) and sandstone and shale of other Ecca Group Formations as well as Dwyka Group diamictites (all of the Karoo Supergroup). This geology gives rise to shallow, skeletal soils. Region is classified as Fc land type (to a large extent), with Ib land type playing a subordinate role.

Climate Probability of rain is given for the entire year, but it is higher in winter. MAP slightly above 200 mm. There are two slight rainfall optima: one in March and another spread from May to August. MAT close to 16°C and incidence of frost relatively high (30 days). See also climate diagram for SKv 6 Koedoesberge-Moordenaars Karoo (Figure 5.65).

Important Taxa Succulent Shrubs: *Hereroa odorata* (d), *Antimima fergusoniae*, *A. maxwellii*, *A. wittebergensis*, *Aridaria noctiflora* subsp. *straminea*, *Crassula nudicaulis*, *C. rupestris* subsp. *commutata*, *Cylindrophyllum comptonii*, *Drosanthemum framesii*, *D. karrooense*, *D. lique*, *Euphorbia decussata*, *E. eustacei*, *E. mauritanica*, *Hoodia gordonii*, *H. grandis*, *Lycium oxycarpum*, *Manochlamys albicans*, *Peersia macradenia*, *Pelargonium crithmifolium*, *Ruschia grisea*, *R. intricata*, *Salsola aphylla*, *Sarcocaulon crassicaule*, *Sceletium rigidum*, *Tetragonia robusta* var. *psiloptera*, *Trichodiadema barbatum*, *Tylecodon reticulatus*, *T. wallichii* subsp. *wallichii*, *Zygophyllum flexuosum*. Tall Shrub: *Diospyros pallens*. Low Shrubs: *Pteronia incana* (d), *Amphiglossa tomentosa*, *Aptosimum indivisum*, *A. spinescens*, *Asparagus burchellii*, *A. capensis* var. *capensis*, *Athanasia minuta* subsp. *inermis*, *Barleria stimulans*, *Berkheya spinosa*, *Chrysocoma ciliata*, *Eriocephalus africanus*, *E. ericoides*, *E. pauperrimus*, *E. spinescens*, *Euryops lateriflorus*, *Felicia filifolia*, *F. macrorrhiza*, *F.*

muricata, *F. scabrada*, *Galenia africana*, *G. fruticosa*, *Garuleum bipinnatum*, *Helichrysum lucilioides*, *Hermannia grandiflora*, *H. multiflora*, *Lessertia fruticosa*, *Limeum aethiopicum*, *Melolobium candicans*, *Menodora juncea*, *Microloma armatum*, *Monechma spartioides*, *Muraltia scoparia*, *Pelargonium hirtum*, *Pentzia incana*, *Polygala seminuda*, *Pteronia adenocarpa*, *P. ambrariifolia*, *P. empetrifolia*, *P. glauca*, *P. glomerata*, *P. pallens*, *P. scariosa*, *P. sordida*, *Rhigozum obovatum*, *Senecio haworthii*, *Tripteris sinuata*, *Zygophyllum microphyllum*, *Z. retrofractum*, *Z. spinosum*. Semiparasitic Shrub: *Thesium lineatum*. Woody Climbers: *Asparagus fasciculatus*, *A. racemosus*, *A. retrofractus*, *Microloma sagittatum*. Herbaceous Climber: *Fockea sinuata*. Semiparasitic Epiphytic Shrub: *Viscum capense*. Herbs: *Atriplex suberecta*, *Felicia bergeriana*, *Gazania jurineifolia* subsp. *scabra*, *Hermannia althaeifolia*, *H. pulverata*, *Lepidium africanum*, *L. desertorum*, *Leysera tenella*, *Pelargonium minimum*, *P. nervifolium*, *Syncarpha dregeana*, *Ursinia nana*, *Zaluzianskya inflata*, *Z. peduncularis*. Geophytic Herbs: *Drimia intricata*, *Geissorhiza karooica*, *Ixia marginifolia*, *I. rapunculoides*, *Ornithogalum adseptentrionesvergentulum*, *Oxalis obtusa*, *Romulea austinii*, *R. tortuosa* subsp. *tortuosa*, *Strumaria karooica*, *S. pubescens*, *Trachyandra thyrsoides*. Succulent Herbs: *Astroloba foliolosa*, *A. spiralis*, *Brownanthus vaginatus*, *Crassula deceptor*, *C. muscosa*, *C. tomentosa*, *Deilanthe thudichumii*, *Haworthia marumiana* var. *archeri*, *Mesembryanthemum stenandrum*, *Pectinaria articulata*, *Piarranthus parvulus*, *Psilocaulon coriarium*, *P. junceum*, *Quaqua arenicola* subsp. *arenicola*, *Q. arida*, *Q. ramosa*, *Stapelia pil-lansii*, *S. rufa*, *Stapeliopsis exasperata*, *Tetragonia microptera*, *Tripteris aghillana* var. *integrifolia*. Parasitic Herb: *Hyobanche glabrata*. Graminoids: *Aristida adscensionis*, *A. diffusa*, *Ehrharta calycina*, *E. delicatula*, *Enneapogon scaber*, *Fingerhuthia africana*, *Karoochloa tenella*, *Pentaschistis airoides*, *Stipagrostis ciliata*, *S. obtusa*.

Biogeographically Important Taxa (^{GKB}Great Karoo basin endemic, ^{RH}Roggeveld-Hantam endemic, ^SSouthern distribution limit, ^WWestern distribution limit) Succulent Shrubs: *Deilanthe peersii*^W, *Hereroa crassa*^{GKB}, *Pleiospilos nelii*^{GKB}, *Rhinephyllum graniforme*^{GKB}, *Ruschia crassa*^{GKB}, *R. perfoliata*. Low Shrubs: *Felicia lasiocarpa*^{GKB}, *Sericocoma pungens*^S. Herbs: *Helichrysum cerastioides* var. *aurosicum*^W, *Ifloga molluginoides*^S. Geophytic Herbs: *Brunsvigia comptonii*^S, *Drimia karooica*^W. Succulent Herbs: *Aloe longistyla*^W, *Crassula hemisphaerica*^W, *Pectinaria longipes* subsp. *longipes*^{RH}, *Piarranthus comptus*^{GKB}, *Quaqua parviflora* subsp. *gracilis*^{RH}, *Tridentea parvipuncta* subsp. *parvipuncta*^{GKB}.

Endemic Taxa Succulent Shrubs: *Antimima karroidea*, *A. loganii*, *Calamophyllum teretiusculum*, *Cerochlamys gemina*, *Drosanthemum comptonii*, *Ruschia karrooica*, *Tanquana archeri*, *Trichodiadema hallii*, *Tylecodon faucium*. Low Shrub: *Pelargonium stipulaceum* subsp. *ovato-stipulatum*. Semiparasitic Shrub: *Thesium marlothii*. Geophytic Herbs: *Lachenalia comptonii*, *Strumaria undulata*. Succulent Herbs: *Haworthia nortieri* var. *pehlemanniae*.

Conservation Least threatened. Target 19%. Only a very small portion enjoying statutory conservation in the Gamkapoort Nature Reserve. Transformed only to a very small extent. No serious alien plant invasions recorded. Erosion is moderate



Figure 5.70 SKv 6 Koedoesberge-Moordenaars Karoo: Karoo shrublands with *Pteronia pallens* near Matjiesfontein (Western Cape). The Witteberge with dry quartzite fynbos are visible in the background.

(88%) and only to lesser extent high or very low.

Remark Koedoesberge-Moordenaars Karoo remains poorly researched from the vegetation-ecological point of view, despite its proximity to major university centres in the Western Cape as well as good accessibility (N1 road cuts through the region in east-west direction).

SKv 7 Robertson Karoo

VT 26 Karroid Broken Veld (77%) (Acocks 1953). Worcester-Robertson Karoo (Acocks 1979). LR 58 Little Succulent Karoo (83%) (Low & Rebelo 1996). BHU 87 Robertson Broken Veld (81%) (Cowling & Hejnis 2001). Bosjiesveld (local name).

Distribution Western Cape Province: Broad valley of the middle reaches of the Breede River around Worcester, Robertson and Ashton. Altitude 160–960 m.

Vegetation & Landscape Features Undulating flats and adjacent hills (sometimes with very steep flanks) supporting dwarf succulent shrubland to succulent thicket of medium height dominated by succulent species of *Euphorbia*, *Crassula* (and related genera) and vygies (*Drosanthemum* and *Ruschia* the major structural players). *Euphorbia mauritanica* (var. *corallothamnus*) is usually dominant on heuweltjies, which are an important element of the landscape and vegetation of the Robertson Karoo (Midgley & Musil 1990, Van Wyk & Smith 2001).

Geology & Soils Shale of the Devonian Ceres and Bidouw Subgroups (Bokkeveld Group, Cape Supergroup) as well as diamictite and shale of the Carboniferous Dwyka and Ecca Groups (Karoo Sequence). Jurassic Enon conglomerates occur as well. The soils are deep, red, apedal and loamy to loamy-sandy with a high clay and sodium content. Fc land type is representative of half of the region, while Fb and Ic are of lesser importance.

Climate Robertson Karoo is a semi-arid region with a mainly winter-rainfall regime and with maximum precipitation occurring in August (61 mm for Worcester, Smitheman & Perry 1990). Another slight precipitation peak is in June. MAP 125–350 mm; most of the region receiving about 300 mm. The low precipitation of this region surrounded from all sides by various Fynbos Biome vegetation units is ascribed to the rainshadow effect due to the high surrounding mountain ranges. MAT is above 16°C. Summer temperatures are high and in January vary from 30–40°C (an average of 34.5°C in February was recorded for Worcester). Occasional northwestern berg winds may intensify the heat. Winter nights might experience light frost—7 days a year on average. See also climate diagram for SKv 7 Robertson Karoo (Figure 5.65).

Important Taxa Succulent Shrubs: *Aloe microstigma* (d), *Cotyledon orbiculata* var. *orbiculata* (d), *Crassula rupestris* subsp. *commutata* (d), *Euphorbia burmannii* (d), *E. mauritanica* (d), *Lycium oxycarpum* (d), *Ruschia caroli* (d), *R. cymosa* (d), *Senecio junceus* (d), *Tylecodon paniculatus* (d), *Adromischus filicaulis* subsp. *marlothii*, *A. maculatus*, *A. mammillaris*, *Antimima fergusoniae*, *A. peersii*, *Cephalophyllum curtophyllum*, *C. purpureo-album*, *Crassula atropurpurea* var. *anomala*,

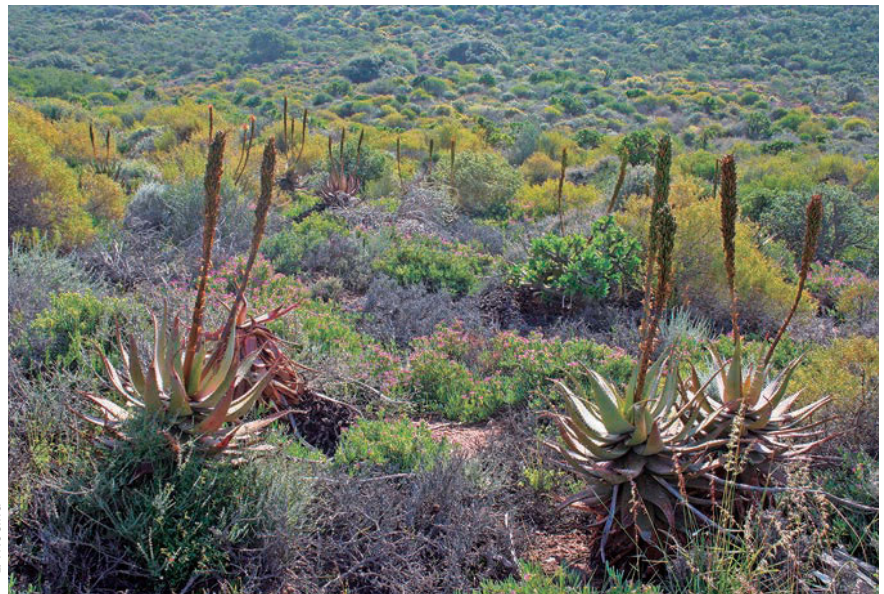


Figure 5.71 SKv 7 Robertson Karoo: Succulent shrubland in the Worcester Veld Reserve of the Western Cape Department of Agriculture, with *Aloe microstigma* (Asphodelaceae), *Ruschia caroli* (Aizoaceae) and *Galenia africana* (Aizoaceae).

C. cultrata, *C. nudicaulis*, *C. subaphylla*, *C. tetragona* subsp. *tetragona*, *Drosanthemum micans*, *D. striatum*, *Hereroa tenuifolia*, *Lampranthus dependens*, *L. haworthii*, *Leipoldtia schultzei*, *Pelargonium alternans*, *Phyllobolus grossus*, *P. nitidus*, *P. splendens*, *Ruschia multiflora*, *Tetragonia fruticosa*. Tall Shrubs: *Euclea undulata* (d), *Lebeckia cytisoides*. Low Shrubs: *Pentzia incana* (d), *Pteronia incana* (d), *Amphithalea spinosa*, *Anginon difforme*, *Asparagus burchellii*, *Ballota africana*, *Carissa haematocarpa*, *Chrysocoma ciliata*, *Elytropappus rhinocerotis*, *Eriocephalus africanus*, *E. ericoides*, *Felicia filifolia*, *Galenia africana*, *G. fruticosa*, *Helichrysum hamulosum*, *Hirpicium integrifolium*, *Microdon polygaloides*, *Oedera genistifolia*, *Pelargonium ramosissimum*, *Prenia englishiae*, *Pteronia fasciculata*, *P. paniculata*, *Selago ramosissima*, *Wahlenbergia thunbergiana*. Semiparasitic Shrub: *Thesium patulum*. Woody Succulent Climber: *Sarcostemma viminale*. Geophytic Herbs: *Albuca maxima* (d), *Drimia altissima* (d), *D. capensis* (d), *Kniphofia sarmentosa*, *Moraea viscaria*, *Oxalis pes-caprae*. Succulent Herbs: *Psilocaulon junceum* (d), *Crassula capitella* subsp. *thyrsiflora*, *C. cotyledonis*, *C. muscosa*, *Duvalia elegans*, *Gasteria disticha*, *Haworthia arachnoidea*, *Mesembryanthemum longistylum*, *Psilocaulon bicorne*, *Senecio radicans*, *Stapeliopsis breviloba*. Graminoids: *Ehrharta calycina*, *E. delicatula*, *E. longiflora*, *E. ramosa* subsp. *aphylla*.

Biogeographically Important Taxa (^SSouthern distribution limit, ^WWestern distribution limit) Low Shrub: *Pteronia flexicaulis*^W. Herbaceous Climber: *Cyphia angustifolia*^S. Herb: *Arctotis cuprea*^S.

Endemic Taxa Succulent Shrubs: *Drosanthemum speciosum* (d), *Antimima biformis*, *A. hamatilis*, *A. leipoldtii*, *Brianhuntleya intrusa*, *Delosperma macrostigma*, *Drosanthemum anomalum*, *D. laxum*, *D. leptum*, *D. papillatum*, *D. pickhardii*, *D. pulchrum*, *D. thudichumii*, *D. tuberculiferum*, *D. worcesterense*, *Euphorbia nesemannii*, *Phyllobolus caudatus*, *Ruschia subteres*, *Sceletium varians*, *Stayneria neilii*. Low Shrubs: *Aizoon karooicum*, *Aspalathus ferox*, *Polhillia obsoleta*. Herbaceous Succulent Climbers: *Ceropegia fimbriata* subsp. *connivens*, *C. occulta*. Herb: *Pelargonium oxaloides*. Geophytic Herbs: *Eriospermum bowieanum*, *Pelargonium violiflorum*. Succulent Herbs: *Astroloba rubriflora*, *Conophytum ficiforme*, *Crassula simulans*, *Haworthia herbacea* var. *herbacea*, *H. maculata*, *H. maraisii*, *H. pubescens*, *H. reticulata*, *Stapelia paniculata* subsp. *scitula*.



L. Mucina

Figure 5.72 SKv 7 Robertson Karoo: Steep shale slopes with *Tylecodon paniculatus*, *Aloe microstigma* and numerous *Crassula* species at De Wet wine cellar near Worcester (Western Cape).

Conservation Least threatened. Target 16%. Small area statutorily conserved in the Vrolijkheid Nature Reserve as well as on the premises of the Karoo Desert National Botanical Garden in Worcester (Oliver 2000) and in the Department of Agriculture Field Reserve (Oliver 1979). Marginal patches of the Robertson Karoo are under protection of private reserves such as Matroosberg, Drooge Riviers Berg, Langeberg-wes, Riviersonderend and Doornkloof. About 16% has been transformed by urban development as well as by cultivation: vineyards and orchards. Alien plant invasions can be a problem in places. The pressure of natural erosion processes is moderate (45%) to both high (24%) and low (22%).

Remark The region is the heart of the Worcester-Robertson Karoo Centre of Endemism (Van Wyk & Smith 2001). Two genera are endemic to this unit—*Stayneria* and *Brianhuntleya* (Van Wyk & Smith 2001, Chesselet et al. 2003). *Drosanthemum* and *Haworthia* show a high concentration of local endemics.

References Olivier (1966, 1979), Joubert (1968), Acocks (1979, 1988), Boshoff (1989), Midgley & Musil (1990), Smitheman & Perry (1990), Oliver (2000), Cowling & Hejnis (2001), Van Wyk & Smith (2001), Chesselet et al. (2003).

SKv 8 Western Little Karoo

VT 26 Karroid Broken Veld (80%) (Acocks 1953). Ladismith Karoo (Acocks 1979). LR 58 Little Succulent Karoo (85%) (Low & Rebelo 1996). BHU 88 Little Karoo Broken Veld (77%) (Cowling & Hejnis 2001).

Distribution Western Cape Province: The unit covers most of the western basin of the Little Karoo from the confluence of the Groot and Gouritz Rivers in the west as far as Anysberg by surrounding this mountain range and also extending along

the northern flanks of the Klein Swartberg. Two larger patches of the Western Little Karoo are found immediately to the east and south of Touws River and one small isolated patch fringes the Langeberg Mountains in the Montagu area. Altitude 160–1 060 m (most of the area at 300–860 m).

Vegetation & Landscape Features Flat or slightly undulating landscapes dominated by a mosaic of Karoo shrublands of low and medium height encompassing (as dominants) both non-succulent (*Chrysocoma*, *Pentzia*, *Pteronia*, *Rhigozum*, *Tripteris*) as well as succulent (*Crassula*, *Euphorbia*, *Ruschia*, *Tylecodon*) shrubs.

Geology & Soils Sandstone and shale of the Devonian Bidouw and Ceres Subgroups (both belonging to Bokkeveld Group, Cape Supergroup), Devonian sandstone of the Witteberg Group and Silurian sandstone of the Nardouw Subgroup (Table Mountain Group, Cape Supergroup), supporting deep, loamy-sandy (mainly) soils. The region has been classified as Fc land type.

Climate Western Little Karoo has a multimodal precipitation regime with major peaks in May and August and minor ones in March and November. December to January is markedly drier—a hint towards a slight inclination of the local climate towards a winter-rainfall pattern. MAP is around 230 mm (semidesert). MAT 16°C. On average 14 frost days per year. See also climate diagram for SKv 8 Western Little Karoo (Figure 5.65).

Important Taxa Small Tree: *Pappea capensis*. Succulent Shrubs: *Crassula rupestris* subsp. *commutata* (d), *Drosanthemum wittebergense* (d), *Euphorbia mauritanica* (d), *Hereroa odorata* (d), *Ruschia cymosa* (d), *R. spinosa* (d), *Tylecodon paniculatus* (d), *T. wallichii* subsp. *wallichii* (d), *Adromischus filicaulis* subsp. *marlothii*, *A. mammillaris*, *Aridaria noctiflora* subsp. *noctiflora*, *Augea capensis*, *Braunsia geminata*, *Cotyledon cuneata*, *C. orbiculata* var. *orbiculata*, *Crassula cultrata*, *C. ovata*, *C. rupestris* subsp. *rupestris*, *C. subaphylla*, *Drosanthemum chrysium*, *D. lique*, *Euphorbia brachiata*, *E. mammillaris*, *E. multiceps*, *E. mundii*, *E. stolonifera*, *Gibbaeum nuciforme*, *Leipoldtia schultzei*, *Lycium oxycarpum*, *Othonna carnosus*, *Phyllobolus nitidus*, *P. splendens*, *Ruschia archeri*, *R. intricata*, *R. multiflora*, *Salsola aphylla*, *Sarcocaulon patersonii*, *Sceletium rigidum*, *Smicrostigma viride*, *Tetragonia fruticosa*, *T. robusta* var. *psiloptera*, *Tylecodon cacalioides*. Tall Shrubs: *Euclea undulata*, *Putterlickia pyracantha*. Low Shrubs: *Chrysocoma ciliata* (d), *Eriocephalus ericoides* (d), *Felicia filifolia* (d), *F. muricata* (d), *Galenia africana* (d), *Monechma spartioides* (d), *Pentzia incana* (d), *Pteronia incana* (d), *P. pallens* (d), *Rhigozum obovatum* (d), *Rosenia humilis* (d), *Tripteris sinuata* (d), *Amphithalea spinosa*, *Aptosimum procumbens*, *Argyrobolus collinum*, *Asparagus burchellii*, *A. capensis* var. *capensis*, *A. krebsianus*, *A. mucronatus*, *Barleria pungens*, *Berkheya spinosa*, *Carissa haematocarpa*, *Elytropappus rhinocerotis*, *Eriocephalus africanus*, *E. purpureus*, *Felicia macrorrhiza*, *F. ovata*, *F. whitehillensis*, *Galenia fruticosa*, *G. secunda*, *Garuleum latifolium*, *Gnidia deserticola*, *Helichrysum asperum* var. *albidulum*, *H. rosom*, *H. simulans*, *H. zeyheri*, *Hermannia filifolia* var. *grandicalyx*, *H. multiflora*, *Hirpicium integrifolium*, *Indigofera heterophylla*, *Justicia cuneata* subsp. *cuneata*, *Lessertia fruticosa*, *Limeum aethiopicum*, *Macladium spinosum*, *Nenax microphylla*, *Oedera squarrosa*, *Osteospermum microphyllum*, *Pegolettia baccaridifolia*, *Pentzia elegans*, *P. lanata*, *P. spinescens*, *Phymaspermum aciculare*, *Plumbago tristis*, *Polygala asbestina*, *Pteronia adenocarpa*, *P. empetrifolia*, *P. fasciculata*, *P. flexicaulis*, *P. glauca*, *P. membranacea*, *P. oblanceolata*, *P. paniculata*, *P. sordida*, *P. succulenta*, *Rosenia oppositifolia*, *Selago geniculata*, *Sericocoma avolans*, *Zygophyllum microphyllum*, *Z. spinosum*. Semiparasitic Shrub: *Thesium lineatum*. Woody Climbers: *Asparagus racemosus*, *A. retrofractus*, *Cissampelos capensis*, *Microloma sagit-*



Figure 5.73 SKv 8 Western Little Karoo: Succulent shrubland with abundant *Berkheya cuneata* (Asteraceae), a regional Little Karoo endemic, near Barrydale (Western Cape).

tatum. Herbaceous Succulent Climber: *Othonna amplexifolia*. Semiparasitic Epiphytic Shrub: *Viscum rotundifolium*. Herbs: *Cineraria platycarpa* (d), *Cotula bipinnata* (d), *Diascia parviflora* (d), *Foveolina dichotoma* (d), *Heliophila pectinata* (d), *Plantago cafra* (d), *Amellus microglossus*, *Galenia papulosa*, *Heliophila amplexicaulis*, *Hermannia pulverata*, *Leysera gnaphalodes*, *Lotononis pungens*. Geophytic Herbs: *Albuca maxima* (d), *Oxalis obtusa* (d), *O. pes-caprae* (d), *Xenoscapa fistulosa* (d), *Drimia intricata*, *Empodium plicatum*, *Geissorhiza karooica*, *Lachenalia ameliae*, *Oxalis convexula*. Succulent Herbs: *Crassula lanceolata* (d), *C. orbicularis* (d), *Psilocaulon articulatum* (d), *P. junceum* (d), *Aloe variegata*, *Astroloba foliolosa*, *Crassula muscosa*, *Othonna auriculifolia*, *Psilocaulon coriarium*, *Senecio radicans*, *Stapelia engleriana*, *S. pillansii*, *S. rufa*, *Stapeliopsis saxatilis*, *Tetragonia micropetera*, *Tridentea gemmiflora*. Graminoids: *Ehrharta delicatula* (d), *Stipagrostis obtusa* (d), *Digitaria argyrograpta*, *Ehrharta calycina*, *E. erecta*, *Enneapogon scaber*.

