CHAPTER ONE

A Gneiss View

Pre-Cambrian eon – from 1 billion to 3 billion years ago

It was a bright day in early March, the sun was shining and a substantial fall of fresh snow lay pristine under an arching blue sky. I stepped off the train at Lairg, midway along the line that winds its way from Inverness to Wick in the far north of Scotland and wondered whether the postbus would be in the station car park or somewhere between there and Lochinver, lodged up to its headlights in snow.

So I counted myself lucky to be greeted by Donald and his postbus. The morning collection in Lochinver was, by his account, a little hairy – he had to take several runs at the hill out of the village and nearly didn't make it at all – but he got through in the end and by the early afternoon, with a slight thaw under way, we were soon heading off on the final 40 miles of my journey to the top-left-hand corner of Scotland.

I was on a simple expedition, to find Britain's oldest landscape, and I could not have picked a better day for it. For one thing, everything assumes a mantle of unfamiliarity in the snow. The world is turned on its head, with the commonplace all of a sudden rendered ripe and ready for

The Pre-Cambrian Lewisian gneisses

discovery. As a newcomer, with every twist and turn of the road a new experience for me, the layer of snow added dumb secrecy to every moment of the journey, a sense of an approaching surprise, an imminent unveiling, never resolved in its entirety. It also made everything seem quiet, tucked up, quiescent and still; the absolute antithesis of its own creation – of all our creations – a brimstone-fuelled and -filled affair, a sulphurous, acrid hell or a million-year monsoon, the various infernos and biblical deluges that started the world.

Between the wrath of the earth's creation and the stillness of that day, however, the Highlands had not simply ground to a halt quietly over time. Far from it, the Scotland I was travelling to, in particular, was at the centre of enormous turbulence in the earth's formative history and then again over 2.5 billion years later. I was going there on a mission to uncover some of this chaos anew; that was my imminent unveiling.

The postbus barrelled through the ancient mountains of Sutherland, down the single track road to Inchnadamph and beyond. Our 40-mile drive was almost wholly over one feature particularly troublesome to the Victorian geologists and which resulted in fifty years of debate, point-scoring, obstinacy and political careerism (of which, more later) but I was heading for the strip of land beyond – towards a landscape that holds a fascination all of its own.

Despite the thaw, as we made our way up Strath Oykel, there was still plenty of snow around and that was good news for any expedition for which the operational parameters boil down to 'look at the ground' because in those circumstances, snow, as Donald observed, 'reveals more than it conceals'.

He was right in that the overall structure of things becomes more visible when detail is obscured in this way; in such conditions, for example, the thin horizontal terraces – bedding planes – that girdle the mountains are picked out like the lines of ribbing on a gargantuan airship. Reduced to its essentials, snow-bound scenery is an invitation to explore the grand line of nature, the sweeping statement of a landscape rendered by brute force on a planetary scale. If you don't believe me, the next time you experience some severe winter weather, go and look at your local landscape; you will suddenly notice a few details you have never seen before – perhaps the odd hummock or two, or a series of lines on a hillside that reveals how soil creeps slowly downhill over time. It is all there, the detail of it just needs to be hidden in order for us to notice.

As the bus trundled on, a quick glance at the Ordnance Survey map underlined the daunting beauty of the terrain. Feinne-Bheinn Mhor, Coigach, Cul Mor, Quinag and Suilven; the names of draughty peaks came howling from the map like disconsolate wails. Lochs Glendhu, Borralan, Urigill, Culag and Bad a' Ghaill, too, sounded like Tolkein's place names, but the scenery outside the bus was of even more epic proportions. Even a lone stag, magnificently and picturesquely framed on the skyline like a commercial for whisky, water or life assurance, failed to draw my eye for long before it was pulled back to the matter in hand, the potency of the land itself.

West of the road that connects Inchnadamph, Stronchrubie and Knockan Crag, with Durness to the north and Ullapool to the south, that power began to become apparent. Here lies some of the basement rock of Britain – a slab of crust two-thirds the age of the planet on which the entire edifice of Scotland is presumed to rest. This group of rocks – known broadly as the Lewisian gneisses – are metamorphic in origin. That is, they were originally another type of rock altogether and were changed into the form we see today by enough heat and pressure to recrystallise, but not melt, them. They are amongst the oldest rocks in the world and, because they are of metamorphic origin, the Lewisian gneisses were formed somewhere deep, perhaps 30 miles, underground within the crust. From a distance they look a little like granite, but at close quarters they have a distinctive, banded appearance, their alternating dark and light stripes a by-product of their particular formation under extreme heat and pressure. Under the conditions in which the rocks of the Lewisian Complex were formed, minerals that make up the rock were separated out and arranged themselves into alternating layers: the higher density minerals are dark while those of less substance form paler bands within the rock. In places, the stripes twist and turn, squeezed this way and that under monumental force as if the rock once had the structural integrity of toothpaste.

Donald pointed here and there as he told countless stories from the Highlands. Of bank robbers holed-up in isolated shacks; the village bobby turned part-time poacher; and the old lady from Caithness who fought off a military rescue team with a broom during the 1947 blizzard because she believed her rescuers were from another planet.

As Donald stopped to drop off the daily papers at an isolated farmhouse, I saw the chance to take a picture while he struggled with the uncooperative latch of a shed. Climbing out of the postbus, I stood on rock that is close to 3 billion years old, itself just a reiteration of the even older crust that lay here before its mutation into gneiss. When the gneiss was turned into its present form, the earth was much more dynamic; the heat flowing from the planet's core was of a greater intensity than now, largely because there was more radioactivity around – radioactivity which by its very nature, has declined over the life of the earth. The crust that eventually became the gneiss would have been buried by the movement of other bits of crust, gradually building up pressure as it was pushed further down. Under such circumstances, the ground I was now standing on would once have been over 650°C.

