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If the contemporary fauna and flora of tropical Africa include some of the earliest inhabitants of our small blue planet, they are but yesterday's children compared with its fabric of minerals, rocks and soils.

This was impressed upon me by our family friend, geologist 'Great Dane' Max Coster. Singida town, where my father was District Commissioner, sits between two soda lakes, and its buildings, roads, trees and gardens fit in among great outcroppings of rock. Shortly after his arrival I found myself sharing the top of a giant boulder with Max as we watched a flight of flamingos cross a near-setting sun. Our dusk perch was one of many eroded rock formations on the outskirts of the town and we were close to the promise of sundowners at the *Boma*, the massive German-built fort that our family called home. 'The parent gneiss for the rock we're sitting on could go down, say, 40,000 feet beneath us, and it became rock some two billion years ago,' Max explained. The fact that our sandals and trousered butts rested on such venerable material was a routine observation for Max, but a big imaginative challenge for me.

The one constant is that our planet has always had a relatively warmer atmospheric girdle, between two cold poles where the regular, periodic absence of sunshine returns each polar surface to something like Earth's lifeless beginnings. Meanwhile, Africa's equatorial belt harvests evaporation from two oceans, resulting in rain that falls all year, or in two wet seasons in quick succession. Max invoked the example of a boiling kettle that evaporates a lot more water than a cold one. Africa was dry and cold during the Ice Ages and hot and wet during thermal maxima, while over the last few millennia it has been about as ideally suited to humans as it ever could be – something that should never be taken for granted or assumed to be permanent.

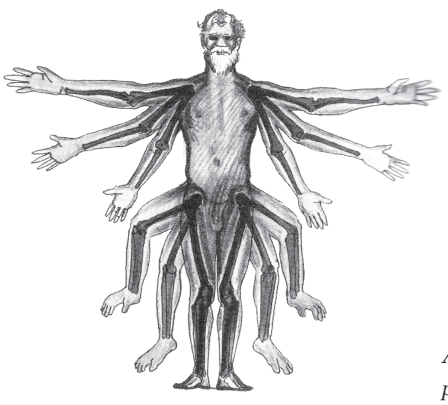
The slow wars of jostling continents have spilt magma at weak points, on land or over the sea floor. Wounds that begin white-hot, quickly cool. They may form conical pustules which come and go as storms, waves and deluges wash them away. These are volcanoes – ecological islands on land, physical islands in the sea (remember that among the tens of thousands of marine mountains, at least one rises 9 km above the sea floor, a lot taller than Everest).

In East Africa the familiar cones of Kilimanjaro, Rungwe, Kenya, Elgon and Bufumbira all invite questions about geological history and the hidden forces that generated our pimpled, rifted landscapes. Inhabiting every mountain top to every shoreline are floras and faunas of countless entities. Their interactions with one another and with their surroundings hold inconceivable complexity. Their histories are yet to be untangled, let alone understood.

Rock-perched musings with Max aside, huge events like global warming and freezing, tectonics, volcanic eruptions, asteroids and their impact on the history of life on Earth were not part of my formal education – I wish they had been. Even so, subsequent expeditions to the heights of Kilimanjaro, Kenya, Rwenzori and Rungwe challenged my senses and sensibilities – every rock has a story to tell. Today, sundry multitudes of scientists are bringing the unique insights of

Baobabs in Kunduchi Bay.

evolution, genetics, biogeography, geology and astronomy to bear on human adaptations and prehistory. We now examine islands, mountains, landscapes and climatic periods, asking what set of circumstances could possibly have given rise to the most interesting and complex of all animals – mammalian primate humans.



Ape and human limb proportions compared.

Kilimanjaro, seen from Mweka, and imagined erupting.

CHAPTER

2

GONDWANA'S CORE

In which frogs, with some help from geologists, gift us a truer and older history of continents. Their legacy, with lungfish and scorpions as guides. Native of a microplate.

In 1963 my dear friend and fellow biogeographer, Wilma George ('Mama-Gundi'), invoked land bridges between fixed land masses to explain some puzzling animal distribution patterns. Given that many offshore islands and sandbanks had long been shown to have had former dry land connections, her speculations were forgivable. Furthermore, her most powerful and influential contemporaries, pundits in the USA and commissars in Russian petroleum industries, all envisaged fixed land and marine surfaces just rising and falling, not slewing and sliding about, *en masse*.

They and Wilma were wrong.

Amid the many mysteries of our planet, the true story of the formation and movement of continents has been among the most recent to be discovered. We owe our knowledge to one of the great heroes of science, Alfred Wegener – geologist, astronomer, meteorologist, explorer, non-stop smoker and a martyr to science. He first presented his research at a 1912 meeting in one of the world's most splendid (and my favourite) of museums, the Senckenberg, in Frankfurt. However, his discovery of what he called 'continental drift' (now more precisely the science of plate tectonics) only found its full acceptance during my lifetime (after a half-century of ferocious rejection by most self-appointed authorities). In 1944 a humble geologist, Arthur Holmes, who had first tried out his field skills in eastern Africa and Borneo, was the first to document the spread of mid-ocean ridges and confirm that continents slither, like fragments of loose peel over the surface of our global tangerine. Wegener, Holmes and the science of plate tectonics explain the eruption of volcanoes far out in the mid-ocean, like the Galápagos, Hawaiian, St Helena and Mauritian islands. Most important of all, evidence from many disciplines has now been brought together to allow a reconstruction of Pangaea, the supercraton mother of all continents. Even then, her vast amalgam of land and rock took up less than a third of Earth's surface (Mother Earth for us primates, but Mother Ocean for whales and extra-terrestrials). Estimated to have held together for some 150 million years, Pangaea's equatorial waistline then arched obliquely over today's Sahara, but mainly it warmed a much more extensive belt of sea.

Pangaea's fracture into northern Laurasia and southern Gondwana is thought to have begun about 300 million years ago when a rift valley first split Morocco's Atlas Mountains away from New England's Adirondack Mountains. An

Schematic maps of Pangaea and Gondwana's breakup.

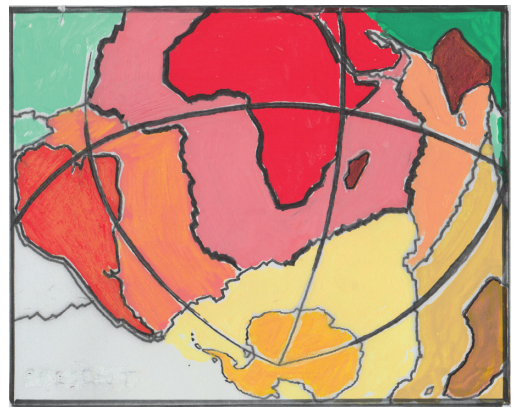
embryonic 'sea of Tethys', the future North Atlantic, swept into the cleft. Then the sea's floor steadily widened, just as Arthur Holmes was the first to show.

The mental challenge of imagining events such as oceans cascading into rift valleys or over a Gibraltar waterfall brings with it a peculiar sort of thrill. Authors of the Old Testament understood this well enough when they concocted the scene of Noah's ark floating off on a Mesopotamian flood (real enough for some likely originators of the story). Moses striking his magic staff to part the waters of the Red Sea and let the Israelites pass over could plausibly have had its origins in some upstream landslide creating a dam, or a super-drought somewhere in Mesopotamia. The big difference is that Wegener and Holmes dedicated their lives to extracting true stories, backed up by their own and their colleagues' painstaking research into natural processes. However, contemporary idolisers of 'sacred books' tend to bring literal minds to bear upon symbolic stories that invite interpretation (perhaps designedly so) in more than one way. Expulsion from the garden of Eden was once understood as the end of childhood, while Cain's murder of brother Abel was allegory for the farmers' displacement of nomadic foragers – both tales referencing the personal experiences of the Middle-Eastern authors, and other early converts to these fledgling faiths. For all their poesy, here are ambiguous and misleading materials for mullahs, mothers and grandmothers to tell bedtime stories. Richard Dawkins and Dave McKean have explored this dichotomy brilliantly in their very beautiful book *The Magic of Reality*, which should be in the library of every school, worldwide.

Had I been raised by such mentors with such school-books, and innocent of an over-arching, global civil war, I might have seen my environment very differently. Luckily, I can go on learning and discover that I was born close to the centre of a grand and fertile stretch of territory – the VM or 'Victoria Microplate'. Much of my life has been spent exploring fellow animal and plant inhabitants right out to the lakes, mountains and rift valleys that demarcate the VM's far-flung and often heart-quickeningly beautiful borders.

Living on the fertile slopes of Kilimanjaro, watching a setting sun paint those beloved hillsides orange, brief as flame, conjured biblical visions in

Afro-Arabian continent about 62 million years ago (below) and today (right).

