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Jasper Knight · Christian M. Rogerson *Editors*

The Geography of South Africa

Contemporary Changes and New Directions

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1 The Development and Context of Geography in South Africa

Jasper Knight and Christian M. Rogerson

Abstract

The discipline of Geography in South African universities has a history of more than 100 years. Within that time span different themes have been at the forefront of research which has been produced about the country's physical and human landscapes. Arguably, contemporary South African Geography is more inclusive, integrated and applied than in the past, and the discipline is being reconfigured to address more explicitly the challenges of the post-apartheid world. Contemporary South African Geography is investigating an array of topics which aligns it with international trends in geography. This said, local aspects of the discipline of geography as well as the contemporary South African human landscape continue to bear imprints of the apartheid past. Accordingly, the distinctive character of the development and contemporary directions of South African Geography must be recognised by the international academy.

Keywords

Contemporary geographical debates · History of geography · Human geography · Physical geography · South Africa

1.1 Introduction

South Africa enjoys international attention for a number of reasons. On the one hand, issues of governance, political corruption and struggles with post-apartheid inequality have dogged socioeconomic life in South Africa. Ironically, these issues have meant that South Africa is an excellent laboratory for human geography research. On the other hand, culture, heritage, ecosystems and the spectacular physical environment continue to draw international tourists to the country as well as guide much research activity in physical and environmental geography.

We would submit that, as compelling as South Africa is for international media and tourism, the country's human and physical landscapes remain fascinating and deserving of increased scholarly attention. At the heart of research debates on South African Geography are the activities of an energetic and vibrant research community. In addition to contributions from local universities, research institutes and government agencies, the physical, environmental and human geographies of South Africa continue to attract scholars from many parts of the world, notably from North America, Europe and Australasia. The internationalisation of research activities, in the post-apartheid era, is a feature in the southern African subcontinent.

1.2 Geography in South Africa

The discipline of Geography in South Africa is now 100 years old (Ballard et al. 2016; Donaldson et al. 2016; Wynn 2016) and the history of the discipline of Geography in different universities across South Africa is documented by Visser et al. (2016). The first lecturer in Geography was appointed in 1917, and Geography as a major discipline area is now being taught at 26 public universities in South Africa, as well as across the school curriculum (Visser et al. 2016). However, the origins of geographical study in the region extend back further, as the themes and early history of Geography at universities in South Africa were based on European traditions (Wesso and Parnell 1992); and mapping, description and analysis of southern African landscapes, resources and peoples predate 1917, with investigations of geology, water,

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Fig. 1.1 (**a**) Photo of a group of Geography students and staff on fieldwork (date unknown, likely late 1940s/early 1950s). The figure in the centre, seated, is likely a local guide. The wording on the upper edge of the bus reads 'Witwatersrand University Congo East Africa Expedition' (from the archives of the School of Geography, Archaeology and Environmental Studies, University of the Witwatersrand). (**b**) A student fieldtrip today – year 1 Geography students from University of the Witwatersrand, on a fieldtrip to Abe Bailey Nature Reserve, Carletonville, Gauteng (2016). (Photo: Jasper Knight)

plants/animals, archaeology and anthropology undertaken throughout the nineteenth century, largely by European explorers, colonial administrators and missionaries. A snapshot of this traditional viewpoint is shown in Fig. 1.1a, of Geography students from the University of the Witwatersrand on a 'Congo East Africa Expedition', likely in the late 1940s/early 1950s (date unknown). These white, male students and staff, in their khaki shorts and pith helmets, exemplify the 'colonial' nature of Geography at this time. Today, however, the political, cultural and socioeconomic context of

Geography in South Africa is very different compared that of the past (Cole 2008; Nicolau and Davis 2002; Oldfield and Patel 2016) (cf. Fig. 1.1b), and is discussed in much depth elsewhere (e.g. Crush 1993, 1994; Wesso 1994). These changed contexts have given Geography as a discipline new relevance and urgency in the post-apartheid era, with respect to its potential contribution to national-scale debates on sustainable economic and environmental development, management of natural resources, and transformation of socioeconomic, cultural and political life (Crush 1993, 1994; Nicolau and Davis 2002; Ramutsindela 2015).

1.3 The Past, Present and Future of South African Geography

Visser et al. (2016) outline the histories of 22 Geography departments at South African universities. From this, and with reference to other studies on the history of the discipline (e.g. Nicolau and Davis 2002; Wesso and Parnell 1992), several points can be identified: (1) Research activities and power have historically been concentrated into a few longstanding and traditional universities in South Africa, such as the University of Cape Town, University of Pretoria, Stellenbosch University, and University of the Witwatersrand. (2) Key figures in the discipline in South Africa through the twentieth century have been mainly (but not always) white men (cf. Wesso 1994). There has thus been a disproportional concentration of academic power and research activity by academic figures from this demographic group. (We are aware of our own positionality in making this statement.) (3) Research, particularly in human geography, has been concerned with only some thematic elements of the discipline with other areas under-represented. For example, urban studies has been a longstanding research strength; historical geography has not.

The outcome of these points is that Geography in South Africa has, for decades, been imbalanced in its scope, emphasis and participation. This may be a legacy of the small size of the geographical community, the consequence of apartheid-era academic sanctions, or just individual researchers' concerns with some aspects of Geography and not with others. This does not by itself mean that Geography has been 'bad' or 'wrong', but rather that a more holistic, integrated picture of the discipline and its wider relevance has been lacking. Today, these imbalances of the past are starting to being addressed – as is described in this book – and from a number of perspectives. Such developments include (1) broadening the areas of research concern by academic Geographers, (2) broadening the topic areas under discussion in school and university teaching programmes in Geography, (3) rebalancing the gender and ethnic make-up of Geographers (of both staff and students) in South African universities, and (4) repositioning of some Geography research and applications to address real-world issues, either in government, industry or local communities. Geography today is thus more inclusive, integrated and applied than in the past, and the discipline of Geography in South Africa is now being reshaped to address more explicitly the challenges of the post-apartheid and globalised world (Beets and Le Grange 2008; Knight 2018; Knight and Robinson 2017; Wesso 1994). However, there is much more that needs to be done (Knight 2018).

Some geographical research in South Africa today is already applied to address real-world issues. This includes, in no particular order, urban sustainability (Cilliers et al. 2014), food security and agricultural production (Battersby 2013; Jones and Thornton 2009), water management (Cameron and Katzschner 2017), mitigation of climate change impacts (Ziervogel et al. 2014; Zinyengere et al. 2013), reduction of soil erosion and land degradation (Mararakanye and Le Roux 2012), maintaining biodiversity and protected areas (Hély et al. 2006), and hazard and risk management (Coetzee et al. 2016). These topic areas indicate the potential breadth and scope of geographical research as applied to contemporary issues in South Africa and the wider region.

1.4 Themes in This Book

This book of original research chapters on contemporary change and new directions in South African Geography is addressed to both a local and an international scholarly audience of Geographers, students, professional practitioners, managers and policymakers. The book builds from previous books and articles which have sought to variously reflect upon, synthesize or offer signposts for South African physical and human geographies over the past 40 years (e.g. Beavon and Rogerson 1981; Grab and Knight 2015; Hammett 2012; Holmes and Boardman 2018; Holmes et al. 2016; Mather and Ramutsindela 2007; Pirie and Moon 1982; Rogerson and McCarthy 1992).