The ancient rocks exposed in this narrow strip of land between the main road from Ullapool to Durness and the west coast from Cape Wrath to Loch Broom, as well as on Lewis and other Western Isles, are not all the same however and the term 'Lewisian gneiss' is a bit of a catch-all expression. Even a casual sampling of gneiss across the region will reveal that, rather than a distinct and discrete band of rocks, an entire geological system has been metamorphosed. Muds, limestones, volcanic lavas and rocks formed from molten magma that cooled very slowly underground[1] were the original rocks – or protoliths – and were all metamorphosed in the same manner, but are now counted almost as a single species, despite having differing chemical compositions. And even where you can be sure that you are standing on just one kind of gneiss, it isn't always that simple because the landscape is dotted with further intrusions into it. You can see how complex the geology can be in a location just north of Laxford Bridge, at a spot where the formerly single-track road was

1. Magma is, in essence, lava that has not reached the surface.

improved and widened. When the Highland Council made the A838 wider in 1991, a number of cuttings were made to accommodate the new carriageway, one of which has now become the site of the most fascinating lay-by in the country.

Following the granting of European Geopark[2] status, the whole west coast road from Ullapool to Durness – which includes the A838 – has now been christened the 'Rock Route' by Scottish Natural Heritage and hosts a dozen colourful sets of context boards outlining the geological spectacles en route. The whole Geopark venture is geared towards conservation, sustainable development and education and it is clear from the educational materials that they make available, that Scottish Natural Heritage have something of a popularising streak.

That desire to explain in clear, layman's language is responsible for one of the stop-offs on the Rock Route, the excellent Knockan Crag Visitor Centre near Elphin, where families, students and solo tourists can cheerfully whittle away the best part of the day becoming surprisingly knowledgeable about Scottish geography. It is horses for courses on the rest of the Rock Route, however. A lay-by is not a long-stay attraction and is often only a place to decant tea from a thermos flask or start a short, pointed argument about map-reading, so any educational effort has to cut its cloth accordingly. With a joviality some may find annoying, the Laxford Bridge lay-by has been labelled as the Multi-Coloured Rock Stop. (It must be hard to select

2. The European Geoparks Network is a group of thirty-four areas – five of them in Britain – all with highly significant geological heritage on display and all promoting themselves as sustainable tourist attractions.

appropriate language and typography for every passing visitor, so the default setting for promoting public interest in science these days seems to be self-consciously 'wacky' – a style which would not be out of place in a hair-gel advert that features three androgynous teenagers getting out of a lift in fluorescent zoot suits with saxophones.)

Arguments about the presentation of science aside, the Multi-Coloured Rock Stop is an astounding feature. Three different ages of rock can be distinguished on the cutting opposite the lay-by and even the artefacts left behind by the road contractor's rock drills – regular parallel incisions down the rock face that look like a geometric overlay – only add to the effect. Pale-grey gneisses represent the original rock. Swirling across it with the twisted teardrop freedom of a Paisley pattern, a dark brown-black basalt which formed as a dyke[3] as it squeezed through a weakness in the gneiss. Finally, streaks of pink granite cut through both the gneiss and the basalt dyke and so must be the youngest of all three. The gneiss of the North West Highlands feature swarms of later dykes and sills – in particular, there is a group of dykes around Scourie, the exposure at the Laxford lay-by being a particularly good showcase.

Wherever the gneiss outcrops, it does so as open rolling lowland moors, for which the official geological adjective appears to be 'hummocky', punctuated by countless lochs and lochans with the odd mountain towering incongruously above. The hummocks are a product of both the geology and ancient history. Glaciers grinding their way

3. A dyke is an igneous rock formed as magma forces its way through a weakness across the bedding plane of a rock. A similar structure is a sill, which is formed in the same way, but runs along the bedding plane.

over the gneiss sought out every imperfection and weakness in it and by the time that the latest glaciation had reached its peak around 20,000 years ago, the sporadic tectonic activity of almost 3 billion years had led to widespread and wholesale faulting along with swarms of the same intrusive magma dykes that we see on display in the Laxford lay-by today. The ice – up to 800 metres thick at its height during the last glaciation – scoured the landscape making countless hollows of every size, which are now occupied with lochs, lochans and Scottish puddles.

In a sense the old lady from Caithness was right, though perhaps not in the way that she thought. Contrary to appearances, the military rescue team arriving in their insectoid helicopters, wearing jumpsuits and helmets with visors, were from planet Earth, after all, but this part of the Highlands looks as forbidding as the landscape of another world entirely. Almost, at least, but not quite; it is more as though it is an artist's impression of another planet, like one of those quarries where the BBC filmed cheap science fiction series in the 1970s. There are rocks everywhere, some of which are scattered around in a seemingly casual fashion. It is difficult to scatter rocks casually when they range in size from a Calor gas cylinder to a family estate car, so what seems like nonchalant positioning is not so much the work of a bright-yellow JCB than the result of movement by glaciers of staggering proportions a few thousand years ago. This is no quarry for parking the Tardis in; there is something elemental at work and man has had no hand in it at all.

Most of the rock seems to grow from the ground, cropping out from between clumps of poor, peaty earth in rounded pillows that form hundreds of tiny crags and cliff faces, each about ten feet high. It is one of those rare landscapes, in twenty-first century Britain, that is devoid of all human detail and, because of those little crags, carries off the look of another landscape in miniature, like an '00' scale model of the Peak District or a 1:20 recreation of Bodmin Moor.

