Part I: The Physical Cradle: Land Forms, Geology, Climate, Hydrology and Soils

Africa emerged from the middle of the supercontinent called Gondwana, splitting from the land masses that became South America, Australia, India and Antarctica (Figure I.1). The rupture was initiated by massive outpourings of flood basalts, which commenced 183 million years ago (Ma) during the early Jurassic period in what is now southern Mozambique. The volcanic overlay spread inland from there at least as far as south-western Zambia. By 160 Ma, a widening trough separated Africa from eastern Antarctica and Madagascar, filled by the proto-Indian Ocean. In the west, the separation of South America from Africa began with lava eruptions in what is now Namibia, initiated around 123 Ma, and the South Atlantic Ocean began opening. Unencumbered by adjoining land masses, Africa drifted slowly northward, and rotated a little anticlockwise. The location of the equator shifted from the southern Sahara region towards its current middle position, with similar portions of the continent to its north and south. Once the continents eventually halted their drift, South America lay almost 3000 km from the nearest point of Africa, while Australia ended up almost 10,000 km distant on the other side of the Indian Ocean. The Tethys Sea separated Africa from Europe.

Following its parting from the other southern continents, Africa's high-lying land surface became progressively worn down by erosion, lowering the hilltops and filling in the valleys. By 66 Ma, when the Cretaceous period ended with the demise of the dinosaurs, a gently undulating plain had been formed over most of the continent. This is known as the African erosion surface. The only mountain ranges lay in the far south and far north. The Cape Fold Mountains were formed during the Permian ~250 Ma, when Africa's land mass pressed against Antarctica, while the Atlas Range was formed much later where Africa's drift northward butted against Eurasia. Freed from the adjoining land masses, Africa's coastal margins tilted upward. With the passage of time, the coastal escarpments became eroded back by as much as 200 km in the east and 50 km in the west. Material removed from the high country accumulated in the Kalahari, Congo and Chad basins and extended shorelines especially in the east and south. Through the interior, low hills emerged where more resistant rocks intruded. Africa's surface probably resembled Australia, worn down and

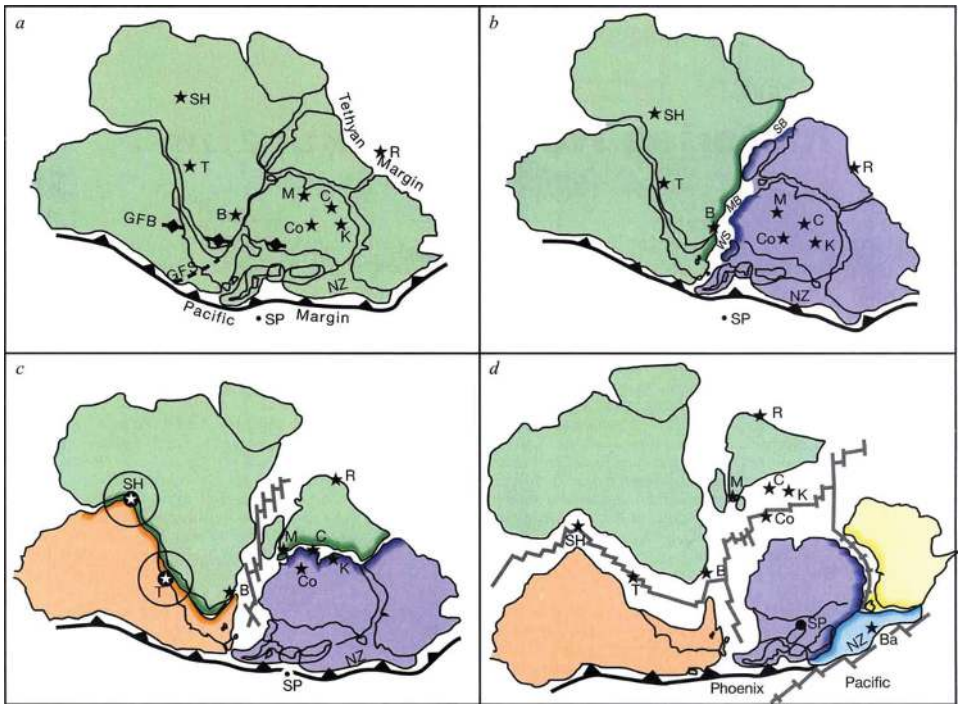

Figure I.1 Stages of the breakup of the supercontinent called Gondwana. (a) 200 Myr, (b) 160 Myr, (c) 130 Myr, (d) 100 Myr (from Storey (1995) *Nature* 377: 301).

depleted of nutrients. Fossil deposits preserve remains of the mammal-like reptiles and early dinosaurs that thronged Gondwana, but record little of the later dinosaurs present in Africa during the late Jurassic and Cretaceous periods. The fragments of their bones were mostly swept from the eroding land surface.