Biogeographically Important Taxa (^{LK}Little Karoo endemic, ^SSouthern distribution limit, ^EEastern distribution limit, ^WWestern distribution limit) Succulent Shrubs: *Drosanthemum delicatulum*^{LK} (d), *Glottiphyllum depressum*^{LK}, *Tetragonia glauca*^S. Tall Shrub: *Freylinia densiflora*^{LK}. Low Shrubs: *Asparagus*

glauca^W, *Barleria stimulans*^W, *Berkheya cuneata*^{LK}, *Eriocephalus pauperrimus*^S, *Euryops imbricatus*^S, *Polygala empetrifolia*^{LK}, *P. uncinata*^{LK}, *Pteronia glomerata*^S, *Rosenia glandulosa*^S. Herb: *Alonsoa peduncularis*^{LK}. Geophytic Herb: *Freesia speciosa*^{LK}. Succulent Herb: *Duvalia parviflora*^{LK}. Graminoid: *Stipagrostis anomala*^S.

Endemic Taxa Succulent Shrubs: *Cotyledon tomentosa* subsp. *ladismithiensis*, *Crassula atropurpurea* var. *muirii*, *Drosanthemum bicolor*, *D. crassum*, *D. globosum*, *D. splendens*, *Gibbaeum nebrownii*, *Glottiphyllum cruciatum*, *G. suave*, *Lampranthus egregius*, *Octopoma octojuge*, *O. quadrisepalum*. Low Shrub: *Dicoma fruticosa*. Herb: *Diascia hexensis*. Geophytic Herb: *Ornithogalum synadelphicum*. Succulent Herb: *Haworthia pulchella*.

Conservation Least threatened. Target 16%. About 4% of the area is statutorily conserved in Anysberg and Dornkloof Nature Reserves and Eyerpoort (private reserve). About 3% has been transformed by cultivation. Alien *Acacia cyclops* and *A. saligna* pose a threat to the vegetation locally. Invasive *Atriplex lindleyi* subsp. *inflata* is a serious local problem for grazing. Erosion is high (54%), moderate (19%) and very low (15%).

Remark This unit is characterised by a high species density of *Asparagus*, *Crassula*, *Diascia*, *Dicoma*, *Euphorbia* and *Pteronia*, a high number of endemic species in *Drosanthemum* as well as the occurrence of one endemic genus—*Octopoma* (Aizoaceae).

References Muir (1929), Acocks (1953, 1988), Vlok (2002), Schmiedel & Mucina (2006).

SKv 9 Western Gwarrieveld

VT 25 Succulent Mountain Scrub (Spekboomveld) (50%) (Acocks 1953). LR 8 Spekboom Succulent Thicket (46%), LR 58 Little Succulent Karoo (45%) (Low & Rebelo 1996). BHU 97 Spekboom Xeric Succulent Thicket (47%), BHU 88 Little Karoo Broken Veld (46%) (Cowling & Hejnis 2001). STEP Vanwyksdorp Gwarrieveld (97%) (Vlok & Euston-Brown 2002).

Distribution Western Cape Province: Region of the western Little Karoo basin covering the northern, western and southern



Figure 5.74 SKv 9 Western Gwarrieveld: Undulating landscape of Noukloof Nature Reserve near Ladismith (Western Cape) supporting gwarrieveld involving low succulent shrublands on the slopes (with high dominance of *Pteronia incana*) with scattered tall shrubs and small trees of *Pappea capensis* and *Euclea undulata*. Linear patches of AZI 8 Muscadel Riviere are found on alluvial terraces on flat bottoms of valleys.

piedmonts of the Rooiberg Mountains roughly from Ladismith to Vanwyksdorp. The area north of the confluence of the Groot and Gouritz Rivers is classified as this unit as well. Altitude 120–800 m (most of area at 200–600 m).

Vegetation & Landscape Features Low hilly country supporting low Succulent Karoo shrublands, peppered with solitary trees and tall shrub groups (*Euclea*, *Lycium*, *Pappea*, *Rhus*).

Geology & Soils Sandstones, siltstones and mudstones of the Devonian Ceres and Bidouw Subgroups (both belonging to Bokkeveld Group, Cape Supergroup) as well as (to lesser extent) sandstones of the Silurian Nardouw Subgroup (member of the Table Mountain Group, Cape Supergroup) supporting loamy-clayey soils. Fc is the overwhelmingly dominant land type of the region.

Climate The overall precipitation regime of this unit is similar to that of SKv 8 Western Little Karoo, but the Gwarrieveld is wetter (MAP 260 mm) and warmer (MAT slightly above 17°C) and it has only 8 frost days a year. See also climate diagram for SKv 9 Western Gwarrieveld (Figure 5.65).

Important Taxa Small Trees: *Pappea capensis* (d), *Schotia afra* var. *afra*. Succulent Shrubs: *Aloe microstigma* (d), *Adromischus mammillaris*, *Cotyledon orbiculata* var. *orbiculata*, *Crassula arborescens* subsp. *arborescens*, *C. rupestris* subsp. *commutata*, *C. subaphylla*, *Drosanthemum framesii*, *D. lique*, *Euphorbia mauritanica*, *E. pillansii*, *E. stolonifera*, *Galenia sarcophylla*, *Leipoldtia schultzei*, *Lycium cinereum*, *Othonna carnososa*, *Phyllobolus splendens*, *Ruschia spinosa*, *Salsola aphylla*, *Sarcocaulon burmanni*, *Sceletium rigidum*, *Senecio articulatus*, *Tetragonia fruticosa*, *T. glauca*, *T. robusta* var. *psiloptera*, *T. spicata*, *Tylecodon paniculatus*, *T. reticulatus*, *Zygophyllum pygmaeum*. Tall Shrubs: *Euclea undulata* (d), *Cadaba aphylla*, *Nymania capensis*, *Putterlickia pyracantha*, *Rhus undulata*. Low Shrubs: *Eriocephalus ericoides* (d), *Pentzia incana* (d), *Pteronia incana* (d), *Aptosimum indivisum*, *Asparagus capensis* var. *capensis*, *A. mucronatus*, *A. recurvispinus*, *Ballota africana*, *Bassia salsoloides*, *Blepharis capensis*, *Carissa haematocarpa*, *Chrysocoma ciliata*, *Elytropappus rhinocerotis*, *Felicia filifolia*, *F. muricata*, *Galenia africana*, *G. fruticosa*, *Garuleum bipinnatum*, *G. latifolium*, *Helichrysum excisum*, *H. zeyheri*, *Hermannia filifolia* var. *grandicalyx*, *H. multiflora*, *Limeum aethiopicum*, *Microdon polygaloides*, *Monechma spartioides*, *Pentzia dentata*, *Polygala asbestina*, *P. myrtifolia*, *P. teretifolia*, *Pteronia flexicaulis*, *P. glauca*, *P. membranacea*, *P. oblanceolata*, *P. pallens*, *Rhigozum obovatum*, *Selago acocksii*, *Sutera subnuda*, *Tripteris sinuata*, *Zygophyllum microphyllum*. Woody Succulent Climber: *Crassula perforata*. Woody Climbers: *Asparagus aethiopicus*, *A. racemosus*. Herbaceous Succulent Climbers: *Crassula roggeveldii*, *Othonna amplexifolia*. Herbs: *Amellus microglossus*, *Cineraria platycarpa*, *Cotula bipinnata*, *Diascia parviflora*, *Dimorphotheca nudicaulis* var. *graminifolia*, *Foveolina dichotoma*, *Galenia papulosa*, *Gazania jurineifolia* subsp. *scabra*, *Heliophila crithmifolia*, *H. pectinata*, *Hemimeris racemosa*, *Hermannia pulverata*, *Leidesia procumbens*, *Lepidium africanum*, *L. desertorum*, *Rhynchopsidium sessiliflorum*, *Sisymbrium capense*, *Trichogyne paronychioides*. Geophytic

Herbs: *Bulbine frutescens*, *Chlorophytum crispum*, *Drimia intricata*, *Freesia refracta*, *Hesperantha acuta*, *Melasphaerula ramosa*, *Moraea polystachya*, *Oxalis obtusa*, *O. pes-caprae*. Succulent Herbs: *Aloe variegata*, *Crassula capitella* subsp. *capitella*, *C. expansa* subsp. *expansa*, *C. muscosa*, *C. orbicularis*, *Haworthia viscosa*, *Mesembryanthemum guerichianum*, *Psilocaulon articulatum*, *P. junceum*, *Senecio radicans*. Graminoids: *Ehrharta calycina*, *E. erecta*, *E. longiflora*, *Enneapogon scaber*, *Fingerhuthia africana*, *Pentaschistis airoides*, *Tribolium hispidum*.

Biogeographically Important Taxa (all Little Karoo endemics) Succulent Shrubs: *Drosanthemum delicatulum*, *Pelargonium curviandrum*. Tall Shrub: *Calpurnia villosa* var. *intrusa*. Low Shrubs: *Berkheya cuneata*, *Polygala empetrifolia*. Succulent Herbs: *Haworthia blackburniae* var. *blackburniae*, *Huernia praestans*.

Conservation Least threatened. Target 16%. Some 3% statutorily conserved in Ladismith-Klein Karoo Nature Reserve and an additional 1% is under less formal protection in private nature reserves such as Taayskloof, Buffelspoort, Rooiberg and Klein Swartberg. Only about 2% has so far been transformed by cultivation, but overgrazing (by sheep) is not uncommon. Aliens, *Acacia cyclops* and *A. saligna*, can be seen as a threat in places. Erosion is high (42%), very low (38%) and moderate (14%).

References Muir (1929), Acocks (1988).

SKv 10 Little Karoo Quartz Vygiveld

VT 26 Karroid Broken Veld (99%) (Acocks 1953). LR 58 Little Succulent Karoo (71%) (Low & Rebelo 1996). BHU 88 Little Karoo Broken Veld (66%) (Cowling & Hejnis 2001).

Distribution Western Cape Province: Especially in the western regions of the Little Karoo, bordered by the Witteberg and Swartberg Mountains from the north and the Riviersonderend, Langeberg and Outeniqua Mountains from the south, between the Koegaberge in the west and Oudtshoorn in the east. The largest patches are found at the northern foothills of the Langeberg Mountains, between Barrydale and Muiskraal. Altitude 220–720 m.



Figure 5.75 SKv 10 Little Karoo Quartz Vygiveld: Quartz fields near Groot Pheasantfontein near Muiskraal in the Western Little Karoo with an undescribed dominant succulent *Sarcocornia* species and *Gibbaeum album* ('stone plant').

Vegetation & Landscape Features Flat and slightly undulating plains covered by open, low vegetation dominated by fruticose or compact leaf-succulent dwarf members of Aizoaceae (*Gibbaeum*), Crassulaceae and Euphorbiaceae, accompanied by nonsucculent asteraceous shrubs and dwarf shrubs.

Geology & Soils Loamy-sandy, shallow to moderately deep, slightly alkaline soils, mainly derived from micaceous sandy shales and mudstones of the Devonian Ceres and Bidouw Subgroups (both belonging to Bokkeveld Group, Cape Supergroup) as well as (to lesser extent) sandstones of the Silurian Nardouw Subgroup (member of the Table Mountain Group, Cape Supergroup). The soil surface is densely covered with characteristic quartz gravel and rubble (derived from weathered quartz veins accompanying the shales). Fc is the overwhelmingly dominant land type.

Climate MAP of 220 mm is multimodal and distributed in similar fashion as in SKv 8 Western Little Karoo and SKv 9 Western Gwarrieveld. A tendency towards winter-rainfall regime can be detected in the western part of the distribution area of the quartz fields, while the influence of summer rainfall increases in an eastwards direction. MAT 16.5°C, high temperatures can be reached in summer (well above 30°C). Winters are mild, with occurrence of occasional light night frost (7 days a year). See also climate diagram for SKv 10 Little Karoo Quartz Vygieveld (Figure 5.65).

Important Taxa Succulent Shrubs: *Gibbaeum gibbosum* (d), *Hereroa tenuifolia* (d), *Sarcocornia* sp. nov. (*Mucina* 160601/110 STEU) (d), *Adromischus filicaulis* subsp. *marlothii*, *Antegibbaeum fissoides*, *Caulipsolon rapaceum*, *Drosanthemum delicatulum*, *Tetragonia robusta* var. *psiloptera*. Low Shrubs: *Pteronia pallens* (d), *Chrysocoma ciliata*, *Macladium rehanioides*, *Pteronia empetrifolia*, *P. succulenta*, *P. viscosa*, *Tripteris sinuata*. Succulent Herbs: *Anacampseros papyracea*, *Crassula columnaris* subsp. *columnaris*, *C. deltoidea*, *C. pyramidalis*, *Psilocalon articulatum*.

Biogeographically Important Taxon (Little Karoo endemic) Succulent Shrub: *Gibbaeum nuciforme* (d).

Endemic Taxa Succulent Shrubs: *Gibbaeum album* (d), *G. dispar* (d), *G. heathii* (d), *G. petrense* (d), *G. pubescens* (d), *Muiria hortenseae* (d), *Zeuktophyllum suppositum* (d), *Cerochlamys pachyphylla*, *Drosanthemum albiflorum*, *Euphorbia susannae*, *Gibbaeum pachypodium*, *G. pilosulum*, *G. shandii*, *Hereroa muirii*, *Rhinephyllum muirii*, *Salsola verdoorniae*, *Zeuktophyllum calycinum*. Succulent Herbs: *Conophytum joubertii*, *C. piluliforme*, *Crassula congesta*, *Quaqua ramosa*.

Conservation Target 16%. Only about 2% statutorily conserved in the Anysberg Nature Reserve, but a further 7% finds some level of protection in the Eyerpoort Private Nature Reserve. Almost 8% of the area has experienced transformation, but most of the quartz-field communities of the Little Karoo are exposed to increasing pressure from the local rangeland farming with sheep, goats, game and ostrich. Erosion is high (84%) or moderate (12%). The level and extent of threats of particular quartz vygieveld communities have been analysed in great detail by Schmiedel & Mucina (2006).

Remark Quartz fields in the arid regions of southern Africa represent edaphically defined special habitats, which house distinct vegetation units typically dominated by a number of habitat endemics. In different regions, the quartz fields are inhabited by similar plant growth forms of distantly related lineages (mainly Aizoaceae). This phenomenon has been interpreted as convergent evolution in adaptation to special habitat conditions. The total cover of the quartz field vegetation (10–20%) is typically significantly lower than that of the surrounding vegetation (20–40%). Geophytic *Caulipsolon rapaceum*, unpalatable *Pteronia pallens* as well as alien *Atriplex lindleyi* subsp. *inflata* are indicators of disturbance by overgrazing or trampling. High erosion pressure has presumably been a typical (and natural) feature of the quartz-field habitats.

References Schmiedel & Jürgens (1999, 2002, 2004), Schmiedel (2002a, b, 2004), Vlok (2002), Schmiedel & Mucina (2006).

SKv 11 Eastern Little Karoo

VT 25 Succulent Mountain Scrub (Spekboomveld) (51%) (Acocks 1953). LR 8 Spekboom Succulent Thicket (43%), LR 58 Little Succulent Karoo (36%) (Low & Rebelo 1996). BHU 97 Spekboom Xeric Succulent Thicket (43%), BHU 89 Oudtshoorn Broken Veld (34%) (Cowling & Hejnis 2001). STEP Blossoms Karroid Thicket (33%), STEP Calitzdorp Karroid Thicket (21%) (Vlok & Euston-Brown 2002).

Distribution Western Cape Province: Eastern basin of the Little Karoo from Calitzdorp in the west as far as Oudtshoorn in the east. The unit continues in a series of narrow belts (alternating with the Willowmore Gwarrieveld unit from the surrounds of Dysselsdorp as far west as the N2 road. A narrow belt of the Eastern Little Karoo fringes the southern flanks of the Kammanassie Mountains along the Kammanassie River as far west as Uniondale. Altitude 320–960 (most of area at 320–550 m).

Vegetation & Landscape Features Irregularly flat plains and undulating piedmont hills covered by dense succulent shrubland dominated by Aizoaceae (*Ruschia*, *Drosanthemum*) and Crassulaceae (*Cotyledon*, *Crassula*, *Tylecodon*,) and nonsucculent, mainly shrubs such as *Nymania*, *Pteronia* and *Rhus*. The spring displays of annual and geophyte flora are spectacular in years with good rain.



Figure 5.76 SKv 11 Eastern Little Karoo: Succulent shrubland with *Tylecodon cacalioides* south of Oudtshoorn in the Little Karoo (Western Cape).

Geology & Soils Fossiliferous shales, mudstones and siltstones of the Devonian Bokkeveld Group (Ceres and Traka Subgroups). Also present are mudstones and sandstones as well as subordinate shale of the Kirkwood Formation together with conglomerates of the Enon Formation (both of the Mesozoic Uitenhage Group). Soils developing over these substrates are of varied structure and texture, but mainly loamy-silty and deep in places. Ag and Fc land types are equally important (and dominant) in the region.

Climate Aseasonal rainfall (MAP almost 290 mm) with slight optimum in March and pronounced dip in December to January (summer). MAT is about 17°C and frost occurs only 9 days per year. See also climate diagram for SKv 11 Eastern Little Karoo (Figure 5.65).

Important Taxa Succulent Tree: *Aloe ferox*. Succulent Shrubs: *Augea capensis* (d), *Leipoldtia schultzei* (d), *Tylecodon cacalioides* (d), *Cotyledon orbiculata* var. *orbiculata*, *C. tomentosa* subsp. *tomentosa*, *Crassula cultrata*, *C. nudicaulis*, *C. ovata*, *C. rupestris* subsp. *commutata*, *Drosanthemum lique*, *Euphorbia colliculina*, *E. mauritanica*, *Glottiphyllum carnosum*, *G. linguiforme*, *Lycium oxycarpum*, *Marlothistella stenophylla*, *M. uniondalensis*, *Othonna carnososa*, *Phyllobolus splendens*, *Pleiospilos compactus* subsp. *compactus*, *Ruschia grisea*, *R. spinosa*, *Smicrostigma viride*, *Tetragonia fruticosa*, *T. robusta* var. *psiloptera*, *Trichodiadema burgeri*, *Tylecodon paniculatus*, *T. wallichii* subsp. *wallichii*, *Zygophyllum morgsana*. Tall Shrubs: *Cadaba aphylla*, *Euclea undulata*, *Nymania capensis*, *Putterlickia pyracantha*, *Rhus lucida*, *R. pallens*. Low Shrubs: *Pentzia incana* (d), *Pteronia incana* (d), *Rhigozum obovatum* (d), *Aptosimum elongatum*, *Asparagus burchellii*, *A. glaucus*, *A. recurvispinus*, *Berkheya spinosa*, *Carissa haematocarpa*, *Chrysocoma ciliata*, *Elytropappus rhinocerotis*, *Eriocephalus ericoides*, *Felicia muricata*, *Galenia africana*, *G. fruticosa*, *G. secunda*, *Garuleum latifolium*, *Helichrysum asperum* var. *albidulum*, *H. simulans*, *Hermannia filifolia* var. *grandicalyx*, *Hirpicium alienatum*, *Limeum aethiopicum*, *Macladidium relhaniaoides*, *Oedera genitifolia*, *Pegolettia baccaridifolia*, *Polygala myrtifolia*, *Pteronia flexicaulis*, *P. glauca*, *P. pallens*, *Rosenia humilis*, *Tripteris sinuata*, *Zygophyllum microphyllum*, *Z. spinosum*. Semiparasitic Shrub: *Thesium lineatum*. Woody Succulent Climbers: *Crassula perforata*, *Sarcostemma viminalis*. Woody Climbers: *Asparagus racemosus*, *A. retrofractus*, *Cissampelos capensis*. Herbaceous Succulent Climber: *Othonna amplexifolia*. Herbaceous Climber: *Fockea sinuata*. Semiparasitic Epiphytic Shrub: *Viscum rotundifolium*. Herbs: *Atriplex semibaccata* var. *appendiculata*, *Chamaesyce inaequilatera*, *Galenia papulosa*, *Galium tomentosum*, *Helichrysum tinctum*, *Hermannia althaeifolia*, *H. pulverata*, *Indigofera porrecta* var. *bicolor*, *Lepidium africanum*, *L. desertorum*, *Sutera caerulea*, *Tribulus terrestris*. Geophytic Herbs: *Chlorophytum crispum*, *Drimia intricata*, *Empodium plicatum*, *Freesia refracta*, *F. verrucosa*. Succulent Herbs: *Psilocaulon junceum* (d), *Astroloba spiralis*, *Crassula capitella* subsp. *capitella*, *C. expansa* subsp. *expansa*, *C. muscosa*, *Gasteria brachyphylla*, *Haworthia truncata*, *Mesembryanthemum guerichianum*, *Psilocaulon articulatum*, *Senecio ficoides*, *Tetragonia microptera*. Graminoids: *Cynodon dactylon*, *C. incompletus*, *Ehrharta calycina*, *Pentaschistis airoides*.

Biogeographically Important Taxa (all Little Karoo endemics) Succulent Shrubs: *Carruanthus ringens*, *Gibbaeum nuciforme*, *Glottiphyllum depressum*. Low Shrub: *Berkheya cuneata*. Succulent Herb: *Crassula tecta*.

Endemic Taxa Succulent Shrubs: *Antimima brevicollis*, *Delosperma calitzdorpense*, *Drosanthemum duplessiae*, *Machairophyllum brevifolium*, *Pleiospilos compactus* subsp. *fergusonae*, *Tanquana hilmarii*, *Tylecodon leucothrix*. Geophytic

Herbs: *Albuca thermarum*, *Eriospermum crispum*, *Syringodea derustensis*. Succulent Herb: *Crassula badspoortense*.

Conservation Least threatened. Target 16%. Only very small portions are statutorily conserved in the Kammanassie and Swartberg East Nature Reserves and in some private reserves (Ortmansgat, Greylands). Much of the area has been transformed either by cultivation or dam-building (Kammanassie Dam, Stompdrift Dam). Local overgrazing can promote invasion of alien *Atriplex lindleyi* subsp. *inflata* and aggravate erosion, which is ranked moderate (76%) and high (13%).