Once you have arrived in this unique landscape, you may be surprised, as I was, that it feels so ancient, so primeval – as well as alien and elemental. All wilderness has a greater or lesser quality of undomesticated menace about it, as if an absence of human civilisation strips away our higher rational thoughts to let the limbic mind loose, with its twilight programme of instinctive fear unfettered or filtered by logical thinking. A human embryo, it is said, has a passing resemblance to all the evolutionary steps taken since our ancient ancestors flipped out of puddles and ponds onto land millions of years ago. Perhaps pre-human landscapes like these feel so old because we recognise them subconsciously and revert to using our palaeomammalian brains but, either way, the gneiss is a terrain that plays all kinds of tricks to subtly subvert the expectations of the observer. For one thing, it is lowland moor which is in itself a rarity; most of us expect a long climb up into the hills before encountering a rocky, boulder-strewn landscape, but here there is rugged and unforgiving terrain at the same altitude as an East Anglian hill, a gentle eminence: a down of the kind you might not even realise you have climbed. The low altitude of the moor, the wide horizons devoid of familiar scale objects and the peculiar landscape-in-miniature effect also conspire to make any genuinely tall mountain that rises from it into a Himalayan behemoth of the first order.

Near the west coast fishing port of Lochinver, one such mountain the rough shape of a policeman's helmet, Suilven (pronounce *sool-ven*), does exactly that and dominates the entire landscape. It stands like an ancient sentinel and draws your mind to seek comparisons with either a lighthouse or a wild version of Tolkein's 'Eye of Sauron'. Officially classified as an inselberg – an isolated peak that rises abruptly from a plain – the scale of Suilven radiates a magnificent primordial quality over the whole scene. You might half expect, as I did, to see a diplodocus in Loch a' Choireachin, but will have to be content instead with my observations – a pair of goldeneye and a bright-yellow rubber duck thrown in by some local wag.

Suilven, like other mountains that poke up from the Lewisian scenery, is made from almost horizontal beds[4] of Torridonian sandstone[5] that was laid down in large, shallow lakes and rivers when this part of Scotland straddled the tropics a billion years ago. It is just one of a group of similar mountains which run down the west coast between Cape Wrath and the Isle of Skye, a group that probably formed one long escarpment until it was scoured and

4. As an aside, the near-horizontal layers of sandstone show us that not everything is always as it seems. You might deduce from their horizontal structure that they have never been tilted, but a subsequent layer of rocks is tilted up to 20 degrees to the east. Since sediments are laid down in horizontal layers, this means that the Torridonian beds were tilted that much to the west at some point after their initial formation, then eroded to form a flat surface. The subsequent rocks were then laid down and a subsequent tilting has restored the sandstone to its original orientation.

5. Rocks that have been formed under the same conditions and in the same period are named after a defining example called a 'type locality'. In this case, the type locality is near the village of Torridon in Wester Ross, hence they are referred to as Torridonian sandstones.

battered, worn down and washed away by a billion years of wind, rain, rivers and glaciers to its present state.

The inselbergs are therefore the eroded remains of an enormous sheet of sandstone and conglomerates[6] that was once at least 4 miles (6.5 kilometres) deep. Rainfall swept sediment off the gneiss hills and deposited it not only in wide valleys, but also in enormous alluvial fans at the base of the mountains. The erosion and deposition were of such a scale that one alluvial fan is about 30 miles (48 kilometres) wide and almost 500 metres deep (it forms the cliffs of Cape Wrath and extends as far as Quinag[7]). The alluvial fanning pattern of all the Torridonian deposits is most evident in the Bay of Stoer, about a 7 mile (11 kilometres) drive along the narrow and spectacular coast road from Lochinver. Around the northern arm of the bay, the sandstone has eroded along some of its bedding planes to reveal a magnificent sight: the surface of an ancient riverbed complete with a sheet of 1 billion-year-old ripples.

Meanwhile, where all of the sandstone has been removed, it leaves the Lewisian gneiss displaying the contours of a landscape frozen at the moment of its inundation by the sandstone. The gneiss was buried when there were no complex organisms on the planet – when even the diplodocus was a distant and unlikely possibility. In fact, when it was overwhelmed, there was no life at all on land because atmospheric oxygen levels were not high enough

6. It's hard to make them sound exciting by telling you that conglomerates are coarse-grained sedimentary rocks made up of rounded fragments (less than 2 mm in diameter) within a finer grained matrix that cements them together, but sometimes the truth just hurts.

7. Pronounced *koon-yag*.

to form an effective ozone[8] layer. Without an ozone layer filtering out the UV radiation from the sun, the surface of the super-continent would have been hostile to all forms of life.

If you look closely around the North West Highlands, you will discover places where it is plain that the billion-year-old Torridonian sandstone lies directly on top of the 3 billion-year-old gneiss. If you do, you will find evidence of an unconformity – a phenomenon which represents a break in the geological record in that, for a period of time, there were either no fresh deposits or those that were laid down were all swept away. In this case, the gneiss has been exposed for a long time before the sandstone was deposited and has been somewhat eroded from its original form as a result.[9] Its exposure to the forces of erosion was long enough to create a landscape which, protected by the shield of Torridonian sandstone, survives to this day. Stripped of what little vegetation grows now on the gneiss, there is no need to imagine the contours of a billion years ago because, between the peaks of the Torridonian inselbergs, they are plain for all to see.

All of this – the inselbergs, the unconformities and the wild, antediluvian overtones – add up to one of the most

8. Ozone is an exotic form of oxygen – one with three atoms per molecule rather than the standard two. It forms a high-level layer in the earth's stratosphere at an altitude of approximately 6 miles (9.5 kilometres). The effect of our ozone layer is to shield us from between 93 and 98 per cent of ultraviolet radiation from the Sun. Earth has had an effective ozone layer for only the last 450 million years.

9. At Slioch, a Torridonian mountain that towers above the shore of Loch Maree near Kinlochewe, you can see how a valley in the old gneiss has been filled in by the sandstone.

extraordinary landscapes you are likely to see in these islands. The North West Highlands are a singular landscape, but one which demonstrates as well as any other part of Britain the tapestry of events responsible for the lie of the land.