This book brings together recent ideas in different thematic areas of physical, environmental and human geography, by key figures in the discipline based in South Africa but also beyond its borders. All chapters are original contributions, providing a state of the art research baseline on key themes in physical, human and environmental geography, and in understanding the changing geographical landscapes of modern South Africa. The contributions set the scene for an understanding of the relationships between South Africa and the wider contemporary world, including issues of broader relevance in the Global South. Although aiming to be wide-ranging and integrative in scope, inevitably some areas of Geography are excluded, which may be topics for a future book. Part I of this volume deals with aspects of the physical and environmental geography of South Africa, including topics in geomorphology, climate, ecosystems; and resources and resource management. Part II discusses aspects of human geography, focusing on both rural and urban settings, and different types of economic and social development and activities, including food, housing and tourism. Part III addresses contemporary and future issues in physical and human environments in South Africa, including globalisation, migration, poverty, climate change, and managing environmental risk. This section also identifies areas of potential future geographical research over the next decades.

In preparing this volume we would like to thank all the contributors for their chapters and to editorial support provided by Arabella Rogerson. All chapters in this book were externally peer-reviewed by at least two independent experts in their fields, and we thank these reviewers for their valuable input.

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Part I

Physical and Environmental Geography

The Making of the South African Landscape

2

Jasper Knight

Abstract

The landscapes of South Africa reflect the impacts of tectonics and climate on the land surface, resulting in weathering, erosion and deposition, and the shaping of distinctive landforms in different environments. Long term geological evolution in the region provides the context for these landscapes. The landscape elements seen today reflect South Africa's more recent geological history (last ~80 million years) but there is considerable variation in the age of these different elements and thus their interpretive context with respect to tectonic or climatic forcing. Increasingly, human activity plays a role in not only landscape change but also in the workings of geomorphological processes, which have implications for future landscape patterns.

Keywords

Climate change · Human activity · Holocene · Quaternary · Tectonics · Weathering

2.1 Introduction

The South African landscape that we see today is the outcome of over two billion years of Earth's history (McCarthy and Rubidge 2005). This evolutionary outcome has taken place by a combination of tectonic and geologic events that are driven by regional to continental-scale processes within the Earth, and climatic processes related to regional to hemispheric-scale ocean and atmospheric circulation. These driving factors have resulted in the operation of different sets of geomorphological processes that shape the land surface and which, in turn, influence patterns of topography, soils and vegetation types, and ultimately human activity. Thus, the different landscapes found across South Africa reflect different processes that have varied across time and space, and their interactions (Fig. 2.1). Several studies have examined the development of different individual elements of the South African landscape over time, including coastal sand dunes (Botha and Porat 2007; Roberts et al. 2014), wetlands (Lyons et al. 2013), mountains (Boelhouwers and Sumner 2003; Mills et al. 2017), rivers (Grenfell et al. 2014; McCarthy and Tooth 2004), slopes (Moon and Selby 1983; Singh et al. 2008), soils (Bell and Maud 1994; Boardman 2014), ephemeral pans in semiarid areas (Holmes and Barker 2006; Telfer and Thomas 2006), karstic landforms (Martini and Kavalieris 1976; Stratford et al. 2014), and alluvial fans (Boardman et al. 2005; Kounov et al. 2014). These studies have focused mainly on the interrelationships between geomorphology, processes of sediment transport and deposition, and forcing factors such as climate and human activity. In addition, some studies have also considered in a more integrated way the geomorphology and landscape evolution of single areas, including the Free State (Holmes and Barker 2006), Soutpansberg mountains (Hahn 2011), and Sabie River basin (Rountree et al. 2000). Many individual studies have been synthesised in recent books, including Holmes and Meadows (2012), Grab and Knight (2015), and Knight and Grab (2016), which can be considered as key texts summarising macroscale landscape evolution in South Africa, in particular during the Cenozoic (last 66 million years).

Although, over long time scales and large spatial scales, tectonics and climate broadly control patterns of landscape change in South Africa, processes of forcing and landscape response are not uniform. Geomorphic and dating evidence shows that landscape change has been more rapid at some times, or in some places, than in others (e.g. with respect to rivers as described by Tooth 2016). This evidence leads to two separate deductions about the nature of change and the evolution of the South African landscape. (1) *That some of today's landscape elements are young in age, and some are old*. Elements of different ages within the same landscape

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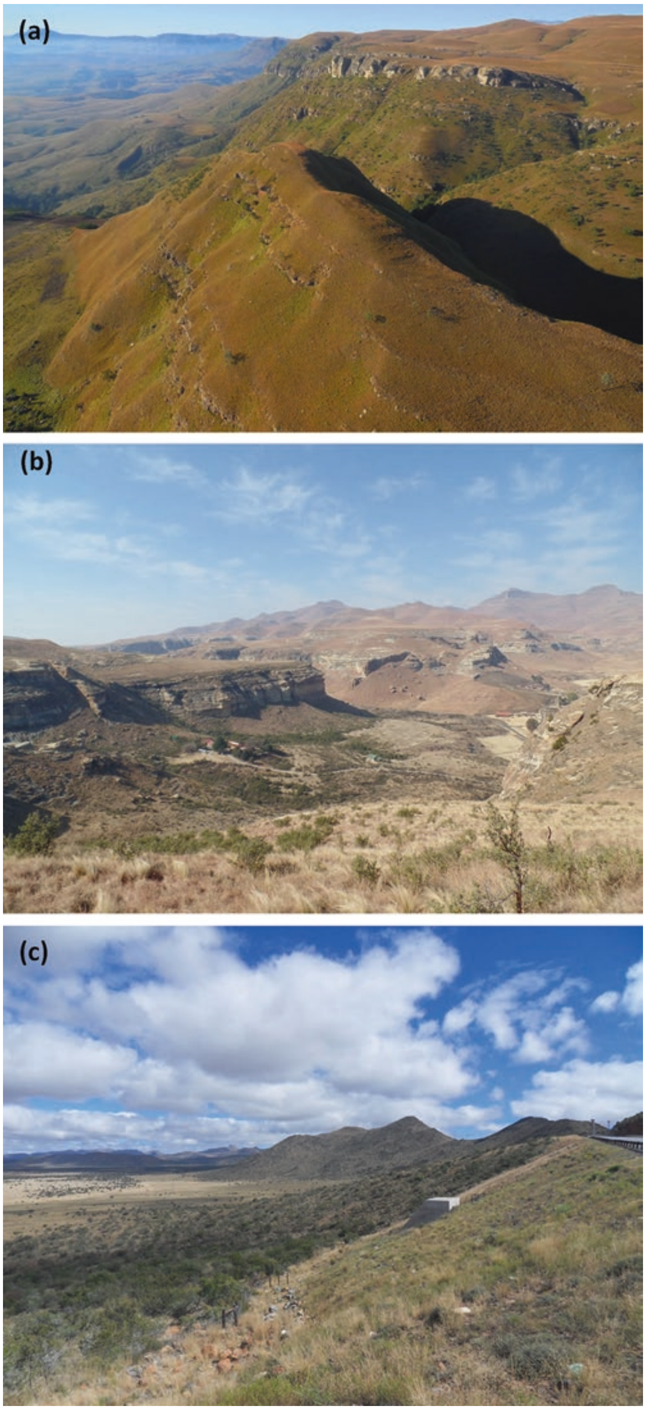

