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The Great Stone Book

Our imaginations may be awed when we look at the mountains as monuments of the slow working of stupendous forces of nature through countless millenniums.

LESLIE STEPHEN, 1871

August 1672 – the high noon of a continental summer. In Milan and Geneva the citizens are sweltering beneath a strong European sun. Many thousands of feet above them, among the snows of the Simplon Pass – one of the major crossing points of the European Alps – shivers Thomas Burnet. Shivering with him is the young Earl of Wiltshire, great-great-grandson of Thomas Boleyn, the father of the ill-starred Anne. The boy, his family have decided, needs educating and Burnet, an Anglican churchman possessed of a prodigious and restive imagination, has taken what will be a decade-long sabbatical from his fellowship at Christ's College, Cambridge, to act as chaperone and cicerone to a succession of teenage aristocrats – of whom the young earl is the first.

For Burnet it is an excuse to see the Catholic continent. They will cross the Simplon Pass with their sullen guide and his train of

braying mules, and then travel southwards, past the long gleam of Lake Maggiore, through the orchards and villages of the foothills, across the green baize of the Lombardy Plains, and down finally to the pale and edifying cities of Northern Italy – Milan first among them – which the boy must see.

Before that, though, the crossing. There is little to recommend the Simplon Pass. A rudimentary hostelry exists at its highest point, but it isn't a pleasant place for a night's sleep. The cold is intrusive, and there are bears and wolves in the area. And the hostelry itself is really a shack, staffed by Savoyards who grudgingly double as shepherds and hoteliers.

Yet, despite these multiple discomforts, Burnet is happy. For here, among the mountains, he has discovered somewhere utterly unlike anywhere else: a place that has for the instant stalled his powers of comparison. This landscape is literally, to Burnet, like nothing else on earth. Despite the summer month, snow lies about in deep drifts, sculpted and frozen by the wind and apparently impervious to the sunshine. In the light it has a gold dazzle to it, while in the shadow it looks the creamy grey-white of cartilage. Rocks as big as buildings are scattered about, and throw complexities of blue shadow around themselves. The sound of distant thunder rolls in from the south, but the only thunderheads to be seen are thousands of feet beneath Burnet, massing over the Piedmont. He is, he realizes with delight, *above* the storm.

Down in Italy are the celebrated ruins of Rome, which Burnet knows the young earl must tour as part of his education in antiquity. Burnet himself is not immune to the magnificence of Rome's broken temples, and the gilded, weeping saints who fill the niches in the churches. But there is something up here, in what he will later describe as 'these sonic mountainous parts', amid the gargantuan rubble of the Alps, which to Burnet is infinitely more suggestive and overwhelming than Rome's ruins. Even though his age demands that he find them hostile and repulsive, Burnet is unaccountably affected by the mountains. 'There is something august and stately in the Air of these things,' he wrote after the Simplon crossing, 'that inspires the mind with great thoughts and passions . . . as all things have that are too big for our comprehension, they fill and overbear the mind with their Excess, and cast it into a pleasing kind of stupor and imagination.'

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During his ten years on the continent Thomas Burnet and his various young wards would cross the Alps and the Apennines on several occasions. Gradually, the repeated sight of these 'wild, vast, and indigested heaps of Stones and Earth' fostered in Burnet a desire to understand the origin of this alien landscape. How had the rocks come to be so dispersed? And why did the mountains have such a powerful psychic effect on him? So deeply did the mountains strike Burnet's imagination and his investigative instincts that he decided he could not 'feel easie, till I could give my self some tolerable account how that confusion came in Nature'.

Thus it was that Burnet began work on his stylish, apocalyptic masterpiece, the first book to envisage a past for mountains, those most apparently timeless of objects. Burnet was writing at an ominous period in Europe. In 1680 and 1682 unusually lurid comets were seen in the skies. Edmond Halley, having taken celestial sightings from the top of a volcano, had tracked and named his own fiery messenger, and had (correctly) forecast its return in 1759. Thousands of pamphlets were printed across Europe predicting the catastrophes which would imminently blight the civilized lands – the deaths of monarchs, storm winds stripping the fields, drought, shipwrecks, pestilence and earthquakes.

It was into this saturated atmosphere of signs and portents that Thomas Burnet's *The Sacred Theory of the Earth* dropped in 1681, published at first in Latin in a discreet print-run of twenty-five copies, and carrying a pert little dedication to the King (which insinuated His Majesty's stupidity). Burnet's book looked not forward to possible future catastrophes, but backward to the biggest disaster of them all – the Flood. It was *The Sacred Theory* which began the erosion of the biblical orthodoxy that the earth had always looked the same, and it was *The Sacred Theory* which would crucially shape the ways in which mountains were perceived and imagined. That we are now able to imagine a past – a deep history – for landscapes is in part the result of Burnet's decade-long rumination on ruination.

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Before Burnet, ideas about the earth lacked a fourth dimension – time. What, it was felt, could be more permanent, more incontestably *there* than mountains? They had been cast by God in their current poses, and would remain thus always and for ever. It was the biblical account of the Creation which, prior to the eighteenth century, determined how the earth's past was imagined, and according to the Bible the beginning of the world had been a relatively recent event. In the 1600s several ingenious attempts were made to compute a date of origin for the earth from the information given in the Bible. Of these the best known was by James Ussher, Archbishop of Armagh, whose dubiously scrupulous arithmetic resolved that the birth of the earth had begun at 9 a.m. on Monday 26 October 4004 BC. Calculated in 1650, Ussher's chronology for the creation of the earth was still being printed in the shoulder notes of English Bibles in the early 1800s.

The orthodox Christian imagination of Burnet's time had thus been inoculated against perceiving a history to the earth. It was widely believed that the earth was less than 6,000 years old, and that it had not aged visibly in that time. No landscape had a past worth contemplation, for the world's surface had always looked the same. Mountains, like everything else upon the earth, had been brought into being during that first frenzied week of creativity described in Genesis. They had been established on the third day, in fact, at the same time as the polar zones were frozen and the tropics were warmed, and their appearance had not altered much since, save for the cosmetic effects of lichen growth and a little light weathering. Even the Flood had left them untouched.

Thus ran the conventional view. It was Thomas Burnet's conviction, however, that the scriptural account of Creation as it was at that time understood could not explain the appearance of the world. In particular, Burnet puzzled over the hydraulics of the Flood. Where on earth, he wanted to know – where, literally, on earth – did the water come from for a Flood so profound that it could, as the Bible specified, 'cover the very highest mountain-tops'?

To achieve a global inundation of that depth, Burnet calculated, it would have taken 'eight oceans of water'. However, the forty days of rain described in Genesis would have provided at most only one ocean: not sufficient liquid even to lap at the feet of most mountains. 'Whither shall we go to find more than seven oceans of water that we still want?' asked Burnet. He reasoned that if there had not been enough water, then there must have been less earth.

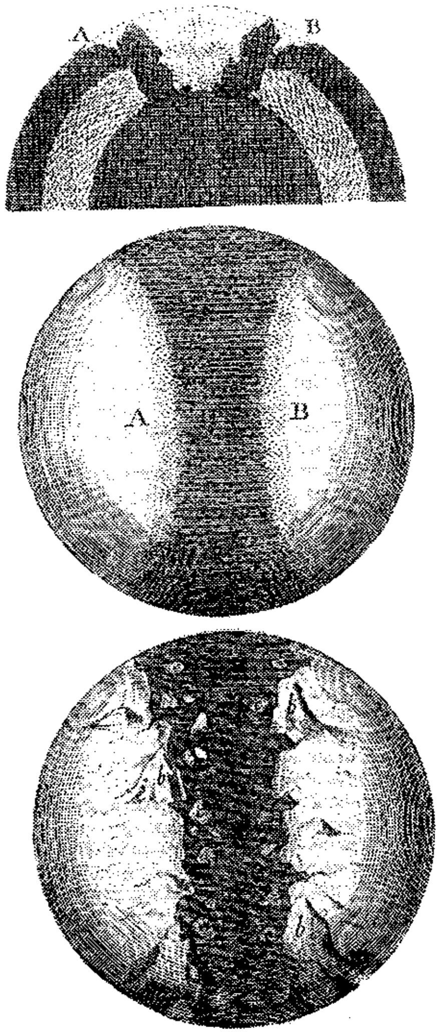
And so he set forth his theory of the 'Mundane Egg'. Immediately after Creation, he proposed, the earth had been a smooth oviform spheroid: an egg. It had been flawless in appearance and uniform in texture, without hill or vale to disrupt its lovely contours. Its porcelain surface, however, belied a complicated inner architecture. The 'Yolk' of the earth – its very centre – was filled with fire, and in increasing

circles about that yolk, like round Russian dolls, were arranged 'several Orbs, one including another'. And the 'White of the Egg' (Burnet was tenacious with his metaphors) was a water-filled abyss upon which the crust of the earth floated. Thus was the Burnetian earth composed.