I needed to write about the North West Highlands first, not just because the top left-hand corner is a good place to start any book, but because this is the area of our islands where the story of Britain started. The landscape of lochan and monadnock (and I'm using the North American name for an inselberg for reasons which will become apparent) around Laxford, Lochinver and Assynt is also an excellent example of one of the key tenets of this book, namely that an unfamiliar landscape need not be foreign; that the exotic can be just around the corner.

However, for the rest of this book I want to turn things around, start from the present day and dig down into our islands to show how the landscape evolved over time. Like all good journeys, however, a detour can be enlightening and it's in this spirit that I offer a chapter on some of the concepts and historical background behind the study of the landscape. You can skip it and pick up the journey at Chapter 3 if you just want to get on with the main story; there's a glossary at the end of the book that clears up any definitions that aren't dealt with en route.

CHAPTER TWO

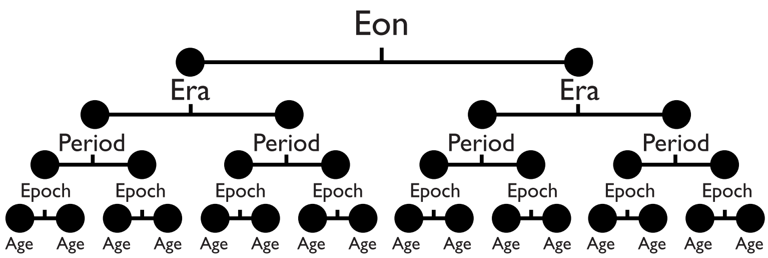
'No vestige of a beginning, no prospect of an end'

On Geological Time

As anyone who concerns themselves with the fascinating prehistory of our islands would be happy to tell you, whether they are archaeologists, anthropologists, geologists or fossil hunters, it is difficult to get a grip on the expanse of geological time that stretches back to the earliest days of our planet's existence. When our lives of decades amount to such relatively short spans on the earth, even historical time seems unwieldy, so what chance does a period of almost 4,600 million years – the approximate age of the planet – have of making a meaningful impression upon us? Geological time is of such an unimaginable extent that even scientists measure it in a series of multi-million-year subdivisions: in epochs, periods, eras, eons and super-eons, of which the shortest is the epoch.

Eon, era, epoch; all of these terms would be likely to be found in the thesaurus under a master heading of 'absolutely ages' (my dream thesaurus would be fairly informal), so it is a little disappointing to find that an epoch (the shortest) is further subdivided into ages, which themselves can last many millions of years. I looked through the geological literature in vain for even finer partitioning; for instance, as all of these terms are little better than synonyms to non-geologists, how about carving up an age into an even more manageable set of units? Perhaps we could call them yonks? While that thought might strike you as being a little facetious, how can a non-scientist, an ordinary person, make any sense of geological time, when one of its shortest units is an epoch (anywhere between 10,000 and 5 million years)?

Eons, eras, epochs, et al



As with any attempt to communicate the scale of something of epic proportions, the numbers soon become so abstract that they lose their meaning altogether and the only way that they can become meaningful again is by recourse to an apt metaphor. In his 1981 book, *Basin and Range*, Pulitzer-winning author John McPhee did just that and explained geological time by using an analogy with the length of the old English yard, a measurement allegedly invented by Henry I as the distance from the tip of his nose to the end of his thumb. On that scale, McPhee wrote, one stroke of a nail file would erase human history. The manicure metaphor is a useful (and literal) yardstick for explaining the puny scale of human affairs when set against the whole history of the earth, but any closer examination of geological time would require a complete understanding of the anatomy of the human arm, shoulder and neck to illuminate the subject fully.

The king's arms notwithstanding, the reductive power of a metaphor can be useful. Large surface areas are almost always expressed as multiples of the area of Wales and large volumes of liquid are framed in terms of the number of Olympic-sized swimming pools that might be filled. With geological time, McPhee's analogy of length is useful, but because we are looking for finer gradations of meaning than are allowed by his single sweep of a nail file that wipes out human history, we should scale it up from a yard to a long journey. As this is a book about Britain's landscape, it seems apt to confine both the timescale and that journey to the landscape of Britain itself.

As we've already seen, our oldest scenery is almost 3,000 million years old. In order to get the best sense of geological time, a very long British journey – a distance of approximately 750 miles (1,200 kilometres) – is the best we can manage without getting on a boat. Which neatly brings us to a scale of 4 million years to the mile and, although it is hard to find a direct road trip of the required length, a slightly scenic route from London to the far north-west of Scotland fits the bill rather well.

As chance would have it, we know that some parts of the area around Cape Wrath, the most northwesterly point of Scotland, were formed around this time, making them the oldest rocks in Britain. At the south-eastern end of the country, there is a lot of geology that is only a few million years old – and even more recent – and the landscape is predominantly capped with very young glacial deposits. London is a convenient choice to represent them: the most recent sediments lie here and there around the M25, down towards the Kent coast and up into East Anglia.

To start with the basics, then: on the scale of a 750-mile journey, a lifetime is equivalent to a journey of a single inch or so, while for the fortunate few who can measure their lives in excess of a century, it is four centimetres from birth to that birthday card from the Queen, the approximate diameter of a toilet roll tube. Everything more than 80 centimetres away – the length of a French stick – is, in a sense, Before Crust (BC/BCE; Before the Common Era, or Christ, if you prefer). The Great Pyramid of Giza was completed approximately 6 feet (1.82 metres) away and, at about 13 feet (3.9 metres) – slightly more than the length of a Ford Fiesta – lies the end of the last glacial period of the most recent ice age, a period of glaciation that lasted for the length of an entire bendy-bus, about 59 feet (18 metres), parked at the far end of the Fiesta. That wasn't the only ice age; there are up to three other major glaciations hypothesised, one of which (on our journey) would extend from Chesterfield to Leeds.