Fig. 2.1 Elements of the South African landscape. (**a**) Basalt mountain landscapes of the Drakensberg, (**b**) sandstone landscapes of the Free State Province, (**c**) residual hills and plains of the Western Cape Province

result in what is termed a landscape palimpsest (Knight 2012). This arises where, for example, tectonic or climatic forcing affects one area rather than another, or where differences in rock hardness influence how quickly denudation occurs (Scharf et al. 2013). Young landscape elements may include present-day rivers that experience patterns of channel erosion and deposition in response to real-time variations in river discharge. Old landscape elements may include bedrock summits that are relatively resilient and experience very slow rates of contemporary weathering. (2) *That different landscape elements experience different sensitivities to be affected by forcing*. Different landscape elements may be affected by different forcing factors. For example, rivers may be highly sensitive to precipitation variations but relatively insensitive to temperature. Bedrock summits may be highly sensitive to temperature (through thermal weathering processes, common in South Africa), but relatively insensitive to precipitation changes. This property is known as geomorphological sensitivity (Knight and Harrison 2013).

The outcome of these two deductions in combination is that we might anticipate spatial and temporal variations in the rate, style and geomorphic signatures of landscape change. However, it is only now that we are beginning to appreciate such nuances with respect to landscape change in South Africa (Knight and Grab 2018a). In order to focus on relationships between different forcings and landscape responses, this chapter summarises regional-scale patterns of geology in South Africa, and then events at three key stages in the development of South Africa's landscape: the breakup of Gondwana around 85–60 million years ago (Ma); Neogene aridity around 5 Ma; and climate cooling during the last global glaciation around 35,000–10,000 years ago (ka). These time periods are chosen because they represent periods of rapid tectonic or climatic change. These examples highlight the fact that landscape change is not linear – the landscape evolves continuously but often with short bursts of rapid change, and these periods of rapid change are separated (very often) by periods of diminished or minimal change, or where there is little preserved evidence for landscape change (Knight and Grab 2018a).

2.2 Geological History and Spatial Patterns of Rock Types in South Africa

Spatial patterns of different rock types in South Africa reflect its long geological history and a wide range of tectonic and climatic events that have affected the surface and subsurface. This background is informed by McCarthy and Rubidge (2005) with more specific technical detail on different rock formations and geological time periods found in the book by Johnson et al. (2006). This summary reflects these two sources. The distribution of major rock types found in South Africa today is shown in Fig. 2.2. This distribution reflects the outcome of tectonic cycles of continental accretion and mountain building, and the development of large sedimentary basins on eroded craton surfaces. The oldest rocks in South Africa (2.9–3.2 billion years ago, during the Archean)

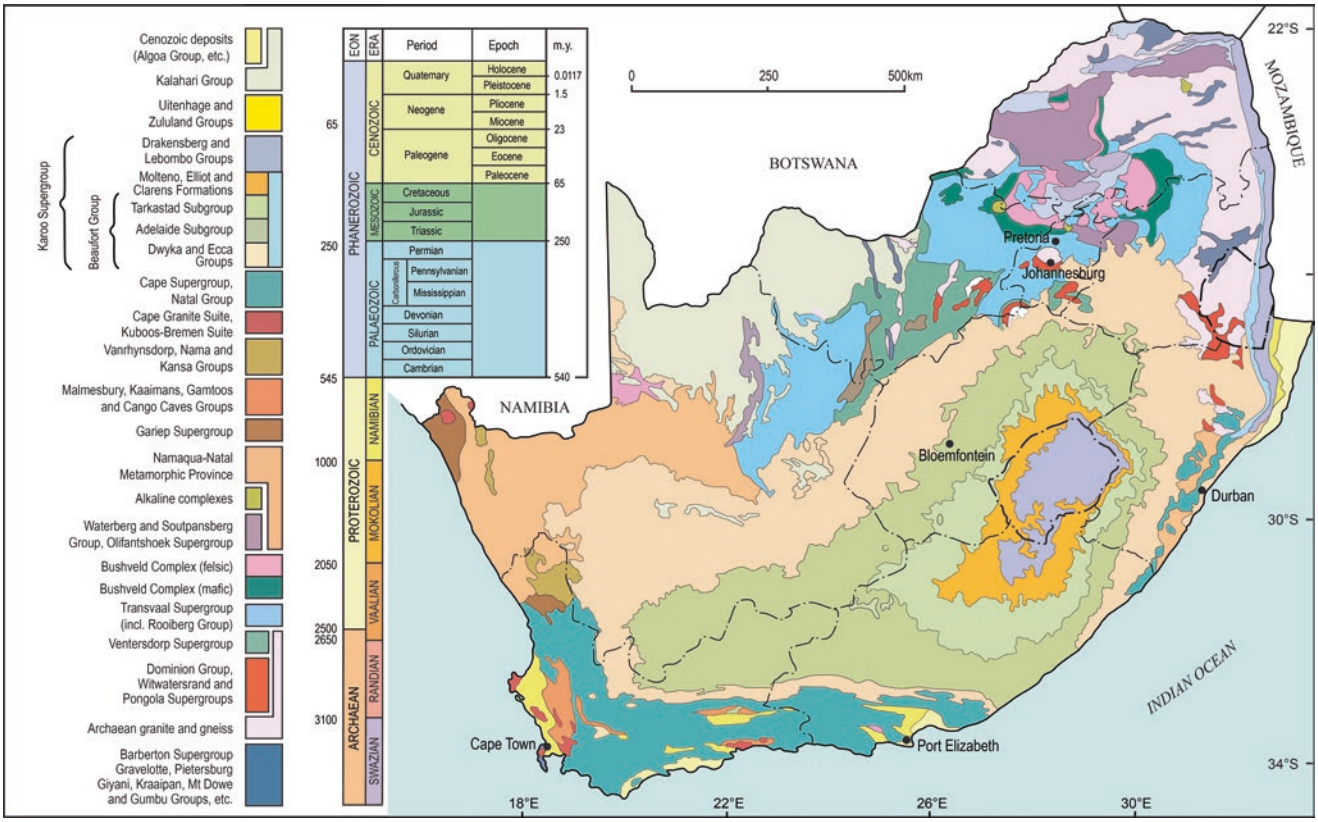

Fig. 2.2 Generalised geology map of southern Africa. (Adapted from Council for Geoscience, in Johnson et al. 2006)