This static situation ended around 45 Ma, when a plume from deep within the Earth's mantle began pushing up in the north-east under present-day Ethiopia, initiating volcanic eruptions. The doming of the land surface caused faults to develop by 25 Ma, which opened the Red Sea and propagated southward through the continent. Massive outpourings of volcanic lava produced layers upon layers of basalt. The raised land surface deflected rain-bearing winds and altered river courses.

This tectonic activity not only reshaped the physical features of the continent; it nurtured the plants and animals that evolved on its surface, including the walking, meat-eating, cerebral and culturally sophisticated ape that became us. The chapters forming this first section of the book establish the interconnected consequences of the tectonic uplift for land forms, climates,

rivers and soils. They present largely an east-side story, but expanded coast-to-coast in the south. West-central and western Africa remained mostly low-lying and rather similar to tropical regions of South America, Australia and Asia in their ecology, and thus feature less in the story.

Suggested Further Reading

McCarthy, T; Rubidge, B. (2005) *The Story of Earth & Life. A Southern African Perspective on a 4.6-Billion-Year Journey*. Struik Nature, Cape Town.

Partridge, TC. (2010) Tectonics and geomorphology of Africa during the Phanerozoic. In Werdelin, L; Sanders, WJ (eds) *Cenozoic Mammals of Africa*. University of California Press, Berkeley, pp. 3–17.

Chapter 1: High Africa: Eroding Surfaces

The formation of High Africa began in the Afar region of north-east Ethiopia around 30 Ma, brought about by the billowing mantle plume. By ~20 Ma, the continental uplift had propagated into South Africa, where the land surface was raised by about 250 m in the east and 150 m in the west. The elevated surface was subjected to a renewed phase of erosion, which produced the Post-African I (or Miocene) landscape. More substantial uplift took place starting around 10 Ma and accelerating after 5 Ma, especially along the eastern side of the continent. The land surface rose by as much as 1500 m in eastern Africa and by up to 900 m in eastern parts of South Africa.[1] This generated the Post-African II (or Pliocene) cycle of erosion, not readily distinguished from the preceding phase I. The product is the high interior plateau extending from Ethiopia through eastern Africa and broadening westward across southern Africa (Figure 1.1; Box 1.1 explains the continental divisions used throughout the book). The elevated continental interior profoundly influenced climates, exposed bedrock, altered river courses, shifted lakes and affected soil formation, as will be outlined in the chapters that follow.

Land Surfaces

Remnants of the African erosion surface persist in South Africa's Highveld region, Manica region of central Zimbabwe, above the Muchinga escarpment in Zambia and over parts of eastern Africa despite blanketing there under lava flows (Figure 1.2).[2] Distinctions between the African and Post-African surfaces are particularly striking in the southern Highveld and Karoo regions of South Africa, where flat-topped hills capped by resistant bedrock retain remnants of the African surface on their crests (Figure 1.2D). Further north in parts of Zimbabwe, Angola and northern Mozambique, erosion has exposed inselbergs composed of basement granite (Figure 1.2E). While erosion lowered the interior surface, it pushed back coastal escarpments. Sandy sediments accumulated in the Kalahari and Congo basins in the west and extended the eastern coastline outward (Figure 1.2F).