References Van Wyk & Smith (2001), Vlok & Euston-Brown (2002), Van Jaarsveld & Van Wyk (2003), Vlok et al. (2003), Cleaver et al. (2005).

SKv 12 Willowmore Gwarrieveld

VT 26 Karroid Broken Veld (54%) (Acocks 1953). LR 54 Central Lower Nama Karoo (69%) (Low & Rebelo 1996). BHU 92 Steytlerville Broken Veld (61%) (Cowling & Heijnis 2001). STEP Gamtoos Gwarrieveld (52%) (Vlok & Euston-Brown 2002).

Distribution Eastern (and to smaller extent) and also Western Cape Provinces: Broad valley between the Droëkloofberge (near Klaarstroom) and Groot Swartberg Mountains and continuing as broad band from Willowmore, along the northern piedmonts of the Baviaanskloof Mountains as far east as Kleinpoort (south of Klein Winterhoek Mountains). A smaller area of this unit also occurs south of the Groot Swartberg, in the valley of the Eastern Little Karoo between Dysselsdorp in the west and the N9 road in the east. Altitude 460–1 140 m (most of area at 480–900 m).

Vegetation & Landscape Features Slightly undulating landscape composed of extensive flats and a series of low hills. Dwarf succulent shrubland punctuated by scattered thickets of medium height and solitary small trees (*Pappea capensis*, *Euclea undulata*). There is a strong north-south aspect effect, with the cooler southern slopes supporting patches of renosterveld (*Elytropappus rhinocerotis* dominant), especially where the soils are a sandy loam. *Portulacaria afra* can still be encountered on northern slopes.

Geology & Soils Shale, sandstone and siltstone of the Bokkeveld Group (mostly the Traka Subgroup as well as the Ceres Subgroup, both Devonian) as well as quartzites of the slightly younger Witteberg Group (all of the Cape Supergroup), supporting loamy-clayey soils. Fc is the dominant land type, with Ae and Ag land types being of lesser importance.

Climate Willowmore Gwarrieveld has a pronouncedly aseasonal, bimodal (autumn-spring) rainfall pattern with slight optima in March and from October to November, with overall MAP 250 mm, which may vary considerably along an east-west gradient. MAT is in the warm-temperate range (16–17°C), but number of frost days here is higher than in the western regions of the Little Karoo. See also climate diagram for SKv 12 Willowmore Gwarrieveld (Figure 5.65).

Important Taxa Succulent Tree: *Aloe ferox*. Small Trees: *Pappea capensis* (d), *Acacia karroo*, *Schotia afra* var. *afra*. Succulent Shrubs: *Drosanthemum lique* (d), *Cotyledon orbiculata* var. *orbiculata*, *Crassula ovata*, *Drosanthemum delicatulum*, *Euphorbia mauritanica*, *E. rectirama*, *Exomis microphylla* var. *axyrioides*, *Lycium cinereum*, *L. oxycarpum*, *Pachypodium succulentum*, *Portulacaria afra*, *Tetragonia fruticosa*, *T. robusta* var. *psiloptera*, *Trichodiadema barbatum*, *Tylecodon paniculatus*. Tall Shrubs: *Euclea undulata* (d), *Cadaba aphylla*, *Diospyros austro-africana*, *D. lycioides*, *Grewia robusta*, *Gymnosporia*



Figure 5.77 SKv 12 Willowmore Gwarrieveld: Park-like landscape near Kleinpoort (south of the Klein Winterhoekberge, Eastern Cape) with scattered individuals of *Pappea capensis* and dwarf succulent *Drosanthemum lique* in the undergrowth.

polyacantha, *Nymania capensis*, *Putterlickia pyracantha*, *Rhus longispina*, *R. lucida*, *R. undulata*. Low Shrubs: *Eriocephalus ericoides* (d), *Galenia africana* (d), *Pentzia incana* (d), *Aptosimum elongatum*, *Asparagus burchellii*, *A. striatus*, *Carissa haematoarpa*, *Chrysocoma ciliata*, *Felicia muricata*, *Garuleum latifolium*, *Hermannia gracilis*, *Jamesbrittenia microphylla*, *Leucas capensis*, *Limeum aethiopicum*, *L. africanum*, *Pentzia sphaerocephala*, *Polygala seminuda*, *Pteronia adenocarpa*, *P. glauca*, *P. incana*, *Rhigozum obovatum*, *Selago fruticosa*, *Tripteris sinuata*. Semiparasitic Shrub: *Thesium lineatum*. Woody Succulent Climber: *Sarcostemma viminalis*. Woody Climber: *Asparagus racemosus*. Semiparasitic Epiphytic Shrub: *Viscum rotundifolium*. Herbs: *Cineraria platycarpa*, *Lappula capensis*, *Leidesia procumbens*, *Lepidium desertorum*. Geophytic Herbs: *Ornithoglossum viride*, *Oxalis pes-caprae*. Succulent Herb: *Tetragonia microptera*. Graminoids: *Aristida diffusa*, *Cynodon incompletus*, *Digitaria argyroglypta*, *Ehrharta calycina*, *Eragrostis obtusa*, *Karroochloa tenella*, *Pentaschistis airoides*, *Sporobolus fimbriatus*, *Tragus berteronianus*, *T. koelerioides*.

Endemic Taxon Low Shrub: *Helichrysum fourcadei*.

Conservation Least threatened. Target 16%. Only very small patches statutorily conserved in the Kammanassie Swartberg East Nature Reserve. Grazing can be a problem in places, but basically only very little of the area has been transformed. No obvious invasions of alien plants detected. Erosion is moderate (52%), high (28%) and very low (11%).

Remark Vlok & Euston-Brown (2002) pointed out that the apparent lack of endemic species (in particular of the genera *Glottiphyllum* and *Haworthia*, showing local endemism in neighbouring vegetation units) is most peculiar.

References Acocks (1988), Vlok & Euston-Brown (2002).

SKv 13 Prince Albert Succulent Karoo

VT 26 Karroid Broken Veld (77%) (Acocks 1953). LR 53 Great Nama Karoo (72%) (Low & Rebelo 1996). BHU 90 Prince Albert Broken Veld (81%) (Cowling & Hejnis 2001).

Distribution Western Cape Province: Broad flat-bottomed, colluvium-filled valleys between the north-facing slopes of the Swartberg and the parallel ridges that lie to the north of the Swartberg, this vegetation unit extends from around Gamkapoort Dam (west of Prince Albert) along the Swartberg foothills, as far as the Bosmanspoort area north of Willowmore. Altitude 480–1 120 m (most of area at 500–950 m).

Vegetation & Landscape Features Flat or only slightly undulating country with prominent parallel stony ridges in places, populated by low scrub where leaf-succulent vygies and small-leaved Karoo shrubs share dominance. Heuweltjies are

an important feature of this vegetation—they occur at a density of about two per hectare, supporting succulent and salt-tolerant plant assemblages (*Augea*, *Brownanthus*, *Drosanthemum*, *Malephora*, *Psilocalon*, *Ruschia*, *Salsola*).

Geology & Soils Sedimentary rocks of the Ecca Group (particularly the Fort Brown and Prince Albert Formations) together with diamictite of the Dwyka Group are most important in the area, and to a lesser extent shales and quartzites of the Devonian Witteberg Group. In places, Tertiary alluvial and slope deposits overlie these Karoo and Cape Supergroup rocks. This geology supports development of various cambisols and leptosols. Fc is the dominant land type, while Ag land type plays only a minor role.

Climate Due to the rainshadow of the Swartberg Mountains, the MAP reaches only 165 mm. The rainfall pattern is equinoctial, with highest incidence from March to April and later from



Figure 5.78 SKv 13 Prince Albert Succulent Karoo: Heuweltjies dominated by *Ruschia spinosa* surrounded by shrubland with *Drosanthemum praecultum*, *Brownanthus ciliatus*, *Pteronia pallens* and *Augea capensis* on the Farm Tierberg near Prince Albert (Western Cape).

October to November. Winter rainfall is about 46% of the total precipitation. The overall MAT is slightly above 16°C, while at the Farm Tierberg (near Prince Albert) MAT is 17.5°C, temperatures ranging from below 0°C to 30°C. Incidence of frost of 26 days a year is quite high. See also climate diagram for SKv 13 Prince Albert Succulent Karoo (Figure 5.65).

Important Taxa (R) Rocky ridges) Succulent Shrubs: *Augea capensis* (d), *Drosanthemum praecultum* (d), *Malephora lutea* (d), *Ruschia spinosa* (d), *Adromischus triflorus*, *Aridaria noctiflora* subsp. *straminea*, *Cotyledon orbiculata* var. *orbiculata*^R, *Crassula subaphylla*, *Drosanthemum lique*, *D. vespertinum*, *Euphorbia atrispina*^R, *E. braunsii*, *E. caterviflora*, *Faucaria bosscheana*, *Glottiphyllum peersii*, *Hereroa fimbriata*, *H. odorata*, *Hoodia pilifera* subsp. *annulata*, *Hypertelis salsoloides*, *Kleinia longiflora*^R, *Leipoldtia schultzei*, *Lycium cinereum*, *L. oxycarpum*, *L. schizocalyx*, *Pachypodium succulentum*, *Peersia macradenia*, *Pelargonium karoicum*, *Prenia tetragona*, *Rhombophyllum dolabriforme*^R, *Salsola aphylla*, *S. tuberculata*, *Sceletium rigidum*, *Tetragonia spicata*, *Tylecodon cacalioides*, *T. ventricosus*^R, *T. wallichii* subsp. *wallichii*, *Zygophyllum lichtensteinianum*. Tall Shrubs: *Cadaba aphylla*, *Gomphocarpus filiformis*. Low Shrubs: *Pteronia pallens* (d), *Aptosimum indivisum*, *Asparagus burchellii*, *A. recurvispinus*, *Ballota africana*, *Berkheya spinosa*, *Blepharis mitrata*, *Chrysocoma ciliata*, *Eriocephalus ericoides*, *E. spinescens*, *Felicia filifolia*, *F. muricata*, *Galenia pubescens*, *Garuleum bipinnatum*, *Helichrysum rosum*, *Limeum aethiopicum*, *Macladium relhanioides*, *Menodora juncea*, *Monechma spartioides*, *Pentzia incana*, *Plumbago tristis*, *Polygala leptophylla*, *Pteronia adenocarpa*, *P. empetrifolia*, *P. glomerata*, *P. viscosa*, *Rhigozum obovatum*, *Rosenia humilis*, *Senecio angustifolius*, *Sericocoma avolans*, *Sutera archeri*, *Tripteris sinuata*, *Zygophyllum microphyllum*. Semiparasitic Shrub: *Thesium lineatum*. Woody Succulent Climber: *Sarcostemma viminale*^R. Woody Climber: *Asparagus retrofractus*. Herbaceous Climber: *Fockea comaru*. Semiparasitic Epiphytic Shrubs: *Moquiniella rubra*, *Septulina glauca*^R, *Viscum capense*^R, *V. rotundifolium*^R. Herbs: *Amellus microglossus*, *Cuspidia cernua*, *Dicoma capensis*, *Galenia papulosa*, *Galium tomentosum*, *Gazania krebsiana* subsp. *arctotoides*, *G. lichtensteinii*, *Hermannia pulverata*, *Lasiopogon glomerulatus*, *Lepidium africanum*, *L. desertorum*, *Lessertia annularis*, *Leysera tenella*, *Lotononis pungens*, *Manulea chrysantha*, *Oncosiphon piluliferum*, *Pelargonium minimum*, *Trichogyne polycnemoides*, *Ursinia nana*, *Wahlenbergia androsacea*, *Zaluzianskya peduncularis*. Geophytic Herbs: *Drimia intricata*, *Tritonia florentiae*. Succulent Herbs: *Aloe variegata*, *Brownanthus vaginatus*, *Conophytum truncatum*^R, *Crassula deltoidea*^R, *C. muscosa*, *C. tecta*^R, *C. tomentosa*^R, *Haworthia semiviva*, *H. viscosa*, *Psilocaulon junceum*, *Quaqua marlothii*, *Senecio radicans*, *Tetragonia echinata*. Graminoids: *Aristida adscensionis*, *A. congesta*, *A. diffusa*, *Cenchrus ciliaris*, *Digitaria argyrograpta*, *Enneapogon cenchroides*, *E. desvauxii*, *E. scaber*, *Eragrostis obtusa*, *Fingerhuthia africana*, *Stipagrostis obtusa*.

Biogeographically Important Taxa (GKB Great Karoo basin endemic, ^SSouthern distribution limit) Succulent Shrubs: *Chasmatophyllum stanleyi*^{GKB}, *Cylindrophyllum tugwelliae*^{GKB}, *H. latipetala*^{GKB}, *Pleiospilos nelii*^{GKB}, *Rhinephyllum luteum*^{GKB}, *Ruschia crassa*^{GKB}, *R. perfoliata*^{GKB}. Low Shrub: *Pentzia pinnatisecta*^S. Geophytic Herb: *Tritonia tugwelliae*^{GKB}.

Endemic Taxa Succulent Shrubs: *Antimima erosa*, *A. piscodora*, *Glottiphyllum nelii*, *Hereroa brevifolia*, *H. carinans*, *Malephora flavo-crocea*, *Ruschia bijliae*, *R. brevipes*, *R. callifera*, *R. heteropetala*. Geophytic Herb: *Xysmalobium fluviale*. Succulent Herbs: *Astroloba herrei*, *Bijlia dilatata*, *B. tugwelliae*.

Conservation Least threatened, although exposed to overgrazing in some parts. Target 16%. Almost 3% statutorily conserved

in the Gamkapoort, Groot Swartberg, Swartberg East and Towerkop Nature Reserves. A small portion is also protected on private land Klein Swartberg, Sunnyside Game Farm, Tierberg Farm. Building of the Gamkapoort Dam irreversibly transformed some portions of the unit. No serious alien invasions have been recorded. Erosion is moderate (76%) or low (14%).

Remark Tierberg Research Station (near Prince Albert) houses one of the finest examples of this vegetation unit and one of the best researched locations of the Karoo (see Milton et al. 1992 for references).

References Milton (1990a, b, 1994, 1995), Esler (1993), Esler & Cowling (1995), Wiegand & Milton (1996), Settele et al. (1999), Cowling & Heijnis (2001).

SKv 14 Steytlerville Karoo

VT 31 Succulent Karoo (74%) (Acocks 1953). LR 54 Central Lower Nama Karoo (93%) (Low & Rebelo 1996). BHU 92 Steytlerville Broken Veld (90%) (Cowling & Heijnis 2001).

Distribution Eastern Cape Province: Valley bottoms delimited by the Grootrivierberge in the north and Baviaanskloof Mountains in the south, spanning Willowmore in the west and the surrounds of the confluence of the Groot and Haaspoort Rivers in the west. Altitude 480–950 m.

Vegetation & Landscape Features Flat lowland regions interrupted by a series of low hills are supporting low karoid shrubland vegetation dominated by succulent vygies (*Drosanthemum*, *Faucaria*, *Glottiphyllum*, *Ruschia*) and asphodeloids (*Haworthia*), and other succulent shrubs (*Euphorbia*, *Zygophyllum*). Local dominance of nonsucculent shrubs such as *Rhigozum*, *Pentzia* and *Eriocephalus* as well as local dominance of C₄ grasses of the genera *Aristida*, *Eragrostis* and *Stipagrostis* points to relationships with karoo shrublands typical of the summer-rainfall area.

Geology & Soils The area is dominated by Traka Subgroup shale and minor sandstone (of the Bokkeveld Group) together with lesser quartzite and shale of the Witteberg Group (Cape Supergroup), and supports (in places) deep loamy-sandy soils. Ag is the dominant land form, followed by Fc land form, both making up almost 100% of the area.

Climate Aseasonal, but clearly bimodal precipitation climate with a major peak in March and another marked precipitation increase between October and December. MAP is almost 220 mm, which can be ascribed to the macrolandscape position of the unit located in a rainshadow valley. MAT 17°C, with 22 frost days per year. See also climate diagram for SKv 14 Steytlerville Karoo (Figure 5.65).

Important Taxa Succulent Shrubs: *Galenia sarcophylla* (d), *Ruschia spinosa* (d), *Antimima maxwellii*, *Augea capensis*, *Delosperma multiflorum*, *Drosanthemum delicatulum*, *D. fourcadei*, *D. lique*, *Euphorbia braunsii*, *E. esculenta*, *E. ferox*, *E. inermis*, *E. mauritanica*, *E. rectirama*, *E. rhombifolia*, *Faucaria bosscheana*, *F. felina*, *Glottiphyllum oligocarpum*, *Hypertelis salsoloides*, *Lycium cinereum*, *Malephora uitenhagensis*, *Mestoklema tuberosum*, *Othonna carnosa*, *Phyllobolus splendens*, *Ruschia indurata*, *Salsola tuberculata*, *Sarcocaulon patersonii*, *S. vanderietiae*, *Tetragonia fruticosa*, *T. robusta* var. *psiloptera*, *Trichodiadema barbatum*, *Zygophyllum flexuosum*, *Z. lichtensteinianum*. Tall Shrub: *Asparagus acocksii*. Low Shrubs: *Eriocephalus ericoides* (d), *Pentzia incana* (d), *Rhigozum obovatum* (d), *Aptosimum depressum*, *A. elongatum*, *A. indivisum*, *Asparagus glaucus*, *A. stipulaceus*, *A. striatus*, *Barleria rigida*, *B. spinulosa*, *Bassia*

salsoloides, *Blepharis capensis*, *B. mitrata*, *Chrysocoma ciliata*, *Euryops anthemoides*, *Felicia filifolia*, *F. muricata*, *F. ovata*, *Galenia secunda*, *Garuleum latifolium*, *Helichrysum dregeanum*, *Hermannia cuneifolia*, *Jamesbrittenia atropurpurea*, *Limeum aethiopicum*, *Monechma divaricatum*, *Osteospermum microphyllum*, *Pentzia pinnatisecta*, *Phymaspermum parvifolium*, *Plinthus karooicus*, *Polygala leptophylla*, *P. seminuda*, *Pteronia sordida*, *Rosenia humilis*, *Selago fruticosa*, *Senecio acutifolius*, *Sutera halimifolia*, *Zygophyllum microphyllum*. Herbs: *Aizoon canariense*, *Cuspidia cernua*, *Chamaesyce inaequilatera*, *Galenia papulosa*, *Hermannia coccocarpa*, *H. pulverata*, *Indigofera pungens*, *Lepidium africanum*, *L. desertorum*, *Lessertia pauciflora*, *Lotononis pungens*, *Pelargonium minimum*, *Tribulus terrestris*. Geophytic Herbs: *Moraea pallida*, *Oxalis depressa*. Succulent Herbs: *Aloe longistyla*, *Crassula muscosa*, *C. orbicularis*, *Mesembryanthemum guerichianum*, *Portulaca oleracea*, *Psilocaulon articulatum*, *Tetragonia echinata*, *T. microptera*. Graminoids: *Eragrostis obtusa* (d), *Aristida adscensionis*, *A. congesta*, *A. diffusa*, *Cynodon dactylon*, *C. incompletus*, *Digitaria argyrograpta*, *Enneapogon desvauxii*, *Eragrostis homomalla*, *E. lehmanniana*, *Panicum stapfianum*, *Sporobolus fimbriatus*, *S. ioclados*, *S. ludwigii*, *S. tenellus*, *Stipagrostis ciliata*, *S. obtusa*, *Tragus berteronianus*, *T. koelerioides*.

Endemic Taxa Succulent Shrubs: *Aloinopsis schooneesii*, *Euphorbia bruynsii*, *Glottiphyllum difforme*, *Pleiospilos compactus* subsp. *minor*, *Ruschia mariae*. Geophytic Herb: *Eriospermum appendiculatum*. Succulent Herbs: *Aloinopsis rosulata*, *Haworthia bruynsii*, *H. sordida*.

Conservation The unit does not feature as threatened. Target 16%. None of the area is conserved in statutory conservation areas, although small portions enjoy some protection within private reserves such as the Monteaux Game Ranch and Timbili Game Reserve. Only about 2% of the area has been transformed and it has not been suffering from invasion of alien plants yet. Most of the area is under moderate erosion pressure.

Remarks This is the easternmost Succulent Karoo unit—a kind of anomaly in terms of the prevailing summer rainfall dominant in the area. It is embedded within a complicated geology and climatic setup in the region where Succulent Karoo, Nama-Karoo, Fynbos and Albany Thicket Biomes meet. Steytleville Karoo shows biogeographical links (through a number of

regional endemics) with the Albany Centre of Endemism on one side, and with a group of Succulent Karoo units (including Prince Albert Succulent Karoo, Willowmore Gwarrieveld and Eastern Little Karoo) on the other.

References Acocks (1988), Milton et al. (1995).

10. Credits

Most of the original introductory text (including sections 1 and 3 to 7) was written by K.J. Esler. Section 2.1 (climate) was provided by L. Mucina and edited by P.G. Desmet and M.C. Rutherford; section 2.2 (geology) was contributed by R.A. Ward; section 2.3 (soils) was written by F. Ellis and J.J.N. Lambrechts and edited by L. Mucina. Section 3 was extended by L. Mucina. The account on climate-change modelling (in section 5) was contributed by G.F. Midgley.

L. Mucina wrote the descriptions of the units SKk 7 and 8, SK 2 and 3, SKv 2–8, 11 and 14. He also contributed to SKr 18 and 19 (with P.G. Desmet), SKn 2 (with P.G. Desmet and N. Jürgens), SKn 3 and 4, 6–9 and 11 (with A. le Roux), SKs 13 and SKv 1 (with C. Boucher), SKv 9 (with conceptual contribution by J.H.J. Vlok and D.I.W. Euston-Brown), SKv 12 (with J.H.J. Vlok, D.I.W. Euston-Brown and M.C. Rutherford) and to SKv 13 (with S.J. Milton). N. Jürgens contributed descriptions of the vegetation units SKr 1–17 and SKs 1–6. Various versions of these descriptions were subject to extensive editorial changes and conceptual editing (both of the text, of the concepts of the vegetation units, and to an extent also of the species lists) by L. Mucina and M.C. Rutherford. U. Schmiedel wrote descriptions of SKs 10, SKk 1–6, SKv 10 (with L. Mucina) and SKs 12 (with A. le Roux and C. Boucher). A. le Roux contributed descriptions of SKn 1 and 4 and SKs 8, 9 and 11 (all with L. Mucina). P.G. Desmet contributed to the descriptions of SKn 2 and 5, SKt 1 (all with L. Mucina) and to SKr 18 and 19 (as second author).

The original mapping concepts were provided by the following authors: Richtersveld by N. Jürgens (with contributions by P.G. Desmet for the SKr units of northern Bushmanland); Namaqualand Hardeveld, Namaqualand Sandveld and Knersvlakte by A. le Roux (Knersvlakte with the assistance of U.

Schmiedel). An unpublished map of the upper Olifants and Doring River region by Boucher (2003) served as basis for the definition of several southern Knersvlakte units and the Succulent Karoo in the Klawer-Citrusdal region. The regions of rainshadow valley and trans-escarpment karoo were mapped by L. Mucina and M.C. Rutherford, with important contributions by J.H.J. Vlok and D.I.W. Euston-Brown's STEP map (Vlok & Euston-Brown 2002) to the definition of the concepts and extent of the Little Karoo units and the Steytleville Karoo. M.C. Rutherford and L. Mucina shaped the conceptual issues (identity and precision of mapping) of most of the vegetation units composing the Succulent Karoo, in particular those of the Richtersveld, northern Bushmanland, the Tanqua-Roggeveld region and the Little Karoo.