are greenstones that are located in the Barberton area (Mpumalanga Province). The record of geological events and processes during this ancient time period is largely not preserved. Formation of the Kaapvaal craton and Kalahari craton by continental accretion around 2600 and 1000 Ma, respectively, was punctuated by periods of sediment deposition indicative of relative land surface stability. For example, prior to Kaapvaal craton formation, between about 3100 and 2600 Ma, the Pongola, Witwatersrand and Ventersdorp Supergroups were deposited. These comprise continental volcanic, pyroclastic and sedimentary rocks (mainly sandstones and conglomerates) that reflect a relatively stable tectonic setting, with some periods of metamorphic deformation and mineralisation. The rocks now outcrop in very restricted areas near Johannesburg and Swaziland (Fig. 2.2). The degree of intraformational volcanic rocks generally decreases over time during this period. Gold mineralisation within the Witwatersrand Supergroup is important because it was exploitation of these resources that allowed for the foundation of the city of Johannesburg (Knight 2018). On the Kaapvaal craton surface, limestones and clastic sediments were deposited in a subsiding basin, forming the Transvaal Supergroup, found today in a broad strip from the Northern Cape to Limpopo. Into these sediments was intruded the Bushveld Complex around 2000 Ma, a suite of layered igneous rocks associated with platinum-group minerals. The Bushveld Complex outcrops in the region north of Pretoria. Following this, deposition of sediments and lavas of the Olifantshoek Supergroup and equivalent-age formations including the Waterberg and Soutpansberg Groups took place around 2000–1800 Ma, in relatively flat floodplain and coastal plain environments on the margins of the Kaapvaal craton. These rocks are found today in Limpopo and Northern Cape provinces. This was followed by a period of relative tectonic stability of the Kaapvaal craton that terminated with the Namaqua Orogeny (around 1200–1000 Ma) that stretched from KwaZulu-Natal to Northern Cape provinces, and was associated with formation of various igneous and metamorphic rocks. Later activity along this tectonic belt was responsible for the formation of rocks of the Gariep Supergroup (around 800–650 Ma) along the west coast of the country. Intrusion of igneous complexes including the Pilanesberg Alkaline Province (at 1400–1100 Ma) and Cape Granite Suite (550–515 Ma) took place during this period. Depositional fluvial to marine basins, some of which were fault-bounded, opened up at this time along the margins of the Namaqua belt, including the Cape Supergroup which extends through most of the Western Cape and into the Eastern Cape provinces. The Karoo Supergroup refers to a wide range of rocks deposited in a very large subsiding sedimentary basin active around 350–170 Ma (early Carboniferous to late Jurassic) and comprising up to 12 km thickness of clastic deposits, dominantly of mudstones and rhythmites around basin margins, and sandstones in the basin centre (Catuneanu et al. 2005). The basal part of the basin fill comprises the Dwyka Group, of diamictites formed in a glacial environment (late Carboniferous to early Permian, around 320–300 Ma), grading up into clastic deposits indicative of warmer and then arid environments. Important fossil remains are contained in particular in the Triassic beds. These clastic sediments outcrop throughout the centre of South Africa, and are in terms of area the most dominant rock types in the country. Also part of the Karoo Supergroup, are igneous rocks belonging to the Karoo Igneous Province around 190–180 Ma (early Jurassic). These include the flood basalts of the Lesotho Formation, which reach up to 1500 m thickness in central Lesotho. These flood basalts are exposed on the land surface today in Lesotho and the Eastern Cape Province. Fold mountains of the Cape Fold Belt in the Eastern Cape and Western Cape provinces (including the Cedarberg, Swartberg and Outeniqua Mountains) were formed during the late Permian and early Triassic (300–250 Ma), possibly associated with subduction of ocean crust. Formation of these fold mountains and volcanic activity of the Karoo Igneous Province may have been precursors of the breakup of the Gondwana supercontinent which started to take place from around 180 Ma (Burke and Gunnell 2008). South America and Africa finally split apart around 115–90 Ma. Cenozoic deposits of the Kalahari Group found in the Northern Cape and North West are mainly sandstones and conglomerates and were deposited on this relatively stable craton surface. It is weathering, erosion and deposition during the Cenozoic that resulted in the formation of many of the geomorphic elements present in today's South African landscape.

2.3 Breakup of Gondwana and Formation of Planation Surfaces

A significant macroscale feature of South Africa's landscape is the presence of discontinuous but persistent flat surfaces found at different altitudes. Three main surfaces have been recognized: the African Surface (85–42 Ma), Post-African I Surface (19–15 Ma), and Post-African II Surface (7–3 Ma) (Partridge and Maud 1987), identified on the basis of degree of weathering and stratigraphy. Today, due to post-formational denudation, these surfaces appear at different altitudes in the landscape. The trigger for the successive development of these surfaces was lithospheric movement in southern Africa (as part of the larger African Plate) following the breakup of the supercontinent Gondwana around the period 135–115 Ma (the precise timings are unknown) during the Cretaceous. At this time, Africa split from South America, broadly establishing today's continental-scale geography of Africa. The causes of lithospheric movement across southern Africa during the late Cretaceous and early Cenozoic are under debate (Burke and Gunnell 2008), but include a combination of isostatic uplift following erosion, development and migration of mantle plumes, and tectonic uplift/continental drift (Moore et al. 2009). Several studies have described the geometric properties of the different Surfaces and have described them as peneplains, or eroded surfaces that represent the land surface response to tectonic uplift (Burke and Gunnell 2008; du Toit 1954; King 1948, 1963; Partridge and Maud 1987). The recognition of different African Surfaces is, however, problematic, because it involves circular reasoning, whereby Surfaces are assumed to be of the same age because they have the same altitude. In detail, however, it is likely that the Surfaces are of composite ages, and they are associated with weathered products (such as laterite, calcrete and silcrete layers) that formed over time by chemical as well as physical processes (Marker et al. 2002). Partridge and Maud (2000) discussed the formation of the different Surfaces and specifically linked different stages of land uplift with regional changes in drainage pattern. This is now known to be somewhat more complex than a simple uplift forcing–response because it is associated with phased changes in drainage divide migration through the passage of mantle swells (Moore and Larkin 2001; Moore et al. 2012), as well as changes in drainage density and drainage pattern morphometry related to precipitation and weathering (Knight and Grab 2018b).

2.4 Neogene Aridification

Globally, climate changes in the Neogene (23–2 Ma) culminated in significant periods of aridity around 14–11 Ma which was associated with the development and spread of desert dunes in the Namib Desert and Kalahari Desert of northwest South Africa and Botswana (Roters and Henrich 2010; Senut et al. 2009), and in mineralogical changes in palaeosols in the Western Cape (Eze and Meadows 2014). This period coincides with other climate changes in the Southern Ocean and Antarctica that suggest very strongly that hemispheric changes in climate were the major drivers of responses in the South African landscape. This includes changes in the distribution of Renosterveld and savanna vegetation, including the balance between C_3 and C_4 vegetation types (Dupont et al. 2013; Sciscio et al. 2016). Such changes are interpreted to reflect migration of the boundary between summer and winter rainfall zones (Pickford et al. 2014). These climate changes during the Neogene also coincide with periods of hominin evolution, in particular associated with development of bipedalism and changes in cranial capacity, that may reflect changes in the environments in which the hominins inhabited, from closed to more open wooded systems (Heaton 2016). Preserved geomorphological evidence from this time period is generally lacking, but may include periods of enhanced windblown sediment transport offshore from arid land surfaces (Senut et al. 2009) and high river sediment deposition within basins inland (Botha and de Wit 1996). In South Africa, this period also coincides with formation of weathering products on the African Surfaces, suggestive of relative land surface stability and low erosion rates (Beukes et al. 2004; Marker et al. 2002; Pickford et al. 1999).