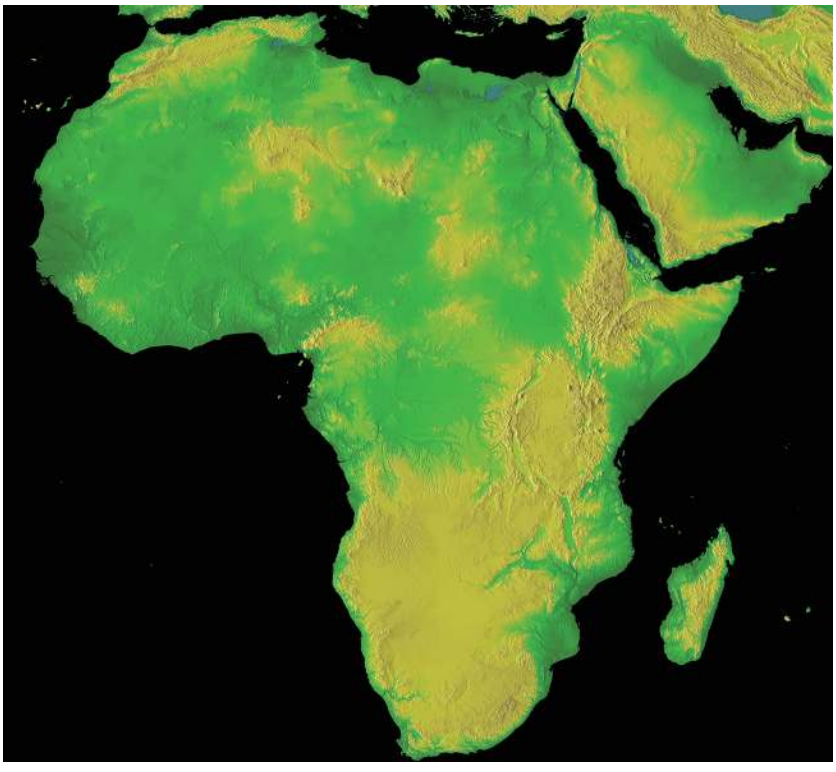

Figure 1.1 Topographic map showing the extent of High Africa stretching continuously from Ethiopia through southern Africa, shown in yellow.

Box 1.1 Geographical Subdivisions of Africa Distinguished in the Text

1. Eastern Africa – the equatorial region encompassing Kenya, Tanzania and Uganda
2. South-Central Africa – the tropical region extending through Zambia, Zimbabwe, Malawi, northern Mozambique and Angola
3. Southern Africa – the region extending into the subtropics encompassing South Africa, Botswana, Namibia and southern Mozambique
4. North-eastern Africa – southern parts of Sudan, Ethiopia and Somalia
5. Western Africa – the region extending from Cameroon to Senegal
6. Northern Africa – the Mediterranean region extending from Egypt to Morocco

Figure 1.2 Land surfaces. (A) The gently undulating Africa surface generated by the early Miocene, represented in Athi-Kaputiei Plains in Kenya; (B) eroding eastern edge of South Africa's Highveld plateau; (C) elevated highlands in eastern Zimbabwe, representing marginal uplift following the breakup of Gondwana; (D) flat-topped hill retaining the Africa surface above the Post-African or Pliocene erosion surface in South Africa's Karoo region; (E) granite inselbergs exposed by erosion into the basement shield in south-eastern Zimbabwe; (F) depositional surface of Kalahari sand in north-western South Africa.

South Africa's Highveld plateau attains its maximum elevation of 2332 m near Dullstroom ~200 km from Johannesburg above the eastern (or Transvaal) escarpment, while the Lesotho highlands above the Drakensberg escarpment rise to 3482 m and retain remnants of the Gondwana surface on hilltops. In

the south-west, highlands near the Namibian capital Windhoek reach 2606 m, while Angola's western escarpment rises ~2500 m above the coastal plain, counteracting the general lowering westward. Serengeti National Park (NP) in Tanzania ranges in elevation from 1200 to 2000 m, while the Ngong Hills near Nairobi reach 2460 m. Plateau regions of Ethiopia exceed 3000 m in elevation.

In contrast, western Africa is mostly low-lying, with only localised high country. The Jos Plateau in central Nigeria forms a tableland at a mean elevation of 1280 m, with its highest point 1829 m above sea level. Further west, the Guinean highland reaches a maximum altitude of merely 1538 m. Other highland regions exist deep within the Sahara. The plateau region of Cameroon and adjoining Nigeria connects with the eastern African highlands via the Ubangi-Shari region of the Central African Republic. Every major city in Africa within the eastern and southern interior lies more than 1000 m above sea level, while no city in the west approaches this elevation (Table 1.1). Higher eminences are all volcanic cones associated with rift valley formation, except for the Ruwenzori range, which is an upthrust block within the Western Rift.