The photographs were contributed by L. Mucina, N. Jürgens, J.C. Manning, E.J. van Jaarsveld, P.G. Desmet, K. Phillips,



L. Mucina

Figure 5.79 SKv 14 Steytleville Karoo: Karoo shrublands with *Pentzia incana*, *Eriocephalus*, *Lycium* and several succulent *Euphorbia* species west of Steytleville (Eastern Cape).

L.W. Powrie and M. Pfosser. L.W. Powrie and M.C. Rutherford prepared all climate diagrams and data for the conservation sections of descriptions of all vegetation units. L.W. Powrie assisted with extraction of species lists from the SANBI databases (PRECIS, ACKDAT) as well as with preparation of mapping material for contributors at various stages of the Project. Selections of the lists of species of particular vegetation units from these databases were done by L. Mucina.

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Desert Biome

6

Norbert Jürgens

with contributions by

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Figure 6.1 Population of rare *Aloe pillansii* (Asphodelaceae) overlooking the rugged desert terrain from Cornellsskop, Richtersveld.

1. Introduction: Delimitation and Global Perspective

The desert of South Africa is a part of the hyperarid region fringing the western South Atlantic seaboard, southern Angola (Mossamedes Desert) and Namibia (Namib Desert). The great age of aridity (presumably dating back to Late Miocene), extraordinary high diversity of organisms (including many endemics), a wide spectrum of adaptations to arid environments and the inclusion of both winter- and summer-rainfall areas make these desert areas one of the most interesting hyperarid regions in the world.

Within South Africa, the desert areas stretch from the Atlantic coast near the mouth of the Orange River and penetrate inland following the course of the lower Orange River as far as the vicinity of Onseepkans and Pofadder in northern Bushmanland. In the eastern part, most of the desert area within South Africa lies within less than 20 km from the Orange River and only very few parts are further than 30 km away from the river. This is mirrored on most of the Namibian side of the river, revealing a relationship between the low elevation of the land surface next to the Orange River and the formation of hyperarid desert conditions. West of 17° longitude the Namibian part of the Namib Desert is no longer limited to the larger Orange River Valley—the desert extends northwards over the whole coastal plain (with some interspersed enclaves of Succulent Karoo in the southwest) throughout Namibia into the southwestern corner of Angola. It must be emphasised that this broad desert area is very varied, containing fundamental biotic and climatic differences within it but the different desert types need more research and analysis. The South African desert covers only 0.5% of the territory of the Republic of South Africa.

The desert of South Africa borders the Nama-Karoo Biome in its eastern parts (summer-rainfall region) and the Succulent Karoo Biome in its western parts (winter-rainfall region). Some of the poorly researched high mountain peaks mapped as desert may show both climatic and floristic affinity to either the Succulent Karoo or Nama-Karoo Biomes.

The unit is characterised by ecological extremes. Of all the biomes, the Desert has the lowest amounts of and the highest variability in rainfall, in places the highest ever measured temperatures in South Africa (47.8°C at a standard weather station at Goodhouse), and in other parts (western areas of the desert) the highest incidence of coastal fog.

In the scientific literature, the concepts of desert vary greatly, depending on the discipline, the regional background and the viewpoint of the individual researcher. These diverse approaches result in a 'desert' varying widely from, for example, areas 'where desert pavement and varnish are common phenomena' (Evenari 1985) to dry woodlands (Evenari et al. 1985). Therefore, many vegetation scientists rather avoid terms like 'desert' and prefer to describe the vegetation structurally or functionally, e.g. by the predominance of annual plants (Rutherford & Westfall 1994).

Annual plants are normally expected to dominate zonal areas of extreme deserts (Van Rooyen 1999). An attempt in southern Africa (Rutherford & Westfall 1994, Rutherford 1997) to define desert explicitly as dominated (averaged over many years) by annual plants becomes complicated by the need to exclude from the defined desert the washes and many other micro-zonal water-concentrating features such as the base of rock slabs with their relatively many perennial plants. Even when all areas in a desert region are included, a structural definition of 'desert' is not necessarily clear. Within the areas of South

African desert, plant functional types have evolved and show very different and specific responses to aridity. In the eastern parts (Gariiep Desert), grasses and woody shrubs are dominant, while in the western parts (Southern Namib Desert) leaf-succulent chamaephytes are most important. At this stage of research, no widely applicable vegetation-structural definition of 'desert vegetation' would be scientifically well founded.

In this publication, the concept of 'desert' is roughly defined by two parameters: (1) the climatic limit of less than approximately 70 mm or approximately 80 mm of MAP in the easternmost parts, and (2) by sparse perennial vegetation of less than 10% canopy cover. By this definition, most of the landscapes along the lower Orange River and the northernmost tip of the Namaqualand Coastal Plain near Alexander Bay are considered 'desert'. Some coastal regions with less than 70 mm of MAP are excluded from 'desert' where vegetation cover exceeds 10%, e.g. some areas of Succulent Karoo north of Port Nolloth, due to additional water supply by fog and to the greater effectiveness of the soft cyclonic rains of the winter-rainfall regions compared to that in areas further east with intense convective rains under hot conditions in summer (Rutherford 1997). Werger (1978a) indicated about 60 mm as the southern climatic limit of his Namib Domain, while Jürgens et al. (1997, p. 194) suggested 100 mm isohyet as an approximation to the boundary of 'desert biome'. This latter limit does not take into account the important role of seasonality of rainfall on the soil water balance. The diversity of opinions on the most plausible climatic limit of 'desert' reflects the continuum (or 'cascade' as understood by Jürgens et al. 1997, p. 195) character of transition between 'desert' and neighbouring semidesert biomes.

As already recognised by Jürgens et al. (1997, p. 194), the true desert regions of southern Africa show clear climatic and biogeographic, and we may also add obviously also evolutionary, dichotomy. The western desert regions are characterised by winter rainfall (albeit erratic) and typical incidence of fog, while the eastern desert regions are characterised by increased summer rainfall. The former shows floristic and evolutionary links to the Succulent Karoo Biome (and is considered as part of the Greater Cape Floristic Region or Kingdom; Jürgens et al. 1997), while the latter shows links to the Nama-Karoo Biome and the Palaeotropical Floristic Kingdom. At this stage we refrain from classifying these two distinct regions as biomes and suggest treating them as separate bioregions, such as the Southern Namib Desert Bioregion (part of Namib Desert) and the Eastern Gariiep Desert Bioregion (part of Gariiep Desert), respectively.

All deserts along the subtropical high pressure belt experience low summer rainfall at their tropical margin and low winter rainfall at their poleward margin (Sahara and Atacama Deserts). The summer-rainfall margins of all these deserts have many vegetation patterns in common, although tall-stem succulents are better represented in the Americas and less important in deserts elsewhere. Winter-rainfall deserts (including parts of the Namib and Atacama Deserts, the driest regions of the Canary Islands and southwestern Morocco), in contrast, show many unique features, among which the increased importance of low leaf-succulent shrubs is the most striking.

2. Climate, Geology and Soils

2.1 Climate

Several special features of the climate system are responsible for the aridity and for the different seasonality of the region. While the stability of the South Atlantic high-pressure Hadley Cell

defines the general aridity of the coastal area, during the summer months, cold fronts of the circum-Antarctic cyclonic belt and, to a lesser extent, coastal lows and the formation of West Coast troughs bring rain to the western parts of the Desert Biome. These sources of rain affect the eastern parts of the Desert Biome (Gariiep Desert) to a much lesser degree. There, a hot low, developing in the hot Orange River basin, is responsible for late summer rains with a high inter-annual variability.

By definition, the area is one of extreme aridity with a MAP generally below 70 mm. All rivers in the biome are consequently nonperennial with the exception of the Orange River which receives its water from well outside the biome.



Figure 6.3 Malmokkie fog cloud as seen in the morning 4 km south of Brandkaros in the lower Orange River Valley.

Many climatic parameters show considerable spatial variation due to significant topographic variation, mountain barriers and, especially, distance from the sea. The higher-altitude mountains are cooler and have somewhat higher levels of precipitation than the lowland areas and deeply cut ravines. Barriers, such as the Stinkfonteinberge, to the advection of winter cyclonic rain from the west create rainshadows in many places to the east. The differences between the west of the biome (Southern Namib) and the eastern part (Gariiep Desert) are clearly exemplified by the climate diagrams of Alexander Bay (Figure 6.2), representing the Southern Namib, and Goodhouse (Figure 6.2), representing the Gariiep Desert. Alexander Bay shows a flat and relatively low temperature curve, without much variation over the months of the year, typical of an oceanic climate determined by the Atlantic Ocean and its low water temperature. The mean temperature is 17.2°C. In contrast, Goodhouse shows a continental curve, with a mild winter and a very hot summer, resulting in a mean annual temperature of 23.3°C. The difference in summer temperature maxima between the two stations is

about 15°C. The Gariiep Desert is the hottest area within the whole of southern Africa. Frost is not of any importance for the desert units close to the coast and at low altitudes further inland, while some frost occurs on higher mountain peaks, especially in the eastern units. MAP at both the above stations is close to 50 mm. However, while Alexander Bay has its rainfall peak clearly in the winter months, Goodhouse has a late summer rainfall peak. Rain at Alexander Bay is far more predictable (CV 43%) than at Goodhouse (CV >65%). This relates to the type of rainfall. At Alexander Bay cyclonic rain events tend to be generally distributed over most of the landscape, while at Goodhouse intense convective rains with thunderstorms often discharge over only a small area. This spatial heterogeneity can be equivalent to the temporal heterogeneity for single sites. In addition, the softer rain and drizzle of the cyclonic precipitation are much more effective for plant growth, when compared to the intense rainstorms which often generate runoff and formation of sheet washes. Also, the lower temperatures that prevail during the rain season greatly reduce evaporation compared to the high evaporation in the high temperature rain season in the east.

Adveective fogs, resulting from the cooling of moist oceanic air as it passes over coastal waters chilled by the Benguela Upwelling System, are a distinctive feature of the Namib climate (Olivier 1992, 1995, Lancaster 2002). Its influence is felt as deep as 100 km inland. Fog is the most important additional source of water for plants in the coastal Namib Desert (Seely 1978) and enhances weathering and mineral breakdown (e.g. Goudie 1972, Eckhardt & Schemenauer 1998). In the Southern Namib, fog is frequent in the extreme west and on seaward hills and ridges on the coastal plain, where strongly wind-driven low cloud can also significantly precipitate water directly on to plants. A narrow band of fog is frequently observed moving inland along or building up above the Orange River Valley. Locally, this phenomenon is named

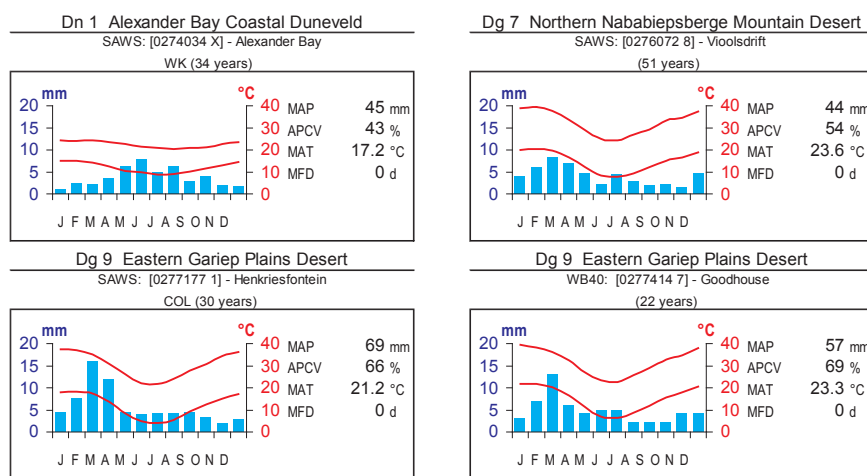


Figure 6.2 Climate diagrams of selected climate stations in Desert units. Blue bars show the mean monthly precipitation. The upper and lower red lines show the mean daily maximum and minimum temperature respectively. MAP: Mean Annual Precipitation; APCV: Annual Precipitation Coefficient of Variation; MAT: Mean Annual Temperature; MFD: Mean Frost Days (days when screen temperature was below 0°C).

'malmokkie' (Figure 6.3). Upstream of the Sendelingsdrif/Lorelei area fog rapidly becomes of little importance and is absent further east.

In the coastal region, especially near Alexander Bay, high wind speeds, predominantly from the south, generate sandstorms with a very strong mechanical impact on plants, topsoils and rocks. Further inland, dust devils are frequently formed in summer.

2.2 Geology and Soils

The geology of the northwestern corner of South Africa and the southern part of Namibia is dominated by two important orogenic events that formed the Namaqua-Natal metamorphic belt (Mokolian Erathem) and the Gariep metamorphic belt (Namibian Erathem). The eastern edge of the Namaqua-Natal metamorphic belt is considered as the western boundary of the Kaapvaal Craton and also extends to become its southern boundary in KwaZulu-Natal.

The Namaqua metamorphic belt (hereby referring to the northwestern part of the larger belt only) formed under high-grade metamorphic conditions around 1 100 mya during a cycle of orogenesis that relates to several belts of similar age in central and eastern Africa. Sedimentary and volcanic rocks of around 1 600–1 300 my old, that were deposited on the edge of the Kaapvaal Craton as well as in the ocean basin to the west, were caught up in the metamorphism. These rocks were intruded by numerous granitoid plutons during the metamorphism and the intrusions continued for a period after the orogenesis had ceased.

The above is a slight simplification because two 1 900 my old fragments of continental crust are caught up in the Namaqua metamorphic belt. The Kheis Province actually separates the Kaapvaal Craton from rocks affected by the Namaqua deformation, and the Richtersveld Terrane of the lower Orange River area is a similar piece of continental crust but has been deformed in part during the Namaqua-Natal event. Both the volcano-sedimentary Orange River Group and the intrusive Vioolsdrif Suite of the Richtersveld support desert vegetation of large areas of the lower Orange River.

At the end of the Precambrian, the supercontinent Gondwana was assembled during the Pan-African orogenic cycle, resulting in the development of several orogenic belts. The Gariep metamorphic belt thus corresponds to a number of other belts in Namibia and South America as having formed in the same period of supercontinent assembly (these other belts include the Damara, Kaoko and the Dom Feliciano). The Saldanha belt of the Western Cape also correlates.

Rocks of the Gariep Belt were deposited on crust formed during the Namaqua-Natal orogeny in a rifting event that opened up an ocean basin to the west of the Namaqua-Natal Belt around 750 mya. During the later closing of this ocean to again form an orogenic belt (the Gariep) at 550 mya, some of this oceanic crust became caught up in the Gariep Supergroup to form a metamorphic rock. The Gariep Supergroup contains a variety of sediments and, very interestingly, contains both carbonate deposits and diamictites (interpreted to be glaciogenic), which are believed to have formed within a short period of time of one another. This is surprising, because it suggests that carbonates, formed in a warm-water environment, are found in the same sedimentary basin as glacial deposits without sufficient time for continental drift to accommodate the expected change in latitude. Other evidence from around the world also points to a possible super-ice age(s) at this point of the earth's history (Hoffman 1999).

The orogenic event also resulted in the formation of a depositional basin into which the Nama Group sediments were deposited.

Since the Gariep orogeny, no mountain-building event has occurred in the region, but erosion has removed a thick portion of the crustal material to reveal the high-grade zones (i.e. deep crustal levels) of the metamorphic belts. This has resulted in the peneplanation of large areas of Namaqualand.

In more recent times the coastal areas have experienced several events of marine transgression, leaving a coastal strip covered in shallow-marine sands as well as aeolian deposits. This coastal strip covers the underlying geology in large areas adjacent to the coast.

The soils of the desert are very slow-forming and subject to being eroded by wind storms in the west and by high-impact rain from convective thunderstorms in the east. The deepest accumulations of alluvial (and some colluvial) material occurs in the washes and in the mobile aeolian sands nearer the coast. For the most part, the substrate is very rocky, with very little to no soil. Unobserved micro-accumulations of soil probably occur in narrow crevices and splits in rocks. Desert algal crusts, where they occur in the coastal fog belt, may assist in resisting erosion. Land types are predominantly Ic with some Fc and Ib. In the washes and flats there are Ag and Ae land types, and Ai and Ia land types are found on the coastal plain.

3. Biogeography: Origins, Diversity Patterns and Classifications

3.1 Palaeogeographic Patterns

Undoubtedly the origin of the coastal Namib Desert, and possibly also of the Gariep Desert found deeper inland, is linked to the origins and further development of the Benguela Upwelling System (Dupont et al. 2005), one of the greatest upwelling systems of the world. The Namib Desert stretches over 2 000 km from about the Orange River mouth at approximately 32° S to where the northern boundary of the permanent upwelling zone and the northern boundary of the Benguela Current (Angola-Benguela Front) coincide with the northern boundary of the Namib Desert at about 15° S (Shi et al. 2000). The origin of the upwelling system dates back to presumably as early as the Late Miocene (Siesser 1980)—it is supposed to have established at around 14 mya as a direct consequence of the establishment of the Antarctic Ice Shield. The upwelling system is closely linked to trade-winds; fluctuation in the intensity of the trade-wind systems reflects deeply in the fluctuations of the intensity of the coastal upwelling (Shi et al. 2000, Udeze & Oboh-Ikuenobe 2005).

The formation of the Namib Sand Sea by aeolian transport of sands originating from river sediments of the lower Orange River System dates back to the Middle Miocene. Already at that time a Namib Dunefield developed, which is well conserved in the form of the Tsondab Sandstone Formation on the Farm Dieprivier. These fossil dunes are rich in fossils. The occurrence of nest sites of modern termites like species of *Pсамmotermes* and *Hodotermes* and even of webs of *Soethyra* spiders indicates that a large proportion of modern Namib Desert organisms had already evolved under very similar ecological conditions in the Middle Miocene (Pickford 2000, Pickford & Senut 2000, 2002).

The fossil record of raised beach levels along the Namib coast, caused by strong sea level fluctuations during the Cenozoic, indi-

cates that the full establishment of the cold Benguela Current only occurred in the Early Pleistocene (Pickford & Senut 2000).

Archaeological data indicate that in the Holocene the Namib region (and especially the Southern Namib along the lower Orange River) did not experience a humid phase, but was more or less at the current level of aridity (Vogelsang 1998).

3.2 *Origins of the Desert Flora and Vegetation*

The formation of this desert flora is directly linked to the formation of the desert climates and associated physiogeographic peculiarities of the complex hyperarid region currently fringing the seaboard (as well as adjacent inland regions) of the Atlantic coasts of northern South Africa, Namibia and southernmost Angola. The age of the Namib Desert is a subject of considerable scientific debate. Following the most recent compilations of geological and fossil evidence (Van Zinderen Bakker 1975, Ward et al. 1983, Schneider 2004, Schneider & Marais 2005), full desert conditions have prevailed since the Middle Miocene (ca. 15 mya), although a phase of more humid climatic conditions appeared towards the Late Miocene.

There is little information on the evolution of the taxa that form the vegetation of the southern African coastal desert today. Current phytogeographic patterns (e.g. sharing number of species and genera) show links of the southern Namib Desert with Succulent Karoo on one hand, and Eastern Gariep Desert with Nama-Karoo (*sensu* Jürgens 1991) on the other.

The desert belt along the coast and the desert belt along the Orange River obviously have formed the routes for major migrations during the Pleistocene, as can be derived from various findings, including pollen analysis (Scott 1995), analysis of deep marine sediments (Shi et al. 1998, 2000), the relict character of inselberg floras (Burke et al. 1998) and disjunct distribution areas (Jürgens 1991, 1997).

It is remarkable that a pollen record from a locality in the Richtersveld, found only 2 km outside the borders of the desert, suggests that karoo-shrub vegetation which included the *Elytropappus/Stoebe* element, occupied the area during the terminal Pleistocene phase (Scott 1995). Disjunct distribution patterns link the Eastern Gariep Desert with the Northern and Central Namib as well as with the Eastern Cape. They are also interpreted as a result of the last glaciation, which led to fragmentation of formerly much larger distribution areas of species of the Nama-Karoo Region (Jürgens 1997).

3.3 *Diversity and Taxonomic Patterns*

Plant species richness of the desert units is very high when compared with other deserts at the same level of aridity globally. Especially in the Richtersveld, diversity is remarkably high and does not differ much from that in the Succulent Karoo part of the Richtersveld. The diversity may be viewed as moderate in some of the plains vegetation units along the lowest Orange River Valley, especially in the Western Gariep Lowland Desert vegetation unit. It is very high in the mountainous desert sections of the Richtersveld (including Noms Mountain Desert, Richtersberg Mountain Desert, Kwaggarug Mountain Desert and Kahams Mountain Desert) and lower in the region around Henkries and Goodhouse (Eastern Gariep Rocky Desert).

In all units west of the Noms Mountain Desert, the families Aizoaceae, Crassulaceae, Zygophyllaceae, Fabaceae and Asterales appear as the most diverse. In the eastern units, the fami-

lies Acanthaceae, Poaceae, Capparaceae and Amaranthaceae are more important.

The high diversity of the flora in the southern African deserts is related to the high age of the deserts and existence of two distinct centres of endemism, such as the Western Gariep CE and East Gariep CE, which might have served as refuge areas during the last glaciation.

3.4 *Biogeographical and Vegetation Subdivisions*

Many previous works have included the region of South African deserts in a much larger arid zone unit, for example the Karoo-Namib phytogeographical (White 1971) or phytochorological (Werger 1978b) (Floristic) Region, which was understood as a part of the Palaeotropical Floristic Kingdom, without recognising the difference between Succulent Karoo and Nama-Karoo. More recently, a fundamental distinction has been drawn between the western and eastern sections of the Karoo in terms of biome classification (Rutherford & Westfall 1986, Rutherford 1997), floristic composition (Bayer 1984, Gibbs Russell 1987) and biogeography (Jürgens 1991, 1997). Thus recognised was an arid part of the Succulent Karoo (biome or phytochorion) with its Fynbos or Capensis affinities in the west, and the arid part of the Nama-Karoo (biome or phytochorion) with its affinities to the Sudano-Zambezian flora in the east (Jürgens 1997).

Even more recent is the recognition of several types of deserts within the borders of South Africa. Most authors recognised that the concept of desert in South Africa was linked to the Namib Desert, located between the coast and the Escarpment. Its southern limit was established just south of Alexander Bay (Werger 1978a) or north of Lüderitz (Rutherford & Westfall 1994). The latter authors viewed the stretch south of Lüderitz as a hyperarid but fog-fed form of the Succulent Karoo Biome. Jürgens (1991) implicitly widened the concept of the desert by (a) including a wide arid belt around the lower Orange River and spanning the Richtersveld in the west and the surrounds of the Pofadder region in the east, and (b) recognising three subunits (districts), such as Eastern Gariep, Western Gariep and Southern Namib (see Figure 4 in Jürgens 1991).

The Southern Namib Desert Bioregion comprises the desert areas along the lowest part of the Orange River between Alexander Bay and Sendelingsdrif and shows the characteristic climatic properties of the southern parts of the coastal Namib Desert, such as a rainfall peak in winter (caused by cyclonic rains), mild temperatures due to the cooling Benguela Current, and a high frequency of fog. The Southern Namib Bioregion corresponds closely to the combination of the South African part of the Southern Namib District (Jürgens 1991) and the West Gariep District (Jürgens 1991). Jürgens (1991) separates the latter biogeographical district as a distinct centre of endemism. In this chapter, the nomenclature of the component vegetation units of the Western Gariep Centre, namely of the Dn 3 Western Gariep Plains Desert, Dn 4 Western Gariep Lowland Desert and Dn 5 Western Gariep Hills Desert, reflects this grouping. A much larger surface area in Namibia forms part of the Southern Namib Desert (Jürgens et al. 1997).