2.5 Quaternary Climate Changes

During the Quaternary (last 2 million years), large scale continental glaciation took place episodically in the northern hemisphere, yet only very small and restricted cirque glaciers were present in highest areas of southern Africa during the last glacial maximum (LGM; ~25 to 19 ka), and these likely only existed under some specific temperature and precipitation conditions (Mills et al. 2012). There was limited impact of the presence of cirque glaciers on mountain landscapes. It is far more likely that cold, periglacial processes were most active and widespread, causing enhanced land surface weathering in mountainous areas and generating some distinctive landforms including blockstreams, blockfields, patterned ground, slope deposits, and turf- and stone-banked lobes (Boelhouwers and Meiklejohn 2002; Hanvey and Lewis 1991; Sumner 2004). Geomorphological responses to Quaternary climate changes are best known from dryer areas of western South Africa, where luminescence dating of river and dune deposits show that variations in moisture availability during different phases of the Quaternary were associated with activation of pans, lakes, caves and springs in wet phases, and Kalahari desert dunes in dry phases (Shaw and Thomas 1996). Reponses by river systems likely varied from one system to another, but include such evidence as formation of river terraces (e.g. Sundays River, Vaal River), channel avulsion or migration (e.g. Modder River), and channel incision (e.g. Orange River) (Keen-Zebert et al. 2013). These different responses are mediated by both the nature of climate variability, and by sediment availability within the system (Tooth 2016). As such, different physical systems responded in different ways to Quaternary climate changes in South Africa. A reason for this might lie in changes in atmospheric circulation and thus precipitation patterns. Precession-driven changes in the position of the intertropical convergence zone (ITCZ) during the Quaternary – one of the primary controls on precipitation seasonality in southern Africa – likely affected the zones of summer and winter rainfall (Tyson 1999). In turn, precipitation seasonality affects both river and vegetation dynamics, and pollen records from key sites such as Wonderkrater, Tswaing, Braamhoek and Princessvlei clearly reflect this seasonality (Scott et al. 2012).

2.6 Discussion

The traditional view of landscape change in South Africa is that it is controlled by cycles of large-scale tectonic and climatic events, followed by regional-scale weathering and erosion of the land surface, infilling terrestrial sedimentary basins such as the Transvaal basin and Karoo basin, and forming distinctive landscape elements such as the African Surfaces (Partridge and Maud 1987). Recent work based on apatite fission track themochronometry data has quantified the amount of erosion taking place during different time periods and in different locations, suggesting for example that up to 5.70 km of vertical thickness of rocks were eroded from the Cape Fold Belt mountains in the early Cretaceous alone (Richardson et al. 2017). Other studies also show that there are significant spatial and temporal variations in weathering and erosion during the Cenozoic, and that land surface feedbacks associated with vegetation/soil development, slope stabilisation and bedrock control are also important in amplifying or suppressing responses to tectonic or climatic forcing (Chadwick et al. 2013). Collectively, these factors mean that today's landforms or landscapes cannot be uncritically considered to reflect either a single time period of formation or a single forcing mechanism. Instead, they should be considered as transient features that evolve over time. The most significant landscape-change processes and products in South Africa, over the timespan of the Cenozoic, are described in the timeline of Fig. 2.3. This shows that there is not a uniform temporal pattern of landscape change, but is driven mainly by changes in tectonic and climatic forcing (not by stable conditions of forcing).

Today's landscapes, however, are not controlled only by tectonics or climate. Human activity has influenced landscape topography, geomorphic and ecological processes, and the distribution of geological and environmental resources, such as fertile soils, water availability, and ecosystem services. In South Africa, human utilisation of the landscape started in concert with hominin (human) evolution 2 million years ago, but has dramatically accelerated in particular over the past several hundred years following European settlement. Today, South Africa can be considered to be an anthropogenic landscape as a result of the transformation of the land surface by mining, agriculture and urbanisation, and the

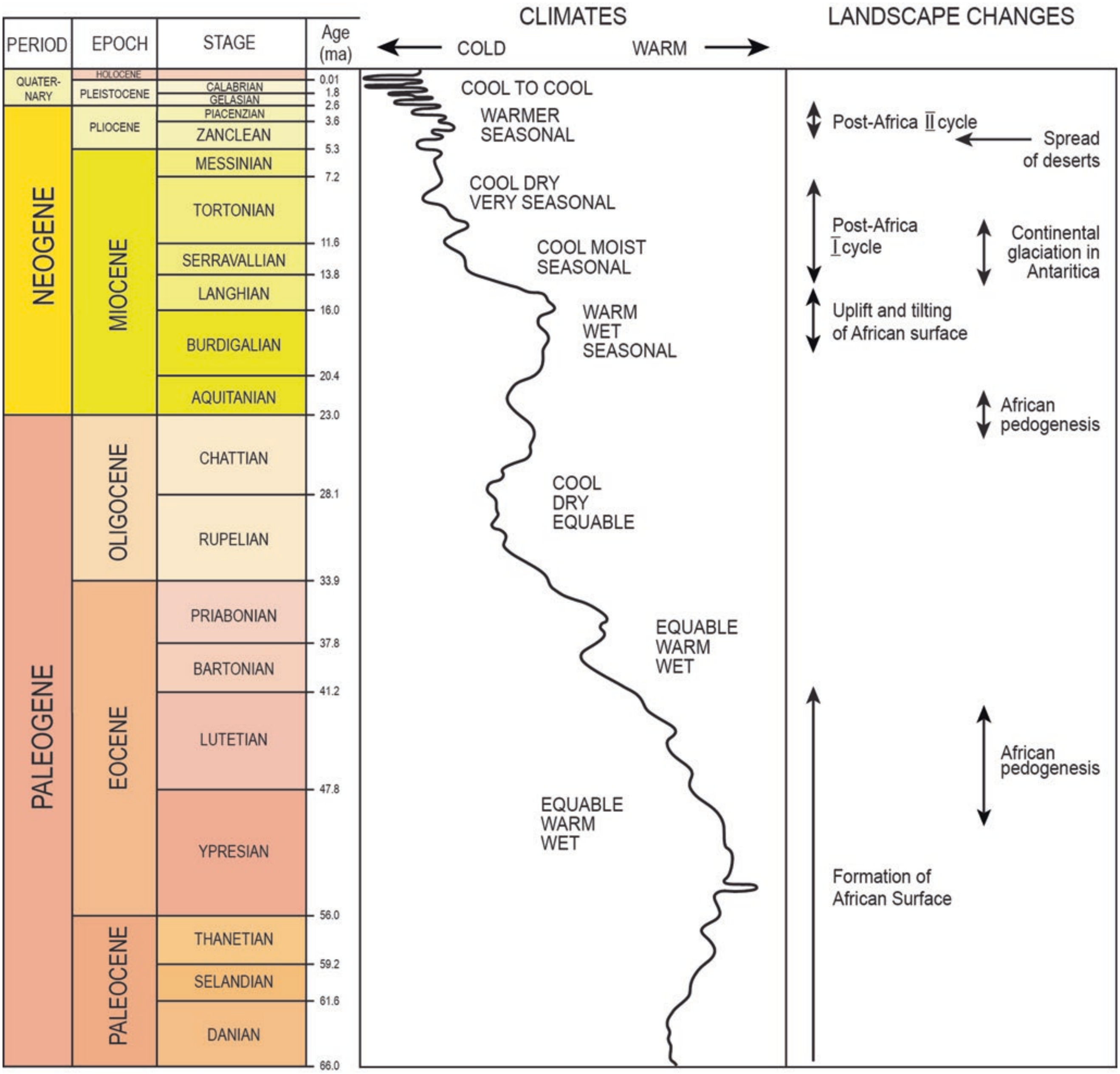

Fig. 2.3 Simplified timeline of the Cenozoic (66 Ma to present), showing the major climatic and human events to have affected southern Africa. (Adapted from Partridge et al. 1995; geologic timescale from the Geological Society of America; http://www.geosociety.org/science/timescale/); and different phases of landscape change in southern Africa

ways in which this landscape may evolve over the next centuries to millennia may be vastly different to those that have shaped the landscape in the past. Key questions for the future include (1) the effects of ongoing climate change on land surface processes, (2) how geological and environmental resources can be used sustainably for assuring future food and water security, and (3) how effective environmental management policies can be developed to conserve landscapes and their resources.