At birth, asserted Burnet, this young globe was unblemished on its surface, but it was not inviolable. Over the years the action of the sun desiccated the crust, and it began to crack and fracture. From beneath, the waters in the abyss started to press more urgently upon the weakened crust until, at a summons from the Creator, came 'that great and fatal Inundation' – the Deluge. The inner oceans and furnaces finally ruptured the shell of the earth. Sections of the earth's crust plunged into the newly opened abyss, and the flood-waters roared up and over the remaining landmasses to create a 'great Ocean rowling in the Air without bounds or banks', as Burnet winningly described it. The physical matter of the crust was swirled about in a mêlée of rock and earth, and when the waters eventually receded they left chaos behind them. They left, in Burnet's phrase, 'a World lying in its Rubbish'.

What Burnet was suggesting was that the globe as the inhabitants of his age knew it was nothing but 'The Image or Picture of a great Ruin', and a very imperfect image at that. At a single stroke, in punishment for the impiety of the human race, God had 'dissolv'd the frame of the old World, and made us a new one out of its ruines, which we now inhabit'. And mountains, the most chaotic and charismatic of all landscape features, had not been created *ab origine* by God at all: no, they were in fact the residue left behind when the Deluge retreated, fragments of the earth's shell which had been swirled round and piled up by the colossal hydraulics of the Flood. Mountains were, in effect, gigantic souvenirs of humanity's sinfulness.

A rash of publications followed the English translation of Burnet's book in 1684. Irritated by his suggestion that the earth was defective in its present design, and by his challenge to conventional understanding

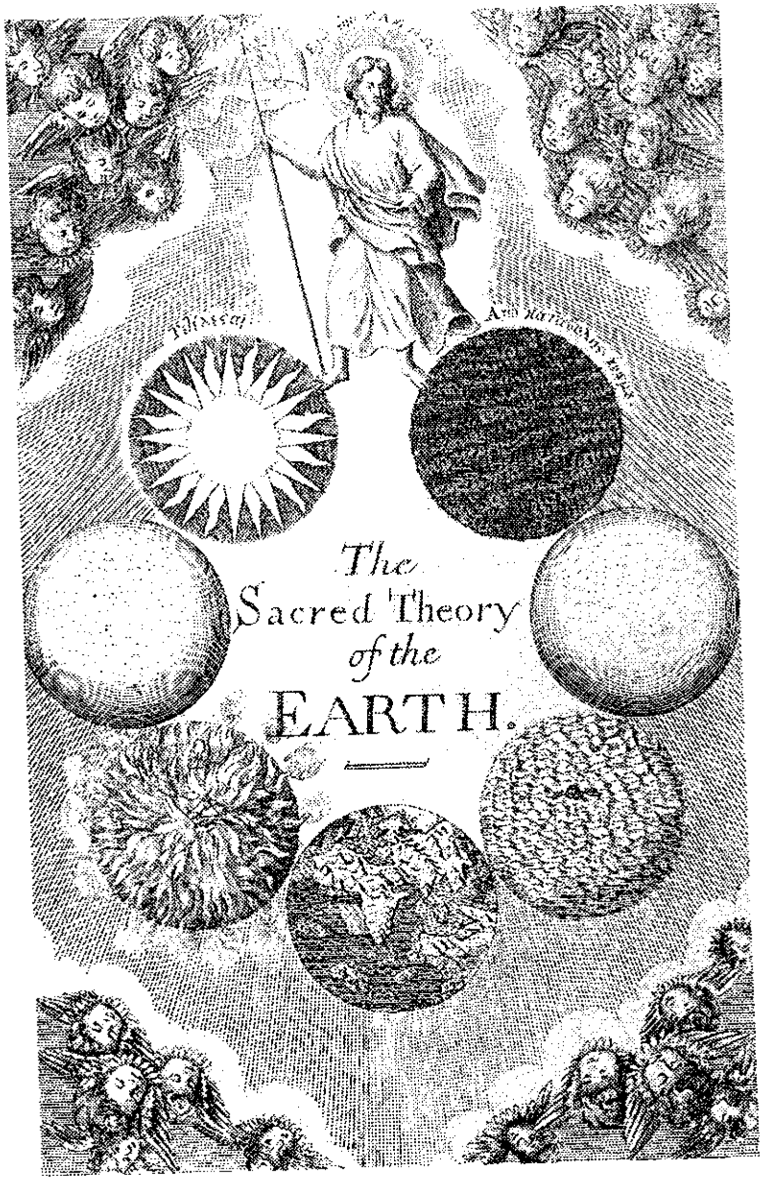


'The Deluge and Dissolution of the Earth', in Thomas Burnet's *The Sacred Theory of the Earth*, 2nd edn (1691). The illustration shows three successive stages in the collapse of the earth's crust into the watery abyss (a). The lowest and last shows the creation of the mountains (b) and the islands (c).

of the scriptures, many wrote to disprove his sacred theory. Quickly, the controversy made Burnet's ideas and the counter-arguments common intellectual currency – defenders and critics alike alluded to *The Sacred Theory of the Earth* simply as 'the Theory', and unspecified references to 'the Theorist' were understood to mean Burnet. Stephen Jay Gould estimates *The Sacred Theory* to have been the most widely read geologic work of the seventeenth century.

So it was that, for the first time, the intellectual imagination became involved in positing possible pasts for the wild landscapes of the earth. Attention was drawn by the Burnet controversy to the appearance of mountains. No longer could they just be wallpaper or backdrop – they had become objects worthy of contemplation in their own right. Importantly, it was also Burnet who fixed the perception of mountains as forms both awful and exciting in the minds of those who came after him: Samuel Taylor Coleridge, for example, was so stirred by Burnet's prose that he planned to render *The Sacred Theory* into a blank-verse epic, and the theories of the Sublime formulated by Joseph Addison and Edmund Burke were both shaped by Burnet's work. Burnet saw and communicated a majesty in mountainous scenery, and in doing so laid the groundwork for a wholly new way of feeling about mountains.

Burnet suffered for his brilliance. Cambridge had thrown a *cordon sanitaire* about itself to prevent the importation of harmful or counter-doctrinal ideas, and by questioning scripture Burnet had breached this line. After the Glorious Revolution he was forced to retire from court duties, and was then passed over for the Archbishopric of Canterbury. But his reputation as a writer would outlive his uneasy achievements as an Anglican divine. For in suggesting that the surface of the earth might not always have looked the same, Burnet started the ongoing inquisition into the history of the earth. 'I have,' he boasted in the preface to *The Sacred Theory*, 'retriev'd a World that had been lost, for some thousands of Years; out



Frontispiece to Thomas Burnet's *The Sacred Theory of the Earth*, 2nd edn (1691). The seven globes represent, with a clockwise chronology, the successive stages in the history of the earth as described in Burnet's book.

of the Memory of Man.' He was right to boast. Burnet was the first of the geological time-travellers, an explorer backwards in history – a conquistador of that most foreign of all countries, the remote past.

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Although Burnet had challenged the belief that the visible world had always looked the same, he had not suggested that it was any older than the six millennia calculated by Ussher. It was not until the mid-eighteenth century that the first significant extensions of the earth's age took place. One of the chief dissenters from the so-called 'young earth' orthodoxy was the flamboyant French natural historian, Georges Buffon (1707–88). In his compendious *Natural History* (1749–88), Buffon sketched a panorama of the earth's history as divided into seven epochs, proposing that each of the days of Creation might in fact be a metaphor for a far longer period of time. Publicly, he estimated the earth to be 75,000 years old, although he sensed that this was too conservative a figure: in his notes was posthumously found a scribbled guess of several billion years.

Buffon's move was a canny one: by turning each biblical day into an epoch of indefinite length, he created the space and time necessary for geologists to begin their work of disinterring an authentic history for the earth, while at the same time staying within the bounds of respect for the scriptures. It was the work of Buffon and others like him which began the transformation of Ussher's implausibly precise dating of 4004 BC into a totem of idiotic biblical literalism.* For,

* Although, as Simon Winchester has recently pointed out, a 1991 poll returned that 100 million Americans believed God to have created man in his own image sometime in the last 10,000 years. The earth is thought by science to be around 5 billion years old; the first humans to have appeared *circa* 2 million years ago.

once the duration of the earth's past was no longer confined to 6,000 years, it was possible to speculate more systematically on what changes might have been wrought over wider spans of time. The science of geology could emerge and define itself in this newly old earth, proofed against accusations of blasphemy.