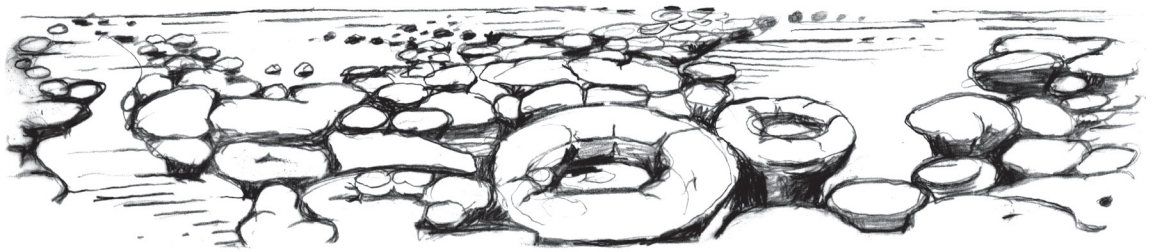


which fountains of magma built the mountain, the very slopes we now inhabited. Humans may not have witnessed Kili's most recent eruptions, but will a day come when people, our people, see the mountain wake and come alive again?

This native of a microplate has lived long enough to expand his habitat and describe it as a sort of 'life on central Gondwana'. These terminologies are very distant from those that territorial colonialism, nationalism and religions have imposed upon us. They are a part of embracing the deep past and its consequences – a necessary part of the emancipations and joys of becoming a naturalist. Gondwana was, perhaps, 150 km thick, which did not stop it from fracturing. Africa became the central supercraton of four – Antarctica, Australia and South America budding off (in that order).

There are Wegener fans who call Australia 'Eastern Gondwana' and South America 'Western Gondwana', while Africa occupies Central Gondwana (central, that is, to the pre-break-up mega-continent). This core is still actively breaking apart, having already sloughed off (about 165 million years ago) those big chunks of ex-Africa that we call Madagascar, India and Arabia, the latter creating the 2,200 km-long, narrow, but still widening Red Sea. Today, an extension of that ex-rift valley is opening as a continental crack that runs from the southern end of the Red Sea to the Zambezi delta, 3,000 km away. Like Arabia some 50 million years ago, all the land lying east of that eastern rift is today pulling away towards the Indian Ocean. The creation of new islands is a violent process. Mount Kenya's slopes are peppered with lava bombs (now cloaked in moss) beside the living grace of Afro-Alpine groundsels and senecios.

The deeply fractured trenches of the western Rift are more complicated. They demarcate the western margins of the VM, now known to be one of the most extensive chunks of thickened crust and mantle in the world. In spite of its thickness, this colossal microplate has been swept along by Africa's swivelling but mainly northward drift. Because it extends more than 100 km down, deep into the Earth's molten mantle, it is particularly 'sticky' along its northwestern hinge with Africa's main body (the Nubian plate). 'Hinge' is tool-language for the Rwenzori mountains, where the VM has crumpled up thousands of metres high



Stromatolite landscape.

(today eroded down to peaks of just over 5,100 m). This vast uplift is due to the sticky VM going into a counter-clockwise swivel against its fracturing junction with the main mass of Africa. The microplate's southern tip, lying beneath my family's little home town of Mbeya, grates against the Nubian plate to the west, while the rift that marks the VM's long eastern margins is pulling a 3,000 km-long strip of land eastward. Like Rwenzori at its northern end, this southern hinge is associated with volcanics and massive uplift. The natural history of the VM's extraordinarily beautiful landscapes, especially around its outer extremities, begged to be explored by my youthful self.

Before our time, it was inconceivable that the surfaces we walked or rode over were anything less than the bedrock of our grasp of reality. Scientific hero Wegener, for all the pedantic style imposed upon him by a provincial academic tradition, showed that we are mariners on rafts moving at rates, varying rates, that can now be calculated.

Before she crashed into the sandy shores of Asian Himalaya, India detached herself from Madagascar and broke records by speeding across the Indian Ocean at 15 cm per year, which is pretty fast for a migrating subcontinent. Australians, their males prone to growing stubble, like to say that *their* continent is moving more slowly, but at the same rate as hair growing on an Aussie chin.

Scientists have estimated that Earth formed from its constituent matter some 4.6 billion years ago and, very tentatively, that life began some 4 billion years ago (give or take quite a few million years).

To find anything resembling 'first life on Earth', visit the slopes of an active, sometimes smoking volcano in the East African Rift Valley. Its perfect cone, nearly 3,000 m high, will tower overhead. Below you, the sun or sky will reflect off the glassy, salty surface of Lake Natron. Standing on the banks of a pretty little stream that flows off Ol Donyo Gelai, look down into water that is disarmingly clear but actually resembles the sort of chemical soup that flowed over the cooling surfaces of planet Earth all those billions of years ago.

In those shallow waters you will see rounded mineral accretions, stromatolites that are the product of mineral-trapping bacteria, by ancestry as ancient as the chemical soup in which they live. In Australia's Shark Bay, stromatolites

take the form of giant mineralised 'mushrooms', which look like a vast gathering of globular tents scattered through extensive lagoons of warm, shallow water. The upper surface of each 'mushroom' consists of a mat of living bacteria, and it is one of life's thrills to watch a fine film of oxygen balloons bubbling over that broad, bland surface and realise that you are witnessing a process that first evolved about 3 trillion years ago and that you owe it to that bubble-wrapped mushroom that you can breathe. Filling and emptying of lungs, steady, even while you sleep, or deep and gasping after a run, is taken for granted until you kneel, warm and wet, beside the altar of a stromatolite, mother of Earth's oxygen.

There are good reasons to feel reverence and gratitude here, because long before the emergence of Pangaea, in the shallow waters of future land-masses, various microbes were busy photosynthesising, and emitting deadly gases such as methane. For more than a billion years, Earth's atmosphere was pretty toxic. Among the photosynthesisers, a single form of bacterium evolved the ability to break a particularly robust bond – the H_2O of water. This oxygen synthesiser consisted of four manganese molecules that freed oxygen out of water, releasing oxygen as a free energy source. Recent research has identified the 'moment' when the oxygen released by bacteria overtook the toxic gases released by other bacteria. That moment, about 700 million years ago, is called The Great Oxidation Event (GOE). Thereafter, complex life and more sophisticated types of photosynthesis evolved but all began with bacteria, drawing life from the rays of a life-giving star – the sun.

Our planet's history is inscribed in rocks and bacteria but also in much more complex living things – take lungfish, old-timers with an ancient phobia for salt water. Africa boasts several lungfish species in the genus *Protopterus*, unambiguously Gondwanan in origin. Compare them with the Barramunda or Australian Lungfish, as well as with the South American Lungfish or *piramboia*, the only lungfish species found in the Americas. It is astonishing to find such close resemblances enduring since the break-up of Gondwana.

*African lungfish (*Protopterus *sp.).*

Fossil lungfish were quite diverse 400 million years ago. Even then they tolerated extremes of drought by aestivating, yet (in spite of being distantly related to those 'living fossils' the coelacanths, deep-sea fishes that can live for more than 100 years) they are completely unable to tolerate salt water.

When I was a boy, the giant eel-like bodies of the African lungfish were often on offer on open market stalls. Chunks chopped up with a *panga* (cutlass) ended up in onion, brinjal and pepper stews. With biologically minded friends, we called them *Protopterus*, or 'gloppy-bloppy-opteruses' because they seemed to swim in slime. An individual *Protopterus* might arrive in market attached to a stout yoke and hanging as tall as the porter carrying it. Given their great size, it was not surprising to be told that they could live as long as a human.

One of my more enduring memories is of two youths crouched in the reeds close to the foreshore below our house in Mwanza. 'What are you digging for?' I asked as they cut and levered away with *panga*, and a sharpened stick. Could it be *Mmaamba* – a crocodile? I recoiled, but it was no crocodile that emerged from all their spading and probing (the same Swahili word is used for crocodile and fish, but the latter is discriminated by drawing out *mmaa*, while a short, blunt *mamba* signifies the reptile). Tearing away another clod, one youth plunged his arm down into the muddy hole he had excavated. Breaking up an envelope of brittle material resembling aerated plaster, he drew out a pale sausage folded over itself and covered in messy slime. The indeterminate creature, a *Protopterus*, writhed in slow motion as it was skewered behind its blunt head, and I too shuddered as I watched the young men set off with it to the open market in Mwanza town.

As its habitat dries out, the fish burrows by biting its way down, allowing mouthful after mouthful of soft mud to escape through gill arches. The passage of its efforts is marked by a hole through which the lungfish can continue to breathe, and it must have been this air-hole and its disturbed surroundings that gave the cocoon away to the young foragers. Once embedded deeply enough, the *Protopterus* foams up a frothy mix of gluey secretions and mud that harden into a cocoon around the ever-more-immobile, usually U-folded, fish.

Lungfish adapted to droughts some 400 million years ago and have survived by outliving the most punishing of global perturbations. Since lungfish have never been able to tolerate salt water, they are true relicts from terrestrial Gondwana.

Having a genome that is 36 times larger than that of a human and 360 times larger than fellow fish *fofu-nungu*, or Long-spine Porcupinefish raises all sorts of interesting and important questions. The answer to one, deduced by geneticists, is that the common ancestor of humans and *fofu-nungu* had 12 chromosomes. How lungfish came to acquire a genome with more than a billion base pairs remains a mystery, but selection for a way of life that has survived for 400 million years has to have some relevance, as well as testifying to the durability of lungfish under the most extreme of conditions.

Killifish from west to east.

This also raises questions about what it was about the southern continents that has allowed lungfishes to survive there but not in the north – a question to be examined in the next chapter.