2.7 Summary

Geological and climatic processes have been the primary drivers of landscape evolution in South Africa – as they are elsewhere – throughout its long geological history. The landscapes seen in South Africa today reflect the outcomes of these processes, but can also offer windows into the past where certain features have not been eroded away but are preserved in the landscape. Transformation of the land surface by weathering and erosion has not taken place uniformly, however, but tends to respond to changes in tectonic or climatic conditions as opposed to periods of stability. Human activity in the Anthropocene is dramatically changing the properties and processes of all landscapes everywhere, and this is set to continue and accelerate in the future. Thus, it could be argued that South Africa's landscapes are now more anthropogenically- rather than geologically-controlled.

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Mapping the Environment, Past and Present

3

Stefania Merlo

Abstract

Maps are descriptions of space, and as such they are products of societal interest and concerns, which may vary geographically and temporally. What is depicted in maps and how this is done has changed through time. The purpose of this chapter is to review the nature and relevance of maps and mapping in South Africa, from colonial times to the present day, focusing on the use of maps to convey environmental information. The chapter considers human understandings of their surroundings, an abbreviated history of mapping in South Africa through examples of maps, and an overview of the nature and scope of environmental mapping. The process of environmental mapping is then discussed, and examples of environmental mapping in South Africa are provided.

Keywords

Environmental mapping · GIS · Spatial data infrastructure · State of the environment · Thematic map · Topographic map

3.1 Background

Maps are the best known way to visualise geographic data, that is, data that refer to the location and the characteristics of objects or phenomena distributed over space on the Earth's surface. Through a map, we seek the answer a number of questions: Where is it? What is it? What is it like? Why is it there? How is it changing? (Brett et al. 2013). Maps allow for the location of geographical objects, while the characteristics of the objects represented are conveyed most commonly by the use of colours and symbols (Kraak 2005; Parry 1999). Maps can not only represent tangible physical elements such as elevation or phenomena such as rainfall and temperature, but can be used to compare intangible social phenomena such as the distribution of income in populations or the electoral preferences of a nation (MacEachren 1994). They allow us to explore geographical patterns and to see geographical processes evolving over time such as sediment transport or urban growth. Map displays offer insight into how environmental phenomena such as air quality and public health might relate to one another. Today, maps can also be used to explore human movement patterns in real-time, for instance, captured by and hidden in users' mobile phones (Kraak and Fabrikant 2017).

The introduction of geospatial technologies such as Global Positioning Systems (GPS) and Geographical Information Systems (GIS), coupled with data acquisition through sensor-led and satellite systems, has revolutionised the map-making process in many ways: (1) by increasing the quality, quantity and variety of geographic information available, both spatially and temporally (Lillesand 2008); (2) by replacing printed maps with GPS as the primary source of positional referencing; (3) by enabling complex spatial and predictive modelling and process simulation (Lahr and Kooistra 2010); (4) by changing the understanding and relevance of some cartographic concepts such as scale and resolution, both representationally and analytically (Miller and Schaetzl 2014); and (5) by changing the distinction between map users and map designers (Griffin et al. 2017). These developments have afforded the scientific community and the general public enhanced ways of understanding and modelling the world. They have also elicited discussions about different spatial knowledges and their regimes, and universal representations versus indigenous and local understandings of what surrounds us, and its meaning and significance (Pickering 2014).

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3.2 Mapping of South Africa: A Historical Timeline Through a Sample of Different Maps

Maps are human descriptions of space and as such they are products of societal interest and concerns, which vary geographically and temporally. What is depicted in maps and how this is done has changed through time and can differ between cultures. The history of mapping is a reflection of the power that maps have to show perceptions of the world (MacEachren 1994; Pickering 2014). Maps are not just pictures of the world but also instruments of its creation (Wood 2010). Maps can describe the configuration of physical phenomena on the surface of the Earth or the spatial distribution of social parameters, but have been in the past and are still used as political and military instruments of power for planning and executing wars, claiming territories and resources, creating, collecting taxes, and dividing and distributing land (Krupar 2015; Wood 2010). Ultimately, maps are neither neutral nor value-free or universal (Wood 2010). Printed map production (also known as cartography – see Friendly 2009 for a historical timeline) is only one of the many manifestations of human spatial practices, which include how humans act in and across space, how they move things and ideas through space, and how they construct regions and places and give them meaning (Edney 2011). For this reason, the cartographic ideal, embodied in modern (and western) industrialised countries, with its focus on the processes by which the world is observed, measured, scaled down and redrawn on sheets of paper, has been put to question (Edney 2011). The brief history of mapping of South Africa, presented below, is limited in scope in that it presents cartographic examples of maps produced in South Africa from the colonial period onwards (and often by colonial administrators). It serves, nevertheless, as a point of departure for the documentation of mapping in South Africa, a neglected field of study.

3.2.1 Early Cartography

The first separately printed map of southern Africa is a map of the region's coastline, produced in Germany in 1513 by Martin Waldseemüller. This map was created without direct knowledge of the area but through information obtained from Arab sources (Duminy 2011). The map defines vaguely the shape of the southern part of the continent but lacks detailed information of any of the interior and in fact it reports, in Latin, *Haec pars Aphricae antiquioribus mansit incognita* (This part of Africa remains unknown from antiquity). The version of this map by Lorenz Fries depicted in Fig. 3.1 is an imaginative and decorative revision of the original, and it introduces a number of embellishments that are characteristic of several maps of the region and of the continent of Africa more generally, up until the 1800s, when more consistently, maps transitioned from decorated representations to rigorously measured and symbolised representations with little embellishment. The coastline presents Portuguese names of localities and the empty interior is occupied by anonymous mountains, a lake, *Sapah* (from which three rivers radiate), seated rulers, an elephant, snakes and a mythological lizard, the basilisk. The Mountains of the Moon are shown as the sources of the Nile. In the lower right corner, the king of Portugal (*Emanuelis Regis*) rides a sea monster. The map enshrines the perceptions that Europeans had of the continent of Africa at the time: an unknown and mysterious land, exotic, intriguing but also scary. It is a map of the imaginary.

The Dutch East India Company set up a trading station at the Cape of Good Hope in 1652. The Company made initially little effort to explore the interior or to chart the coastline (Duminy 2011). Following the first exploration by Pieter Potter in 1659, a number of individuals set out to explore and map the interior, with the intent to look for commodities that could be of interest to the Company's directors (Duminy 2011). The priority of these maps was therefore to provide indications of the routes followed to get to main settlements and resources in the interior, and to chart the locations of mineral deposits, timber, and exotic animals (elephants, giraffes, etc.). The map of southern Africa shown in Fig. 3.2 represents one such effort. The map is one of the many drawings (including illustrations of animals, plants and people) and descriptions that Robert Jacob Gordon, a Dutch army colonel of Scottish descent, made during his four expeditions in the Cape between 1777 and 1786. The original map is held in the Rijskmuseum, Amsterdam, and is nearly 2 m^2 at a scale of 1:750,000. It contains topographical detail (including barometrically measured elevations) and informative notes and drawings that describe the people and animals of the interior (Duminy 2011).