By the start of the 1800s, those thinkers interested in postulating a past for the earth had begun to separate into two loose schools of thought, conventionally called Catastrophism and Uniformitarianism. It should be said that geologists of the later nineteenth century – notably Charles Lyell (1797–1875) – tended to exaggerate the degree to which these two schools waged intellectual warfare on each other, and it is important to realize that, while opinions did differ, battle-lines were never clearly drawn between them.

Catastrophists believed that the history of the earth was dominated by major geophysical revolutions: one or many past *Götterdämmerungs* which had convulsed the earth with water, ice and fire, and all but extinguished life. The earth was a cemetery, a necropolis in which were interred countless now-extinct species. Drastic tidal actions, global tsunamis, severe earthquakes, volcanoes, the passing of comets: these were what had shaped and shaken up the earth's surface into its present disruption. One popular Catastrophic theory of mountain-formation suggested that, since the earth was cooling from a white-hot original state, its volume was slowly reducing and its surface was consequently prone to severe crumpling – just as the skin of an apple crinkles as it dries out. The world's mountain ranges were corrugations or crumples in the earth's skin.

The counter-theory to this violently paroxysmal vision of the earth's history was preached by the Uniformitarians. The earth had never been subject to a global catastrophe, they held. Earthquakes, yes; volcanoes, yes; tidal waves, yes – undoubtedly these phenomena had taken place throughout geological history. They were localized calamities, however: they had only racked and rearranged the landscape in their vicinity. Certainly, the earth's surface had been subject to drastic change – evidence for this was visible in any mountain range, or on any coastline. But this change had been achieved astonishingly slowly, by the forces of wear and tear which were presently at work on the surface of the earth.

Given sufficient time, argued the Uniformitarians, the conventional ordnance of nature – rain, snow, frost, river, sea, volcano, earthquake – could produce the largest effects. So what the Catastrophists took for evidence of disaster was in fact the result of a slow and enduring ground war. The cornerstone of Uniformitarian theory was that 'the present is the key to the past': in other words, the history of the earth could be inferred from the careful observation of present processes at work on its surface. It was a version of the water-dripping-on-stone idea: allow a river or a glacier enough time and it will slice a mountain in half. Time, great time – this was what the Uniformitarians needed for their theories to work, and so they ratcheted the beginning of the earth far further backwards than anyone had previously contemplated.

The most celebrated of the early Uniformitarians, usually credited with paternity of what is now called the Old Geology, was the Scotsman James Hutton (1726–97). Hutton possessed an instinctive ability to reverse physical processes, to read landscapes backwards, as it were. Like all of the founding geologists, Hutton was a prodigious walker, and for decades he strode back and forth across the Scottish landscape, attempting by a blend of induction and imagination to intuit the processes which had brought it to its present state. Fingering the white quartz which seamed the grey granite boulders in a Scottish glen, Hutton understood the confrontation that had once occurred between the two types of rock; saw how under fantastic pressure the molten quartz had forced its way into the weaknesses in the mother granite. To be with Hutton was to inhabit a world with a past so deep as to be terrifying. One of his colleagues and admirers, John Playfair, famously described visiting a geological site on the Berwick coast with him. As Hutton explained the implications of the rock configuration, wrote Playfair, 'the mind seemed to grow giddy by looking so far into the abyss of time'.

Between 1785 and 1799 Hutton's three-volume magnum opus, *Theory of the Earth*, appeared: the distillation of decades of meditation on landscape formation. In it he proposed that the earth we presently inhabit is merely a snapshot in a series of an unknown number of cycles. The apparent permanence of mountains and coastlines is in fact an illusion born of our diminutive life-spans. Were we to live for aeons, we would witness not only the collapse of civilizations, but the utter rearrangement of the earth's surface. We would watch mountains being worn down by erosion to become plains, and we would see new landmasses being formed beneath the sea. Rubble eroded from the continents and laid down in sedimentary layers on the sea-floor would be lithified – turned to stone – by the exothermic core of the earth and then, over millions of years, would be lifted up to create new continents and new mountain ranges. Thus it was, said Hutton, that the shells which could be found embedded in the rocks of mountain-tops had not been washed there by the Deluge, but had been elevated from sea-floor to mountain-top by the patient, implacable processes of the earth.

Hutton put no parentheses around the age of the earth: according to his vision, the earth's history stretched backwards indefinitely into the past and unfurled indefinitely into the future. The final sentence of his book would toll through the centuries: 'The result therefore of our present enquiry is, that we find no vestige of a beginning, – no prospect of an end.' It was this inexpressible deepening of the earth's history that was geology's vital contribution to the common imagination.

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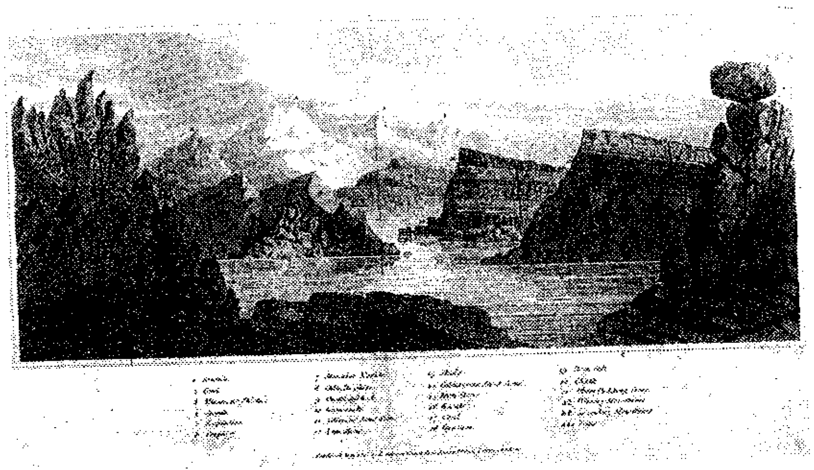
How did this geological revolution affect the way mountains were imagined? Once the geologists had shown the earth to be millions of years old and subject to immense and ongoing change, mountains could never be looked at in the same way again. Suddenly, these effigies of permanence had acquired an exciting, baffling mutability. Mountains, which seemed so durable, so eternal, had in actuality been formed, deformed and reformed over countless millennia: their current appearance was merely a phase in the perpetual cycles of erosion and uplift which determined the configuration of the earth.

A new generation of mountain-goers was drawn to the hills by the ghostly landscapes which had suddenly opened up under the scrutiny of geology. 'What I really saw as never before,' wrote Horace-Bénédict de Saussure in the 1780s, 'was the skeleton of all those great peaks whose connection and real structure I had so often wanted to comprehend.' Geology provided a reason and an excuse – scientific inquiry – for travelling to the mountains. 'A sentiment of curiosity, exceedingly natural, induces travellers from all parts of Europe to visit Mont Blanc, the highest point of the old world, and to examine the surrounding glaciers,' observed an English journalist in 1801. 'These places have recently acquired a new degree of interest – the geologue, the mineralogist, and mere amateur repair thither with avidity; and even women are amply indemnified for the fatigue of the journey by the pleasure arising from the view of objects entirely new to them.' To look at mountains was now also to look *into* them: to imagine their past. The English scientist Humphry Davy put it well in 1805:

> To the geological enquirer, every mountain chain offers striking monuments of the great alterations that the globe has undergone. The most sublime speculations are awakened, the present is disregarded, past ages crowd upon the fancy, and the mind is lost in admiration of the designs of that great power who has established order which at first view appears as confusion.



'Strata Types', frontispiece to Humphry Davy's *Elements of Agricultural Chemistry* (1813), showing the different rock layers which geology had made visible.

Here then was another vertigo – the giddiness inspired by deep time – to add to the more familiar and immediate kind one might feel on a steep mountainside. The experience of going to the mountains had become, as Burnet had suggested a century earlier, one not only of moving upwards in space, but also backwards through time.

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James Hutton might have fathered geology, but he was by no means its most stylish exponent. Aside from its resonant final lines, Hutton's *Theory* was written in a prose as uniformly impenetrable as the Old Red Sandstone of which he was so fond. It would take thirty years and another legendary geologist to make truly popular geology's rapid advances and staggering exposés, and to entice even more people into the mountains. Far more than Burnet or even Hutton, it

was the Scottish geologist Charles Lyell who was responsible for educating the nineteenth century in the language and the imagination of geology.