The aestivation that has helped lungfish to survive the almost unimaginable vicissitudes of all those millions of years is paralleled in another group of extremely ancient salt-water-intolerant fish – the killifish (also known as rivulins and annuals). These tiny, slender fishlets probably evolved in Gondwana, and their survival over the ages has been enhanced by their spending most of those ages as embryos, not adults. Why? Because their fertilised eggs and embryos can survive where adults cannot, and can endure drought, heat and climate change, as well as avoid predators. To achieve this, embryos have thickened their outer membrane to resemble the impervious skin of some ingenious time capsule. Furthermore, that well-protected embryo can respond to other external challenges by delaying its own development at any of three embryonic stages. Just how lengthy such delays might have been in the past remains to be determined. The eruptions, earthquakes and heat-waves that surely accompanied the break-up of Gondwana must have severely tested these animals, among the most advanced forms of life on land at that time.

Male killifish court the dowdy females with some of the most glorious displays of colour and pattern ever to have evolved on this planet. Here, evolution has captured the entire spectrum of the sun's radiance in fish scales. Here, tiny male killifish in seasonal puddles (even rainwater in elephant footfalls) combine all the potentials of touch and vision to caress and impress females, the vessels for their very meaning, their brief moment as males.

Their flat, two-dimensional fins take bill-board advertisement to its extremes. Like many other organisms, segmented beginnings, genetic structures and the structural sensitivities of eyes favour repetition, such as a pattern of spots and stripes. Additionally, sensitivity to colour allows sides and fins to evolve elaborations of these repeated patterns. The outlines of fins alter easily, extensions acquire streaks and stripes, margins enlarge, spots become red, blue, yellow – all to what end? To out-compete other males in the beauty stakes? To seduce drab, functional females? The winning moment is to be there, sperm-ready, fins caressing her as she, visually mesmerised, expels her few and precious eggs.

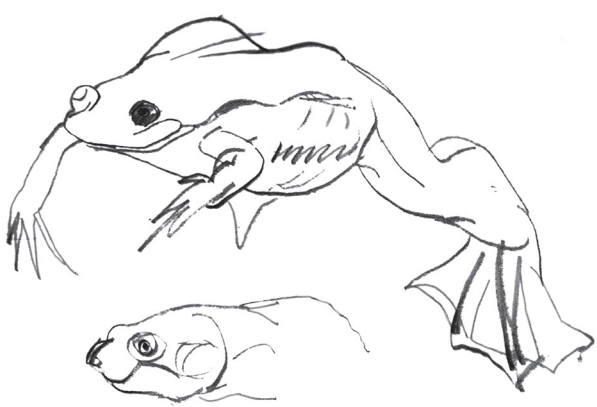
Way out west, in Djallon, female killifish respond to zigzag movements and complex patterns. In Togo, perhaps the hypnotic stare of disembodied eyes is

enough to convince them to release their eggs, but no, a female's girdling by an enormously enlarged male tail could just as well be seen as the fish equivalent of a peahen submitting to the inescapability of the male's quivering galaxy of eyes. In the species south of Benue, it is red and blue stripes that win over the females, while around Buta a jeweller's shop-window of rubies and diamonds set in silver holds the key. The male of one East African species throws the works at his intended. An opalescent eye stares out from a facial mask of fluorescent vermilion. This graduates into a succession of about 30 zebroid stripes of amber, then ruby, each alternately set in turquoise, each just one scale wide. This glowing procession of jewels ends in a tail-tip of blazing orange gold. Remember, a fish that lives for just weeks cannot become the year-round diet of any predator. Killifish males can afford to be as garish, as bling-worthy as wins the race for the longevity of your species, if not for your own month in the sun.

Lest we take too much comfort in our own supposed longevity, remember that male killifishes have been capturing rainbows perhaps for 170 million years. Here, what we call 'beauty' has been thrilling female killifish for all those years. Here, in the briefest of brief moments, we witness life's meaning, moments in which males can dazzle, moments in which male determination to impress meets its maker – the female principle, a male's only guarantor of continuity, the only hope of a future for his kind.

Here life's capacity to surprise found expression before there were human eyes and brains to explore their meaning; long before that same species evolved with a determination to make all nature serve its animal appetites.

Now, let us turn to frogs. Because they had evolved by at least 250 million years ago and cannot tolerate salt water, land-lubbing frogs are a gift to biogeographers. Each continent, even each former continental mass, even odd piles of debris such as the Seychelles and New Zealand, left behind from the safaris of wayward continents, has its own archaic families of frogs. The most ancient forms evolved while all the continents were one mass – Pangaea.



African Clawed Frog (Xenopus laevis).

It is a near-miracle of survival that Pangaean frogs should have survived in New Zealand, but their survival there is a tribute to the durability of land-life-support in just such remote localities. The parting between Laurasia and Gondwanaland, some 175 million years ago, stranded yet more primitive frogs in the southern mega-continent.

Lake Mutanda in the Rain.

In Mwanza our evenings were sometimes punctuated by noisy clicks made by an extremely primitive frog, *Xenopus laevis*, or the African Clawed Frog. *Xenopus* are air-breathers, adapted to burrow down into mud as their freshwater ponds dry out. They can aestivate for a year in a slimy cocoon, and live relatively long lives (15 years is long for a frog).

South America hosts a closely related species, the Sabana Surinam Toad or *Pipa parva*, which has maintained a similar body plan and habits, even though the last common ancestor that it shared with *Xenopus* had lived before South American 'West Gondwana' broke away from Africa's 'Central Gondwana' some 140 million years ago. In eastern Africa, *Xenopus* are most in evidence during the wet season, when the silhouettes of their splayed, black-nailed limbs and bloated-looking, small-eyed bodies seemed to float, like corpses, in many a pond or river-bend. Misleadingly torpid, they dive out of sight and swim away surprisingly fast when disturbed, in spite of being incapable of leaping, only swimming and scrabbling. In their inability to jump or hop, and in their very primitive mouth parts, they are unlike other frogs. Because they lay large eggs and are easy to keep under laboratory or aquarium conditions, *Xenopus* are favourite experimental animals and thousands have been exported and established in labs all over the world. For many years, *Xenopus* was used to test pregnancy in women, because female frogs exposed to the urine of a pregnant woman responded by laying eggs. Today, these frogs, their eggs and tadpoles are employed in countless biology labs for an astonishing array of research topics. In genetics they are used to reveal the function of particular proteins, because the individual genes that control for particular proteins can be easily knocked down and thus reveal their function in the expression of mature structures.

In the mountainous regions of central Africa, high-altitude lakes have formed in valleys peppered with conical hills that are miniatures of neighbouring giants, some of them active volcanoes.

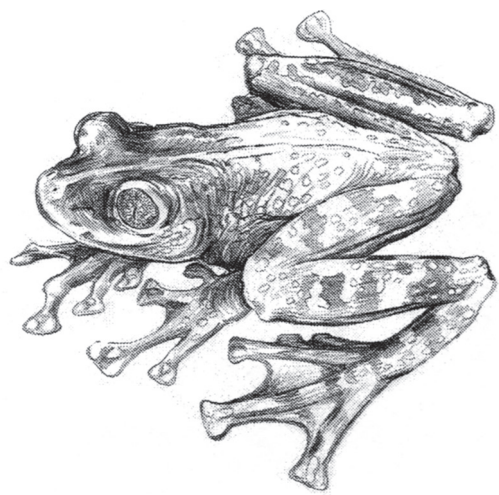
In some of these newly formed lakes *Xenopus* got there before fish, and multiplied enormously. Around Lake Bunyoni, in southwestern Uganda, both otters and the local people adapted to a diet of frogs. It was there that I sampled quite tasty *Grenouille Provençale à la Kigezi*, without knowing my dish's ancient

Table Mountain, South Africa.

ancestry. I wonder how my mental child-scape might have enlarged had I the capacity to imagine such knowledge at the time. With the wisdom of hindsight I can vouch for their tangible reality, because I have contemplated, handled, drawn and even eaten beings that were here in scarcely different form from long before there were dinosaurs.

Another pre-dinosaurian has survived in the shape of 'spookpaddas' or Table Mountain Ghost Frogs, *Heleophryne rosei*. Emerging as a distinct lineage some 140 million years ago, these South African endemics are the epitome of evolution's astonishing capacity to adapt to just about every imaginable vicissitude, to survive against all odds, yet be abruptly extinguished when some vital property of existence is withdrawn, or some novel disease penetrates an organism's defences.

South Atlantic swells have carved this last chilly outpost of Africa, sometimes encircling it as an inhospitable island, but Table Mountain's hard, weather-beaten granitic sandstone has endured, as have spookpaddas and, remarkably, their tadpoles. Chilly waters and a pauper's diet slow their development down to an entire year, yet these hardy little larvae have survived by broadening their lower jaw and adapting their throat skin into a strong adhesive suction-pad that can cling to slithery rocks, while their slipstreamed bodies withstand a year of survival under rushing torrents of near icy water. How could such persistence endure and evolve over so many millions of years, and why?



*Spookpadda or Table Mountain Ghost Frog (*Heleophryne rosei*).*

Their habitat's most durable, most reliable, least changeable but least nutritious resource has been the green algae that coat those slimy rocks, and this is the tadpole's only food, harvested by tongues armed with tooth-like rakes. Only after they have matured into (still rather flattened) adult frogs can they shift to a more nutritious diet of worms and invertebrates, but their webbed and spatulate digits signify that they remain champion clingers, as well as fast, strong

swimmers and expert hiders in crevices, but hopeless hoppers. The steep, shady, once densely forested valley in which the ghost frogs were first found is called Skeleton Gorge, hence the frog's spooky nickname.