Stepping back a bit further, with regards to Homo sapiens, the consensus is that we probably evolved in Africa just a little further away than the other end of that Olympic-size swimming pool, 52 metres or 130,000 years ago.

For longer journeys back in time, a hypothetical central London starting point at City Hall is helpful. From there it's about 320 metres upriver to get to HMS *Belfast*, a journey that marks the point in time 790,000 years ago that scientists believe our close relatives, Homo erectus, had mastered the use of fire. From the deck of the *Belfast*, we have the extinction of the non-avian dinosaurs[1] in our sights. If you have ever wondered where the guns of the ship are trained, it is – for no adequately explained reason – the M1's Scratchwood Services area, 14 miles (22.5 kilometres) as the shell flies, but 16 miles (25.5 kilometres) or so on our trip via the Edgware Road, representing almost 65 million years. Even the mass extinction of 70 per cent of all species and the end of the age of the dinosaurs – caused or at least aided, it is believed, by the impact of a giant asteroid – hasn't got us as far as the M25 and that is a flavour of just how long the furthest reaches of geological time are.

After our barbecued dinosaur snack at Scratchwood Services, we move further away from London on the M1 to reach the M25 at 100 million years and then Luton at between 140 and 130 million years ago, which marks the evolution of flowering plants or angiosperms – amongst them the oldest fossil of a flower bloom, one apparently related to modern magnolias. By the time we reach Milton Keynes and another famous motorway service station, Newport Pagnell, we are approaching 230 million years ago, a period of time during which it is believed the dinosaurs evolved.

Around Nottingham and Derby, roughly 540 million years ago, is the earliest fossil record of trilobites, the now-extinct marine arthropod. A dozen or so miles north of there, the earliest multicellular animal yet discovered,

1. Birds are now considered to be a specialised group of dinosaurs that survived the mass extinction.

Charnia, pops up from 580 million years ago. Named after Charnwood Forest in Leicestershire, where it was discovered, *Charnia* was found in 1957, without the aid of any kind of magical wardrobe, by a schoolboy called Roger Mason. The journey back to our oldest landscape is only about 20 per cent complete and there are still 600 miles (960 kilometres) or about 2.4 billion years to go.

Heading even further north, the metaphor starts to fray around the edges a little and eventually peters out entirely – mainly because we start to know logarithmically less about the prevailing conditions on the planet the further back we go; there are fewer fossils, fewer rock formations that have remained unaltered and less geological evidence generally.

This lack of detail is reflected in the geological timescale itself. The eon in which we currently live – the Phanerozoic – goes back around 544 million years and is made up of three eras that contain twelve periods which in turn contain thirty-seven epochs. The Proterozoic eon which immediately precedes it is four times as long at 2 billion years, also contains three eras and eleven periods – most of which are based on arbitrary dates, rather than dates calculated by fossil finds or distinctive rock beds (for the simple reason that fossils are few and far between) and lacks epochs altogether.

The line between our present Phanerozoic eon and the Proterozoic is an important one. For a long time, it marked the point beyond which there was no fossil evidence at all. The period that was believed, until relatively recently, to start the fossil record is known as the Cambrian. The sudden abundance of fossilised life at a point around 530 million years ago is called the Cambrian Explosion or

Eon	Era	Period	Millions of years ago
Phanerozoic	Cenozoic	Quaternary	2.5
		Tertiary	65
	Mesozoic	Cretaceous	145
		Jurassic	200
		Triassic	251
	Paleozoic	Permian	299
		Carboniferous	359
		Devonian	416
		Silurian	443
		Ordovician	488
		Cambrian	542
Pre-Cambrian super-eon			
Proterozoic			2,500
Archean			4,000
Hadean			4,600

Radiation. So profound was this apparent rapid and abrupt diversification of life on earth, Charles Darwin considered it might stand in the way of his theory of natural selection and devoted a whole chapter of *On the Origin of Species* to dealing with it.

To the geologists of the nineteenth century, during which the science flourished in its own radiation of discovery, the abundance of fossils which marked the Cambrian Explosion – compared with the lack of evidence preceding it – drew something of a line under the period. The entire passage of earth's history to that point was formerly classified as Pre-Cambrian, the bottom drawer of the geological cabinet where it was perhaps presumed that answers would never be forthcoming. Eventually, however, more fossils were discovered in the Pre-Cambrian eras (there are signs of life from as far back as 3.45 billion years ago) but the name stuck and is now the informal name of a super-eon that covers the whole 4 billion years. Doubtless, it will eventually become deprecated by the body that oversees such things (the International Commission on Stratigraphy) but geologists still seem content to use it because the term is as convenient as it is historic.

It is easy to forget, amongst all the bewildering numbers that, of over 4.5 billion years of earth's history, only the last half a billion years or so can be accounted for with any degree of scientific certainty. While patches of time in the late Pre-Cambrian become gradually more illuminated following the occasional discovery, the earliest reaches of our planet's history remain much more distant, based on little in the way of physical evidence and much more on computer modelling and elegantly constructed theory. In this book's own bottom drawer, a postscript devoted to the earliest eons of the planet's life, some of these theories are outlined for the sake of completeness. In that postscript, 'A Quick History of the World Before Britain', you will find that the story of what happened during the first 800 million years or so of the earth owe much to a number of serious theories which are based on evidence contained in mineral fragments no more substantial than the width of a human hair.

That scientists can put forward theories based on such physically flimsy trace evidence owes a lot to the principle of uniformitarianism which, even though it sounds like an evangelical belief system, is actually the basis of an entire scientific philosophy: namely that the processes that have shaped the world so far are the same as those that are shaping the planet today. The philosophy of uniformitarianism even reaches out into space with the inference that the universe as a whole is governed by the same laws of physics as those found on earth.

In geology, uniformitarianism is frequently reduced to the helpful dictum that 'the present is the key to the past'. Given the impossibility of observing the processes of the past, the assumption that those processes are the same as they have always been and always will be, started to underscore the scientific thinking of the late eighteenth and early nineteenth centuries.