Charles Lyell was a lawyer before he was a geologist, and his forensic training had equipped him with a writing style of extreme clarity and elegance. Between 1830 and 1833 he published in three volumes *The Principles of Geology: an Attempt to Explain the Former Changes of the Earth's Surface by Reference to Causes Now in Operation*, a work which carefully and beautifully laid out the arguments behind the Uniformitarian view that the study of the present was the key to the past. *Principles* quickly became required reading for the chattering classes of its day and was widely translated: eleven revised editions had been published by 1872.

Lyell's brilliance lay primarily in his marshalling of detail. As Charles Darwin would do later in *The Origin of Species by Means of Natural Selection* (1859), Lyell won over his audience with a combination of irresistibly accumulating facts – in this respect his writing resembled the processes it was describing – and illuminating anecdotes. There was something appealing, too, in the democracy of the knowledge Lyell was outlining. You did not need special equipment or long training to decipher the earth's history: only an acute pair of eyes, a basic knowledge of Uniformitarian principles, and curiosity and courage enough to peer over the edge of the 'abyss of time'. Given these minimal qualifications anyone could attend the most exciting show on earth – its past.

To witness in action this new way of feeling about mountains, let us turn to the year 1835, and to the town of Valparaíso, ledged precariously on the Pacific coastline of Chile. The town's name means Paradise Valley, and a less fitting name could not have been found for it. To begin with it does not occupy a valley, but rather the thin strip of approximately horizontal ground that runs between the Pacific combers and the range of red rock mountains which rise steeply up behind the town. And it is positively not paradisal. The steady offshore breeze which scours the surface earth, the steepness of the ground and the salty soil mean that there is no vegetation to speak of. There is little other life to be found here save for the human inhabitants, who have made their homes in huddles of low white-washed houses with red-tiled roofs, which congregate in the stream-cuts and ravines. Near the shoreline, dories bob in rows, ready to service the big ships that come to anchor out in the deeper water – for Valparaíso, unlikely as it may seem, is Chile's principal sea-port. Over the whole scene hangs the clear, dry air of the coastal summer.

It is from Valparaíso on 14 August 1835 that Charles Darwin sets out on horseback for a long excursion into the Andean hinterland. Out in the bay is moored his ship, the ten-gun brig HMS *Beagle*, on which he is serving as scientific observer. While studying at Cambridge, Darwin had become interested in geology, and before he sailed south from Devonport on a ferociously stormy evening in December 1831, he packed the first volume of Lyell's *Principles* as reading for the long voyage out towards South America. He tested Lyell's theories in the field during a stop at the Cape Verde Islands, and by the time the *Beagle* first sighted the flatlands of Patagonia, Darwin's imagination was primed to interpret the landforms he encountered in Lyellian terms: to infer a deep past for their present appearance. 'I always feel as if my books came half out of Lyell's brains,' he would later write to a friend, Leonard Horner, 'for I have always thought that the great merit of the *Principles*, was that it altered the whole tone of one's mind & therefore that when seeing a thing never seen by Lyell, one yet saw it partially through his eyes.'

Leaving Valparaíso, Darwin first rides northwards along the coast for a day, in order to see the beds of fossilized shells which he has been told he must visit. They are astonishing – long banks of calcified molluscs which have been elevated, Darwin correctly deduces, by gradual crustal movement to their present resting-place several metres above the level of the sea. Having seen the shells – and having watched a gang of locals with pick and shovel plunder barrowloads of them for lime-burning – Darwin turns his horse inland, and canters up through the wide and fertile valley of Quillota ('whoever called Valparaíso Valley of Paradise must have been thinking of Quillota', he would observe later to his journal). The valley is densely packed with olive groves, and with stands of orange, peach and fig trees which have been manicured into tiny square orchards by the valley's inhabitants. On its higher slopes prolific fields of wheat flash in the sunlight, and above them rises the Bell of Quillota, a 1,900-metre peak from which there are reputed to be magnificent views. It is this mountain which Darwin has come to climb.

After spending a night in a hacienda at the foot of the mountain, Darwin procures a gaucho guide and fresh horses, and begins with difficulty to make his way up through the groves of thick-trunked palms and tall bamboo which flourish on the mountainside. The paths are not good, and by nightfall the two men are only three-quarters of the way to the summit. They pitch camp beside a spring, and beneath an arbour of bamboos the gaucho kindles a fire on which he fries beef strips, and boils water for *maté*. In the darkness the firelight dances off the walls of their arbour, and the bamboo seems briefly to Darwin like the architecture of some exotic cathedral, illuminated by flickering flames. The atmosphere is so clear and moonlit, the air so lucid, that Darwin can make out the individual masts of the ships anchored twenty-six miles away off Valparaíso, like little black streaks.

Early the following morning Darwin clambers up the greenstone blocks to the flat summit of the Bell. From there he looks across to the white towers and ramparts of the Andes, and down at the scars left on the flanks of the lower hills by the voracious Chilean gold-mining industry. The view astonishes him:

> We spent the day on the summit, and I never enjoyed one more thoroughly. The pleasure of the scenery, in itself beautiful, was heightened by the many reflections which arose from the mere view of the grand range . . . Who can avoid admiring the wonderful force which has upheaved these mountains and even more so the countless ages which it must have required, to have broken through, removed, and levelled whole masses of them? It is well in this case to call to mind the vast shingle and sedimentary beds of Patagonia, which, if heaped on the Cordillera, would increase its height by so many thousand feet. When in that country, I wondered how any mountain-chains could have supplied such masses, and not have been utterly obliterated. We must not now reverse the wonder, and doubt whether all-powerful time can grind down mountains – even the gigantic Cordillera – into gravel and mud.

From his eagle's-nest perspective, Darwin's eye roves around not only in space but also within time. Indeed, the pleasure of viewing the *actual* scenery laid out before him is secondary compared with the visions he has of the *imagined* scenery – the masses of snow-capped peaks and ranges which must once have existed here but, thanks to the 'wonderful forces' of geology, no longer do. Darwin is, in effect, gazing at range on range of mountains of the mind, made newly and marvellously visible to him by Lyell's doctrines.

Moments like this litter Darwin's journals. One of the principal thrills for the many readers of his published account of the trip, *The Voyage of the Beagle* (a bestseller in its day), was to travel with Darwin not only to the storm-hammered tip of Tierra del Fuego and the silver deserts of Patagonia, but also back and forth within the recently discovered expanses of geological time. The HMS *Beagle* was one of the world's first time-travel ships – a prototype of the *Starship*

Enterprise, whose warp drive was fuelled by a mixture of Darwin's prodigious imagination and Lyell's insights.

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Anyone who has spent time in wild landscapes will have experienced in some form this deepening of time which John Playfair sensed in Berwick and Darwin felt in Chile. Early one March I walked the length of Strath Nethy, a long Scottish valley which runs round the back of the Cairngorm mountains. In cross-section the glen, like all the glens in that part of the world, is shaped like a flattened U. It is shaped like this because until around 8,000 years ago the Scottish Highlands were overrun with glaciers, as were parts of Wales and Northern England, most of North America and significant sections of Europe. These glaciers moved gradually over the land: scooping it out, grinding it down, resculpting it.

Walking the glen that day, I could see, two-thirds of the way up either flank, the high-tide mark of the glacial ice, plotted by the boulders which had been cast up there in a ragged line like sea-shore flotsam. The flanks of the valley were also incised laterally with dozens of little stream-cuts. The stream-cuts had been harrowed into the bedrock granite during the millennia since the glaciers retreated from the valleys. They had been cut by the insistent fretwork of the rainwater which ran away down the sides of the ridges. Once it has found a channel, water works away at deepening it – carrying off particles of rock, using those particles to strike other particles free – until it settles into its groove, and its groove becomes its channel, and its channel its stream-cut.

Following the line of one of the stream-cuts, I scrambled up the eastern slope of the glen to the wrack-line. The heather was slippery with clumps of melting snow, and I often had to put a hand down into it to steady myself. As I neared the boulders I startled a ptarmigan, and it flew kekking up into the white sky, where it became a silhouette.

By the time I reached the boulders my hands were cold. I rubbed them noisily together, and then began to walk up the valley, from boulder to boulder, imagining the ice filling up the glen like a bath. Each rock was moated with dark earth, where the warmth it had gathered during the day had leached out and melted the surrounding snow. I kept walking along until the gradient steepened and I had to drop off again into the valley floor. The path took me near a patch of exposed rock perhaps ten square metres in area. I walked over, and crouched down to examine it. The horizontal striations scored into it showed that this rock had once been a scratching-post of the glacier which had created the valley and was one of the places where it had rubbed its tremendous underbelly along the ground.