The city of Cape Town is built on lowlands lying east of Table Mountain. The town draws its waters from reservoirs built high up on Table Mountain, which capture and store an abundance of rain coming off the cold South Atlantic. Overflows still course down steep, once spookpadda-friendly canyons, but European colonisation brought several unprecedented changes. Reservoir water gets heated by the sun, so the overflows, even when sheltered from the sun, are warmer. I have also seen for myself how fast-growing commercial conifer and poplar plantations have replaced the indigenous forests that were felled long ago. Also introduced exotics, such as livestock and the goat-like Himalayan Tahr, churn up banks and streams, making once crystal-clear waters turbid and contaminated. Worldwide, the Cape is celebrated for its flora and for an abundance of supposedly lesser beings such as spiders and some spectacular insects. Notwithstanding all the vicissitudes that the Cape has suffered at the hands of vandals, generations of noble conservation-minded locals have done much to mitigate some of the horrors associated with pioneer urbanisation. Thanks to their efforts a splendid Cape Peninsula National Park now administers and protects those spookpadda habitats and other wildlife-rich areas that remain.

While almost every geological era has retained vestiges of history in the form of living frogs, India's detachment and cruise away from Madagascar and Africa allowed it to transport many plants and at least two distinct Gondwanan frogs, one survivor being the *Xenopus*-like, miniature-headed Purple Frog or Nasika Frog, *Nasikabatrachus sahyadrensis*, that just survives in one corner of the southwestern Ghats.

*Seychelles frog (*Sooglossus *sp.).*

The Seychelles archipelago (fragments of granite left behind during India's cruise across the ocean) still hosts several species of Gondwanan palm frogs of the genus *Sooglossus*. These extraordinary miniature frogs develop from eggs deposited in a cluster on damp ground. A parent then guards this crèche until the eggs hatch into froglets, upon which they wriggle their way up onto the parent's back. Here, glued by some strange batrachian mucus, they grow to maturity. The vicissitudes of

West-facing view from our home in Mwanza; oil painting by Dorothy Kingdon, 1941.

their islands' long oceanic isolation presumably included periods in which natural ponds dried out, favouring this strangely contrived ontogeny.

In a very real sense, lungfish, killifish and frogs are older than the continents and almost all the world's mountains, including the mighty Himalayas, which are but recent by comparison. In Mwanza I shared the lake shore with fellow beings, fish that were bigger and heavier than me, that had been around in little-changed form for all those many millions of years.

My personal good fortune was to be at home beside a short stretch of lake foreshore where gloppy-bloppy-opteruses, killifish, spiders, *ngo-mwenye-sumu* (scorpions) and an orchestra of frogs lived within the ambit of our verandah. By the time we left Mwanza it had been home for nearly half of my then lifetime. Even now, among the many recollections of an already long life, those two and a half years beside the great lake still seem to occupy a disproportionately large portion of my memory. I am sure that many more of my perceptions were formed there than I can now begin to re-examine or unearth.

Robert Blackburn's map of airfields from London to Cape Town.

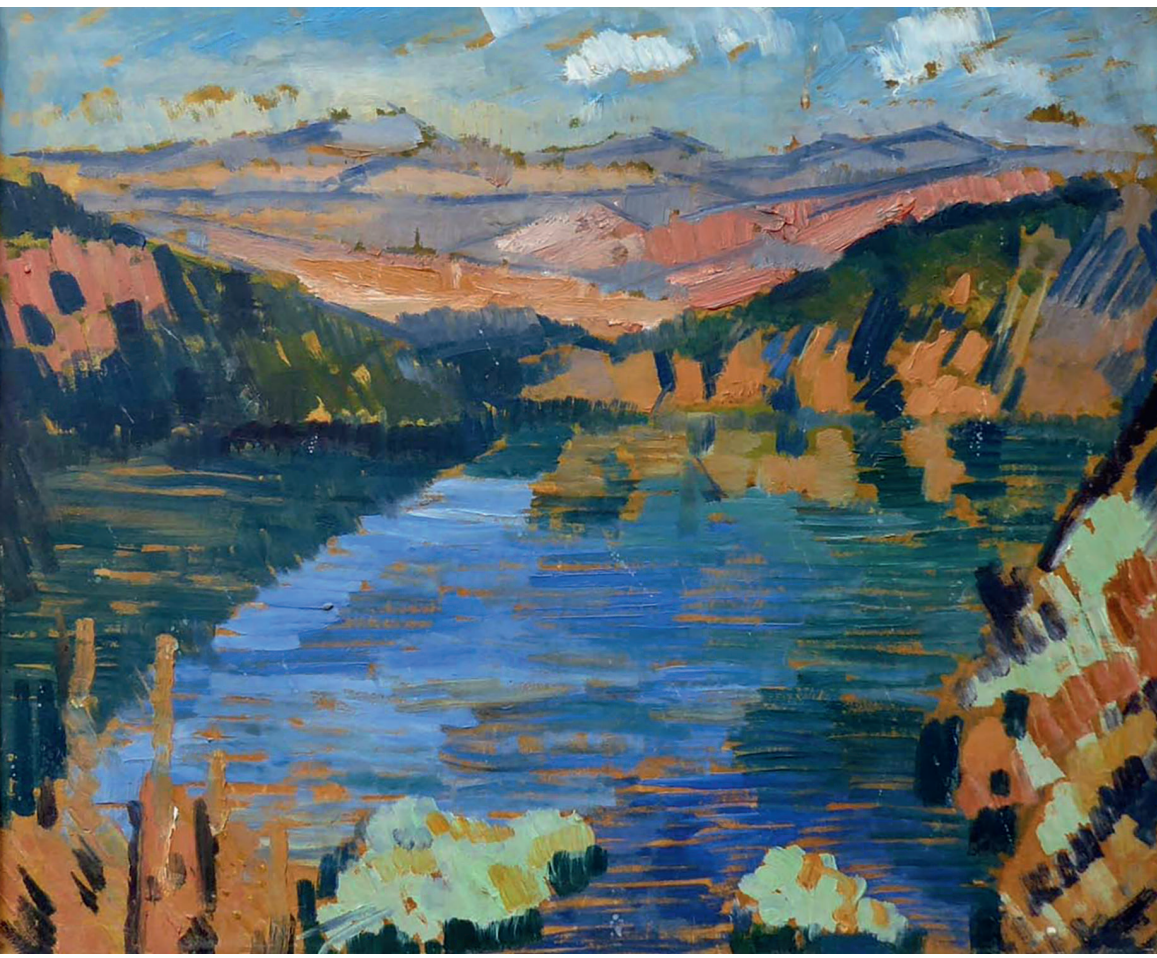
Had I known it at the time, perhaps some such explanation might have tamed some fearful moments that I can still remember as animal terror. My Mbeya School bed bouncing about as if it was being shaken by an amorphous angry dog – cracks opening up across the plastered walls of our dormitory – being peppered by bits of loosened thatch – very loud, rumbling growls from deep, deep below during the darkest hours of night.

An explanation of what was going on might have been calming – but for an eight-year-old animal on his own in a strange bed for the very first time in his short life, perhaps not. Anyway, I never forgot that first earthquake in Mbeya school, where some of us, children of World War II, could imagine we were bound for an abattoir where at least one of our teachers seemed to preside over an educational slaughter-house. That notwithstanding, I remember us as a cheerful little bunch.

Less than three decades before my incarceration in that school, a pioneer plane-builder called Robert Blackburn had an unlikely role in the creation of Mbeya township. During World War I he had turned his factories over to build a fleet of aeroplanes that fought and triumphed over those of the Kaiser's regime. After witnessing his fleet scuttled in 1918 and its remnants sold off to post-war Germany, he became one of the founders of Imperial Airways. Thereafter he battled a succession of British governments almost as incompetent as contemporary Brexiteers. Wanting to develop more versatile routes than the scatter of sea bays, lakes and broad rivers that Imperial's 'flying boats' or 'sea planes' had to splash down onto, he looked for an alternative. He saw that large planes with stout wheel carriages, able to land on *terra firma*, offered much more direct and profitable routes between Africa's capital cities. A brand new London to Cape Town service would link Nairobi and Harare (the latter a copy-cat 'Salisbury' at that time), but the two pioneer cities were nearly 2,000 km apart. Exactly halfway between them lay a broad, flat valley below a tiny Safwa hamlet called Mbeya. Here, Imperial Airways installed an airstrip, a post office, a fuel dump and a small hotel. The sudden, totally unexpected arrival of an airfield with international connections invested Mbeya like no other inland

town with a new sense of being linked to the big, bad world outside. It also attracted Nazi party members, who set up a school there to indoctrinate German children. Such were the precursors for our earthquake-prone, ex-Nazi, Mbeya School.