John Arrowsmith's (1790–1873) map of southern Africa, published in 1834, is an example of the mapping conducted by the British after assuming control of the Cape in 1795 (Fig. 3.3). The British authorities were ignorant of the extensive surveys and mapping of the coastal areas that had been undertaken under Dutch rule, and they considered the country unmapped (Liebenberg 2008). They were eager to obtain reliable topographic information, in particular since a large part of the colony was inhabited by Boer frontier farmers who had fled from the Cape (Liebenberg 2008), and restarted most of the measuring from scratch using estimates of directions and distances travelled, supplemented by astronomical observations of latitude (Duminy 2011). The map was issued both separately and published in Arrowsmith's *The London Atlas of Universal Geography* (Duminy 2011). The informa-

Fig. 3.1 Lorenz Fries' reduced version of the Waldseemüller map. This woodcut map, with added colour, is dated 1541. (Source: Historic Maps Collection, Princeton)

tion presented in the map is mostly copied from an older map made in 1830 by L. Herbert, who himself consulted maps made by military and civilian land surveyors and narratives of travellers, and is supplemented through the comparison of several thousand sheets of maps, charts and plans (Liebenberg 2008). It displays eleven magisterial districts and provides historically important documentation of travel and exploration in South Africa. It shows well-worn and new tracks used by explorers and travellers. This and subsequent updates of the map provide one of the best cartographic records of the expansion of the Boer settlements to the north and east of the Cape Colony. The map also shows the approximate location of indigenous groups, assigning a large area to the 'Koras or Koranas'. Arrowsmith's map was considered the most reliable cartographic representation of southern Africa at the time and was accepted as the standard map of the Colony by the mid-1830s (Liebenberg 2008). Largely compiled from exploratory materials and not based on accurate surveys, Arrowsmith's map is not planimetrically accurate and would eventually be dismissed by later surveyors. Alongside Herbert's, it represents the most complete cartographic portrayal of southern Africa of the time and in particular the occupation of the British colony on the eve of the Great Trek (Liebenberg 2008).

3.2.2 Topographic Maps

The genesis of modern topographic maps, traceable to the Dutch occupation of the Cape and initially based on the Land Registry used in the Netherlands, is intimately bound up historically with the system of land registration, whereby the position and extent of all land as originally ceded by the government is recorded (NGI 2013). In the initial system, title deeds were accompanied by diagrams showing boundaries and areas, but the grant of land had not been fixed by survey.

Fig. 3.2 Detail of the upper left part of Gordon's great map of southern Africa, dated 1777–1795. The inscriptions are almost all in hand S3, which suggests that it may be an unfinished fair copy of the map on which Gordon himself worked. (Source: https://robertjacobgordon.nl/drawings/rp-t-1914-17-3-a)

Measurements were carried out by pacing a circular shape of around 4 km radius around a central position (NGI 2013). Efforts were made to improve this system since the early 1800s, but it was only the Land Survey Act of 1927 that established the practice of cadastral surveying in South Africa (Wonnacott 2010). In 1928, experiments commenced with terrestrial photogrammetry which eventually led to a decision in 1936 to map the country at 1:50,000 scale. A 15 year plan was commenced using aerial photography, plane table methods and a variety of photographic interpretation techniques. In 1948 the first photogrammetric stereo-plotters were commissioned and the capture of topographical data from aerial photography commenced. By the early 1960s, only 20% of the country had been mapped at 1:50,000 scale, and the complete coverage of South Africa was only achieved in 1976 (Wonnacott 2010). Two major developments required the revision and reprint of 1:50,000 maps: the adoption of the metric system in 1970, which required the re-compilation of about 60% of the country's contours and was completed in 1992, and the replacement of the Cape Datum – which formed the basis of the South African geodetic system since the 1830s – with the Hartebeesthoek94 Datum in January 1999 (Zakiewicz 2011). The 1:50,000 scale topographic sheets are produced and published by the National Geo-spatial Information (NGI), the South African national surveying and mapping agency, and is a series consisting of a total of 1913 map sheets covering the entire country. A standard 1:50,000 topographical map covers a rectangle of 15 min of latitude by 15 min of longitude, or approximately 640 km^2. These topographic maps depict the location of natural and built features by means of symbols and colours, and elevations by means of spot heights and contours (generally 20 m intervals). Additional information such as place names, boundaries and magnetic data is also included in the map. A new Computer Assisted Map Production System was introduced in 1997. GIS was used to systematically transfer analogue maps into digital format and value-added products such as digital elevations models and orthophoto maps at a scale of 1:10,000 started being produced. Today, all maps produced by NGI are available in digital format, upon request to the Mowbray offices, both as scanned raster of paper maps and as vector layers.

Fig. 3.3 Map held at the Library of Congress Geography and Map Division, Washington DC. It is a copy, dated 1842, of Arrowsmith's map of southern Africa published in 1834. (Source: Library of Congress)

3.2.3 Thematic Maps

Maps used to record the distribution of variables such as geology, climate, vegetation or a particular 'event', such as the location of people who had a contagious illness or the extent of a flood, started appearing worldwide in the 1700s and in South Africa in the later 1800s. These types of maps are a combination of locational information of geographical elements such as hydrology and topography, political boundaries, and a representation of the variable of interest. These are known as thematic maps.

E. J. Dunn's *Geological sketch map of Cape Colony* was published in 1872 and was based on field observations made by himself and a number of other geologists. Three years later, Dunn visited England and published a more extensive map, *Geological sketch map of South Africa* (1875), which included the Transvaal (Fig. 3.4). This map is a summary of several years of fieldwork, and can be considered the first detailed geological map of the whole union and also the first coloured geological map to be printed in South Africa (Hatch and Chalmers 2013).

Alexander Buchan (1829–1907) was a Scottish climatologist and meteorologist. His map of mean annual rainfall of South Africa (Fig. 3.5) is one of a series of meteorological maps of the country which included monthly rainfall from averages of observations in 1894, and makes use of isolines to show contours of equal value in precipitation on a coordinate grid system (a method developed by Edmund Halley in the early 1700s; Friendly 2007), which are then filled in with the same colour shade. This early weather map is strictly climatological. It is an attempt to chart average conditions over a decade and shows horizontal patterns, without incorporating vertical motions, the representation of which will nevertheless soon be charted in circulation diagrams. Buchan created a series of colour maps showing mean temperatures, isobaric lines, and prevailing winds over the globe for each month of the year and for annual values, which accompanied 347 pages of text and tables in his publication *Report on Atmospheric Circulation based on the observation made on board* HMS Challenger *during the years 1873–1876 and other meteorological observations* (Royal Society 1914).