I looked up from the rock. It had snowed recently, and the hills visible beyond the confines of the glen were grey beneath a thin fall of snow; their outlines softened. In the far distance their bulks could hardly be seen against the white winter air; only a few dark strokes defined them at all. They reminded me of charcoal sketch-work, or the simple lines of a Chinese water-ink painting.

After two hours I reached the gateway to the valley, guarded to the west by the cone of Stac-an-Iolaire, the Crag of the Eagle, and to the east by Bynack More and Bynack Beg. Looking down towards the forests of the north, I saw – russet against white – a herd of red deer, perhaps half a mile away from me, jogging across the hillside, picking up their knees where the heather or the snow deepened. I stood and watched for a few minutes the procession of the deer, the only moving objects in the landscape, and was suddenly swallowed up by time. Twenty thousand years ago, during the Upper Pleistocene era, the heathered granite across which the deer were moving would have been submerged beneath millions of cubic litres of ice. Sixty million

years ago floods of basalt lava would have been sluicing the land, as Scotland tore violently away from the landmasses of Greenland and North America. One hundred and seventy million years ago, Scotland would have been drifting through the northern tropics, and arid reddish deserts would have covered the area on which I was standing. About 400 million years ago, a Himalayan-scale range of mountains would have existed in Scotland, of which only the eroded stubs remain.

To understand even a little about geology gives you special spectacles through which to see a landscape. They allow you to see back in time to worlds where rocks liquefy and seas petrify, where granite slops about like porridge, basalt bubbles like stew, and layers of limestone are folded as easily as blankets. Through the spectacles of geology, *terra firma* becomes *terra mobilis*, and we are forced to reconsider our beliefs of what is solid and what is not. Although we attribute to stone a great power to hold time back, to refuse its claims (cairns, stone tablets, monuments, statuary), this is true only in relation to our own mutability. Looked at in the context of the bigger geological picture, rock is as vulnerable to change as any other substance.

Above all, geology makes explicit challenges to our understanding of time. It giddies the sense of here-and-now. The imaginative experience of what the writer John McPhee memorably called 'deep time' – the sense of time whose units are not days, hours, minutes or seconds but millions of years or tens of millions of years – crushes the human instant; flattens it to a wafer. Contemplating the immensities of deep time, you face, in a way that is both exquisite and horrifying, the total collapse of your present, compacted to nothingness by the pressures of pasts and futures too extensive to envisage. And it is a physical as well as a cerebral horror, for to acknowledge that the hard rock of a mountain is vulnerable to the attrition of time is of necessity to reflect on the appalling transience of the human body.

Yet there is also something curiously exhilarating about the contemplation of deep time. True, you learn yourself to be a blip in the larger projects of the universe. But you are also rewarded with the realization that you do exist – as unlikely as it may seem, you do exist.

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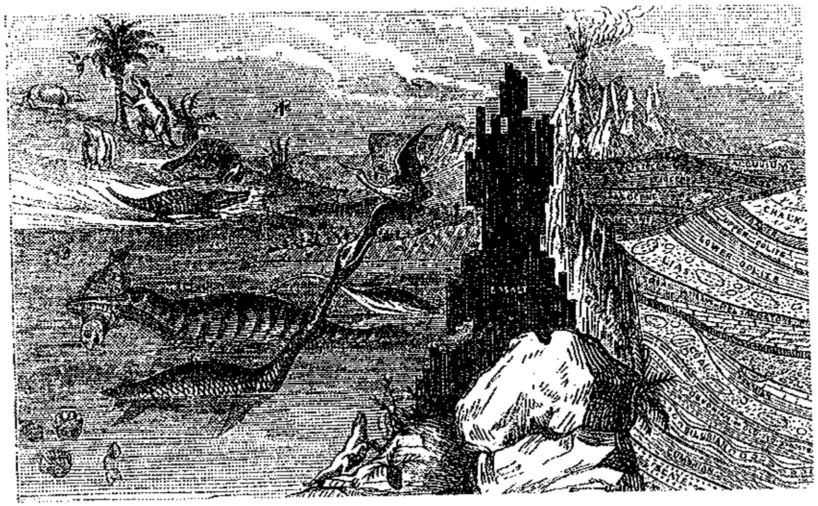
Charles Lyell's *Principles of Geology*, and the dozens of popular geological works which soon afterwards sought to emulate its success, opened the eyes of the nineteenth century to the dramatic hidden past of the earth. The common imagination began to respond to the aesthetics of inordinate slowness; to gradual changes wrought over epochs. And whatever one's position *vis-à-vis* the grand tectonics of geological debate, or any of the many minor upsets and scuffles which disturbed the science in the nineteenth century, what was irrefutably wondrous – and terrifying – was the age of the earth: its inexpressible antiquity. In little under half a century, geology had unfolded the world backwards by billennia.

The seventeenth and eighteenth centuries had been the centuries when space was extended, when the realm of the visible had suddenly been increased by the invention of the microscope and the telescope. We have images from that era which remind us of quite how astonishing that sudden stretching of space must have been. There is the Dutch lens-grinder Antony van Leeuwenhoek, peering down his rudimentary microscope in 1674 to see a host of micro-organisms teeming in a drop of pond-water ('The motion of most of these animalcules in the water was so swift, and so various upwards, downwards, and round about, that 'twas wonderful to see . . .'). There is Galileo scrying upwards through his telescope in 1609, and becoming the first human to realize that there are 'lofty mountains' and 'deep valleys' on the moon. And there is Blaise Pascal's mingled wonder and horror at the realization that man is poised teeteringly between two abysses: between the invisible atomic world, with its 'infinity of universes, each with its firmament, its planets, and its earth', and the invisible cosmos, too big to see, also with its 'infinity of universes', stretching unstoppably away in the night sky.

The nineteenth century, though, was the century in which time was extended. The two previous centuries had revealed the so-called 'plurality of worlds' which existed in the tracts of space and the microcosms of atoms. What geology revealed in the 1800s was a multitude of 'former worlds' on earth, which had once existed but no longer did. Some inhabitants of these former worlds offered an excitement beyond the general thrill of antiquity. This was the range of monstrous creatures which had formerly lived on the earth: mammoths, mammals, 'sea-dragons' and dinosaurs (literally 'fearfully great lizards'), as they were christened in 1842 by the palaeo-anatomist Richard Owen. Fossilized bones and teeth had been plucked from the earth for centuries, but not until the early 1800s was it realized that some of these relics belonged to distinct, and extinct, species.

The French natural historian Georges Cuvier (1769–1832) did more than anyone to bring about this realization. For it was Cuvier who affirmed to the world the controversial fact of extinction, and in so doing created the conceptual framework needed to understand dinosaurs as fossil animals. Cuvier's test-case was the woolly mammoth: by comparing the structures of fossilized mammoth bones with those of contemporary African and Indian elephants, he proved that the fossil bones belonged to a different species. In 1804, to an astonished audience at the Institut National in Paris, Cuvier announced that huge and hirsute elephants – no longer alive upon the earth – had once inhabited France and had almost certainly stomped and herded through what were now the immaculate gardens



'The Rocks and Antediluvian Animals', frontispiece to Ebenezer Brewer's *Theology in Science* (1860).

of Versailles. In terms of girth, Cuvier was a not inconsiderable man, and inevitably he was soon nicknamed 'The Mammoth'.

Cuvier became a celebrity in his day, in part for his capacious brain (he was reputed to have memorized the 19,000 books in his library) but above all for his skill as an anatomist. Where James Hutton had been possessed of a remarkable ability to deconstruct rocks, Cuvier was able to reconstruct the megafauna of Europe from their petrified bones: to reimagine what the beasts that once roamed the earth might have looked like. He strung outsize skeletons together with wire, embedded archipelagos of bone in cement frames, and with the help of illustrators developed the first drawings of dinosaurs. To many, Cuvier's work appeared more like thaumaturgy than taxidermy, for it conjured not only creatures but whole ages to life. 'Is Cuvier not the greatest poet of our century?' Balzac would later write ecstatically of him. 'Our immortal naturalist has reconstructed worlds from blanched bones. He picks

up a piece of gypsum and says to us "See!" Suddenly stone turns into animals, the dead come to life, and another world unrolls before our eyes.'