Rift Valley Formation

The rifting that began in Ethiopia eventually spread through northern Mozambique, spanning a distance of ~6000 km (Figure 1.3). The downward subsidence in the trough was counterbalanced by raised rift shoulders due to the local pressure release. In some regions there was only a single fault, generating a 'half-graben' rather than a two-sided full graben. The rift valleys accumulated sedimentary deposits, and thus played a crucial role in preserving fossils of past faunas. They trace much of our knowledge of the course of human evolution. Volcanic cones rose beside the rifts and fissure eruptions spread volcanic deposits more widely. Minerals contained in the lava deposits can be used to date the time line of evolution.

In Ethiopia, the rift depression dividing the Simien Mountains in the north-west from the Bale Mountains in the south-east forms a valley 50-km wide. On its margin, Ras Dashen in the Simien range reaches an altitude of 4624 m, while the floor of the Danakil depression in neighbouring Eritrea lies 125 m below sea level. The Eastern (or Gregory) Rift extended through northern Kenya after 12 Ma and reached northern Tanzania by 5 Ma, where it fades out. The Western or Albertine Rift branched off along the border of the Congo DRC with Uganda, Rwanda, Burundi and western Tanzania. Incipient signs of rifting appeared in the Semliki region of Uganda around 8 Ma, but its current configuration was attained only after 3 Ma. The Western Rift continued propagating through southern Tanzania and Malawi to reach the Mozambican coast

Table 1.1 Altitudes of major African cities situated away from coastal regions and their mean annual and dry season rainfall totals (source: Wikipedia and climate-data.org)

City	Country	Altitude (m)	Mean annual rainfall (mm)	Dry season rainfall (mm)
Johannesburg	South Africa	1753	790	67
Windhoek	Namibia	1728	359	12
Gaborone	Botswana	1014	457	28
Lilongwe	Malawi	1050	860	13
Harare	Zimbabwe	1490	831	23
Lusaka	Zambia	1277	831	3
Huambo	Angola	1721	1366	39
Dodoma	Tanzania	1120	564	2
Nairobi	Kenya	1795	869	139
Kampala	Uganda	1190	1293	457
Goma	Congo DRC	1460	1192	381
Kigali	Rwanda	1567	1000	226
Addis Ababa	Ethiopia	2200	1143	111
Juba	South Sudan	550	941	101
Abuja	Nigeria	840	1389	49
Yaoundé	Cameroon	726	1643	355
Bangui	Central African Republic	369	1535	290
Ndjamena	Chad	298	481	0
Niamey	Niger	218	505	2
Bamako	Mali	350	953	5

Note: Dry season rainfall is averaged over the five driest months.

near Beira. A minor south-western offshoot extended through Zambia's Luangwa Valley into northern Botswana, ending in the faults blocking drainage from the Okavango Delta. Most rift activity took place between 9 and 5 Ma in the north-east, then again 1–2 Ma extending through the south, associated with the two phases of tectonic uplift.

Lake Naivasha in the rift floor lies at an elevation of 1884 m, higher than the elevation of the city of Nairobi to the east (Figure 1.4A). The lowest region of the rift near Lake Turkana in northern Kenya is only 375 m above sea level. The rift margins in the Turkana Basin are separated by ~300 km, but become narrowed to under 60 km near Nairobi.[3] Approaching its terminus in northern

Figure 1.3 Map of the African Rift Valley System extending through eastern Africa from Ethiopia in the north to Mozambique in the south (from Wood & Guth, www.geology.com/articles/east-africa-rift).

Tanzania, the Eastern Rift splits into three arms. The western arm extends through Lake Eyasi, the central one reaches south of Lake Manyara, and the eastern one goes past the town of Moshi near Kilimanjaro. The road heading towards Serengeti ascends the margin of the Eastern Rift while passing Lake Manyara (Figure 1.4B).