The Gariep Desert Bioregion includes the desert areas from Sendelingsdrif to the vicinity of Onseepkans/Pofadder and shows the characteristic climatic properties of the continental part of the Namib Desert. Fog is unimportant and absent as one proceeds eastwards within the Gariep Desert Bioregion. This is the hottest area within the whole of southern Africa. Rainfall is mainly caused by convective thunderstorms in summer, with

very low predictability and high temporal and spatial variability. Air humidity is much lower than in the Southern Namib Desert Bioregion. The Gariiep Desert Bioregion corresponds to a limited subset, yet core area, of the East Gariiep District (Jürgens 1991), later called the East Gariiep Centre (Jürgens 1997, Jürgens et al. 1997). The East Gariiep Centre includes a much wider area than the bioregion, taking in a much larger part of the surrounding Nama-Karoo Biome or considered within the Nama-Karoo Region (*sensu* Jürgens 1991), especially in Namibia (Jürgens 1991, 1997). Rutherford (1997) adopted the concept of desert occurring inland of the coastal belt, but viewed much of the desert corridor extending up the Orange River Valley as less than 20 km across (the explicit scale limit set for a biome) and hence limited the inland part to the area where it is at its widest, mainly in Namibia north of Noordoewer (on Orange River).

In the interface zone between the two bioregions, at a more detailed scale, many mountains and valleys have vegetation of the Southern Namib Desert (and Succulent Karoo) on south-western slopes and that of the Eastern Gariiep Desert (and Nama-Karoo) on northeastern slopes.

While the large number of endemic species along the Orange River have often been seen as a single centre of endemism (e.g. Gariiep CE of Van Wyk & Smith 2001), a more detailed appraisal confirms that there are two very different centres of endemism, albeit located close to each other (Jürgens 1991, 1997). While these two centres of endemism are climatically well separated, it has been proposed that they formed refugia for survival during the last glaciation for most of the endemic taxa (Jürgens 1991, 1997, Midgley et al. 2001). Conservation of taxa may have been mainly supported by gorge systems within dissected mountain areas, inselbergs, and dunes in the coastal Sandveld.

The substantial number and kinds of differences between the southern Namib Desert and Gariiep Desert Bioregions (see above) could well be considered adequate grounds for these two units being recognised as two different biomes. However, due to the need for availability and analysis of floristic data and climatic conditions in other hyperarid regions particularly to the north of our mapped desert units, conclusive arguments cannot be put forward at this stage. See further discussion in the chapter on Biomes and Bioregions.

4. Ecology and Plant Adaptations

Almost all research on functional ecology and ecophysiology of plant species that occur in the South African desert has been carried out in the adjacent Succulent Karoo Biome (Rutherford 1991, Von Willert et al. 1992, with the exception of Rundel et al. 1995). The research findings are probably to some degree also applicable to the same species in desert, especially where a research site in the Succulent Karoo was located close to the edge of the desert (see the chapter on Succulent Karoo in this book).

Adaptations to the desert conditions are very different within the two bioregions. Within the Southern Namib Desert Bioregion leaf-succulent woody chamaephytes and low or thin stem succulents probably form the most obvious adaptation (Jürgens 1986) to relatively predictable rains falling during the cooler time of the year, as is also characteristic for the Succulent Karoo (see the chapter on Succulent Karoo in this book). In addition, a high number of species show peculiar growth forms, which are sunken into the soil surface. Only certain parts of leaves and/or stems appear above ground for at least a larger part of the year, allowing for photosynthesis, flowering and fruiting.

In some cases, e.g. *Fenestraria rhopalophylla*, translucent windows allow entry of light into the inner parts of leaves, which are embedded into the soil, thereby allowing for photosynthesis below ground level.

Another special adaptation to desert conditions is the formation of sticky surfaces, which fix mineral sand grains to plant surfaces. These so-called 'psammophorous plants' (i.e. sand-carrying plants) are understood as an adaptation shielding the plants against the mechanical impact caused by the very frequent and strong sand storms of the coastal desert environments (Jürgens 1996).

Most leaf-succulent plant species of the West Gariiep Centre are relatively short-lived, as is found in the Succulent Karoo regions of the Richtersveld (Jürgens et al. 1999, Gotzmann 2002). For these species, a well-adapted seed production, as well as dispersal, germination and establishment are critically important.

Within the Gariiep Desert Bioregion with its extreme unpredictability of rainfall, other adaptations are of importance. Grasses are well adapted to survive long periods of drought without activity due to their sheath morphology which shelters their shoot apex and allows rapid growth in response to rains during the hot summer months. Woody shrubs within this unit do not bear succulent leaves, but rely on available groundwater ('phreatophytes'). Thus, woody shrubs and trees are restricted to topographical sites that store groundwater for a long period of time. These are mainly dry river beds, tilted plains above bedrock and mountain areas with fissured rock types.

Water storage within plants appears to require much larger volumes of water than in the Southern Namib Bioregion with its more predictable rainfall and shorter drought periods. Therefore, large stem succulents without leaves and with a green stem cortex like *Euphorbia gregaria* and *E. virosa* also form an important part of the vegetation at sites without persistent groundwater. Even longer periods of drought can be survived by plants remaining dormant, especially in those stem-succulent plants that possess a bark and form leaves only during the rainy season in summer (species of *Commiphora*), or in winter (*Pachypodium namaquanum*, *Tylecodon paniculatum*). The special adaptation of the northern orientation of the winter-leaved terminal part of the trunk of *Pachypodium namaquanum* is probably not a water-conserving measure but a way of almost doubling the midwinter radiation absorbance that it would have had with horizontal orientation (Rundel et al. 1995).

There are several strategies for plant survival common to both parts of the desert. Apart from the preponderance of survival through seed in annuals and the sometimes very short-lived ephemerals as well as facultative perennials, severe droughts can be survived by many of the plants by a stepwise death of parts (e.g. shedding of leaves, twigs, branches or stems) and regeneration of these organs after rain. Some species of *Salsola*, *Pteronia* etc. also fragment themselves actively into radial portions of the stem and root system ('stem splitting'; for definition see Schenk 1999), allowing survival of those radial portions of the plant with roots that have access to water. There are also a remarkable number of succulent annuals in the Southern Namib Desert. Underground storage organs like bulbs and tubers allow survival in both bioregions. Optimising short-term productive growth of the individual plant seems to be relatively unimportant in these areas. Several species are very flexible in their physiological response to availability of water. For example, the drought-deciduous *Ceraria fruticulosa* shows a highly flexible CAM expression (CAM-cycling, full-CAM and CAM-idling) in response to changes in availability of water (Veste et al. 2001).

Thorniness or spinescence is a common feature of some of the vegetation, with a study revealing the Namib Desert to contain 'highly spinescent nodes' (Milton 1991).

Wind is one of the most important dispersal mechanisms (anemochory) in the arid western areas of South Africa (Van Rheede van Oudtshoorn & Van Rooyen 1999). In the desert, examples include *Pharnaceum croceum* and *Hypertelis sal-soioides* with dust-like (very light) seeds, *Dicoma capensis* and *Pelargonium crithmifolium* with plumed seeds, and *Tripteris amplexens* and *Foveolina dichotoma* with winged seeds. Even within the same dispersal type, efficacy of movement can vary much. For example, under experimental conditions, seeds of *Pelargonium crithmifolium* need less than half the wind speed to start moving than that needed for *Dicoma capensis* (2.9 versus 7.2 km/hr, respectively; Van Rheede van Oudtshoorn & Van Rooyen 1999). Some species are adapted for both promoting and restricting movement. For example, the seed of *Heliophila thunbergii* var. *macrostylis* has a broad wing but produces copious amounts of mucilage from the epidermis of the testa when wet which acts as an anchoring mechanism (myxospermy), also after dispersal. There are a range of other mechanisms by which many desert plants hinder the long-distance dispersal of their seed (antitelechory). In deserts, space already occupied is usually the most suitable for growth. Also, many species are annuals and the space occupied by the mother plant becomes available the following season (Van Rheede van Oudtshoorn & Van Rooyen 1999).

With regard to the composition and structure of communities, the respective parts of the desert units can be seen as a filtered subset of Nama-Karoo (not dominated by leaf-succulent shrubs) or of Succulent Karoo (dominated by leaf-succulent shrubs). Another feature, especially in the eastern portion of the desert, is that plant communities are reduced to very few member taxa or even form monotypic populations in some habitats.

It is possible that some of the findings from the nearby Numees site in the Succulent Karoo Biome may apply to some extent in the Southern Namib Desert Bioregion. This may include the remarkably high turnover of some leaf-succulent Mesembryanthemaceae shrubs (Jürgens et al. 1999, Gotzmann 2002). However, climate-driven dynamics are likely to develop in longer cycles in desert.

Such a cycle of at least 18 years could be described at Numees in the Richtersveld (MAP 78 mm, mainly winter-rainfall). Subsequent to two drought years (1978 and 1979), annual observation of permanent plots allowed the documentation of the slow regeneration of populations and community during the subsequent 18 years (Jürgens et al. 1999, Gotzmann 2002).

In the areas with very highly variable summer rainfall in the eastern part of the desert units (Gariiep Desert Bioregion), population dynamics are very slow. Succulents store large amounts of water (*Euphorbia virosa*, *Commiphora* species, *Pachypodium namaquanum*) in order to buffer very long periods of drought.

5. Status

Desert environments are not very attractive for humans, especially human habitation. Nevertheless, even a low level of human activity can have a high impact due to the sensitivity of desert environments. Archaeological information shows that during most of the Holocene only a very limited human population based their life as hunter-gatherers on the arid fauna and flora (Vogelsang 1998). There is no evidence that the arrival

of stock, approximately 1 300 years ago (Webley 1997) led to any significant changes to the vegetation. Grazing pressure remained at a low level for another 1 800 years until white farmers and hunters (biltong production) impacted negatively on the natural ecosystems. By the second half of the 20th century the populations of game like zebra, oryx, kudu, ostrich and springbok were nearly exterminated. The influence of the resulting changes in the grazing regimes on vegetation remains unclear. The diet selection of goats in the communally grazed Richtersveld National Park has been studied in detail by Hendricks et al. (2002).

Forced removals from other regions and settlement programmes contributed to the increase in desert land use, e.g. in the southern Richtersveld. While communal land tenure was the traditional form, the state supported the subdivision and fencing of economic units in parts of the desert biome, e.g. in the southern Richtersveld. A number of private farms were also established along the lower Orange River.

Communal farming has remained in place in the northern Richtersveld communal area (which does not apply in south-western Namibian desert areas that are also largely conserved in statutory reserves), whereas in the past a traditional semi-nomadic system was developed in adaptation to the seasonal changes in the different grazing resources. These include the coastal plains (Sandveld), the mountains, the desert plains (especially after good summer rains) and the perennial Orange River with its gallery forest and drinking water. The unique combination of a perennial river near the boundary between winter-rainfall and summer-rainfall climate resulted in a lower impact on the environment and vegetation than in the farming units further south (Jürgens 2001). However, strong degradation took place at stockpost sites (Hendricks et al. 2005), around the permanent settlements like Kuboes, Eksteenfontein and Lekkersing, and in those habitats that were particularly attractive for pastoral use in the close vicinity to the permanent settlements. Early photographic documents from 1914 show that since that time the Annisvlakte plain (Dn 4 Western Gariiep Lowland Desert) lost its original vegetation cover. What had been a community with *Brownanthus pseudoschlichtianus* has been replaced by *Euphorbia gummiifera* and *Mesembryanthemum hypertrophicum*. In the same time span, the fertile loamy-sandy soil which is always correlated with the *Brownanthus pseudoschlichtianus* community, was lost and replaced by a coarser saline soil. Also the adjacent populations of the tall succulent tree *Aloe pillansii* show a strong decrease in number of adult individuals. A detailed study by Bolus et al. (2004) analyses the complex population structures and interprets the decrease as a signal of climate change. A similar decline in *Brownanthus pseudoschlichtianus* over the past 60 years can be observed in the Koeroegabvlakte. The highest density of stockposts within the Richtersveld National Park is observed in the Koeroegab (H. Hendricks, pers. comm.). Along the slopes of the Goariiep Mountain, young gully erosion underlines the decline of vegetation of mountain ecosystems.

Repeat photography also shows signs of severe desertification in the coastal plains near Alexander Bay. However, these changes as well as those on the Annisvlakte plain could well be a consequence of climate change. Recent analysis of the population dynamics of *Aloe dichotoma* (Foden 2002) is interpreted as a result of climatic change, which is mainly expressed by a decline in precipitation over the past decades.

Alien biological invasions in the desert appear to have had limited impact thus far. *Prosopis* is present at a number of settlements and along the Orange River, but it is not spreading further outside the river alluvium. *Nicotiana glauca* has become an

element of nearly all dry river beds, and along the Orange River *Ricinus communis* is also being found more frequently. Other alien problem plants of the arid zone further south, like *Atriplex lindleyi*, appear to have stopped their migration northwards in the southern Richtersveld.

Already in the 18th century, mining and prospecting added to the other human impacts on the ecosystem. Open-cast diamond mining has created big, although local, wounds in the landscapes along the Orange River from Alexander Bay to the Rosyntjieberge. An additional impact is caused by the deposition of the overburden within the wider landscape. For example, in the lower Annisvlakte near Swartwater, a huge deposition of soil material has taken place over a number of years, which has already destroyed a large proportion of local endemic species such as *Euphorbia melanohydrata* (named after Swartwater).

Hyperarid regions are very sensitive to disturbance and degradation. Regeneration takes very long, especially if the soil and the seed bank are also degraded. Therefore, a hyperarid region with high biodiversity deserves a high protection status.

At present, less than 20% of the surface area of all the desert units enjoys a statutory form of protection. The largest conservation area is formed by the Richtersveld National Park, followed by the Nababiep Nature Reserve, established at and west of the Modderdrif Helskloof. Recently the formation of the Richtersveld Community Conservancy added some form of protection status to a wider area in the southern Richtersveld. In addition, two very small areas have been proclaimed National Heritage Sites: the lichen field near Alexander Bay and the Cornellskop with the famous population of *Aloe pillansii*. The rest of the Desert Biome does not enjoy any conservation status. However, a large proportion of the species and communities of the Desert also occur in Namibia north of the Orange River. Here, the Namibian part of the Richtersveld-Ai-Ais Transfrontier Park and the Sperrgebiet National Park constitute large-scale protection areas. The wider public perceive the region to be of high conservation value because it forms a centre of endemism as well as a hotspot of diversity.

6. Threats

Currently, seminomadic pastoral land use is still in place within the Richtersveld National Park and is entrenched within the contractual agreement between the South African National Parks and the northern Richtersveld community. It is very difficult to provide scientific evidence for the quality and quantity of the long-term impact of this dominant land use form, also outside the park. Furthermore, modern life styles, especially the use of motorised vehicles are slowly changing the patterns of land use. The use of these vehicles results in a concentration of stockposts along the roads, for example.

Until recently, the population growth has remained so low that settlements have not become a major driver for habitat conversion. However, the increase of roads and tracks is likely to exacerbate the dramatic erosion, especially in the more loamy soil types of the *Brownanthus pseudoschlichtianus* community. With the access by roads, illegal collecting of plants was made possible during the second half of the 20th century. The number of plants of mature *Pachypodium namaquanum* and *Aloe dichotoma* for example, planted in private gardens, around town halls and mine headquarters, make it obvious that large quantities of plants have been removed from their populations. An estimation of losses of smaller succulents is nearly impossible. Tourism is steadily growing and potentially adds to the problems associated with access by roads. Unfortunately, in 2004 new

tourist accommodation facilities were constructed within the very sensitive arid semidesert ecosystems of the Richtersveld National Park, away from the Orange River.

Irrigation agriculture is another form of land use, currently expanding along the Orange River. While in the early 20th century irrigation agriculture was developed at the lower Orange River at Grootderm and Arrisdrijf, these activities are now expanding into formerly untouched vegetation for ostrich and cattle farming. Further upstream, larger areas are used for cereals, grapes, melons, etc. The extraction of water from the river and the pollution by agrochemicals could well become a major problem for the ecosystems along the river. Furthermore, the belt of irrigation agriculture is interrupting the interactions between the river and the ecosystems further away.

Continuing mining at existing mines poses an ongoing threat to desert ecosystems and species, for example at Swartwater. In the last few years, small-scale mining has also been started in several places, exploiting formerly untouched smaller gravel deposits along the Orange River, e.g. at Grootderm and at Grasdrif. Further upstream, occurrence of minerals other than diamonds also causes scattered mining activities with local impact.

Another threat is global climatic change (Hulme 1996, Hulme et al. 1996), which is very difficult to assess or to predict (compare the discussion in the respective chapters for Nama-Karoo and for Succulent Karoo). However, a southward shift of the Namib Desert may already have taken place over the past decades, as the comparison of old photographs and analyses of aerial photography would show (N. Jürgens, unpublished data). An initial assessment of the possible susceptibility of the plant species of the Richtersveld National Park to climate change indicated that a significant proportion of the flora may be at risk with future climate change (Rutherford et al. 1999a). An independent broad-scale assessment of the effects of climate change on a few species currently found in the Desert Biome (Rutherford et al. 1999b) indicates that these species may all find the future climate unsuitable. Microhabitats may, however, still enable survival of many species in the area.

7. Actions

Irrespective of the question whether incentives towards sustainable management are generated by market mechanisms or by the tax system, it would be advisable to minimise the impact of the threats mentioned in the previous section. This would include: a reduction of stock, especially on the sensitive soil types; shifting tourism infrastructure from sensitive arid ecosystems to already disturbed settlements or to the Orange River; and using the overburden in diamond mines to refill existing holes and trenches. Especially the coastal devastation by mining should be subject to an ecological restoration programme along the lines proposed for the similarly degraded coastal belt north of the mouth of the Orange River (Burke 2001). From a botanical point of view, game should be reintroduced to previous levels. The flora probably evolved under strong grazing pressure in adaptation to and in co-evolution with herbivores, as the widespread toxicity and thorniness (Milton 1991) of the plants indicate. The eradication of wild game and their replacement with sheep and goats could have had a negative impact on plant diversity.

Small stock farming, conservation, mining, irrigation agriculture and tourism can co-exist in the wide spaces of the desert units, even to mutual benefit. However, this requires a discussion process and integrated planning.

8. Further Research

It is obvious that the desert unit as mapped in this publication has received virtually no ecological research interest. Research has been concentrated on the more productive ecosystems of the country, including the Succulent Karoo part of the Richtersveld which has received relatively much research attention. Even countrywide activities such as the Acocks's (1953) vegetation mapping did not consider the desert, due to the low farming potential and inaccessibility.

Research in all fields of study and at all scales is therefore needed. Assessment of the distribution areas of species and communities is still not sufficient, especially with regard to the mountainous regions. Monitoring of changes in vegetation and ecosystems has been established for the Succulent Karoo parts of the Richtersveld, but should be extended to the desert units. Such monitoring work should include research on population dynamics, based on individual plants. Phenology and triggering of phenological phases by environmental factors has not been covered at all. The role of seed banks is probably of very high importance at the edge of the Namib Desert, but data are lacking. The role and response of plant functional types and their very peculiar traits (e.g. psammophory) should be studied in more depth, as well as the response of plants to the predicted climatic changes, taking the possible role of local refugia into account.

With regard to the various forms of degradation and destruction, rehabilitation work and experimental research on the appropriate tools and methods, is necessary.

The fate of the Orange River with regard to water quality and the quantity of water flow with increasing water consumption for irrigation agriculture, is another crucial topic affecting the future development of the desert units, and requires research for management purposes.

Integrated management is needed for this sensitive region. It is therefore hoped that the present construction of the first phase of the Gariiep Ecology Research Station will create suitable infrastructure to not only attract more researchers to this remote region, but also establish web-based information arising from all the data generated there.

9. Descriptions of Vegetation Units

Southern Namib Desert

Dn 1 Alexander Bay Coastal Duneveld

VT 34 Strandveld of West Coast (100%) (Acocks 1953). LR 55 Strandveld Succulent Karoo (81%) (Low & Rebelo 1996).

Distribution Sandy coastal forelands between the mouth of the Orange and Cape Voltas south of Alexander Bay. The unit borders on the Richtersveld Coastal Duneveld of the Succulent Karoo Biome to the south. Altitude 0–60 m.

Vegetation & Landscape Features Mainly flats with few hills, supporting a plethora of habitats differing especially in substrate characteristics (e.g. sand sheets, exposed crusts, gravel or rocks). Vegetation is sparse, composed of low shrublands dominated by deciduous, woody shrubs and leaf-succulent shrubs on gently undulating sandy substrates. Primary determinants of vegetation patterns are depth of sand over dorbank, calcrete or bedrock, and mobility of sand.

Geology & Soils White to beige, semimobile aeolian sands (Quaternary) over dorbank, gypsum deposits or metavolcanic bedrock (schist, chlorite, subordinate amphibolite) of the Grootderm Formation (Gariiep Supergroup, Namibian Erathem).

Climate Winter rainfall with MAP 45–50 mm, but rainfall highly variable between years. At Alexander Bay WO (Figure 6.2) rainfall has been recorded from 17 mm in the driest year to 90 mm in the wettest. Mean monthly maximum and minimum temperatures at this weather station are 35.7°C and 4.4°C for April and July, respectively. Temperature is moderated by the cold Atlantic Ocean, except on infrequent occasions when easterly winds occur and temperatures can exceed 40°C. Frost not recorded. Annual daily cloud cover averages about 50% at 08:00 and about 25% at 14:00. Heavy dew and fog occur frequently. Very strong southerly winds dominate throughout the year and are the primary determinant of the distribution of sand substrate types.

Important Taxa Leaf-succulent Shrubs: *Amphibolia rupis-arcuatae* (d), *Galenia fruticosa* (d), *Salsola zeyheri* (d), *Stoeberia beetzii* (d), *Tetragonia fruticosa* (d), *Crassula atropurpurea* var. *cultriformis*, *Drosanthemum ramosissimum*, *Hypertelis angraepequena*, *Jordaniella cuprea*, *Lycium decumbens*, *Othonna sedifolia*, *Pteronia glabrata*, *Stoeberia utilis*, *Zygophyllum clavatum*, *Z. morgsana*. Leaf- & Stem-succulent Shrubs: *Brownanthus marlothii*, *Psilocaulon dinteri*. Stem-succulent Shrub: *Euphorbia burmannii*. Other Shrubs: *Lebeckia sericea*, *Tripteris oppositifolium*. Perennial Herb: *Crotalaria meyeriana*. Graminoid: *Cladoraphis cyperoides*.

Conservation Target 28%. None conserved in statutory conservation areas. Open-cast diamond mining has destroyed most of this vegetation type.

Remarks Floristically this unit is similar to the SKs 1 Richtersveld Coastal Duneveld to the south. It is separated from this unit by the shorter, sparser vegetation and stronger sand movement. According to Werger (1978a, b) this unit is the southernmost coastal unit to fall altogether within the southern extension of the Namib Desert. If sand is transported across this unit, it moves as a continuous thin sheet across the landscape and there are no mobile dunes.

References Acocks (1988), Desmet (1996), Low & Rebelo (1996, 1998), Desmet & Cowling (1999), Jürgens (2004).