Today, Mbeya town sprawls over the southern tip of the VM, a region of uplifted rift walls (some of them sheer cliffs dropping into lake waters) and long ranges of hills and mountains. A few kilometres south of the town stands Rungwe mountain, a currently dormant volcano, rarely revealing its summit through the clouds that envelop it. The entire region is freckled with volcanic craters, hot springs and avalanches of pumice. I soon became as blasé as any other locals about earthquakes – they were that frequent. In Mbeya the rumble of Gondwana's fracturing feels as real as those so-ancient continental partings that stranded lungfish and clawed frogs on its floating fragments.

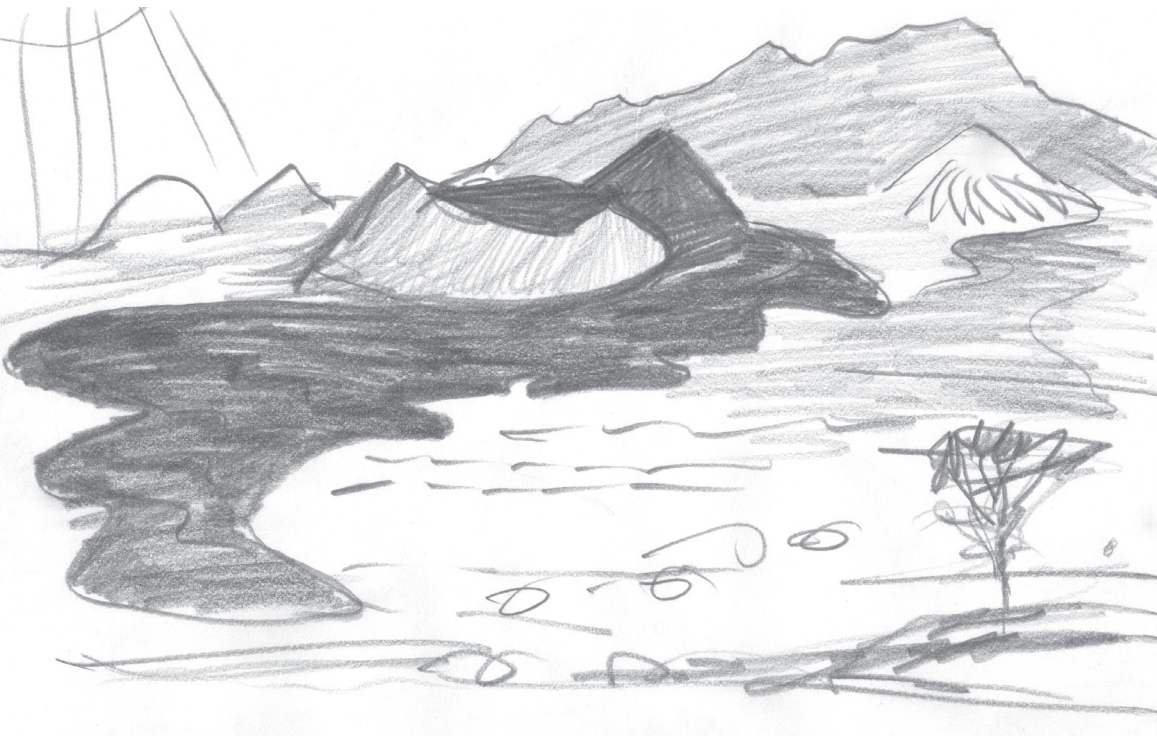


Mbeya valley, as seen from Crater Lake, Mbisi.

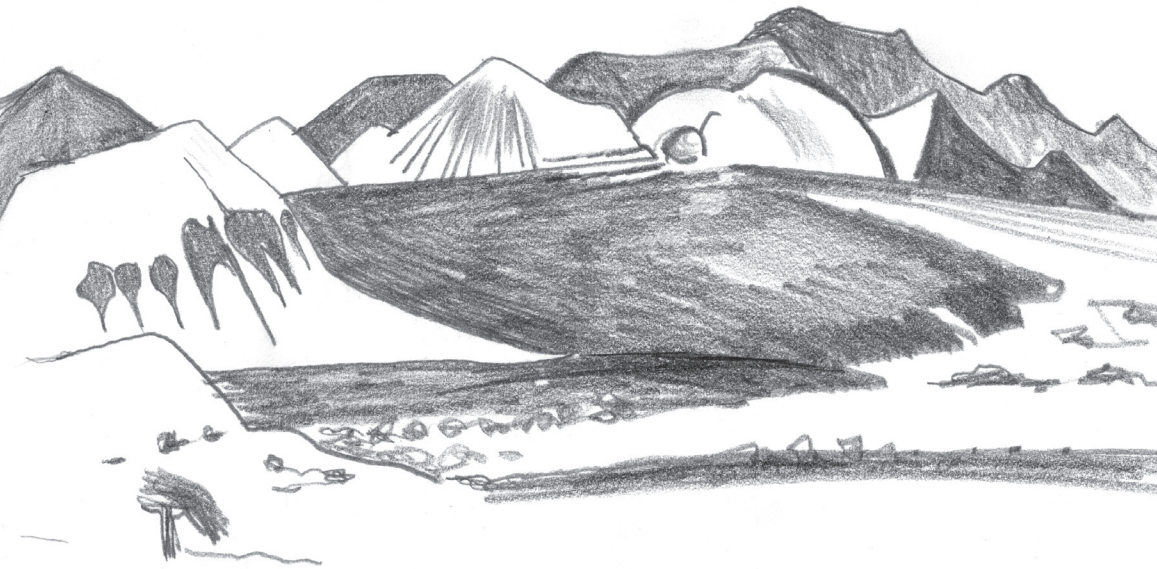
Lake Tanganyika, showing Bujumbura, Mpulungu, Tabora and the eastern Congo watershed.

Old Gondwana's break-up finds something of a replay in Lake Tanganyika, even though the rift it fills began to form a mere 12 million years ago. That rifting has been progressive, the lake deepening and extending south by stages. The lake actually comprises two distinct underwater basins, but its waters have risen and fallen many, many times.

Most fascinating of all, Wegener has taught us that the Earth's land surfaces have pitched and rolled, like floating lilos or the decks of sluggish catamarans caught in cross currents. In Africa it has been suggested that periodic overspills might, at different times, have sent Tanganyika's waters towards at least three points

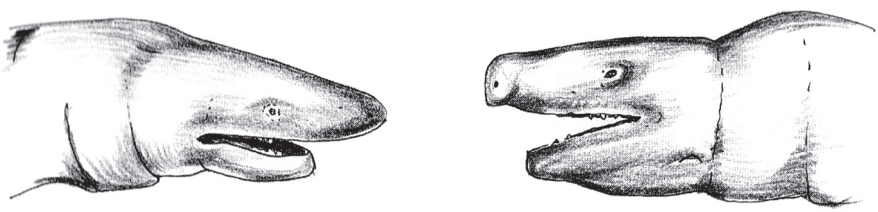


Lava flow near Mzima springs.

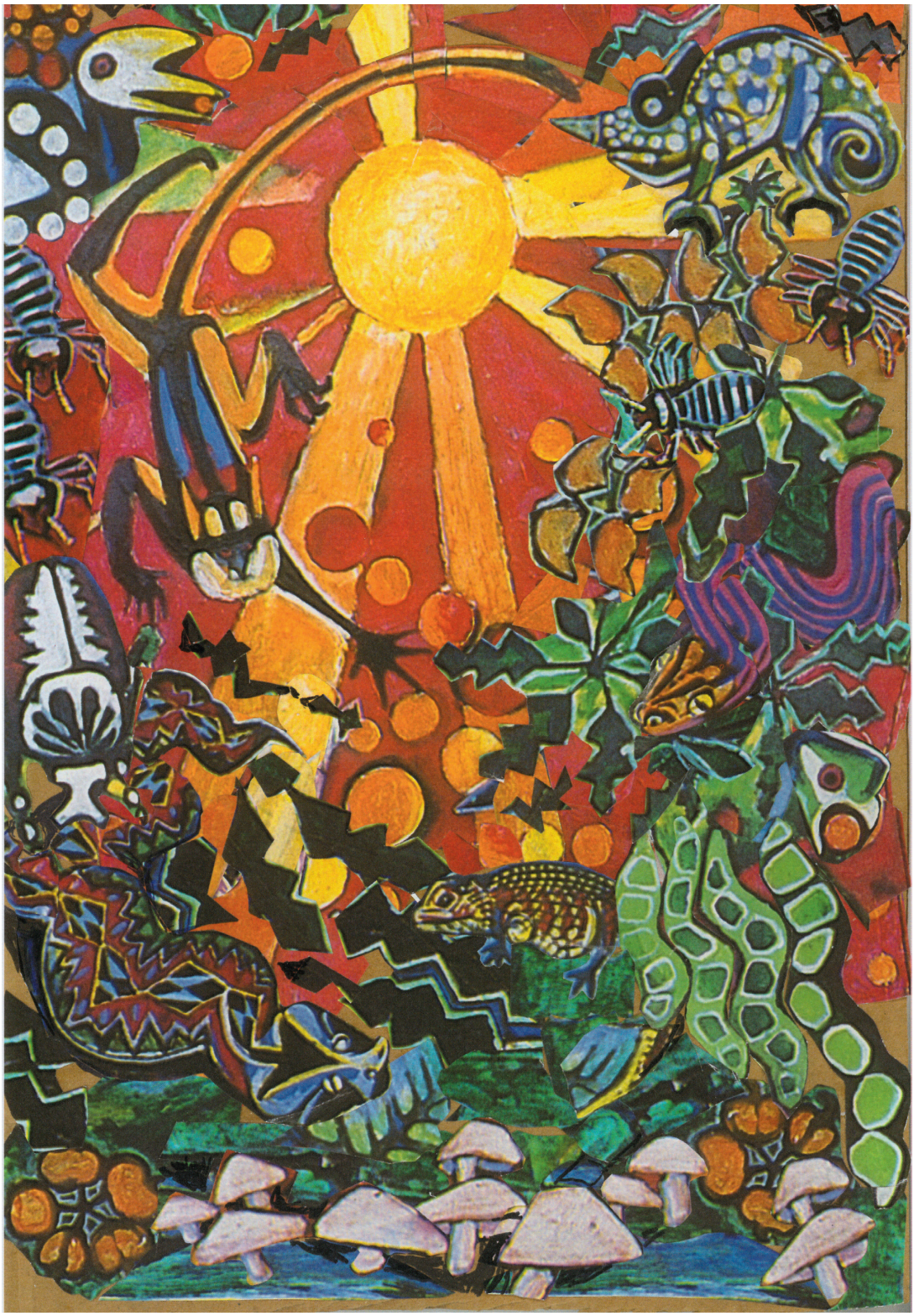


Chyulu hills from Kilaguni.