We have the 'father of modern geology', James Hutton (1726–97), to thank for the concept of uniformitarianism. In his paper *The Theory of the Earth; or an Investigation of the Laws observable in the Composition, Dissolution, and Restoration of Land upon the Globe*, which he and his friend Joseph Black[2] read in two parts to meetings of the Royal Society of Edinburgh in 1785, Hutton was the first to conclude that the earth maintains itself in an infinite cycle.

Of course, if the very gradual processes we can observe now are the same processes that have formed the world, uniformitarianism implies that the earth is very old indeed. Hutton certainly believed so and famously noted that, in terms of the history of the earth, 'we find no vestige of a beginning, no prospect of an end.'

This view was diametrically opposite to the commonly

2. Joseph Black was an eminent physicist and chemist himself, discovering latent heat, specific heat, and carbon dioxide. Some of the chemistry buildings at the Universities of Edinburgh and Glasgow are named after him and he was the mentor of James Watt, the inventor and engineer who did so much to improve the steam engine.

held ideas of the time, both scientific and theological. The opposing scientific theory was catastrophism; whereas Hutton believed that gradual changes occurred over long periods, catastrophists believed that sudden, high magnitude events occurred over much shorter spans of time.

The roots of catastrophism were in the dominant ideas of the time, which were nine parts theology and one part geology, perhaps a reflection of early attempts to date the earth from a verbatim reading of the Bible. In his *Annals of the Old Testament, deduced from the first origins of the world* of 1650, James Ussher, the Anglican Archbishop of Armagh, pinned down the start of the world to the night before the 23 October, 4004 BC. The Ussher chronology, as it has become known, arrives at this precise time by totting up all the generations from Genesis onwards.

It is easy to mock the efforts of Ussher in the light of what we know now, but framed in the methods and knowledge of 1650 AD, Ussher's chronology was a serious attempt to solve the mystery of the age of the earth. Amongst all the dates that he worked out for Biblical events was that of Noah's Flood, which he calculated at 2348 BC. The story of a great deluge is, perhaps, one of the most striking fables we hear in childhood, whether it is Noah of the Judaeo-Christian story in the Book of Genesis or the Islamic Noah found in the Koran, whether it is the Aboriginal Dreamtime story of a flood from the mouth of a laughing frog or one of the many sunken land myths like Lyonesse, Cantre'r Gwaelod or Atlantis.

There were a lot of floods in catastrophism – which predicated a large number of high-magnitude disasters over a relatively short span of time – though none of the ages of the earth put forward by the proponents of catastrophism were as short a span as Ussher's chronology which advanced a figure of 6,000 years as the absolute age of the world. Floods were also central to Neptunism, the late eighteenth-century theory that stated that all rocks had crystallised from minerals in the sea. Neptunism's leading exponent was Abraham Gottlob Werner, a deeply charismatic man who worked as an inspector of mines as well as a professor of mining and mineralogy at Freiberg in Saxony. Werner's lectures brought students in from all around Europe, who then returned to their native lands and spread the principles of Wernerian geology as if they were his disciples.

Werner's geology artfully straddled the science and theology of the day – there was even a place in the science of the Neptunians for a good old-fashioned Noachian flood. But by the early nineteenth century, more and more geologists were recruited to the opposite camp of plutonism, which held that the ultimate origin of all rocks on the earth was from volcanic or igneous activity. The concept of plutonism was first proposed by James Hutton and, along with uniformitarianism, it turned out to be the engine of one of his other theories: that of deep time or, as we now know it, the geological timescale.

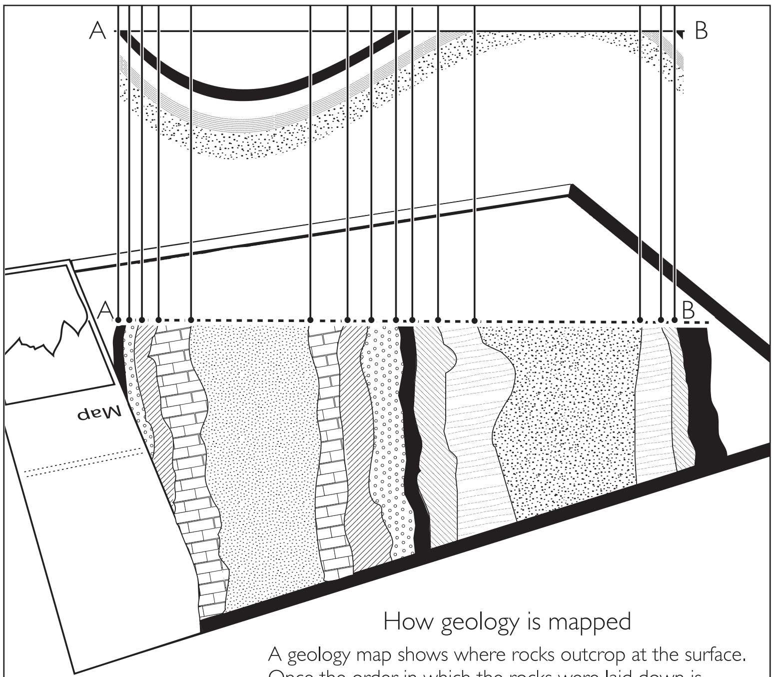
While Hutton was developing the concepts that underpin much of the modern science, an English mineral surveyor[3] called William Smith was noting the arrangements of rock strata as part of his job for the Mearns Pit coal mine at High Littleton in Somerset and then, a few

3. While the early history of geology is populated by curious clergymen and the gentlemen geologists of the landed gentry, mineral surveyors were the first professional field geologists.

years later, as the surveyor for the Somersetshire Coal Canal Company. In the spirit of the times – halfway through the British Agricultural Revolution and at the dawn of the Industrial Revolution – surveying was a boom business. Not only were roads and canals to be built to move coal about the country but the landed gentry and aristocracy were laying out and landscaping the grounds of country estates, whose parks led, in turn, to the notion of an ideal and classically British kind of countryside.