Dn 2 Namib Lichen Fields

VT 34 Strandveld of West Coast (100%) (Acocks 1953). LR 55 Strandveld Succulent Karoo (100%) (Low & Rebelo 1996).

Distribution Series of small patches on coast-facing hill slopes, about 3.5 km from the coast immediately southeast of Alexander Bay and covering some 75 ha. Altitude 65–94 m.

Vegetation & Landscape Features Mainly on the southwestern slopes of a series of low hills, which form the highest elevation in the otherwise flat or slightly undulating landscape east and south of Alexander Bay. The lichen field generally forms a 10 cm high dense carpet of fruticose individuals. Within the unit, two habitat types can be distinguished which are clearly visible as a well-developed, striking upslope zonation. The upper part of the hill, characterised by gypsum-rich topsoils, is dominated by the orange *Teloschistes capensis*. Further downslope, with gypsum only at a deeper position in the soil, the light green *Ramalina capensis* is dominant. Lichens grow abundantly as epiphytes on the very few angiosperms, such as *Asparagus capensis*. Within the lichen field proper the angiosperm species outnumber lichens, but are less conspicuous. There is a



L. Mucicna

Figure 6.4 Dn 2 Namib Lichen Fields: Lichen field at Alexander Bay (Northern Cape) dominated by *Teloschistes capensis*, with a view of Western Gariep Plains Desert in the background. The succulent shrublets in the foreground are *Stoeberia beetzii*.

pronounced occurrence of plants with bodies sunken into the soil in response to summer drought (*Fenestraria rhopalophylla*, *Lithops herrei*, *Euphorbia ramiglangans* and *E. stapelioides*). In the rainy season the uptake of water causes expansion and the plants reappear above the soil surface.

Geology & Soils The area straddles the divide between the metavolcanics of the Grootderm Formation and the schists and gneisses (metasediments) of the Oranjemund Formation, both of the Gariep Supergroup (Namibian). The former is mostly covered by quaternary coastal sediments—soft and powdery white clay soils (clay minerals kaolinite or chlorite) with gypsum crusts or gypsum deposits in the topsoil on the mid- to upper slopes and more sandy soils on the lower slopes. Salinity much higher than soils of the surrounding vegetation; some surface pebbles present.

Climate MAP of about 45 mm and rainfall is erratic, predominantly occurring in winter. High frequency of fog, estimated to be greater than 100 days per year, compared to 67 fog days per year measured at the Alexander Bay airport in the lee of the lichen fields outcrop. Fog carried inland by strong winds during the day makes close contact with the ground and the lichens during their period of photosynthesis. MAT 17.2°C. No frost recorded. Although strong southerly winds predominate, the lichen field has no wind-blown sand and lies in a localised corridor outside the general area of moving sand (note that *Ramalina capensis* can grow in habitats with high incidence of sandstorms).

Important Taxa Lichens: *Ramalina capensis* (d), *Teloschistes capensis* (d), *Diploschistes* sp., *Lecidella crystallina*, *Toninia* sp., *Xanthoparmelia walteri*, *Xanthoria flammea*. Leaf- & Stem-succulent Shrubs: *Brownanthus marlothii*, *Pelargonium crithmifolium*, *Psilocaulon dinteri*. Stem-succulent Shrubs: *Euphorbia ramiglangans*, *E. stapelioides*, *Sarcocaulon patersonii*. Leaf-succulent Shrubs: *Amphibolia rupis-arcuatae*, *Cephalophyllum ebracteatum*, *Crassula deceptor*, *Drosanthemum luederitzii*, *Eberlanzia sedoides*, *Fenestraria rhopalophylla*, *Lithops herrei*, *Psammophora modesta*, *Pteronia glabrata*, *Stoeberia beetzii*.

Conservation The lichen field near Alexander Bay is unique in its kind in South Africa. Together with the larger, but less

dense lichen fields in Namibia, it forms a globally unique vegetation type. Of the lichen fields along the Namib coast, the one near Alexander Bay has the highest biomass and highest species diversity. It therefore deserves a very high conservation status with a target of 100%. The lichen field has been negatively affected by several small roads and off-road vehicle tracks. It is unknown whether the air pollution originating from motor vehicles on the tar road between Port Nolloth and Alexander Bay is causing damage to the lichens. The top of the hill has been used as a quarry and later as a rifle range. The lichen field has recently been declared a Natural Heritage Site and it is protected by a solid fence against off-road driving. The unit should still be regarded as vulnerable if not endangered owing to persisting effects of past damage, possibly insidious pollution effects and very close proximity to other potential human influences, as well as to its remarkably small area.

Remarks Desert lichens are normally negligible in terms of biomass and they are rarely conspicuous. In this unit near Alexander Bay total biomass can attain a very high level of 600g/m². Lichen diversity is high, with about 30 species recorded so far. Similar lichen fields dominated by *Teloschistes capensis* covering a much larger area (several hundred square kilometres) in the coastal Central Namib Desert in Namibia, north of Swakopmund, have a much lower biomass and biodiversity (Lalley & Viles 2005). Similar smaller lichen fields, dominated by *Ramalina capensis* are also known from many other places along the coast of the Richtersveld and the Sperrgebiet in Namibia.

References Jürgens & Niebel (1991), Schieferstein & Loris (1992), Jürgens & Niebel-Lohmann (1995), Jürgens (2004), Oguz et al. (2004).

Dn 3 Western Gariep Plains Desert

VT 34 Strandveld of West Coast (60%) (Acocks 1953). LR 57 Lowland Succulent Karoo (58%) (Low & Rebelo 1996).

Distribution On the plains from east of Alexander Bay and south of Grootderm, extending about 15 km to the east and south. The unit borders on Succulent Karoo to the south. Altitude 10–160 m.

Vegetation & Landscape Features The landscape is dominated by plains, although slightly undulating hills and rocky outcrops do occur in places. The flat surface is partly due to its former position below the Atlantic Ocean and partly to being shaped by the frequent sand storms to form an aerodynamic planation surface. The unit is characterised as a sand movement corridor, fed by material from the sandy beaches south of Cape Voltas. Most of the open plains of this unit are seemingly bare of any vegetation, with the exception of scattered individuals of *Sarcocaulon patersonii* or very sparse grasslands of *Stipagrostis geminifolia*. A closer look reveals quite a number of species sunken into or even (for well-defined periods of time) underneath the soil surface (subterrestrial chamaephytes, e.g. *Fenestraria rhopalophylla*). A number of rocky outcrops allow dense stands of many very small succulent chamaephytes, the growth forms of these individuals also shaped by the frequent

sandstorms. With the strong winds and sandblasting, a high frequency of sand-fixing (psammophorous) plants is observed, e.g. *Psammophora modesta* and *Chlorophytum viscosum*.

Geology & Soils Underlying rocks are mainly metasediments and metavolcanics of the Gariiep Supergroup (Late Proterozoic). Quartz-feldspar gneiss, schist, subordinate amphibolite and minor ultramafic rocks are all largely covered by young superficial deposits. Quaternary sediments have developed gypscretes in places, often with high salinity. Generally shallow wind-swept soils with desert pavement are caused by very strong movements of wind-blown sand over the soil surface. Land types Ai and Ia.

Climate MAP 45–55 mm and rainfall erratic, but predominantly in winter. High frequency of fog. Extreme wind speeds and sandblasting from a southern direction and high frequency of sand storms which usually peak in the afternoon. No occurrence of frost. See other similar climate features under Dn 1 Alexander Bay Coastal Duneveld as well as Figure 6.2.

Important Taxa Stem- & Leaf-succulent Shrubs: *Brownanthus marlothii* (d), *Psilocaulon dinteri*. Stem-succulent Shrubs: *Euphorbia stapelioides*, *E. tuberculata*, *Sarcocaulon pater-sonii*, *Tylecodon schaeferianus*. Leaf-succulent Shrubs: *Cephalophyllum ebracteatum* (d), *Othonna lasiocarpa* (d), *O. sedifolia* (d), *Stoeberia beetzii* (d), *Amphibolia rupis-arcuatae*, *Cheiridopsis brownii*, *C. verrucosa*, *Conophytum saxetanum*, *Crassula deceptor*, *Dracophilus dealbatus*, *Drosanthemum paxianum*, *Eberlanzia sedoides*, *Fenestraria rhopalophylla*, *Juttadinteria deserticola*, *Psammophora modesta*, *Pteronia glabrata*, *Zygophyllum clavatum*, *Z. prismatocarpum*. Other Shrubs: *Asparagus capensis*, *Hermannia gariiepina*, *Lycium decumbens*. Graminoid: *Stipagrostis geminifolia* (d). Geophytic Herb: *Pelargonium sibthorpiiifolium*. Lichens: *Ramalina capensis* (d), *Teloschistes capensis* (d).

Conservation Target 28%. None conserved in statutory conservation areas. Some 2.6% transformed, almost half of that by roads. The unit is highly sensitive to mechanical destruction of the soil surface. It also occurs at least to some extent in Namibia, where it is protected within the Sperrgebiet National Park. From a South African perspective, this vegetation has a high conser-

vation value as it houses the main populations of some near-endemic species that are more frequently found in Namibia.

Remarks The densest and most diverse lichen field in southern Africa is located near the border on the western edge of this unit, out of reach of the sand movement corridor due to the steep rocky shore at and north of Cape Voltas (see Dn 2 Namib Lichen Fields).

References Jürgens (1991, 1996, 2004), Jürgens & Niebel (1991), Jürgens & Niebel-Lohmann (1995), Jürgens et al. (1997), Oguz (2000), Stöcker (2000), Van Wyk & Smith (2001), Oguz et al. (2004).

Dn 4 Western Gariiep Lowland Desert

VT 31 Succulent Karoo (100%) (Acocks 1953). LR 57 Lowland Succulent Karoo (97%) (Low & Rebelo 1996).

Distribution Northwestern Richtersveld, mainly including the lower portion of the large tilted plain of the Annisvlakte pediment west of Kuboes and the hilly mafic lava rock landscape close to Arrisdrijf, Brandkaros and Grootderm, close to the lowest reaches of the Orange River, thus extending some 43 km from the southwest to the northeast. The unit borders on Succulent Karoo to the south. Altitude 40–240 m.

Vegetation & Landscape Features On both the eastern plains and in the rocky hilly landscape in the west, sparse low shrubland with mainly leaf- and stem-succulent chamaephytes predominates. The leaf-succulent megachamaephyte (or small nanophanerophyte) *Ruschianthemum gigas* can be dominant or co-dominant with the nanophanerophyte *Euphorbia gummifera* and occurs on a more sandy soil. The low cushions of *Brownanthus pubescens* and the dwarf stem succulent *Euphorbia melanohydrata* show a stronger link to gypsum in the topsoil, while *Brownanthus pseudoschlichtianus* prefers calcareous soils. The vegetation of vast areas is heavily degraded and invaded by the annual *Mesembryanthemum hypertrophicum* (= *Opophytum aquosum*) and the annual or biennial *M. squamulosum* as well as nonsucculent annuals. In the western half of the unit (west of Arrisdrijf), high loads of sand originating from the sandveld in the south are transported over rocks by frequent strong winds. This region is characterised by a mosaic of rocky

outcrops, formed by mafic lava, and sand-filled valleys and plains. *Euphorbia gummifera* and *Ruschianthemum gigas* are dominant on deep sands above bedrock. Shallower sands are covered by (sometimes well-developed) grasslands with *Stipagrostis geminifolia* or *S. ciliata* dominant, but including *Chlorophytum viscosum*, *Foveolina dichotoma*, *Zygophyllum clavatum* and *Eberlanzia sedoides*. Very dry and shallow sandvelds are sometimes dominated by *Sarcocaulon pater-sonii*. Rocky outcrops can harbour *Aloe gariepensis* and *Sarcostemma viminale*, together with locally rarer elements like *A. dichotoma* var. *ramosissima* (westernmost population near Brandkaros), *Crassula atropurpurea* var. *cultriformis* and *Othonna clavifolia*. At the interface between rocks and shallow sands, the subterranean chamaephyte *Fenestraria rhopalophylla* with its window leaves is found, but also many geophytes, as in the sandy patches between and on the rocky hills.



Figure 6.5 Dn 3 Western Gariiep Plains Desert: Gravel pavement shaped by frequent desert sand storms. The yellow flowers belong to the cryptic succulent 'window plant' *Fenestraria rhopalophylla* (Aizoaceae).

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Figure 6.6 Dn 4 Western Gariep Lowland Desert: Scattered individuals of succulent *Sarcocaulon patersonii* (Geraniaceae) serving as sand traps and forming small, sandy, phytogenic hillocks in the desert 6 km south of Brandkaros in the lower Orange River Valley.

Geology & Soils Outcrops of the Grootderm Formation (Gariep Supergroup) consist of chlorite-schist and other metamorphic rocks between which filled valleys and plains are found in the west and unconsolidated sandy Quaternary pediments in the east. Biotite granite of the Kuboos Pluton (Cambrian) also occurs in the east. Mispah and Glenrosa soil forms also with red-yellow apedal freely drained soil and high base status are deeper than 300 mm. Gypsum crusts frequent. Along the slope of the large tilted plain of the Annisvlakte, running from the Goariep Mountain (Ploughberg) down to the Orange River, a catena of soil types is observed with silcretes in the upper portion, calcretes in the middle part and gypcretetes in the lowest section (Ellis 1980). Land types Fc and Ae.

Climate MAP from about 45–60 mm with winter rains predominant. Fog frequency estimated to be 50–60 days per year. Temperatures are generally relatively mild due to the cooling effect of the nearby Atlantic Ocean, but can be up to 48°C on berg-wind days. No occurrence of frost. Winds and sandstorms are frequent and strong in the western regions of the unit.

Important Taxa Tall Stem- & Leaf-succulent Shrub: *Aloe dichotoma* var. *ramosissima*. Stem- & Leaf-succulent Shrubs: *Brownanthus arenosus* (d), *B. pseudoschlichtianus* (d), *B. pubescens* (d), *Portulacaria pygmaea*. Stem-succulent Shrubs: *Euphorbia gummifera* (d), *E. ephedroides* var. *imminuta*, *E. melanohydrata*, *E. stapelioides*, *Sarcocaulon flavescens*, *S. multifidum*, *S. patersonii*, *Tylecodon schaeferianus*. Leaf-succulent Shrubs: *Ruschianthemum gigas* (d), *Cheiridopsis verrucosa*, *Crassula atropurpurea* var. *cultriformis*, *Didelta carnosa* var. *tomentosa*, *Dracophilus dealbatus*, *Eberlanzia sedoides*, *Fenestraria rhopalophylla*, *Juttadinteria deserticola*, *Othonna clavifolia*, *Psammophora modesta*. Other Shrubs: *Gnidia suavis-sima*, *Rhysolobium dumosum*. Graminoids: *Stipagrostis geminifolia* (d), *Centropodia glauca*, *Chaetobromus involucratus* subsp. *involucratus*, *Cladoraphis cyperoides*, *C. spinosa*, *Dregeochloa pumila*, *Stipagrostis ciliata* var. *capensis*, *S. dregeana*, *S. lutescens* var. *lutescens*, *S. schaeferi*, *S. subacaulis*. Geophytic Herbs: *Ammocharis longifolia*, *Babiana namaquensis*, *Chlorophytum viscosum*, *Ferraria schaeferi*, *Hexacyrtis dickiana*, *Strumaria bidentata*. Annual Herb: *Foveolina dichotoma*.

Conservation Target 28%. None conserved in statutory conservation areas in South Africa. The unit also partly occurs in Namibia, where it is protected within the Sperrgebiet National Park. Some 3% transformed, mainly by cultivation (near the Orange River). As with the Dn 3 Western Gariep Plains Desert, this unit is part of a centre of endemism (West Gariep CE; Jürgens 1991), which also includes parts of neighbouring desert units and a part of Namibia. The unit is heavily affected by domestic stock, mainly small stock. Photographs from 1914 show that parts of the Annisvlakte which used to be *Brownanthus pseudoschlichtianus* communities on typical deep loamy-sandy soils are now degraded to poor and saline habitats of *Euphorbia gummifera* and *Mesembryanthemum hypertrophicum*. The unit has also suffered considerable damage from diamond mining. The fate of endangered species like *Euphorbia melanohydrata* depends on the protection on the Namibian side of the Orange River.

Remarks At a finer mapping resolution, the strongly degraded landscapes east of Arrisdrijf could be classified as a separate vegetation unit. A number of species (*Euphorbia herrei*, *E. melanohydrata*, *E. stapelioides*, *Portulacaria pygmaea*, *Psammophora modesta*, *Ruschianthemum gigas*, *Sarcocaulon flavescens*, *S. multifidum*), endemic to the West Gariep Centre (Jürgens 1991), have their core area of distribution within the Western Gariep Lowlands unit. They also occur to some extent in the adjacent desert units, especially the Dn 5 Western Gariep Hills Desert as well as in the Sperrgebiet National Park in Namibia.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Jürgens et al. (1997), Oguz (2000), Stöcker (2000), Van Wyk & Smith (2001), Oguz et al. (2004), Veste et al. (2004).

Dn 5 Western Gariep Hills Desert

VT 31 Succulent Karoo (66%) (Acocks 1953). LR 56 Upland Succulent Karoo (50%) (Low & Rebelo 1996).

Distribution In the triangle between Sendelingsdrijf, Kuboes and Sanddrijf in the northern Richtersveld. It shares a border on the east with the Central Richtersveld Mountain Shrubland of the Succulent Karoo Biome. Altitude 60–360 m.

Vegetation & Landscape Features Very heterogeneous broken landscape, mostly hilly but including some smaller and larger plains. Some of the plains are covered by quartz gravel, others by loamy sand or by gravel from different rocks, with strong contrasts between different mosaic elements. The main vegetation unit includes quartz fields, which are covered by dwarf cushions of the *Brownanthus pubescens* community and the *Hartmanthus pergamentaceus* community (Jürgens 2004), the latter being restricted to this unit. The undulating hills, especially on southwestern slopes, are covered by the *Ruschianthemum gigas* desert shrubland community (Jürgens 2004), while rocky outcrops sometimes support populations of the spectacular *Aloe pillansii* (e.g. Cornellskop).

Geology & Soils Metasediments of the Gariep Supergroup dominate this area. They include quartzite, limestone, dolomite,

diamictite and schist which occur in a structurally complex succession, making up the Port Nolloth Group (Namibian). Mispah and Glenrosa soils dominate, with lime generally present in the entire landscape. The dominant land type is Fc.

Climate Predominantly winter rainfall with MAP from about 45–60 mm. High summer maximum temperatures up to 50°C. Frost absent. Fog less frequent than at coast but still estimated to be 40–50 fog days per year, becoming less frequent further up the course of the Orange River.

Important Taxa Succulent Tree: *Aloe pillansii* (d). Stem- & Leaf-succulent Shrubs: *Brownanthus pubescens* (d), *Portulacaria pygmaea*. Stem-succulent Shrubs: *Euphorbia chersina*, *E. ephedroides*, *E. gummifera*, *Sarcocaulon crassicaule*, *S. multifidum*. Leaf-succulent Shrubs: *Ruschia inconspicua* (d), *Ruschianthemum gigas* (d), *Anacampseros papyracea*, *Cephalophyllum numeesensis*, *Cheiridopsis robusta*, *C. verrucosa*, *Didelta carnosa* var. *carnosa*, *Dracophilus dealbatus*, *Eberlanzia ebracteata*, *Hypertelis salsoloides*, *Othonna cylindrica*, *O. opima*, *Ruschia glauca*, *Senecio sarcoides*, *Zygophyllum prismatocarpum*, *Z. schreiberanum*. Low Shrub: *Aptosimum spinescens*. Succulent Herbs: *Mesembryanthemum hypertrophicum*, *M. pellitum*, *Zygophyllum simplex*. Geophytic Herb: *Trachyandra muricata*. Annual Herbs: *Gazania lichtensteinii* (d), *Tripteris microcarpa* (d), *Amellus nanus*, *Gorteria corymbosa*, *Oncosiphon piluliferum*. Graminoid: *Stipagrostis obtusa*.

Endemic Taxa Leaf-succulent Shrubs: *Astridia citrina*, *Hartmanthus pergamentaceus*.

Conservation Target 28%. Some 11% statutorily conserved in the Richtersveld National Park. About 1% transformed by several active and historical mines. The unit has a high conservation value due to its endemic and other localised species and recommendations have been made to SANParks to incorporate most of it into the Richtersveld National Park. Elsewhere within the unit, Cornellskop has been declared a Natural Heritage Site. The unit also occurs at least to some extent in Namibia where most of it is protected within the Sperrgebiet National Park.

Remarks The distribution of *Brownanthus pubescens*, *Dracophilus dealbatus*, *Ectadium virgatum*, *Euphorbia herrei*, *Jutta-*

dinteria deserticola, *Leipoldtia alborosea*, *Portulacaria pygmaea*, *Psammophora modesta*, *Rhynchosia emarginata*, *Ruschianthemum gigas*, *Sarcocaulon flavescens*, *S. multifidum* and *Zygophyllum schreiberanum* is limited to this unit and the adjacent Western Gariep Lowlands Desert and parts of the Sperrgebiet National Park in Namibia along the northern bank of the Orange River. Although the unit as a whole falls within the Desert Biome, single outcrops at higher altitudes (up to 538 m) and south- to southwest-facing slopes show transition to the adjacent units of the Succulent Karoo.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Schmiedel (1994, 2002a, b, 2004), Jürgens et al. (1997), Schmiedel & Jürgens (1999, 2002, 2004), Van Wyk & Smith (2001).

Gariep Desert

Dg 1 Noms Mountain Desert

VT 33 Namaqualand Broken Veld (100%) (Acocks 1953). LR 56 Upland Succulent Karoo (100%) (Low & Rebelo 1996).

Distribution Northernmost part of the Richtersveld National Park, east of Sendelingsdrif, north of Koerogab and the Kook River, south of the Orange River. The unit borders on units of the Succulent Karoo Biome to the south. Altitude 100–600 m, with a few higher peaks.

Vegetation & Landscape Features Most of the unit is formed by rugged, generally low mountains with bare rock and very sparse vegetation. Habitats differ according to topography, rock type and climate (see below). On the rocks, succulents like *Aloe dichotoma*, *Ceraria namaquensis*, *Pachypodium namaquanum*, *Tylecodon hallii*, *Commiphora capensis*, *Zygophyllum segmentatum*, *Schwantesia herrei*, but also the rare *Portulacaria armiana* occur. In the valley bottoms, *Dicoma capensis*, *Pharnaceum croceum*, *Dimorphotheca polyptera*, *Mesembryanthemum gariusanum*, *Sesuvium sesuvioides*, *Euphorbia phylloclada*, *Leucophrys mesocoma* and *Stipagrostis namaquensis* are frequent. Relatively more mesic vegetation occurs towards the upper end of the moisture gradient from the hyperarid Orange River Valley to higher altitudes and in some of the gorges.

Geology & Soils Predominantly calc-alkaline, acid and intermediate metavolcanic rocks and quartzitic metasediments of the De Hoop Subgroup (Orange River Group). Also granodiorite, adamellite, leucogranite, tonalite and diorite of the Vioolsdrif Intrusive Suite (Mokolian Erathem) are found. Hardly any deep soils developed. Land type Ic.

Climate MAP approximately 45–60 mm. Variable, transitional climate between winter and summer rainfall. High maximum temperatures, reaching up to 50°C in summer. Frost is very rare, but occurs at higher altitudes. Fog infrequent, particularly in the eastern part of the unit.