of the compass – northwards into the Nile, south into Lake Rukwa and beyond, and its present intermittent overflow westward into the Atlantic, via the Congo basin. The rifting margins of slumping valley bottoms often rise up, tilting up former flats until they become near-vertical stratified hills or mountains such as the Rwenzoris. Upstart 'nations' or 'peoples' often use such margins and rifts as natural territorial boundaries. These ancient ranges, especially those that encircle the VM, have served as refuges that harbor interesting endemic biota such as relictual spiders, proteas, *Podocarpus* trees and worm-like amphibian caecilians. I visit all of these in later chapters.



Two caecilians from the Seychelles: (left) Hypogeophis rostratus*; (right)* Grandisonia seychellensis.



CHAPTER

3

DAWN AND CONSEQUENCES FROM CHANCE

In which the dawn of Earth as we know it today is shown to be the aftermath of a cosmic car-crash. The Chicxulub Crater. More frogs and more survivors in The Cape. The Mouse that ate the Laws.

On 20 July 1944, chittering monkeys hugged one another while dogs howled and spurfowl clattered out their evensong. Believers in The Day of Judgement prostrated themselves in terrified prayer. For those in East Africa and India who were unprepared for the sun's eclipse, it was a frightening experience. For those already alerted, pieces of exposed film were held up to witness the moon glide between viewers and the sun, its traverse an ever-larger nibble of The Big Orange until, for a brief moment, a perfect disc appeared, its halo blazing. Then, as the moon moved relentlessly on, sunlight returned to the Earth sliver by sliver.

Was it the sun that moved? Or the moon? Or the Earth beneath us? The ability to predict that eclipse was ultimately a byproduct of countless curious minds, over lifetimes of seasons, all registering links between sky-gazing, shadow-watching and ground-living. These were minds that put a value on close observation, the sharing of facts via language and print, devoted to keeping records and to explaining the sun's prodigality in the tropics – its annual withdrawal at the poles. Sunbeams fathering sunflowers. What we learn from science helps us reassure the little girl who thinks her shadow wants to bite her heels.

Seeing the sun climb, seemingly all wet, out of the sea, then, as it soared slowly overhead, watching crisp shadows glide from pointing west to pointing east until the sun hid behind the Usambara mountains – all of this was physical sensation. At dusk I felt robbed of all that hot light. Mosquitoes arrived and I was packed off to bed under a mosquito net. To interpret and translate such mysteries, a hungry mind depends upon what it is fed by parents, priests, teachers or scientists.

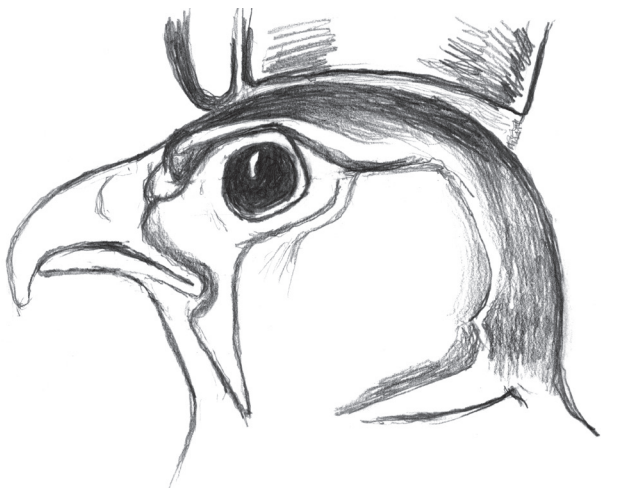
My father's efforts to teach me how Earth circles the sun and how the moon circles Earth were early and memorable. With an orange for the sun in one outstretched hand and a physalis berry for the Earth in the other, he slowly pirouetted himself and the berry around the orange as if he were a ballet dancer –'A full circle is one year.' Then he spun the berry between thumb and digits – 'While the berry faces the orange that's a day, and because it spins, like your top, half of its spin is in the dark – that's a night.' Then he made a much tighter, faster manoeuvre with a pea, making it whizz around the berry. 'That's the moon, but notice that when it's fully lit by the sun but we are in our night-time cycle we

OPPOSITE: *The sun as furnace of life on Earth.*

call it a full moon but while the Earth cuts out more and more of the sun's rays the lit portion of the moon declines, only to enlarge again while what we call a lunar month goes by. When the moon comes between us and the sun, the sun's light gets blocked out for some people somewhere on Earth, and that we call an eclipse.' Such intimate modelling served to reduce the unimaginable vastness of the Universe, let alone the sun, moon and weather, and translate it down to a scale that a child can imagine or visualise.

People have long tried to explain the movements of planets, comets and the starry, moonlit Universe above them in terms of their own little patch of terrestrial territory.

A most surprising and entirely unforeseen connection to ancient Africa and its inhabitants appeared above me during a visit to Egypt, dominated by museums, pyramids and a launch up the Nile. My mind and imagination seethed with exquisite images of Thoth, Horus, Seth and beautiful queens served by regiments of commoners, all depicted in sculptures, bas-reliefs and paintings from Africa's greatest and longest-lived civilisation, all built on the banks and delta of our longest river.



Gold head of Horus with polished onyx eye, Antiquity Museum, Cairo. Extraordinary attention to detail and proportion suggests it was modelled from specimens, alive or mummified, or both.

To avoid a scorching midday we were on a dawn outing to a mosque built on Cairo's not-very-high heights. Emerging straight out of a freshly risen sun, a Peregrine Falcon came stooping down to strike one out of a panicked flock of feral pigeons. Here, right before my own eyes, was Horus, Sun God and falcon-god, announcing his arrival to metropolitan inhabitants of the World's Centre, a city of plump pigeons as well as donkeys and people.

The cliffs of Jebel Iweybid were too far east for ancient Cairenes to learn that Horus and his predecessors spent their nights roosting there. Even so, I cannot be the only non-Egyptian to feel moved by the exquisite crafting that was

lavished upon images, even mummies, of this bird – a smallish raptor that made manifest the abstract wonder of dawn breaking over this precious globe of ours as we all hurtle, spinning as we go, through space.

My father's astronomy lessons were augmented by a Royal Navy-issued telescope that he had inherited from his own father. Perhaps it was my grandfather's subordination to naval discipline and his imposition of it upon his offspring that influenced Teddy's stress on order, in both society and in the known Universe.

If so, our sessions gazing at the moon through his telescope forced him to concede that her plenitude of impact craters showed that the moon had been peppered by almost countless comets, meteors and asteroids. Was it only the moon that was some sort of a target on a shooting range? Or were bits and pieces of cosmic rubbish a perennial hazard out there?

Stained-glass window of moons and moonflowers, Rondo Chapel, south Tanzania.

Teddy was forced to admit that disorder could rupture his predictable fruit salad universe, as he knew at first hand.

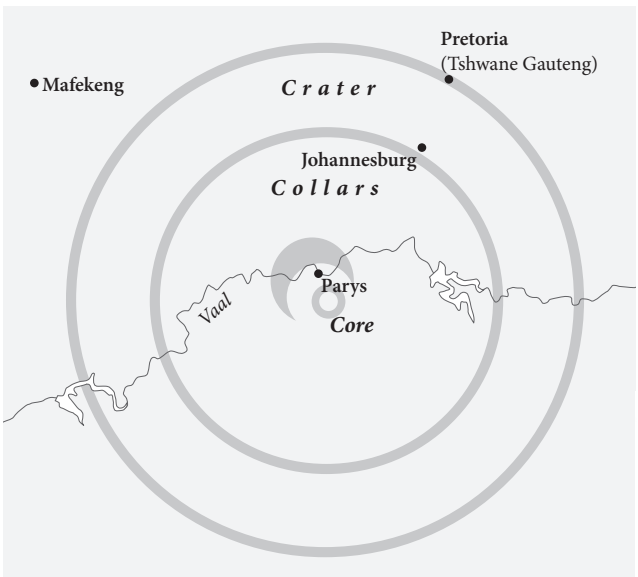
In 1930 Teddy was in Mwanza when a bolide was seen to burn up in the atmosphere, scattering fragments all over the Sukuma hamlet of Malampaka. He also described the night skies of 1933 being lit up with frequent showers of meteors, burning up as they entered the atmosphere.