While at Mearns Pit coal mine, Smith had noticed that there was a pattern to the succession in the strata of rocks, all of which could be identified by means of embedded fossils; that each local sequence was part of a universal sequence of strata and that these could be traced for some distance by reference to the fossils contained within. The miners told him that they had individual names for the different beds of coal and Smith soon learned to recognise the differences between these. He was so fascinated by the arrangements of the beds of rock that he was given the nickname 'Strata Smith'.

The mine and the subsequent surveying he undertook for the canal that would take the coal from it to Bath, Bristol and London were the perfect work for Strata Smith. In 1799 he produced the first modern geological map, of an area centred on the city of Bath. He had noticed a map of soil and vegetation type, confined to the same area, in the *Somerset County Agricultural Report*, where its creators, John Billingsley and Thomas Davis, had used an overlay of colours to denote the individual soil and land types. The Billingsley–Davis soil map was a revelation to Smith, and one that he sorely needed. He was already proficient in representing strata vertically, but he was less sure about the techniques



How geology is mapped

A geology map shows where rocks outcrop at the surface. Once the order in which the rocks were laid down is taken into account, the structure beneath the ground – such as through cross-section A-B – can be inferred. (Rear of map obscured for clarity.)

required to represent them on a map. His 1799 Bath map, though unrefined and only showing a selection of rock types, eventually led to his far more polished and now-famous geological map of England and Wales sixteen years later.

While it is true that rocks erode, sediments deposit and continents drift at less than the pace of a snail, the science of geology has raced ahead in the two centuries since Smith, completely unaided, compiled his map. Yet, for all the progress, William Smith's solo effort bears an uncanny similarity to the modern British Geological Survey map, compiled by hundreds of people with the aid of instruments and techniques unheard of and beyond the wildest dreams of surveyors in Smith's day.

If you look at the modern geological map of Britain, it quickly becomes apparent that we live in a geologically diverse country. Resembling nothing so much as the results of an explosion in a paint factory, the British Geological Survey's 25 miles to the inch chart is almost as iconic to generations of geologists as the Tube map is to followers of twentieth-century history and design. Strangers to the science will, however, find it as baffling as William Smith or James Hutton would find the London Underground, but it is only really a question of familiarising yourself with the conventions until you can find your way around.

The different colours of the modern map broadly follow Smith's original selections and indicate the age of what is called the 'solid geology' or 'bedrock'. The bedrock is the consolidated rock that lies under the surface of the earth, beyond the topsoil and the subsoil, as well as any 'drift' or 'surface geology'.[4] The depth at which the bedrock lies varies from place to place. It can be hundreds of feet underground or it can outcrop at the surface.

Geology sometimes seems to be all about rocks and

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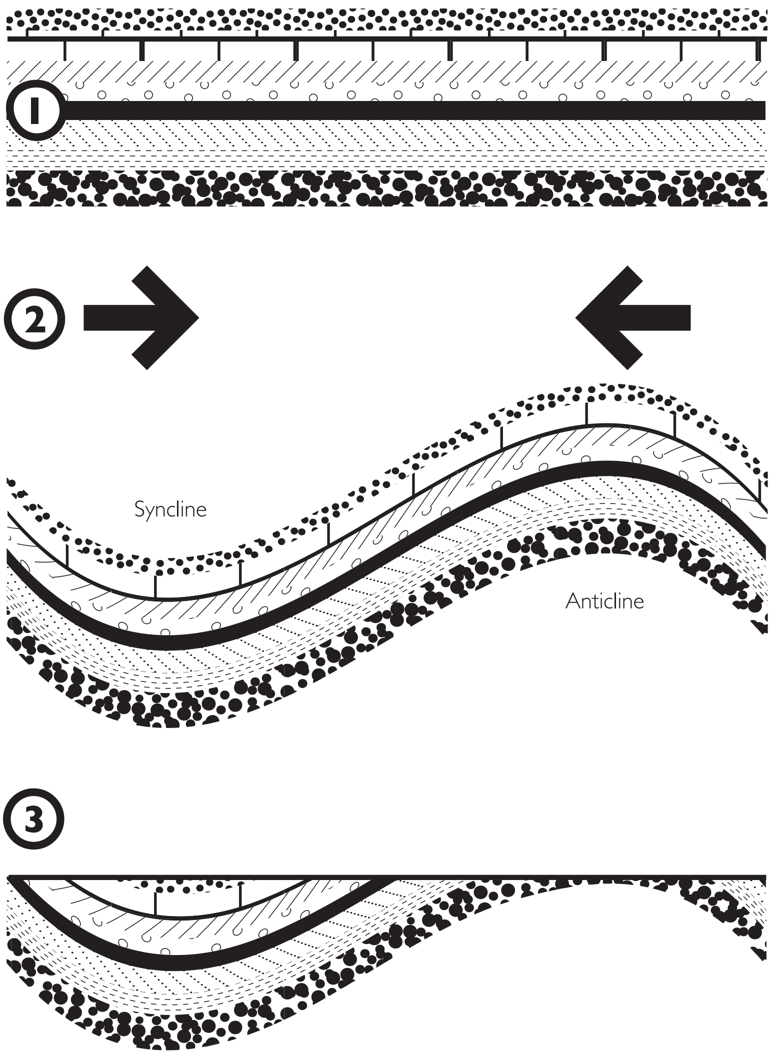
4. Drift is a layer of broken rock debris transported from elsewhere by rivers and glaciers. The distinction is important; bedrock geology of the North Norfolk coast and its hinterland is made up of chalk and some shelly soft sands and clays, but there are glacial deposits that overlie it on a huge scale that you will not see on the bedrock, solid geology maps. These deposits of boulder clay (the name does not need any further explanation) were heaved towards the coastline, by a conveyor belt type process that is inherent in glaciers, towards the snout. In Norfolk, the snout of one such glacier during the last glacial period of the current ice age left behind enough boulder clay to form a line of hills known as the Cromer Holt ridge. At over 300 feet, they are the highest hills in East Anglia.