The Western Rift is somewhat narrower than the Eastern Rift and includes several deep basins filled by large lakes. The Ruwenzori Mountains were formed as an upthrust block within the rift subsidence, with Mount Stanley reaching 5120 m above sea level. Lake Kivu's surface lies at 1460 m, while the surface elevation of Lake Tanganyika to the south is much lower at 773 m. Lake Tanganyika attains a maximum depth of 1470 m, meaning that its floor lies well below sea level. The Western Rift is still widening at a rate of a few millimetres per year, portending a split of the Somali plate including much of eastern Africa from the rest of the continent in some distant future. The Virunga volcanoes lie to the east of this rift, with Mount Karisimbi attaining

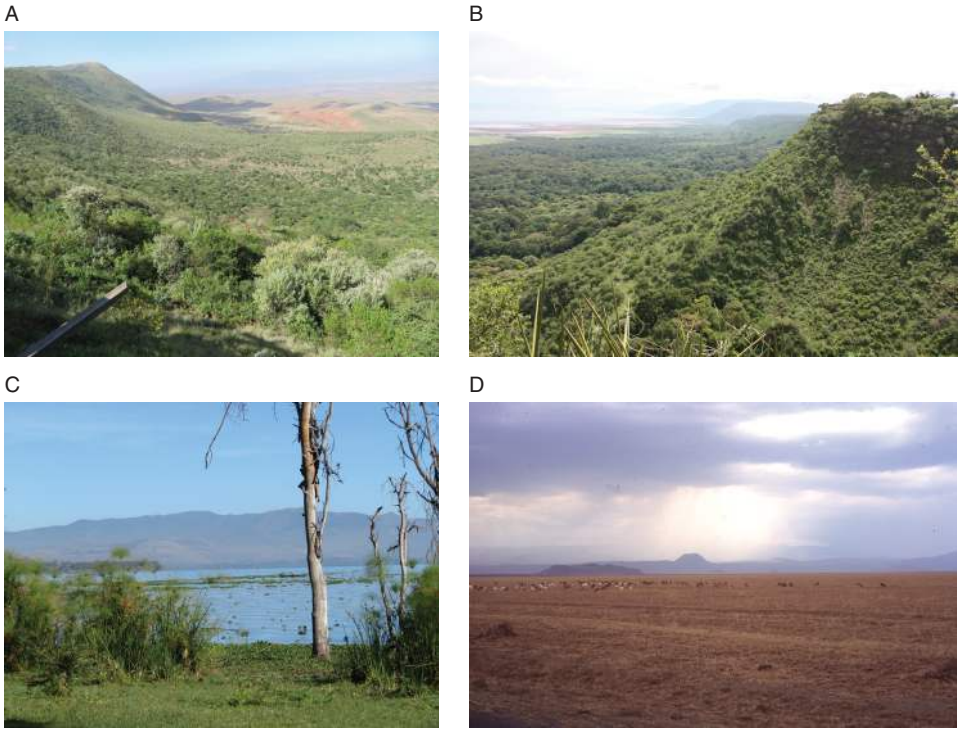

Figure 1.4 African Rift Valley views. (A) Eastern Rift Valley descending from the Ngong Hills in Kenya; (B) Eastern Rift shoulder above Lake Manyara in Tanzania; (C) rift wall rising beyond Lake Naivasha; (D) arid floor of the Eastern Rift near the equator in Kenya.

an elevation of 5109 m. Mounts Nyamulagira and Nyiragongo are still active. The low volcanic cones and associated crater lakes in Queen Elizabeth National Park in Uganda were generated quite recently.

Numerous volcanoes are allied with the Eastern Rift, most of them on adjoining platforms rather than within the rift subsidence. Mount Elgon (4321 m), situated on the border between Kenya and Uganda, was formed around 22 Ma before local rifting began. Mount Kilimanjaro (5895 m) rose to its full height between 2.5 and 1 Ma. Mount Kenya (5199 m) formed earlier around 2.6 Ma and was initially much higher than it is today. Ngorongoro Crater, with its rim rising to 2380 m, is the remnant of a volcano blasted open by a tremendous explosion around 2 Ma, producing the world's largest caldera. Oldoinyo Lengai, situated in the Ngorongoro highlands, still spews carbonatite tuffs over earlier lava flows.

Volcanic cones occur also in the Cameroon highlands, with Mount Cameroon rising to an altitude of 4040 m. Other volcanoes formed the islands of Sao Tome and Principe in the Gulf of Guinea. Southern Africa's land surface