Stimulated by the new fervour for what had popularly become known as the Ancient Earth, fossil-hunting and palaeontology quickly became the European craze of the early nineteenth century. Every day, it seemed, a new dead species was discovered. An energetic sub-tribe of geologists, the fossil-hunters, sprang up. The fossil-hunters went with their knapsacks, hammers and soft brushes to where the rock was exposed: to the sea-side – like the rich Jurassic shale beds at Lyme Regis from which the renowned fossil-hunter Mary Anning prised ichthyosaurs and plesiosaurs – to creeks, quarries and river-cuts, and, of course, to the mountains. Athletically inclined fossil-hunters clambered up cliff-faces, past the different folds and pleats of rock, and wrote of how they felt themselves to be moving at speed through time, ascending an epoch with a single movement.

Many fossil-beds were pillaged by the collectors – the Victorian predilection for rendering species extinct extended even to already extinct species. Moneyed amateurs filled rooms with their finds, and for their smaller specimens invested in 'fossil chests': waist-height cabinets with rows of slide-out, glass-topped drawers, divided beneath the glass by matchwood partitions into dozens of little square holding-pens. In each pen, carefully labelled, was placed a fossil: a shark's tooth, say, or a fern impressed delicately on to a shard of shale. Fashionable little cemeteries of this sort stood in many affluent households, and people would come to gaze through the glass at these relics from former worlds, to ponder their own mortality and to contemplate the ineffable age of the earth.

The fossil craze is significant to our inquiry for two reasons. First, because it intensified the nineteenth-century fascination with the past ages of the earth. Fossils, Charles Lyell had adroitly observed in his *Principles*, are 'ancient memorials of nature . . . written in a living language', and palaeontology, like geology, taught people how to read a landscape as a history book: for what it told of the past. Indeed geology was *the* popular science of the first half of the 1800s. By 1861, even the Queen had a mineralogist by appointment. Geological tourism became a growth industry: those about to embark on a geological tour in the 1860s could pick from a range of lecture courses which would tutor them in the ways of rocks. For those who preferred the personal touch, Professor William Turl of Green Street in London offered (so his advert ran) 'individual instruction for tourists so that they can acquire sufficient knowledge to identify all the ordinary components of the crystalline and volcanic rocks to be encountered in the European mountains'.

The second and connected significance of the fossil craze was that it encouraged thousands of people outdoors, and fostered a more hands-on approach to rocks and cliffs. Indeed, the foundations of Western geology were laid down in the mountains, and mountaineering has always walked hand-in-glove with geology. Many of the pioneering early geologists – Horace-Bénédict de Saussure, and the Scotsman James David Forbes, for instance – were also pioneering mountaineers.* Saussure's four-volume *Voyages dans les Alpes* (1779–96) was both a founding work of geology and one of the first wilderness travel books. When the Geological Society of London formed in 1807, its members, aware that the implications of their science ran against the religious grain of the time, were keen to be perceived neither as fuddy-duddies nor as iconoclasts. They ended up styling themselves 'knights of the hammer': chivalric men of science

* Geology remained a driving force in mountaineering until well into the twentieth century – the first three Everest expeditions (1921, 1922 and 1924) were funded in part as scientific expeditions aimed at bringing back geological (and botanical) knowledge of the Everest region.

who sallied forth into the wilds in quest of knowledge. Robert Bakewell, in his *Introduction to Geology* (1813) observed that 'an additional recommendation to the study of geology, [is] that it leads its votaries to explore alpine districts . . .' As if to prove his point, the frontispiece to the first edition of his *Introduction* showed Bakewell sitting happily among the rock columns on the top of Cadair Idris.

Geology, therefore, for the early nineteenth-century public, came to suggest both a healthy outdoorsiness and a romantic sensibility: not just tinkering with old bones and stones. More than this, geology was perceived by many as a form of necromancy, which made possible a magical voyage into a past where one would encounter – as one knight of the hammer put it – 'prodigies more wonderful than fiction'. After the 1820s, when the rudiments of classical geology diffused in Europe and America, it was realized by increasing numbers of people that the mountains provided a venue where it was possible to browse the archives of the earth – the 'great stone book', as it became called.

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I had two stone books as a boy. One was slim paperback called *A Guide to Rocks and Crystals*, and it provided descriptions and photographs of hundreds of different stones, whose resonant names I would roll round my mouth – *red and green serpentine, malachite, basalt, fluorspar, obsidian, smoky quartz, amethyst* – until I had learned them. I spent hours beachcombing on the Scottish coast, not for the serendipitous discoveries of the tide-line – the single flip-flop which had leapt off a passing liner, the neon globe of a fishing-float or the vulcanized corpse of a jellyfish – though these were certainly wonderful, but for the rocks which cobbled the beaches. Crunching across that geological pot-pourri with my guide in hand, I swooped upon stone after stone, gathering them up and stashing them in a canvas shoulder-bag I carried, where they clunked and squeaked against each other. It felt like being given free range in the world's finest sweet-shop: I could never quite believe I was allowed to take the stones away. I lugged them home, arranged them in troughs on the window-sill and kept them glossy and sleek with water.

I loved the colours of the stones, and their feel – the big flat ones which fitted warmly into the palm of the hand like a discus, and had rings of blue or red cutting through the background smoky grey; or the heavy granitic eggs, smoothed by epochs of oceanic massage; or flints, more jewel than stone, translucent as dark beeswax, and as deep to look into as a hologram. But what began truly to fascinate me, as I read more widely in geology, was the realization that each stone had a story attached to it: a biography which stretched backwards in time for epochs. I felt obscurely proud that my life had intersected with each of these inconceivably ancient objects; that because of me they were on a window-sill and no longer on a beach. Occasionally, I would take two stones and, cupping one in my hand, use it to shatter the other. There would be a crack, an orange sprig of fire and a smudge of rock-smoke. I would briefly be pleased that I had achieved what billennia of geophysical forces had not.

I paced over the Scottish hills and through the long glens of the Cairngorms looking for mineral treasures. My most sought-after specimens from the hillsides were lumps of rose quartz, tumbled into roundness by the rivers: beautiful with their chalky pink-and-white complexion, and their soft, pulsing luminosity. I also prized the Scottish granite, which with its fleshy pink feldspar and fatty flecks of quartz resembled a geological pâté. I read more widely about geology, and I began to understand the grammar of the Scottish landscape – how its constituent parts related to one another – and its etymology; how it had come to be. And I appreciated its calligraphy; the majuscule of the valleys and peaks, the intricate engravings of streams and rivulets, and the splendid serifs of ridge top and valley bottom.

From the summit or the slopes of every mountain I climbed with my family, my father would select a rock and carry it down in his orange canvas rucksack. He grouped them together, dozens of them, to make a rock garden. I remember a nubbed lump of gneiss, a black basalt pillow, a yard-long slab of silver mica as bright as salmon skin, and a hunk of dark igneous rock in which dozens of tiny quartz nodules were embedded. The finest of all, to my mind, was a rounded boulder of yellow-white quartz, as smooth and soft to touch as thick cream.

The other geological book I owned as a child was the chauvinistic *Boy's Guide to Fossils*. During one summer I spent in a cottage near the Scottish coast, it became my constant companion. Up among the cliff-top outcrops where the sediments lay with their rounded edges, my brother (seven) and I (nine) gathered belemnites. They were pointed and hard as bullet casings. We searched the seashore strata – hopelessly, I now realize – for trilobites. We levered rock nodes from the sea-cliffs with knives and smashed them open with hammers. We walked up to the hill lochs in the mountains above the sea, carrying little rods and minuscule black flies, and twitched trout from their water: dark little fish no more than a hand's-span in length which seemed, to my newly elongated imagination, at least a billion years old – more coelacanth than trout. But beyond the belemnites, there were no real fossil finds that year. No ammonites or ichthyosaurs. Certainly no archaeopteryx or giant prehistoric sharks. Our lack of success didn't stop me dreaming, of course: of pulling a plesiosaur skull from a soft chalk bank, or of striding over the Siberian permafrost, stubbing my toe on the tip of a tusk, and looking down into the ice to see a mammoth staring tremulously back out at me.

Two summers after the Scottish holiday, our family set off to tour the National Parks of the American desert states. In Utah we saw the rock faces of Zion, the arches of Arches and the fretted pink obelisks of Bryce Canyon, which were arrayed up and down the valley like baroque missiles. I think it was near Zion that we pulled up at a roadside pump to feed our big American car with petrol. At one edge of the gravel forecourt was a man wearing a baseball cap. He was sitting on a dining-room chair, with an electric circular saw mounted on a frame in front of him, and a pyramid of rough rock spheres stacked like oranges to his left. We walked over to the man, and there was a conversation between him and my father. 'Pick a rock,' my father said, turning to me. The man stood up and watched me as I examined the rock pile. I wondered if they were dragon's eggs. I weighed one in my hand. It felt lighter than I expected. I whispered to my mother that it was light.