minerals, their age and their position, but our landscape is much more elaborate than a list of materials from different epochs lying in an assortment of orientations. The chalk of the South Downs, for instance, was laid down between 100 million and 80 million years ago. Over a period of about 20 million years, the microscopic remains of tiny creatures piled up on the bed of a warm sea to a depth of over 300 metres. It wasn't for at least another 60 million years, however, that the seabed with its lithified cargo of chalk along with the clays, pebbles and sands that followed it, was lifted out of the sea by the force of Africa colliding with the southern edge of Europe. That collision left the Alps as its crumple zone, but the effects were felt as far as southern England and north-east France, where the rock layers were gently buckled, like a ruck in a rug, into a 590 feet (180 metre) high long fold. This ruck – which we know as the Weald–Artois anticline[5] – was then eroded down over millions of years to form two inward-facing escarpments – the North and South Downs.

So, the North and South Downs are not just the age of the rocks they are made of. The uplift of the chalk played an important part, as did the erosion that followed. Those two features were just as responsible for the shape of the Downs' escarpments as the marine snow of tiny shells and tests which fell in the warm sea. So it is that the formation of what is rather a simple system is not a one-step process: in fact it is an ongoing process, as is the formation of every acre of our landscape. This is the crux

5. An anticline is an upfold of strata with the oldest rocks at its core. A simple aid to distinguishing between an anticline and its opposite – the syncline – is that an anticline 'points' up like the capital 'A' and a syncline is a 'sink' shape.

Synclines and anticlines



1. Beds are laid down over time.
2. Compression caused by the collision of two plates forces the beds into a form like a ruck in a rug
3. Millions of years of erosion levels the surface

of uniformitarianism: that the present is the key to the past and, as Hutton would say, 'we find no vestige of a beginning, no prospect of an end'.

In terms of this book, of course, we have already found the 'vestige of a beginning' in the shape of the gneiss of the North West Highlands. But even our most ancient patch of ground is, in a sense, older than 3 billion years. Like many ancient rocks, the gneiss is metamorphic, meaning it has been formed by the application of enormous pressure and heat to an even earlier rock. Geologists measure the age of metamorphics from the time they were metamorphosed and were recrystallised,[6] not when the original rocks – or protoliths, to give them their proper scientific name – were formed. The earth was already 1.5 billion years old, time enough for countless reiterations of the minerals and rocks on offer.

There are two types of metamorphism: contact and regional. Contact metamorphism occurs when molten rock meets solid rock, such as when an enormous blob of it bubbles up through existing rock as it did in what is now south-west England, and forms an aureole of altered rock around it through the action of localised heating. More of that in a minute. Regional metamorphism occurs on a grander scale, when masses of rock come under extremes of pressure and heat of the kind produced by mountain building. Examples of metamorphosed rocks include slate, gneiss and marble.

Aside from metamorphic, all rock is either igneous or sedimentary. Igneous rock is formed as it cools from a

6. A metamorphic rock is one that has recrystallised under the effects of heat and/or pressure without completely remelting.

molten state like lava or magma. The pumice stone that sits, mostly unused, on the side of your bath is an igneous rock formed when a certain kind of viscous lava is violently ejected from a volcano. Like all lavas, which are rapidly cooled – either by air or by water – pumice solidifies very rapidly and there is no time for its component crystals to grow. As a consequence, volcanic rock is made of fine, tiny crystals.

Not so with the other form of igneous rock, plutonic, named not after a cartoon dog, but the Roman god of the underworld. Plutonic igneous rock cools more slowly deep within the earth and crystals grow to an extent where they can be clearly seen with the eye. Granites, such as those we have just alluded to on the moors of south-west England, were formed like this as swarms of plutons rising from the base of the crust, where they slowly solidified at depths between 3 and 20 miles (5 and 32 kilometres) underground.

Much of the earth's upper crust is made of igneous rocks, but you wouldn't know just to look at it because of the widespread layer of sedimentary rocks that rests on top. Sedimentary rocks (sandstone, shale, limestone, chalk and many others) are formed by deposited sediments, usually – but not exclusively – underwater. Sediments can either be mineral in nature (mud dumped at a river's outlet to the sea, for example), or biological in origin; chalk is formed from billions of tiny shells discarded by single-celled organisms and some limestones are made from coral reefs. The one thing that all sedimentary rocks have in common is that they are formed in horizontal layers – beds, or strata in geological parlance – and build up one on top of another. Because of this simple fact, in any given series of bedrock, the youngest formations are always at the top. It sounds too much like common sense to be the subject of a scientific law, but the boffins like to call it the Law of Superposition, anyway. However, it isn't always that easy to work out where the 'top' and 'bottom' of a geological formation is, because once they have been laid down, sedimentary beds are often tilted – even folded, sheared and inverted, in some cases – by the massive forces that occur when continents drift towards one another.

At the end of this brief tour of the annals of geology, its guiding principles and methods, it is time to turn back to the landscape itself. I started this book in the North West Highlands of Scotland standing in a landscape that was between 1 and 3 billion years old. But even the oldest landscape is, in a sense, still being formed, worked upon by the same forces of erosion that have shaped it so far. Meanwhile, the more recent scenery of southern Britain is merely an expression of the almost eternal process of how the materials of the earth recycle themselves. Having established the parameters, much like the journey we started this chapter with, we are now going on one that takes us from the most recent to the most ancient, digging down through the ages as we go. We take the first steps of this journey along the southern coast of Britain.