On several occasions Teddy drove the family out to Mbozi where we picnicked beside 'Kimondo', a then barely exposed meteorite. This chunk of iron and nickel has now been calculated to weigh 25 metric tons. Eating sandwiches, we sat on a surface which, with some imagination, could be said to resemble the back of some prehistoric reptile. Yet no-one has yet devised a date for this metallic bullet's ballistic impact. All traces of its crater were overlaid by later geological upheavals (which have been very substantial all around this disjunction between two rift valley lakes). The oldest craters are now invisible on Earth's surface, but meteors can leave a magnetic record deep underground. Thus, the misbehaviour of compasses in central Africa long ago revealed what has come to be called the 'Bangui Magnetic Anomaly'. Some geologists think this might betray the impact of a meteor strike well over 540 million years ago. Other scientists suggest that perhaps early basalts go down unusually deep below central Africa.

Earth has been hit by random comets many times (more than 300 impacts are on record).

One particularly well-known crater (dated to a mere one million years ago) is hugely popular in Ghana. Close to Kumasi City, this crater is called Lake Bosomtwe. Formed by the vertical strike of an iron meteorite not less than 500 m wide, it created a 10 km-wide, nearly circular crater with its central bore-hole about 8 km wide and 750 m deep. That the levels of the lake's waters have fluctuated wildly is betrayed by fossil fish being found near the peaks of surrounding hills, and by divers finding drowned tree stumps on the lake's floor.

Known to have shrunk to a puddle during past periods of drought, this lake figures in a telling folk-tale from long before the Ashanti became the populous people they are today. Pursuing what was probably the water-loving Sitatunga antelope, a legendary hunter lost all sight of his quarry when it submerged itself into what was then a vestigial lake lining the then forested crater's depths. Impressed by what he took to be the intervention of a god with a special fondness for antelopes, the legendary hunter and his audience named the lake after that 'God of the antelope' – Bosomtwe.



The Vredefort crater, also known as the Parys crater. BELOW: *An 8,000-year-old image of a hippopotamus is engraved on one of the crater walls.*

For the most pictorial visual effect, a perfect circle of cliffs in the Kalahari, some 70 km across, is perhaps the closest Earth gets to our equivalent of a lunar impact crater. Morokweng crater (with the charmingly named hamlet of Pom-Pom perched upon its rim) is dwarfed by its near neighbour, the 2 billion-year-old Vredefort crater which, with a diameter of 300 km, is the largest known crater on our planet. The meteor's effects are particularly well known because

its impact liquefied the Earth's surface, melting a pond of minerals that included a lot of gold and uranium. The margins of this pond solidified into a series of very hard rings, known today as the Witwatersrand reef, and 100 years of gold extraction have left a landscape of mine tailings that eerily mimic the mounds of harvester ants, on a gigantic scale. Seen from the seat of an airliner, one rim of the inner crater is still just visible. Billions of years of erosion and the more recent cut of the Vaal river have blurred the rest of the imprint of a freakish bolt from outer space.

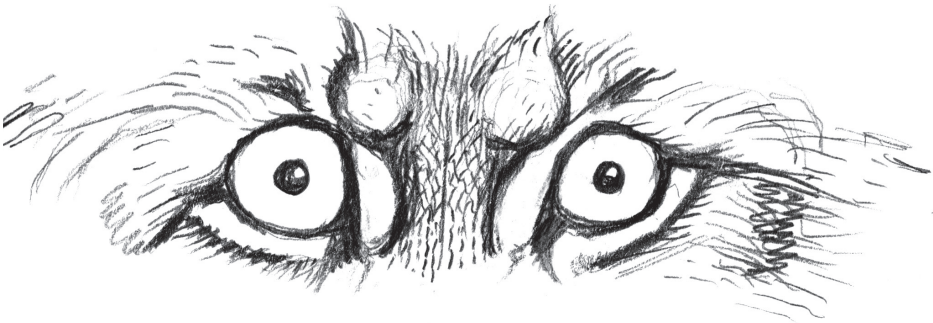
Was this the most grievous wound ever inflicted upon a world that just happened, at that very moment, to be in the path of a stray asteroid?

For the random event that has shaped our very existence, we must now turn to one fateful April moment 66 million years ago when a meteor, like many before it, nearly shot past the Earth. A matter of minutes, earlier or later, and gigantic reptiles might still be the dominant form of life on Earth. Instead, there was a cosmic car crash, as much an 'accident' as any collision on an autobahn.

We owe the story of that collision to a great father/son scientific duo: Luis and Walter Alvarez. It was their pursuit of an inexplicably rare mineral, iridium, that led them to be the first to describe the many dreadful consequences of a 10 km-wide meteor slanting in from the south to slam into today's Caribbean Sea, at about 25 km per second. The impact ignited a fireball reaching temperatures of 1,300°C and gouged a crater 14 km deep and 180 km wide. The whole site, sometimes labelled 'Cemetery of the Dinosaurs', is now under about 1 km of limestone, a tombstone that stromatolites and corals have helped to thicken with each passing year.

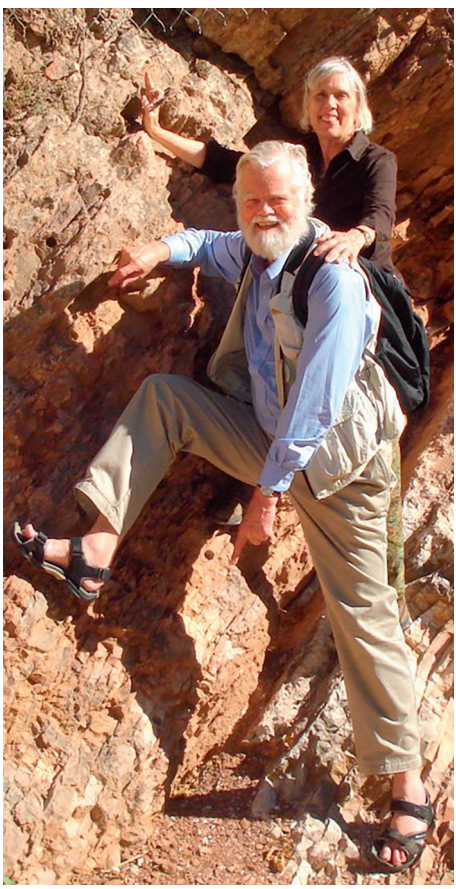
The closest contemporary on-land settlement to the point of impact is a Mayan village on the Yucatan peninsula, called Chicxulub. Get used to this tongue-twister because the Alvarez team gave this name to their giant, now underground, under-seafloor crater, and I will use it throughout this book for my single most important temporal point of reference.

The Chicxulub meteorite (just as correctly called an asteroid or a bolide) came in loaded with extraterrestrial iridium. When the meteorite and the walls of its crater vaporised, iridium, together with the tiniest of glass spheres, shocked quartz and traces of new, shock-induced minerals got blown through Earth's atmosphere and stratosphere. Some of this iridium-laced cloud of material continued onwards out into space. Eventually falling back to Earth, it left its momentary autograph all over our planet, with its heaviest particles falling closest to the crater, along the path of its blast and in the tsunamis and fireballs it engendered. The 'iridium layer' has become the geological and chemical marker that lies between the C(K)retaceous (K) and then Tertiary (T) periods of geological history. In Italy, that iridium layer can be seen with the naked eye as a very thin black stratum, separating the once life-filled K and near-lifeless early T. It is called the KT boundary and the catastrophe it marks is known as the 'KT Event' (often revised into 'C-Pg', but the more euphonius KT remains more popular).



The lynx's eyes.

We owe much of this vocabulary to Papa and Son Alvarez and their many collaborators, some of them Italian. Because Italy has a long and illustrious tradition in both science and in ceramics, her soils have long been explored and analysed by thoughtful minds and attentive eyes. The phrase 'eyes of a lynx' was appropriated by a brotherhood or academy of scientists founded by an 18-year-old in 1603 and based in secular Rome – this body is still called 'The Lynxes' or 'Academia dei Lyncei'. It was natural for Luis and Walter Alvarez to turn to Italian sources to lead them to a rugged gorge close to the hill-town of Gubbio, famous for its Maijolica pottery and a historic source of knowledge about local minerals. There, for every passer-by to see, is the KT Event writ large in coloured rocks.



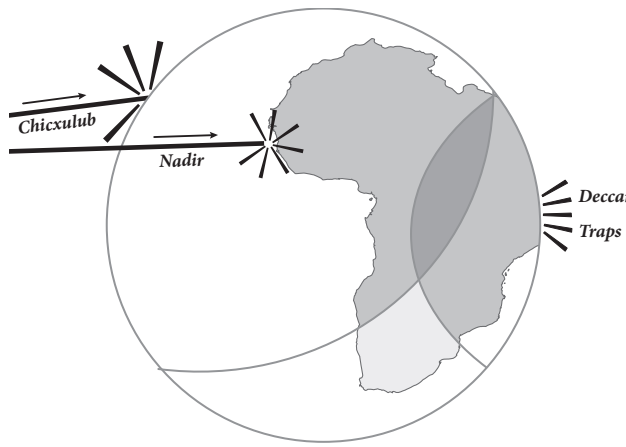
Jonathan and Laura straddling the KT boundary at Gubbio, Italy.