Important Taxa Succulent Tree: *Aloe dichotoma*. Small Trees: *Boscia albitrunca*, *Schotia afra*. Stem- & Leaf-succulent Shrubs: *Brownanthus pseudoschlichtianus* (d), *B. nucifer*, *Ceraria namaquensis*, *Psilocaulon subnodosum*, *Senecio sarcoides*, *Tylecodon buchholzianus*, *T.*



Figure 6.7 Dn 5 Western Gariep Hills Desert: Extraordinary spring flower display (2006) with *Gazania lichtensteinii* (pale yellow form), *Amellus nanus* and *Didelta carnosa* var. *carnosa* dominant on hills near Anniskop south of Sendelingsdrif in the Richtersveld. The sparse shrubland contains various species of *Euphorbia*, *Sarcocaulon*, *Cephalophyllum*, *Cheiridopsis* and *Zygophyllum*. The white quartz patches are the habitat of a *Brownanthus pubescens* community. Trees of the rare *Aloe pillansii* are visible in the background.

hallii. Stem-succulent Shrubs: *Commiphora capensis*, *Euphorbia decussata*, *E. dregeana*, *E. gariiepina*, *E. guerichiana*, *E. gummifera*, *E. virosa*, *Kleinia longiflora*, *Othonna arbuscula*, *O. opima*, *Pachypodium namaquanum*, *Sarcocaulon crassicaule*. Leaf-succulent Shrubs: *Aloe gariepensis*, *Ceraria fruticulosa*, *Cheiridopsis robusta*, *Crassula sladenii*, *Drosanthemum floribundum*, *D. inornatum*, *D. otzenianum*, *Eberlanzia ebracteata*, *E. schneideriana*, *Hypertelis salsoloides*, *Leipoldtia grandifolia*, *Portulacaria armiana*, *Prenia tetragona*, *Ruschia leucosperma*, *R. subaphylla*, *Schwantesia herrei*, *Zygophyllum microcarpum*, *Z. prismatocarpum*, *Z. retrofractum*, *Z. segmentatum*. Other Shrubs: *Sisyndite spartea* (d), *Adenolobus gariepensis*, *Aptosimum spinescens*, *Calicorema capitata*, *Chrysocoma schlechteri*, *Dyerophytum africanum*, *Eriocephalus ericoides*, *Euryops multifidus*, *Gaillonia crocylis*, *Hermannia stricta*, *Hermbstaedtia glauca*, *Indigofera pungens*, *Jamesbrittenia fruticosa*, *Kissenia capensis*, *Monechma mollissimum*, *Montinia caryophyllacea*, *Peliostomum leucorrhizum*, *Pteronia lucilioides*. Graminoids: *Leucophrys mesocoma* (d), *Cyperus marginatus*, *Stipagrostis ciliata*, *S. namaquensis*. Perennial Herbs: *Acanthopsis disperma*, *Dicoma capensis*, *Forsskaolea candida*, *Pharnaceum croceum*. Geophytic Herb: *Trachyandra muricata*. Succulent Herbs: *Mesembryanthemum gariusanum*, *Trianthema triquetra*. Annual Herbs: *Dimorphotheca sinuata*, *Gazania lichtensteinii*, *Leysera tenella*, *Oncosiphon piluliferum*, *Tripteris microcarpa*.

Conservation Least threatened. Target 34%. 100% statutorily conserved in the Richtersveld National Park. The unit has a high conservation value due to high concentration of endemic taxa of the East Gariiep CE. Very little transformed but there is some diamond mining at Oenas, close to the Orange River. Domestic grazing is permitted in the park in terms of its status as a contractual park. This unit contains one of the largest aggregations of *Pachypodium namaquanum*. It is also found across the border in Namibia where it is, at least in part, protected within the Ai-Ais National Park.

Remarks Within the unit there is a climatic gradient, running from the hottest and driest parts along the Orange River to the relatively humid transition to the Succulent Karoo north and

northwest of the Kodus Peak and the Koeroegabvlakte. In these more humid and cooler parts at higher altitude, vegetation units and taxa belonging to the Succulent Karoo (see Jürgens 2004) also occur (e.g. *Brownanthus pseudoschlichtianus*, *Cheiridopsis robusta*, *Ceraria fruticulosa*). These form scattered patches of SKr 1 Central Richtersveld Mountain Shrubland, which cannot be mapped at present. The unit shares many of the endemics of the East Gariiep Centre (Jürgens 1991) e.g. *Brownanthus nucifer*, *Tylecodon hallii*, *Schwantesia herrei*, some *Euphorbia gariiepina*, *Mesembryanthemum gariusanum*. *Portulacaria armiana* occurs here and in a very limited area north of the Orange River.

References Van Jaarsveld (1981), Nußbaum (2003), Jürgens (2004).

Dg 2 Richtersberg Mountain Desert

VT 33 Namaqualand Broken Veld (100%) (Acocks 1953). LR 56 Upland Succulent Karoo (100%) (Low & Rebelo 1996).

Distribution Northeastern part of the Richtersveld National Park, south of Kook River and north of the Springbokvlakte and Tatasberg including the mountains of Rooiberg, Richtersberg, Claim Peak and Nabasberg. The unit borders on units of the Succulent Karoo Biome to the west. Altitude 100–882 m (on the summit of Rooiberg).

Vegetation & Landscape Features Rugged mountain ranges with bare rock and valleys some of which (e.g. lower Gannakouriep River) form deep canyons. At high altitudes vegetation cover is sparse; plant cover (including *Commiphora capensis*, *Aloe dichotoma*, *Tylecodon hallii*, *Schwantesia herrei*, *Euphorbia gariiepina* and *E. virosa*) is more conspicuous in some gorges and on slopes covered with a mixture of boulders and rubble. On valley bottoms within this vegetation unit sparse grassland mainly with *Leucophrys mesocoma* and *Stipagrostis namaquensis* occur, but also *Stipagrostis obtusa* and *S. ciliata*, after good rains combined with rich populations of opportunistic life forms like *Mesembryanthemum gariusanum* (sometimes flowering in masses), *Dicoma capensis*, *Pharnaceum croceum*, *Dimorphotheca polyptera*, *Sesuvium sesuvioides* and *Euphorbia phylloclada*. But also see remarks under Dg 3 Richtersveld Sheet Wash Desert.

Geology & Soils Granodiorite and adamellite of the Vioolsdrif Suite dominate the area together with the metavolcanics and metasediments of the De Hoop Subgroup of the Orange River Group (Mokolian). Granite of the Tatasberg Pluton (part of the Kuboos-Bremen Suite) also features. Very rocky substrate, with very shallow to no soils. Sands occur in valley bottoms. Land type 1c.

Climate Very variable transitional (winter to summer rainfall) climate. MAP about 45–70 mm. High summer maximum temperatures reach up to 50°C. Frost very rare, but occurs at high altitudes. Fog insignificant. At a new rain meter at 440 m altitude near Claim Peak a MAP of 47.1 mm has been recorded over a six-year period.

Important Taxa Succulent Tree: *Aloe dichotoma* (d). Low Trees: *Boscia albitrunca*, *B. foetida*, *Parkinsonia africana*.



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Figure 6.8 Dg 1 Noms Mountain Desert: Sheet-wash plains (with scattered *Boscia albitrunca*) form the foreground to the mountainous Noms Desert. *Aloe dichotoma* var. *dichotoma*, *Pachypodium namaquanum*, *Zygophyllum cylindrifolium* and other plants are found on the seemingly barren mountain slopes.



Figure 6.9 Dg 2 Richtersberg Mountain Desert: A view over the Hidden Valley (part of Dg 3 Richtersveld Sheet Wash Desert) towards Richtersberg as seen from the foot of Tatasberg.

Stem- & Leaf-succulent Shrubs: *Brownanthus pseudoschlich-tianus* (d), *Ceraria namaquensis* (d), *Brownanthus nucifer*, *Psilocaulon subnodosum*. Stem-succulent Shrubs: *Euphorbia gariepina* (d), *E. virosa* (d), *Commiphora capensis*, *C. cervifolia*, *Euphorbia decussata*, *E. gummifera*, *E. phylloclada*, *Sarcocaulon crassicaule*. Leaf-succulent Shrubs: *Anacampseros papyracea*, *Ceraria fruticulosa*, *Galenia crystallina*, *Salsola zeyheri*. Other Shrubs: *Sisyndite spartea* (d), *Adenolobus gariepensis*, *Aptosimum spinescens*, *A. tragacanthoides*, *Berkheya fruticosa*, *Cadaba aphylla*, *Calicorema capitata*, *C. squarrosa*, *Eriocephalus ericoides*, *Helichrysum obtusum*, *Kissenia capensis*, *Wellstedia dinteri*. Graminoids: *Stipagrostis ciliata* (d), *S. obtusa* (d), *Enneapogon scaber*. Perennial Herbs: *Acanthopsis disperma*, *Dicoma capensis*, *Forsskaolea candida*, *Pharnaceum croceum*. Geophytic Herbs: *Cyanella hyacinthoides*, *Gladiolus saccatus*, *Trachyandra muricata*. Succulent Herbs: *Mesembryanthemum gariusanum*, *M. pellitum*, *Trianthema triquetra*. Annual Herbs: *Cleome angustifolia* subsp. *diandra*, *Dimorphotheca sinuata*, *Gazania lichtensteinii*, *Helichrysum gariepinum*, *Indigastrium argyroides*, *Oncosiphon piluliferum*, *Trichodesma africanum*, *Tripteris microcarpa*.

Conservation Least threatened. Target 34%. 100% statutorily conserved in the Richtersveld National Park. Also found across the border in Namibia, where it is (at least in part) protected within the Ai-Ais National Park. High conservation value due to its concentration of endemics of the East Gariep CE. Very little transformed. Grazing of private herds is permitted in the park in terms of its status as a contractual park.

Remarks The unit is similar to the neighbouring Dg 1 Noms Mountain Desert. The main difference is that the Dg 2 Richtersberg Mountain Desert is clearly dominated by taxa of the East Gariep

CE of the Nama-Karoo Floristic Region, while the Noms Mountain Desert has a mixture of numerous taxa and minor vegetation units (Jürgens 2004) which are also found in the Succulent Karoo, e.g. in the SKr 1 Central Richtersveld Mountain Shrubland. Dg 2 Richtersberg Mountain Desert is, in contrast, rich in populations of species like *Euphorbia virosa* and *E. gariepina*, which are much less visible in the Noms Mountain Desert. The vegetation of the valley bottoms in the unit could as well be seen as small elements of the vegetation unit Dg 3 Richtersveld Sheet Wash Desert. The unit shares many of the endemics of the East Gariep CE (Jürgens 1991), e.g. *Brownanthus nucifer*, *Tylecodon hallii*, *Schwantesia herrei*, *Euphorbia gariepina* and *Mesembryanthemum gariusanum*.

References Van Jaarsveld (1981), Jürgens (1991, 2004), Nußbaum (2003).

Dg 3 Richtersveld Sheet Wash Desert

VT 33 Namaqualand Broken Veld (93%) (Acocks 1953). LR 56 Upland Succulent Karoo (100%) (Low & Rebelo 1996).

Distribution The unit is represented by many scattered smaller and larger valleys and plains in the northeastern Richtersveld. The largest areas (that can be shown on a map) include the Springbokvlakte, the Maerpoort, parts of the mid-upper reaches of the Abiekwa and Gannakouriep catchments, the lower Kourougab with the Kook River and the lower Kouams River. At a finer scale, many more parts of this unit would become visible in the northeastern parts of the Richtersveld. Altitude approximately 120–600 m.

Vegetation & Landscape Features Sloping, often broad, valley floors, planated by the runoff from rare but strong thunder-



Figure 6.10 Dg 3 Richtersveld Sheet Wash Desert: The Springbokvlakte in the valley and the Kwaggarug Mountain Desert in the background as viewed from Tatasberg.



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Figure 6.11 Dg 3 Richtersveld Sheet Wash Desert: *Sisyndite spartea* (Zygophyllaceae) dominating a sheet wash east of the Gannakouriep River in the Richtersveld.

storms and often funnelled by the surrounding bare rock of the mountains. Habitats differ according to water flow and water storage in the soil. Large amounts of runoff water from adjacent hills and mountains can be stored in the deep gravel and sand of the sheet wash valleys, thereby providing a long-lasting water resource. In response, phreatophytes, especially trees such as *Boscia albitrunca*, *B. foetida*, *Schotia afra*, *Parkinsonia africana*, *Maerua gilgii*, *M. schinzii* and *Euclea pseudebenus* are found, mainly on sites sheltered from the destructive forces of the floods. They form a sparse scattered pattern of single trees despite the availability of underground water. The stem-succulent nanophanerophyte *Euphorbia gregaria* is situated in a sheltered (somewhat elevated) part of the lower Springbokvlakte. The force of water flow is often destructive to plants, resulting in a cover of opportunistic life forms on the larger sheet wash plains or valley bottoms. Short-lived plants, after good rains, are *Mesembryanthemum gariusanum* (sometimes flowering in masses), *Sesuvium sesuvioides*, *Dicoma capensis*, *Pharnaceum croceum*, *Dimorphotheca pluvialis*, *D. polyptera*, *Euphorbia phylloclada*, *Monsonia parvifolia* and *Tribulus cristatus*. The longest-lived plants here include grasses (especially the hardy *Leucophrys mesocoma*, *Stipagrostis namaquensis*, *S. obtusa* and *S. ciliata*), but also some other plants such as *Codon royenii*, *Dyerophytum africanum*, *Gaillonia crocyllis*, *Kissenia capensis*, *Monechma mollissimum*, *Prenia tetragona*, *Rogeria longiflora*, *Sisyndite spartea* and *Solanum namaquense*.

Geology & Soils Coarse to fine alluvial sediments created from a variety of rock types mainly of the Violsdrif Suite and De Hoop Subgroup (Orange River Group, Mokolian Erathem), but also of the Dwyka Group (Karoo Supergroup), where these glacial deposits cover the older Mokolian rocks. Eroded sediments are shallow to generally deep.

Climate MAP about 45–70 mm. Very variable, transitional climate between winter and summer rainfall, showing a tendency towards summer rainfall in the east (e.g. lower Springbokvlakte). Rare thunderstorms are the most important source of rainfall. High summer maximum temperatures reach 50°C. Frost is very rare, but occurs at high altitudes. A new rain meter near the Tatasberg recorded a MAP of 55 mm over a six-year period.

Important Taxa Small Trees: *Boscia albitrunca*, *B. foetida*, *Euclea pseudebenus*, *Maerua gilgii*, *M. schinzii*, *Parkinsonia africana*, *Schotia afra*. Stem-succulent Shrub: *Euphorbia phylloclada*. Leaf-succulent Shrubs: *Prenia tetragona*, *Zygophyllum microcarpum*. Other Shrubs: *Sisyndite spartea* (d), *Adenolobus gariensis*, *Calicorema capitata*, *Codon royenii*, *Dyerophytum africanum*, *Gaillonia crocyllis*, *Kissenia capensis*, *Monechma mollissimum*, *Solanum namaquense*. Graminoids: *Leucophrys mesocoma* (d), *Stipagrostis ciliata* (d), *S. namaquensis* (d), *S. obtusa*. Perennial Herbs: *Cleome angustifolia* subsp. *diantra*, *Rogeria longiflora*. Geophytic Herb: *Trachyandra muricata*. Succulent Herb: *Mesembryanthemum gariusanum* (d). Annual Herbs: *Pharnaceum croceum*, *Sesuvium sesuvioides*, *Trichodesma africanum*.

Biogeographically Important Taxon

Euphorbia gregaria. One large population on the lower Springbokvlakte between the Tatasberg and Grasdrif forms the

only known population in South Africa west of Violsdrif and is the southwestern outlier of the large distribution area in southern Namibia and the vicinity of the Orange River Valley between Violsdrif and Kakamas.

Conservation Least threatened. Target 34%. All mapped parts of this unit are statutorily conserved in the Richtersveld National Park. Very little transformed, but the road network is often biased towards these areas. By definition, this unit is subject to sheet erosion. The unit has a natural high turnover rate and is adapted to frequent disturbance.

Remarks This vegetation unit shares many of the endemics of the East Gariep CE, (e.g. *Mesembryanthemum gariusanum*). The unit shares a number of species with the Dg 6 Helskloof Canyon Desert in which sheet washes also occur. The Springbokvlakte houses the largest patch of the unit and its species composition shows slight deviations from other parts of the unit. Sheet wash features are found in many other Desert units at a wide variety of scales, often at a scale so detailed that it is not possible to separate them out at the mapping scale. Various forms of sheet wash features occur, from those in the winter-rainfall areas to those of the summer-rainfall areas (i.e. Dg 9 Eastern Gariep Plains Desert), from those largely sandy to those with significant amounts of colluvial material (e.g. Dg 6 Helskloof Canyon Desert). These features will have to receive further attention in future mapping work.

References Van Jaarsveld (1981), Nußbaum (2003), Jürgens (2004).

Dg 4 Kwaggarug Mountain Desert

VT 33 Namaqualand Broken Veld (100%) (Acocks 1953). LR 56 Upland Succulent Karoo (100%) (Low & Rebelo 1996).

Distribution South of the Springbokvlakte sheet wash plain and north of the Rosyntjieberge. It includes the Kwaggarug Mountain, the lower slopes of Mount Terror and most of the catchment of the Oudannisiep River. The unit borders on SKR 8 Rosyntjieberg Succulent Shrubland of the Succulent Karoo Biome to the south. Altitude approximately 150–800 m.

Vegetation & Landscape Features Patchy mosaic of isolated hills and mountains, surrounded by limited plains of sheet wash character. Some plains are covered by desert gravel pavements, including quartz fields with their typically associated vegetation; towards the south, on lower slopes of larger mountains with succulent dwarf shrub vegetation.

Geology & Soils Metavolcanics and metasediments (including quartzite) of the Mokolian Orange River Group are most abundant (both the De Hoop Subgroup and Rosyntjieberg Formation are represented). Dwyka diamictite is also present and the Vioolsdrif Suite occurs on the northern and western fringes of the area. Very rocky, with little developed soils or no soil cover. Sands are found in sheet washes and on valley bottoms. Land type lc.

Climate MAP about 45–70 mm. Transitional, highly variable climate between winter and summer rainfall. No significant occurrence of fog. High summer maximum temperature can reach up to 50°C. Frost is very rare, but occurs at high altitudes.

Important Taxa Succulent Tree: *Aloe dichotoma*. Small Trees: *Boscia albitrunca*, *B. foetida*, *Euclea pseudebenus*. Stem- & Leaf-succulent Shrubs: *Brownanthus pseudoschlichtianus*, *Ceraria namaquensis*, *Psilocaulon subnodosum*. Stem-succulent Shrubs: *Commiphora capensis*, *Euphorbia decussata*, *E. gariepina*, *E. virosa*. Leaf-succulent Shrubs: *Augea capensis*, *Ceraria fruticulosa*, *Conophytum wettsteinii*, *Galenia crystallina*, *Hypertelis salsooides*, *Zygophyllum decumbens*. Other Shrubs: *Calicorema capitata*, *Dyerophytum africanum*, *Fagonia isotricha* var. *spinescens*, *Gaillonia crocyllis*, *Sisyndite spartea*. Graminoids: *Stipagrostis ciliata*, *S. obtusa*. Perennial Herbs: *Dicoma capensis*, *Forsskaolea candida*. Geophytic Herb: *Trachyandra muricata*. Succulent Herbs: *Mesembryanthemum gariusanum*, *Trianthema triquetra*. Annual Herbs: *Chamaesyce glanduligera*, *Cleome angustifolia* subsp. *diandra*, *Geigeria vigintiquamea*.

Conservation Least threatened. Target of 34% already reached since all units is statutorily conserved in the Richtersveld National Park.

Remarks There is a steep aridity gradient from the border with the Succulent Karoo, through rich Nama-Karoo flora on the higher mountain areas to the species-poor flora in the hyperarid vicinity of the Orange River. This unit shares many of the endem-

ics of the East Gariep CE (*Brownanthus nucifer*, *Euphorbia gariepina*, *Mesembryanthemum gariusanum*, *Schwantesia herrei* and *Tylecodon hallii*).

References Van Jaarsveld (1981), Jürgens (2004).

Dg 5 Kahams Mountain Desert

VT 33 Namaqualand Broken Veld (95%) (Acocks 1953). LR 56 Upland Succulent Karoo (100%) (Low & Rebelo 1996).

Distribution Located between the Stinkfonteinberge basal apron in the west and the Orange River and Helskloof Canyon in the east, and between the Rosyntjieberge in the north and the Rooiberg in the south. The unit borders on units of the Succulent Karoo Biome to the north, south and west. Altitude 150–1 078 m on the summit of the Black Face Mountain.

Vegetation & Landscape Features Highly dissected landscape with rugged mountains with bare rock and very sparse shrubland vegetation becoming somewhat less sparse to the west.

Geology & Soils The granodiorite, adamellite, leucogranite, tonalite and diorite of the Vioolsdrif Suite (Mokolian Erathem) are intruded by syenites and granites of the Richtersveld Suite (Namibian Erathem). These together account for three quarters of the area. Calc-alkaline, acid and metavolcanic rocks and quartzitic metasediments of the De Hoop Subgroup, Orange River Group (Mokolian Erathem) are also significant. Very rocky substrate, with little to no soils. Land type lb.

Climate MAP about 45–70 mm. Very variable, transitional climate between winter and summer rainfall with tendency towards summer rainfall in the east. Fog absent. Maximum summer temperatures reaching up to 50°C. Frost is very rare, but occurs at higher altitudes. Characterised by steep gradient of increasing aridity from west to east. In the east, hot and dry conditions are typical for the low altitudes along the Orange River, while in the western parts at higher elevations (close to the foothills of the Stinkfonteinberge) the climate is relatively more humid and cooler.

Important Taxa Succulent Tree: *Aloe dichotoma*. Small Trees: *Boscia foetida*, *Maerua gilgii*. Stem- & Leaf-succulent Shrubs: *Brownanthus nucifer* (d), *Ceraria namaquensis* (d), *Brownanthus ciliatus*, *B. pseudoschlichtianus*. Stem-succulent Shrubs: *Euphorbia gariepina*, *E. gummifera*, *E. virosa*. Leaf-succulent Shrub: *Hereroa hesperantha*. Other Shrubs: *Adenolobus gariepensis*, *Dyerophytum africanum*, *Euryops sub-carnosus* subsp. *vulgaris*, *Nymania capensis*, *Pelargonium desertorum*, *Petalidium parvifolium*, *Pteronia divaricata*, *P. lucilioides*, *Sisyndite spartea*. Succulent Herb: *Trianthema triquetra*. Annual Herb: *Manulea cheiranthus*.