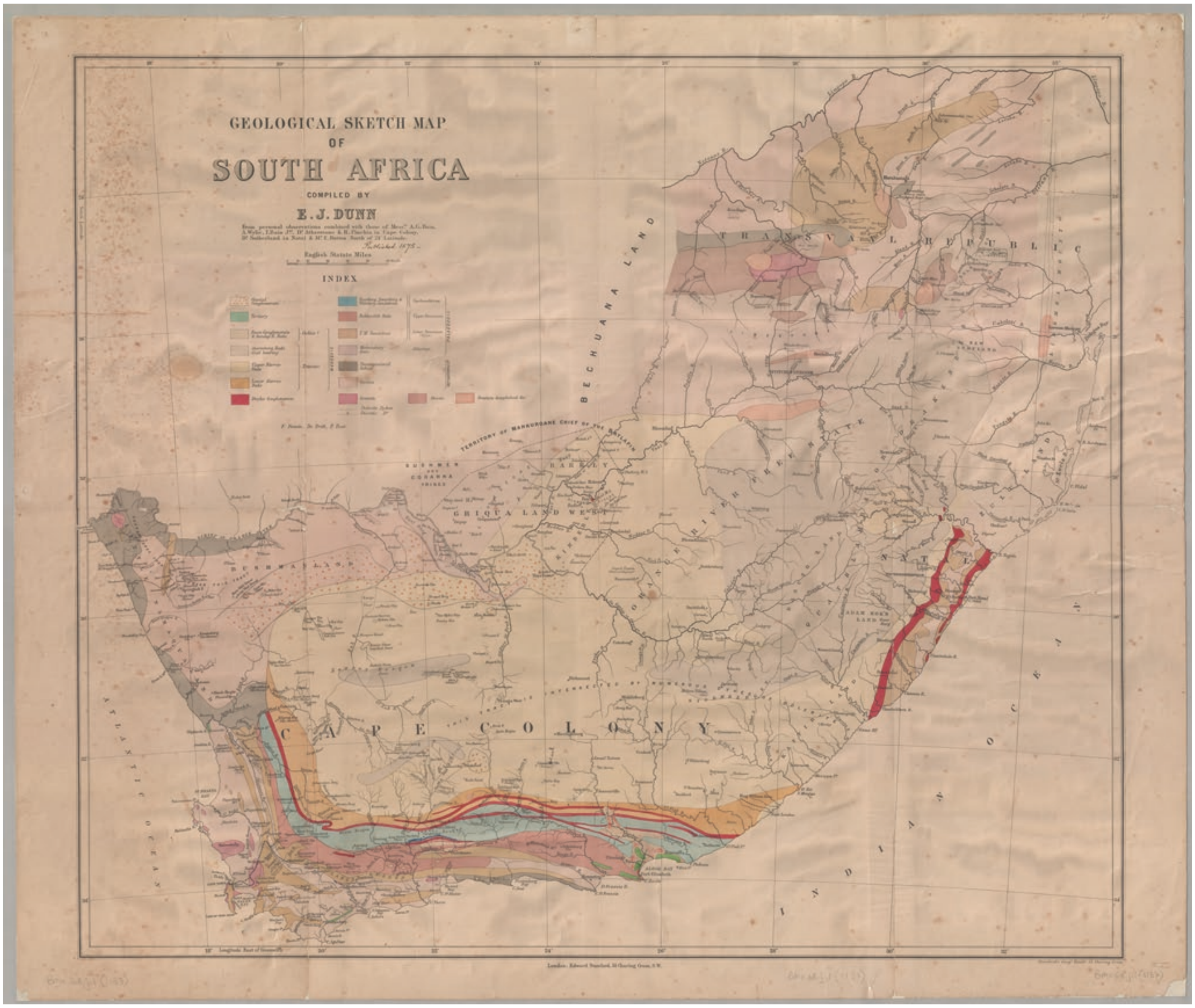

Fig. 3.4 Geology sketch map of South Africa, by E. J. Dunn, 1875. This map combines topographic detail with geological information on the main formations of South Africa. The formations are colour shaded and an index is presented in the legend. The location of some mines is also shown. (Source: University of Cape Town Libraries)

The first malaria survey of the Union of South Africa was carried out in 1921 for the Department of Health (le Sueur et al. 1993). This resulted in the division of the country into five scheduled areas, which were geographically recorded on a coloured map. This map (Fig. 3.6) represents, using the same methodology, the results of a similar survey carried out in 1938 (the 1921 map is no longer available). This map was only revised in 2000, informed by case notifications and evidence of the presence of suitable transmission vectors (Morris et al. 2013) and as such it is one of the longest-lived maps in the history of mapping in South Africa.

The last map in this brief history of mapping in South Africa is an environmental map produced from digital datasets in 2011 (Fig. 3.7). This map was created by R. Pravettoni from GRID-Arendal, a Norwegian foundation collaborating with UNEP, and published in *Working for the Environment, South Africa* by the Department of Environmental Affairs. The aim of the publication was "to inform and educate the general public in South Africa on the vital the work currently being done by the government to protect the environment and alleviate poverty" (DEA 2011). The map is designed to show that environmental pressures tend to occur in overlapping geographical areas and result in amplified environmental threats in already disadvantaged regions, through positive feedback loops (DEA 2011). It is different from previous maps in many respects. First, it is the combination of different datasets and variables. It displays primary data such as wildfire locations and high alien invasive plant cover, but also secondary, calculated distributions, such as potential arable land and moderate and severe land degradation. These

Fig. 3.5 Map of South Africa showing a representation of the mean annual rainfall based on data from rainfall stations (red dots) observations from 1885 to 1894. The map was created by Alexander Buchan (1829–1907). (Source: University of Cape Town Libraries)

are calculated based on established threshold parameters and are not measured directly in the field. Second, the map is not meant for administrators or experts but for the general public, and as such is devoid of jargon, does not make use of grid coordinates or scales, and is very easy to interpret. It is an example of a new generation of maps in South Africa that combine complex and varied datasets and are conceived for the general public (Grainger et al. 2016).

3.3 Environmental Mapping and Its Process

Whilst the first forms of environmental mapping are known from the eighteenth century (Pereira et al. 2018), the interest in environmental mapping has greatly increased in parallel with the increasing interest in environmental monitoring and reporting after the Rio Conference in 1992, when the Rio Declaration on Environment and Development and Agenda 21 were adopted (United Nations 1992) and people recognised the need for sound environmental information for improved decision-making (CBD 2010). Ultimately, protecting the environment from increased human-driven detrimental impacts has been recognised as a priority, including evaluating the physical, chemical and biological factors that impact on the environment and predicting trends in environmental degradation and amelioration (Artiola et al. 2004). In South Africa, this value is embodied in the Constitution (Act 108 of 1996, section 24) and National Environment Management Act (NEMA) Act 107 1998, which state that every person living in South Africa has the right to an environment that is healthy and not harmful to their wellbeing, and the right to have the environment protected from degradation.

Environmental mapping, the process of collecting and representing spatially-referenced data about the environment (Armitage 2010), provides a framework not only for understanding, modelling and determining the state of the environment but also for assessing and predicting environmental impacts and trajectories. It is not an end product, rather a process consisting of various operations, namely data acquisition, data processing, data storage, analysis and visualization, all driven by decisions around what aspects of the environment are to be mapped, for what reason, and for the interest of which stakeholder (Armitage 2010).

Environmental mapping is used for a wide variety of purposes: monitoring, modelling, planning, policymaking, man-