Inspired by the Alvarezs' thrilling adventures in collaborative research across multiple disciplines, I and my wife, Laura, visited the gorge where their team had studied this particularly graphic exposure of the KT boundary. It was a thrill, perhaps a perverse one, to stand (and even be photographed) with one foot in the Cretaceous, the other in the Tertiary, each separated by that thin but portentous black line.

The prime victim of the KT Event was North America, where extermination of life was almost total. Europe and northern Asia fared little better. Australia, southeastern Asia and southern South America were all devastated, but their hardiest organisms, including particularly sturdy plants and some small animals, survived to inherit the Earth. Most of Africa was caught among three global catastrophes, all, so far as is known, deriving from the colossal jolt of impact.

At the same time as Chicxulub, a detached fragment known as 'Nadir' hit the continental shelf off Guinea. In a third, simultaneous cataclysm, a series of enormous outpourings of super-heated magma belched forth from the western edge of India (at that time a vast migratory island) – these lava flows are known as the Deccan Traps.

'Hot-spots' drive mid-ocean spread, so it is possible that Chicxulub may have jolted or influenced the opening-up of an already weak furrow cut by India's deep actively moving western margin, thus exacerbating this huge eruption of lava.



Combined impact of Chicxulub, Nadir and the Deccan Traps on Afro-Arabia 66 million years ago.

For most of Africa, the effects were dire. At the time of Chicxulub, Africa's northern reaches included today's Arabia, and all of this vast territory was caught between the three major sources of global destruction.

Southern Africa seems to have presented a brighter prospect. The previous chapter discussed the many resemblances between the biota of South Africa, southern Australia and southernmost South America, in terms of their including some survivors from ancient Gondwana. That may apply to some families of ancient vertebrates, invertebrates and plants, but by the time of Chicxulub many tens of millions of years had passed since the break-up of Gondwana.

We now know that the comet hit in the southern autumn – time to hibernate.

This potential for survival from Chicxulub's devastation can be illustrated by a lineage that has given rise to two frog genera that reinforce the likelihood that underground hibernation favoured survival after Chicxulub. Shovelnose frogs, *Hemisus*, and short-headed rain frogs, *Breviceps*, are deep burrowers, able to go

Two drawings of Isinana, *the Spotted Shovelnose Frog (*Hemisus guttatus*).*

into long-lasting torpor deep underground, or in crevices. Such a strategy could have allowed frogs or other animals to outlive the KT catastrophe, whether in adult, larval or egg stages.

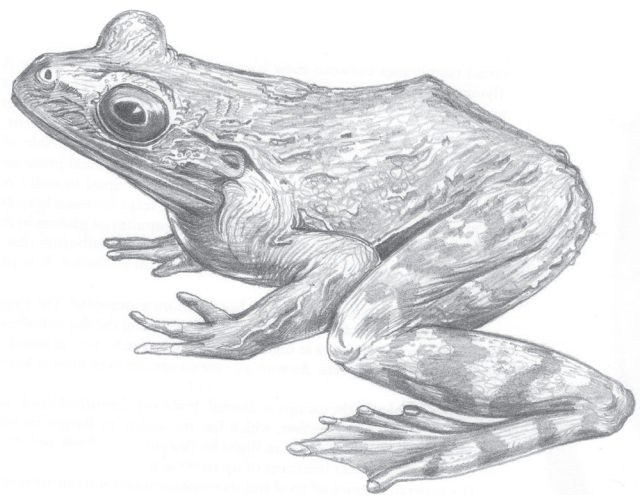
As a small boy in what is now Kwazulu-Natal, I was shown a Spotted Shovelnose Frog, *Hemisus guttatus*, locally known as *Isinana*. This burrower can survive long periods deep underground with all obvious life-signs suspended. In the rains it emerges to copulate and to release developing tadpoles or froglets, and to perhaps enjoy a brief aquatic existence. Today *Isinana* only survives on flat flood-plains beside a very few river basins in Kwazulu-Natal. It has a horny-tipped nose, fingertips and heels. Where muscular hind legs serve sudden and surprising leaps in other frogs, in shovelnose frogs they power forceful, persistent rowing through sandy soil. Females guard a jelly-cushioned underground nest containing some 200 eggs.

Their survival is consistent with the south being the only, albeit precarious, refuge from Chicxulub in Africa, but their mole-like behaviour has allowed closely related but somewhat more versatile species to expand their range. Among them are the rain frogs; family Brevicipitidae.

I remember my father charging me as a teenager with excavating three *hafirs* or reservoirs to irrigate his coffee shrubs. More than 2 m underground I encountered a fat, cappuccino-coloured frog, encased and immobile within its cramped little follicle. How this Rungwe Rain Frog, *Probreviceps rungwensis*, had managed to insinuate itself so deep underground was a mystery only just explicable while deeply cracked soils were so sodden that this apparently feeble frog could

Rungwe Rain Frog
*(*Probreviceps rungwensis*).*

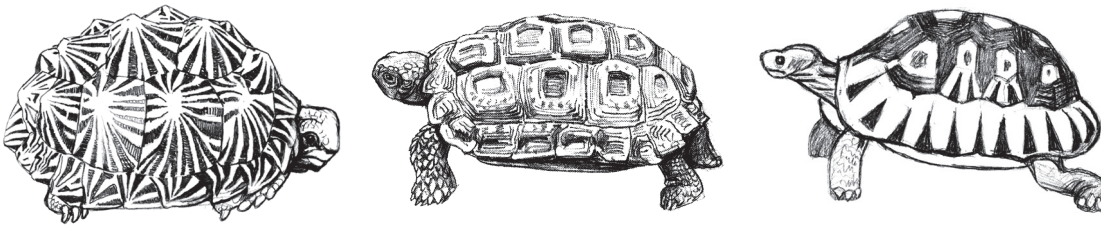
Goliath Frog
*(*Conraua goliath*).*



half-dig, half-swim its way down many hundreds of times its own length through soils that become impermeable in the dry season. When attacked, both rain frogs and shovelnose frogs can inflate their bodies to almost spherical proportions, while sweating out noxious, glue-like exudates that deter most potential predators.

Another lineage that gave rise to many other African frogs includes the Goliath Frog, *Conraua goliath*. This species begins life conventionally enough, its eggs and tadpoles resembling those of related torrent frogs (among frogs, 'close' cousins can be more than 60 million years apart!). Goliaths earn their name by growing, growing and growing, until they reach up to 3.25 kg, with legs as long as a child's. As builders and sentries of stony, weedy frogs' nests beside rushing torrents in a few West African rivers, these, the largest frogs in the world, are doomed by collectors, zoos, road-side gourmands and most of the many afflictions that threaten frogs today.

In contrast to weak frog forefeet, many animals, especially the digging mammals, have hardened claws on tough, muscle-bound forelimbs. These



*Three Cape tortoises: (left) Geometric Tortoise (*Psammobates geometricus*); (middle) Speckled Cape Tortoise (*Chersobius signatus*); (right) Angulate Tortoise (*Chersina angulatus*).*

adaptations for subterranean life are undoubtedly ancient, not recent contrivances. Whether the ancestors of two deep-digging mammal lineages, the Aardvark and the golden moles, had parted ways by Chicxulub is still debated, but their divergence seems most likely to date from Chicxulub. Aestivating tortoises were other likely survivors.

Contrary to popular belief, ancestral mammals have been around just as long as ancestral reptiles. Less certain is just how far the radiation of placental mammals had proceeded before Chicxulub. Scientists working with molecular clocks reckon that many ancestral stocks had already evolved. Clearly, Chicxulub was the main 'releaser' for the radiation of mammals, but the rarity of their fossils before 66 million years ago tells us that most mammal lineages (as well as most of those of birds, and even frogs) radiated after KT.

To further complicate matters, these questions interact with controversies over *where* placental mammals first evolved. Mark Springer, at the University of California at Riverside, argues that the most primitive of surviving placental mammals are found in Africa, and that an early freak transport took one lineage to South America where sloths and armadillos are among their descendants. Nonetheless, neither Africa nor South America is the mammals' Eden – that distinction belongs to Asia.

Among Africa's survivors (first named 'afrotheres' by my dear friend Alan Walker) are Aardvarks and golden moles. These burrowing afrotheres are especially interesting in the context of Chicxulub because (in common with armadillos) they were perfectly adapted to survive the devastation by living underground. Even today, golden moles scarcely exist north of the equator and they are among the many groups of animals and plants that have found their main refuge in South Africa (where promoters of agro-forestry, sugar and other industrial crops now seem dedicated to their extermination). Burrowing afrotheres are interesting not only as survivors of Chicxulub, but also as models to exhibit some of the advantages mammalian hot-bloods had evolved over reptilian cool-bloods long, long before the meteor struck. In Chicxulub's wake, Earth became a sort of planetary bomb-site. On a blasted continent that was effectively a vast oceanic island, its southern extremities became the main source of survivors.

(continued...)

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I