Conservation Least threatened. Target 34%. About 7% in the far north of the unit is statutorily conserved in the Richtersveld National Park. Although most of the remainder of the unit falls within the Richtersveld Community Conservancy, parts have been heavily impacted by grazing and there is small-scale mining in the unit too. That part of the Orange River that borders this unit is the most popular stretch of the lower

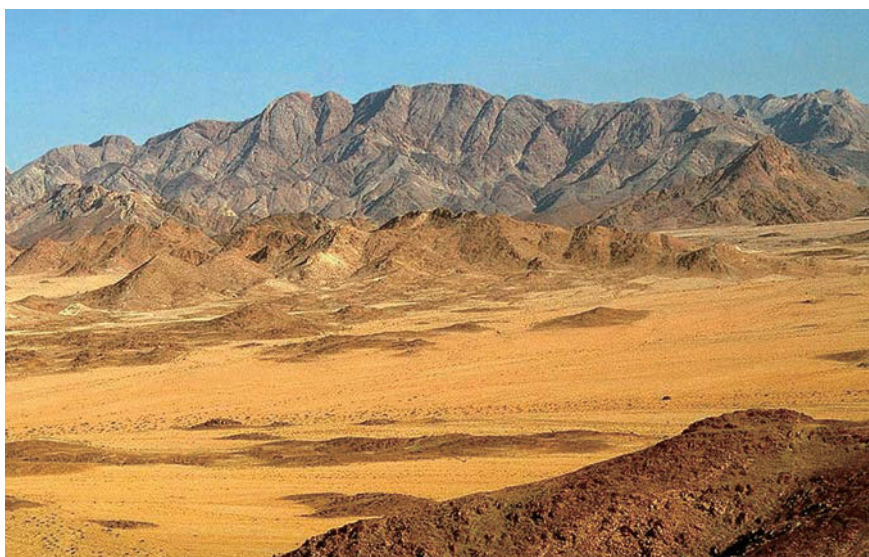


Figure 6.12 Dg 4 Kwaggarug Mountain Desert: On the Kwaggarug hills immediately across the Springbokvlakte with the much larger Mount Terror and eastern Rosyntjieberg massif (Succulent Karoo) behind.

L. Mucina

river for canoeing and rafting with ad hoc overnight camping, which may lightly impact on the vegetation here.

Remarks Although no strict endemics are known, the unit contains a number of endemics of the East Gariiep CE, such as *Brownanthus nucifer*, *Euphorbia gariiepina*, *Lithops geyeri*, *Mesembryanthemum gariusanum*, *Pelargonium desertorum*, *Sarcocaulon herrei*, *Schwantesia herrei* and *Tylecodon hallii*.

Reference Jürgens (2004).

Dg 6 Helskloof Canyon Desert

VT 33 Namaqualand Broken Veld (100%) (Acocks 1953). LR 56 Upland Succulent Karoo (100%) (Low & Rebelo 1996).



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Figure 6.13 Dg 6 Helskloof Canyon Desert: Sparse vegetation on the valley bottom (sheet wash) in the Helskloof at Modderdrif west of Vioolsdrif, with *Hermbstaedtia glauca*, *Gaillonia crocyllis* and *Zygophyllum* species.

Distribution A small area of canyon landscape in the eastern Richtersveld, between the Nababijsberge in the east and the Rooiberge in the west, south of Modderdrif on the Orange River and encompassing the lower reaches of the Groen River. Altitude about 160–300 m.

Vegetation & Landscape Features The unit superficially represents the South African equivalent of the Namibian Fish River Canyon. It comprises the canyon floor and initial slopes of the north-south trending canyon, approximately 1 km wide and almost 10 km long. The canyon walls tower 250–350 m above the floor and are more precipitous on the eastern side. Habitat types range from bare rocks and large hamma-like stone areas to dry river beds supporting sparse small trees and shrubs (*Schotia afra*, *Maerua gilgii* and *Adenolobus gariepensis*). On the rocky slopes, scattered populations of succulents such as *Aloe dichotoma*, *Brownanthus ciliatus*, *B. nucifer*, *Ceraria namaquensis*, *Euphorbia gariiepina* and *E. virosa* occur. In the debris and washes of the canyon bottom trees such as *Boscia foetida* and *Parkinsonia africana*, or shrubs such as *Sisyndite sparteae*, *Calicorema capitata* and *Gaillonia crocyllis* are frequently found.

Geology & Soils Mainly quartzite of the Kuibis Subgroup, Nama Group (Namibian Erathem), with fringes of the area occurring on the metavolcanics and metasediments of the De Hoop Subgroup (Orange River Group, Mokolian Erathem) and also the shale, quartzite and limestone of the Schwarzrand Subgroup (Nama Group, Namibian Erathem). Soil is alluvial sediment with colluvial material in places. Land types Ag and Ae.

Climate MAP roughly 40–60 mm per year tending to peak in late summer, but very variable. Some localised winter water input through drainage from the winter-rainfall area to the south. High summer maximum temperatures often reach 40°C and occasionally 50°C. The bottom of the canyon is one of the hottest environments in the Richtersveld. No incidence of frost.

Important Taxa Succulent Tree: *Aloe dichotoma*. Small Trees: *Boscia albitrunca*, *B. foetida*, *Euclea pseudebenus*, *Maerua gilgii*, *M. schinzii*, *Parkinsonia africana*, *Schotia afra*. Stem- & Leaf-succulent Shrubs: *Ceraria namaquensis* (d), *Brownanthus ciliatus*, *B. nucifer*, *B. pseudoschlichtianus*, *Psilocaulon subnodosum*. Stem-succulent Shrubs: *Euphorbia gariiepina* (d), *E. virosa* (d), *Commiphora cervifolia*, *C. gracilifronsosa*, *Euphorbia decusata*, *E. dregeana*, *E. gummifera*, *E. phylloclada*, *Kleinia longi-*

flora, *Sarcocaulon crassicaule*. Leaf-succulent Dwarf Shrubs: *Cephalophyllum regale*, *Ceraria fruticulosa*, *Cheiridopsis herrei*, *Drosanthemum inornatum*, *D. otzenianum*, *Eberlanzia cyathiformis*, *E. ebracteata*, *Hereroa hesperantha*, *Hypertelis salsoloides*, *Prenia tetragona*, *Ruschia paucipetala*, *Salsola zeyheri*, *Schwantesia herrei*, *Zygophyllum decumbens*, *Z. microcarpum*, *Z. retrofractum*, *Z. rigidum*. Other Shrubs: *Sisyndite sparteae* (d), *Adenolobus gariepensis*, *Aptosimum spinescens*, *Blepharis furcata*, *Cadaba aphylla*, *Calicorema capitata*, *Chascanum gariepensis*, *Fagonia capensis*, *F. isotricha* var. *spinescens*, *Gaillonia crocyllis*, *Hermbstaedtia glauca*, *Indigofera pungens*, *Kissenia capensis*, *Limeum aethiopicum* subsp. *namaensis*, *Monechma mollissimum*, *Nymanina capensis*. Perennial Herbs: *Codon royenii*, *Forsskaolea candida*, Geophytic Herb: *Bowiea gariepensis*. Succulent Herbs: *Sesuvium sesuvioides*, *Trianthema triquetra*. Annual Herbs: *Geigeria vigintisquamea*, *Pharnaceum croceum*, *Trichodesma africanum*. Graminoid: *Cyperus marginatus*.

Conservation Least threatened. Target 34%. The unit is partly protected in the Nababiep Nature Reserve and has been only very little transformed.

Remarks No species restricted to this unit are known, but the Helskloof is an area where eastern Richtersveld endemics meet with the Bushmanland elements (e.g. *Ozoroa namaquensis*).

Reference Jürgens (2004).

Dg 7 Northern Nababijsberge Mountain Desert

VT 33 Namaqualand Broken Veld (100%) (Acocks 1953). LR 56 Upland Succulent Karoo (100%) (Low & Rebelo 1996).

Distribution A large plateau of black limestone, south of the Orange River, west of Vioolsdrif, east of Helskloof with a southern boundary 15–20 km south of the river. Altitude about 180–765 m.

Vegetation & Landscape Features Very rocky plateau interrupted by deep gorges. Extreme differences between vegetation on the plateaus and in the gorges. Plateaus often almost

devoid of vegetation. The most important chamaephytes with nevertheless very sparse populations are *Zygophyllum rigidum* and *Z. decumbens*. *Ruschia subaphylla* and *Wellstedtia dinteri* are often found on loose rock debris. Depending on local hydrological conditions, the bottoms of the gorges can be covered by woody phreatophytes, which form low gallery shrublands (as in the Helskloof Canyon Desert) or they are bare.

Geology & Soils Mainly shale, quartzite and limestone of the Schwarzrand Subgroup with a small area underlain by the quartzite of the Kuibis Subgroup (both Nama Group, Namibian Erathem). Very rocky with no soils to little and extremely shallow soils. Land type Ic.

Climate MAP about 45–70 mm with rainfall peak in late summer and early autumn. High summer maximum temperatures often higher than 40°C, occasionally reaching 50°C. Frost is very rare, but occurs at high altitudes. See also Figure 6.2.

Important Taxa Succulent Tree: *Aloe dichotoma*. Small Trees: *Boscia albitrunca*, *Euclea pseudebenus*, *Maerua gilgii*, *M. schinzii*. Stem- & Leaf-succulent Shrub: *Brownanthus ciliatus*. Stem-succulent Shrubs: *Commiphora namaensis*, *Euphorbia gariiepina*. Leaf-succulent Shrubs: *Ruschia paucipetala* (d), *Zygophyllum decumbens* (d), *Z. rigidum* (d), *Ruschia subaphylla*. Other Shrubs: *Adenolobus gariiepensis*, *Calicorema capitata*, *Cryptolepis decidua*, *Hermannia stricta*, *Nymanina capensis*, *Petalidium parvifolium*, *Sisyndite sparteae*, *Wellstedtia dinteri*. Perennial Herbs: *Chascanum gariiepense*, *Rogeria longiflora*, *Tribulus cristatus*. Succulent Herbs: *Mesembryanthemum gariuanum*, *Trianthema triquetra*.

Conservation Least threatened. Target 34%. None conserved in statutory conservation areas. Large parts mostly inaccessible, hence well preserved.

Remarks The area is not well researched. Possibly it is the most sparsely vegetated of all desert vegetation units.

Reference Jürgens (2004).

Dg 8 Southern Nababiepsberge Mountain Desert

VT 33 Namaqualand Broken Veld (91%) (Acocks 1953). LR 56 Upland Succulent Karoo (100%) (Low & Rebelo 1996).

Distribution South of the Nababiepsberge and north of the Steinkopf Plateau, east of the Groen River and west of the Koubank River. The unit borders on units of the Succulent Karoo Biome to the south (SKr 12 Kosiesberg Succulent Shrubland and SKr 16 Umdaus Mountains Succulent Shrubland). Altitude about 250–984 m (Bluff).

Vegetation & Landscape Features Diverse habitats in a rugged mountain area with plateaus and larger plains and a spectrum of vegetation types, which include relatively tall stands of *Pachypodium namaquanum* and *Aloe dichotoma* on rocky slopes to dwarf succulents on quartz fields and shrubby riverine vegetation in gorges.

Geology & Soils The shales, quartzite and limestone of the Nama Group (Namibian Erathem), both of the Schwarzrand and of the older Kuibis Subgroups. Younger sediments overly granodiorite and adamellite of the Vioolsdrif Intrusive Suite as well as the andesitic lava and acid volcanics of the Haib Subgroup (Orange River Group, Mokolian Erathem). Very rocky with little to no soils. Land type Ic.

Climate Very variable, transitional climate between winter and summer rainfall tending towards summer rainfall in the east.

MAP about 50–100 mm. Less extreme maximum temperatures and higher frequency of frost days (<10 per year) than in the neighbouring desert units, especially at higher altitudes.

Important Taxa Succulent Tree: *Aloe dichotoma*. Small Trees: *Boscia albitrunca*, *Euclea pseudebenus*, *Maerua gilgii*, *M. schinzii*, *Schotia afra*. Stem- & Leaf-succulent Shrubs: *Brownanthus ciliatus*, *B. nucifer*, *B. pseudoschlichtianus*, *Ceraria namaquensis*, *Psilocalon subnodosum*. Stem-succulent Shrubs: *Euphorbia dregeana*, *E. gariiepina*, *E. gummiifera*, *E. virosa*, *Othonna arbuscula*, *Pachypodium namaquanum*. Leaf-succulent Shrubs: *Drosanthemum inornatum*, *Eberlanzia cyathiformis*, *E. ebracteata*, *Hereroa hesperantha*, *Hypertelis salsoloides*, *Ruschia paucipetala*, *Zygophyllum prismatocarpum*. Other Shrubs: *Adenolobus gariiepensis*, *Aptosimum spinescens*, *Cadaba aphylla*, *Calicorema capitata*, *Petalidium parvifolium*. Perennial Herb: *Rogeria longiflora*. Succulent Herbs: *Trianthema triquetra*, *Tripteris microcarpa*.

Conservation Least threatened. Target 34%. None conserved in statutory conservation areas. Large parts are inaccessible.

Remarks This unit shares many of the endemics of the East Gariiep CE and neighbouring areas in the south, such as *Brownanthus nucifer*, *Mesembryanthemum gariuanum* and *Cheiridopsis schlechteri*. As with a number of other desert mountain units, substantial altitudinal gradients result in significant climatic and vegetation gradients.

Reference Jürgens (2004).

Dg 9 Eastern Gariiep Plains Desert

VT 33 Namaqualand Broken Veld (91%) (Acocks 1953). LR 51 Orange River Nama Karoo (97%) (Low & Rebelo 1996).

Distribution Comprises the sheet wash plains east of the Richtersveld, which lead down to the Orange River at Henkries, Goodhouse, Kabis, Klein Pella/Kambreek and the vicinity of Onseepkans. Also mapped on plains west of Pella to south of Vuurdoodberg Mountain (and Goodhouse) in the west, forming a broad east-west passage between the mountains to the north that fringe or are close to the Orange River and the more broken east-west line of hills and mountains to the south (for example Annakoppies, Grootberg, Witberg, Haramoebberge, Bantamberg and Amankop). Also found at lower reaches of the Kaboep River in the east. This unit also occurs north of the Orange River in Namibia. Altitude roughly 250–900 m.

Vegetation & Landscape Features Often sloping plains, sharply contrasting with the surrounding rocky hills and mountains. Typical wash vegetation in the breaks between the mountains to the Orange River. Grassland dominated by 'white grasses', some spinescent (*Stipagrostis* species), on much of the flats with additional shrubs and herbs in the drainage lines or on more gravelly or loamy soil next to the mountains.

Geology & Soils Quaternary sheet-wash alluvial deposits, sands, deep in places; in south, red-yellow apedal, freely drained soils with a high base status. Land types Ag and Ae.

Climate MAP about 45–80 mm, with rainfall peak in late summer and early autumn, becoming more pronounced eastwards. Summer maximum temperatures are often higher than 40°C, and occasionally reaching 50°C at low altitudes. Frost very rare. Mean monthly maxima and minima for Goodhouse are 44.9°C and 1.9°C for January and July, respectively. See also Figure 6.2.

Important Taxa Small Tree: *Parkinsonia africana*. Stem- & Leaf-succulent Shrubs: *Brownanthus pseudoschlichtianus*, *Psilocalon subnodosum*. Stem-succulent Shrub: *Euphorbia*

gregaria. Leaf-succulent Shrub: *Zygophyllum microcarpum*. Other Shrubs: *Sisyndite spartea* (d), *Calicorema capitata*, *Gaillonia crocyllis*, *Hermbstaedtia glauca*, *Monechma spartioides*, *Petalidium setosum*. Graminoids: *Stipagrostis brevifolia* (d), *S. ciliata* (d), *Schmidtia kalahariensis*, *Stipagrostis obtusa*. Perennial Herbs: *Codon royenii*, *Rogeria longiflora*. Succulent Herb: *Mesembryanthemum guerichianum*.

Conservation Target 34%. None conserved in statutory conservation areas. Few intact examples of this vegetation remain. Heavy grazing and arid climate combined with the ease of accessibility of the vegetation to stock mean that pastoral activities in the past have significantly altered the structure and composition of vegetation of this unit. In some areas *Prosopis* shows potential to become a serious problem, especially around natural springs or aquifers. Some very restricted areas are cultivated, mainly with date palms and grape vines.

Remarks In the east, this unit is transitional to NKb 3 Bushmanland Arid Grassland to the south. The boundary is diffuse and probably dynamic over time due to shared substrate being modified by land use (e.g. grazing) and medium-term climate changes. The presence and increasing dominance of *Sisyndite spartea* and *Euphorbia gregaria* is indicative of this unit, with these species being characteristically absent from the Bushmanland Arid Grassland unit. In the west the unit forms a transition to SKr 17 Eenriet Plains Succulent Shrubland. Here, the boundary is distinct due to substrate differences (sandy versus rocky) and forms a mosaic of patches, controlled by soil type and distance to inselbergs.

References Van Jaarsveld (1985), Jürgens (1991), Van Wyk & Smith (2001).

Dg 10 Eastern Gariep Rocky Desert

VT 33 Namaqualand Broken Veld (98%) (Acocks 1953). LR 51 Orange River Nama Karoo (99%) (Low & Rebelo 1996).

Distribution All the rocky desert areas along the Orange River, including Groot Pellaberge, Dabenorisberge, Abbasasberge and many smaller mountains between Pella and Vioolsdrif. Also some mountains mapped further south well away from the Orange River such as the Haramoebberge and Witberg. Altitude about 250–1 205 m at the highest peak of the Groot Pella.



Figure 6.14 Dg 9 Eastern Gariep Plains Desert: Sandy sheet-wash plain on the Farm Klein Pella (lower Orange River Valley), with *Euphorbia gregaria*, *Stipagrostis brevifolia* and *S. ciliata*.

Vegetation & Landscape Features Hills and mountains (up to 650 m of relative altitude from their base), mostly with bare rock outcrops and covered with very sparse shrubby vegetation in crevices. Separated by broad sheet-wash plains (Dg 9 Eastern Gariep Plains Desert). Habitats are mainly controlled by topography, aspect, local climate and lithology. On the Groot Pellaberg, for example, there is a sparse shrubland on the southern foothills (with, for example, *Aloe dichotoma*, *Rhigozum trichotomum* and *Petalidium setosum*) and a higher cover of plants in the southern ravines and rocky drainage lines (e.g. *Abutilon pycnodon*, *Asparagus suaveolens*, *Ficus cordata*, *Rhus populifolia* and *R. viminalis*). On the higher southern slopes *Justicia orchioides* is often dominant, with localised grassland directly below steep cliffs (*Enneapogon scaber*, *Triraphis ramosissima* and *Danthoniopsis ramosa*). The south-facing quartzite cliffs and steep slopes support chasmophytes (cremnoophytes) such as *Ficus ilicina*, *Aloe dabenorisana* and *Bowiea gariensis*. On the summits and higher northern slopes there is a much higher preponderance of succulent plants including *Euphorbia avasmontana*, *Aloe dichotoma*, *A. microstigma* subsp. *microstigma*, *Pelargonium aridum* and *Kleinia longiflora*. Succulent plants are also important on the northern foothills and also include *Aloe dichotoma*, *Euphorbia avasmontana*, *Sarcostemma viminale* and the diminutive *Lapidaria margarethae* (Van Jaarsveld 1985).

Geology & Soils In the east mainly leucocratic biotite gneiss and quartz-feldspar gneiss of the Stalhoek Complex and lesser amounts of leucocratic biotite gneiss occur, with intercalations of calc-silicate rocks, mafic gneiss, and a quartzite-schist association of the Hom Subgroup, Bushmanland Group. In the west the area consists of granodiorite, adamellite, leucogranite, tonalite and diorite of the Vioolsdrif Suite and intermediate and acid volcanics of the Haib Subgroup of the Orange River Group (all of the above of Mokolian age). Very rocky substrate, with little or no soils. Land type 1c.

Climate MAP about 45–80 mm with rainfall peak in late summer and early autumn, becoming more pronounced eastwards. Summer maximum temperatures often more than 40°C, occasionally reaching 50°C at low altitudes. Frost is very rare, but occurs at high altitudes.

Important Taxa (^WMainly western part, ^EMainly eastern part) Succulent Tree: *Aloe dichotoma* (d). Small Trees: *Acacia mellifera*, *Boscia albitrunca*, *B. foetida*, *Ehretia rigida*, *Euclea pseudebenus*, *Maerua gilgii*, *Pappea capensis*. Stem- & Leaf-succulent Shrubs: *Brownanthus pseudoschlichtianus*, *Ceraria fruticulosa*, *Psilocaulon subnodosum*, *Ruschia barnardii*. Stem-succulent Shrubs: *Ceraria namaquensis*, *Commiphora capensis*^W, *C. cervifolia*^W, *C. gracilifrons*^E, *C. namaensis*, *Euphorbia avasmontana*, *E. friedrichiae*, *E. gariensis*, *E. gregaria*, *E. guerichiana*, *E. virosa*. Leaf-succulent Shrubs: *Aloe dabenorisana*, *A. gariensis*, *Mesembryanthemum inachabense*, *Prenia tetragona*, *Trianthema parvifolia*, *Tylecodon rubrovenosus*, *Zygophyllum decumbens*, *Z. microcarpum*, *Z. rigidum*. Other Shrubs: *Adenolobus gariensis*, *Antherothamnus pearsonii*, *Aptosimum tragacanthoides*, *Barleria lancifolia*^E, *B. rigida*, *Cadaba aphylla*, *Calicorema capitata*, *Diospyros acocksii*, *Dyerophytum africanum*, *Eriocephalus scariosus*, *Hermannia stricta*, *Justicia orchioides*, *Monechma mollissimum*,



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Figure 6.15 Dg 10 Eastern Gariiep Rocky Desert: Pellaberg near Pella with *Euphorbia gregaria*, *Sutera maxii* and *Boscia foetida* subsp. *foetida*.

Petalidium setosum, *Rhigozum obovatum*, *Rhus populifolia*, *Sisyndite spartea*. Graminoids: *Enneapogon scaber*, *Schmidtia kalahariensis*, *Stipagrostis anomala*, *S. ciliata*, *S. obtusa*. Perennial Herbs: *Abutilon pycnodon*, *Chascanum garipense*, *Codon royenii*, *Rogeria longiflora*, *Tribulus cristatus*. Geophytic Herb: *Bowiea gariepensis*. Succulent Herb: *Mesembryanthemum guerichianum*. Annual Herbs: *Cleome angustifolia* subsp. *dian-dra*, *C. foliosa* var. *lutea*.

Endemic Taxa Small Tree: *Ozoroa namaquensis*. Leaf-succulent Dwarf Shrub: *Tylecodon sulphureus*.

Conservation Target 34%. None conserved in South Africa in statutory conservation areas. This unit also occurs north of the Orange River in Namibia where it is potentially conserved through the ownership of the Farm Tsams by the Namibian Ministry of Environment and Tourism.

Remarks The southernmost mapped mountains are transitional to Bushmanland Inselberg Shrubland. The higher mountains mapped in the unit, especially in the east such as the Pella Mountains, have considerably higher rainfall on the upper slopes with some plant species more characteristic of less hyperarid areas (e.g. *Triraphis ramosissima* on the higher southern slopes and *Euphorbia avasmontana* on the higher and lower northern slopes; Van Jaarsveld 1985). The unit comprises part of the Gariiep CE (Van Wyk & Smith 2001). From a phytogeographical point of view, the area belongs to the Namaland Domain of the Nama-Karoo Floristic Region (Jürgens 1991), which approx-

imates the Nama-Karoo Biome as defined by Rutherford & Westfall (1986), but not the Nama-Karoo Biome of Rutherford (1997) as well as in the present work. It may appear necessary to reconsider the current concept of the Eastern Gariiep Rocky Desert and to split it into two (possibly near Goodhouse). This step would also corroborate the east-west difference in geology (see above). While the western half is floristically very similar to parts of some of the eastern Richtersveld mountain desert units, the eastern section has many species with a wider savanna- or Kalahari-related distribution.

References Van Jaarsveld (1985), Jürgens (1991, 1997, 2004), Jürgens et al. (1997), Van Wyk & Smith (2001).

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