'That's a good sign,' said the man, taking the rock from me, sitting back down on the chair and placing his legs either side of the saw blade. 'Light means there's space inside. Have that one.'

He gunned the saw. Its silver-grey fangs seemed to spin first one way, then the other, and then blurred into a single immobile edge. The saw's engine began rhythmically to puff blue smoke into the air of the forecourt. 'Watch this,' my father mouthed to me over the noise of the saw. I wondered what would happen if the saw fell forwards into the man's lap. Using a handle, the man lowered the saw's edge slowly on to my rock egg, which he had vised into position. It took a minute or so for the saw to move, squealing, through the rock. When it was done the man cut the engine and raised the saw upwards, out of the rock. The rock dropped from the vise on to a blanket he had placed beneath it and fell apart like a halved apple. He dried off the halves with a yellow towel, and held them out to me. 'You've been lucky,' he said slowly. 'You chose well. You chose a geode. Most people aren't as lucky as you.' I held a half in each hand, and looked at them. Each half was hollow inside, like a cavern, and the walls of each cavern were lined with numberless tiny blue crystal

teeth. As we drove out of the forecourt, gravel bits clattering up against the chassis of the car, I held the two halves together to remake the rough rock sphere, and then pulled them apart, astonished again and again by what I saw.

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Between about 1810 and 1870, the scale of deep time was constructed and labelled. It will be familiar to anyone who has opened a geology textbook; as resonant a litany as the shipping forecast: Precambrian, Cambrian, Ordovician, Silurian, Devonian, Carboniferous, Permian, Triassic, Jurassic, Cretaceous, Tertiary, Quarternary . . . The compressive power of language – more powerful even than the geophysical forces it was describing – was set to work on the geological past, and hundreds of millions of years were effortlessly compacted into a few letters. A late developer among the sciences, during the nineteenth century geology rushed on precociously fast, naming and labelling as time unrolled further and further behind it. Popular geology handbooks proliferated, and the reading public was brought increasingly to understand what the more lyrically inclined geologists were starting to call the 'symphony of the earth' – the repeating pattern of uplift and erosion which produced mountains and seas, basins and ranges. Innumerable articles were published on geology and its revelations in periodicals across Europe and America. Everyone was made privy to the secrets of the earth's past. 'The wind and the rain have written illustrated books for this generation,' wrote Charles Dickens in a piece for his periodical *Household Words* in 1851, 'from which it may learn how showers fell, tides ebbed and flowed, and great animals, long extinct, walked up the craggy sides of cliffs, in remote ages. The more we know of Nature, in any of her aspects, the more profound is the interest she offers to us.'

As well as being excited by the spans of time uncovered by geology, the nineteenth-century imagination was aroused by the concept of geophysical force – the inconceivable power necessary to knead sandstone like pastry, to collapse trees into shiny seams of coal and to crush marine life into blocks of marble. Romanticism had left the collective nineteenth-century nervous system attuned to appreciate excess, and this inherited lust for the grandiose and the gigantic in part explains the enthusiasm with which geology was embraced.

In mid-century Britain, John Ruskin read widely in the writings of geology, and in turn began to write brilliantly himself about the slow-motion drama of mountain scenery. The 1856 publication of Ruskin's *Of Mountain Beauty* was, like the appearance in 1830 of Lyell's *Principles*, a seminal moment in European landscape history. 'Mountains are the beginning and end of all natural scenery', pronounced Ruskin at the outset, and he brooked no quarrel with that statement throughout the rest of the book. Where Lyell was a teacher, Ruskin was a dramaturge. Before his gaze, the landscape offered up the stories of its making. Meditating on the nature of granite, with its medley of minerals and colours, Ruskin dreamt of the violence inherent in its making: 'The several atoms have all different shapes, characters, and offices; but are inseparably united by some fiery, or baptismal process which has purified them all.' Basalt he perceived to have at one stage in its career possessed 'the liquefying power and expansive force of subterranean fire'. Seen through the optic of Ruskin's prose, geology became war or apocalypse; the view from the top of a mountain became a panorama over battlegrounds upon which competing armies of rock, stone and ice had warred for epochs, with incredible slowness and unimaginable force. To read Ruskin on rocks was – and still is – to be reminded of the agencies involved in their making.

In America, too, between 1820 and 1880 there emerged a dynasty of landscape artists – Frederick Edwin Church foremost among

them – who drew their inspiration from the dramatic natural scenery of the States. While they were clearly influenced by the British triumvirate of Ruskin, Turner and John Martin, these painters were filled also with a distinctively American desire to express both awe at and pride in the landscape of their country: to celebrate God's chosen land. To this end, they produced immense and often lurid canvases of American wildernesses – the red rock citadels of the desert states, the mountainous throne-rooms of the Andes, the flaring skies and mirror lakes of the Rockies, or the vaporous magnificence of the Niagara Falls. Their giant pictures emphasized the puniness and transience of man: often one or two minuscule human figures can be seen in a corner of the canvas, dwarfed by the massive profiles of the landscape. These artists were also thoroughly versed in botany and geology: some of the pictures contained so much landscape detail that, when they were first exhibited, viewers were supplied with opera glasses so that they could see the extraordinary geological accuracy of the painting – a reminder of how intertwined were geology and representations of mountains.

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Oil painting is an appropriate medium to represent the processes of geology, for oil paints have landscapes immanent within them: they are made of minerals. Oil paints were first devised in the fifteenth century, when Flemish painters – the van Eyck brothers foremost among them – tried mixing linseed oil with various natural pigments, and found they had created a substance which was not only more vibrant in colour, but also more malleable in terms of drying time than traditional egg tempera. Many of the pigments they blended with the oils were mineral in origin. Unburnt pit-coal was used to render the shadows of flesh, particularly by the Flemish and

Dutch painters of the seventeenth century. Black chalk and common coal were used to furnish a brown tint. The light blues employed to render mountains as films in the far background in the work of, say, Claude or Poussin would have come from copper carbonates or compounds of silver. The 'scumbling' effect of which the Dutch masters were so fond for their skyscapes (it gives a cloud-like texture to the skies which superbly imitates the consistency of cirrostratus) was achieved using ground glass as a pigment and ashes as a context. 'Sinopia', or red earth, was used to give rouging tints to faces or clothing, or to provide the first tracing of a fresco on to plaster. Geology, therefore, is intimate with the history of painting; in oil paintings of landscapes, the earth has been pressed into service to express itself.

An even closer coincidence between medium and message can be found in the 'scholar's rocks' which became popular in the T'ang and Sung dynasties of China. Seven centuries before Romanticism revolutionized Western perceptions of mountains and wilderness, Chinese and Japanese artists were celebrating the spiritual qualities of wild landscape. Kuo Hsi, a celebrated eleventh-century Chinese painter and essayist, proposed in his *Essay on Landscape Painting* that wild landscapes 'nourished a man's nature'. 'The din of the dusty world,' he wrote, 'and the locked-in-ness of human habitations are what human nature habitually abhors; while, on the contrary, haze, mist and the haunting spirits of the mountains are what human nature seeks.' This venerable Eastern esteem for wilderness explains the popularity of scholar's rocks, single stones which have been carved into intricate, dynamic shapes by the powers of water, wind and frost. They were harvested from caves, river-beds and mountainsides, and mounted on small wooden pedestals. The stones – which scholars kept on their desks or in their studies, much as we might now keep a paperweight – were valued for how they expressed the history and the forces of their making. Each detail on a rock's surface, each groove or notch or air-bubble or ridge or perforation, was

eloquent of aeons. Each rock was a tiny, hand-held cosmos. Scholar's rocks were not metaphors for a landscape, they were landscapes.

Many of these rocks have survived and can be seen in museums. If you stare at one closely enough, and for long enough, you lose your sense of scale, and the whorls, the caverns, the hills and the valleys which nature has inscribed in them can seem big enough to walk through.

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Not everybody, it should be said, was exhilarated by the advances of geology in the nineteenth century. There was a widespread feeling that geology, like the other sciences, had in some way displaced humanity. Scientific inquiry and methodology had been invited into the heart of the human project, and from there it had proved – in the most merciless and irrefutable way possible – that human beings were no more or less important than any other agglomeration of matter in the universe. It had eroded the Renaissance world-view of man as the measure of all things. The desolating expanses of time revealed by geology were more persuasive proof than any other of humankind's insignificance. To understand that mountains decayed and fell was inevitably to sense the precariousness and mortality of human endeavours. If a mountain could not withstand the ravages of time, what chance a city or a civilization? 'The hills are shadows,' wrote Tennyson in his elegy for stasis *In Memoriam*, 'and they flow / From form to form, and nothing stands; / They melt like mist, the solid lands, / Like clouds they shape themselves and go.' And 'From' flowed into 'form': philology was showing that language was subject to the same ceaseless shiftings as everything else. Not even words stood for what they once did. Nothing endured any longer except change.

By and large, however, the disclosures of geology were found inspiring rather than menacing. As well as explaining the forces of the earth, Ruskin urged his public to interpret landscapes for their absence as much as their presence: what had been subtracted from the hills by cataclysm or by the ceaseless work of erosion. In Ruskin's writing, hills on imaginary hills arose before one's eyes in a fantasia of contingency, might-have-been and once-was. Like a magnificent Prospero, Ruskin summoned up the ghosts of mountains past; had them arise in the space above the skylines and ridges of the present day. Wild nature, he taught, was a ruin of something once even more astonishing – a dilapidation of what he called 'the first splendid forms that were once created'. Even the Matterhorn, whose upwards flourish drew admirers in their thousands to the Zermatt valley, Ruskin pointed out to be a sculpture: gouged, chiselled and pared from a single block by the furious energies of the earth. As John Muir would do later in the United States, John Ruskin taught his many readers that the geological past was everywhere apparent – if only one knew *how* to look.

John Ruskin also believed that mountains moved. And this was perhaps his most important contribution to the formation of our mountains of the mind. Before publishing *Of Mountain Beauty*, Ruskin had spent years pacing the lower paths of the Alps; sketching, painting, observing, meditating. He had concluded that the apparently arbitrary jaggedness of mountain ridges was an illusion. In fact, examined with due diligence and patient eyes, mountains revealed their fundamental form of organization to be the curve, and not the angle as might be concluded by superficial observation. Mountains were inherently curved, and mountain ranges were shaped and arranged like waves. They were waves of rock – 'the silent wave of the blue mountain' – and not waves of water.

Moreover, said Ruskin, mountain ranges, like hydraulic waves, were prone to motion. They had been cast up by colossal forces, and were still being moved by them. That the movement of mountains could only be imagined and not witnessed was – as James Hutton had pointed out – a function of the minute life-span of a human being. They were not static, but fluid: rocks fell from their summits, and rainwater poured off their flanks. For Ruskin, this perpetual motion was what made mountains the beginning and end of all natural scenery. 'Those desolate and threatening ranges of dark mountain,' he wrote:

> which, in nearly all ages of the world, men have looked upon with aversion or terror and shrunk back from as if they were haunted by perpetual images of death are, in reality, sources of life and happiness far fuller and more beneficent than all the bright fruitfulness of the plain . . .

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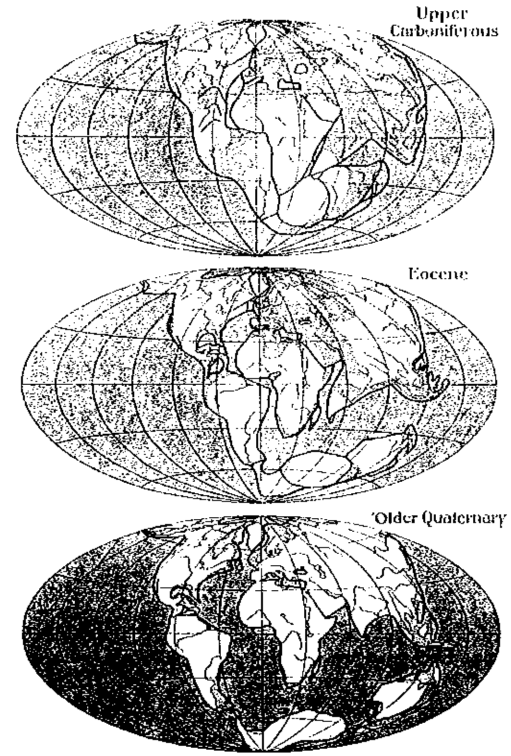
Ruskin's intuition that mountains moved was proved unexpectedly correct during the course of the twentieth century, in what is the final significant shift in Western imaginings of the past of mountains. In January 1912, in an incident now legendary among earth scientists, a German called Alfred Wegener (1880–1930) stood up before an audience of eminent geologists in Frankfurt, and told them that the continents moved. Specifically, he explained that the continents, which were composed primarily of granitic rock, 'drifted' on top of the denser basalt of the ocean floor, like patches of oil on water. Indeed, 300 million years ago, Wegener informed his increasingly incredulous audience, the landmasses of the world had been united into a single supercontinent, an ur-landmass, which he called Pangaea (meaning 'all-lands'). Under the divisive power of various geological forces, Pangaea had been riven into many pieces and these pieces had subsequently drifted apart, ploughing over the basalt to their present positions.

The mountain ranges of the world, Wegener argued, had been created not by the cooling and wrinkling of the earth's crust – a theory which had come back into vogue at the start of the twentieth century – but by the crash of one drifting continent into another, causing buckling around the impact zone. The low-lying Urals, for example, which nominally separated European Russia from Siberia, were, according to Wegener, the product of an ancient collision between two mobile continents which had occurred so long ago that the effects of mountain building in the impact zone had been largely flattened by erosion.

For proof, said Wegener, just look at the globe. Look at the dispersal of the continents. Move them around a bit and they fit together like a jigsaw puzzle. Slide South America towards Africa and its eastern coast locks into Africa's western perimeter. Wrap Central America around the Ivory Coast, and North America over the top of Africa and you have half a supercontinent already. The same trick, he pointed out, worked for India's angled western littoral, which fits snugly against the straight side of the Horn of Africa, just as Madagascar slots neatly back on to the divot on the south-eastern coast of Africa.

Wegener had harder evidence to support his claim. He had spent years working in the extensive fossil archives of the University of Marburg, and had deduced that identical fossil specimens had been found in the rock record at precisely the zones Wegener suggested had once been united: on the west coast of Africa, for example, and the east coast of Brazil the coal deposits and fossils matched. 'It is just as if we were to refit the torn pieces of a newspaper by matching their edges,' he wrote, 'and then check whether the lines of print ran smoothly across. If they do, there is nothing left but to conclude that the pieces were in fact joined in this way.'



Reconstructions of the Map of the World for three periods according to Wegener's displacement theory. From Alfred Wegener's *The Origins of Continents and Oceans*, trans. J. A. Skerl, 3rd edn (London: Methuen & Co., 1924).

Wegener was not the first to suggest the interconnectedness of the continents. The sixteenth-century cartographer Ortelius had noticed the jigsaw-puzzle composition of the continents, and had suggested that they were once attached, but had been sundered by drastic floods and earthquakes. He was disbelieved. The endlessly perceptive Francis Bacon mentioned in 1620 in his *Novum Organum* that the continents could fit together 'as if cut from the same mould', but seems to have thought no more about it. And in 1858, a French-American called Antonio Snider-Pelligrini devoted an entire treatise – *Creation and Its Mysteries Revealed* – to showing how the continents had once been united.

But in the mid-nineteenth century there was simply no context for such a radical overhaul of geological theory; no other pieces of knowledge with which the theory itself could fit. A mainstay of nineteenth-century geology was a belief in the existence of enormous land-bridges which had at one point joined the world's continents, but had since then crumbled into the oceans. These land-bridges explained the existence of the same species on different landmasses, and seemed far more plausible than mobile continents.

In 1912, therefore, Wegener was arguing against the grain of prevailing wisdom: if his theory were correct, it would nullify many of the founding assumptions of nineteenth-century geology. Worse still, Wegener was an intruder, a trespasser on the turf of the geologists. For his main field of research was meteorology – he was a pioneer in weather-balloon study and a specialist in Greenland, where he led several successful, and one fatal, Arctic research expeditions. How could a weatherman presume to dismantle at a single stroke the complex and magnificent edifice of nineteenth-century geology?

The opposition to Wegener's theory, as to that of Burnet so many years earlier, was immediate and voluble ('Utter, damned rot!', said the president of the American Philosophical Society, eloquently). But Wegener, a stoic visionary, remained phlegmatic in the face of early antagonism. In 1915 he published *The Origins of Continents and Oceans*, a careful explanation of his theory, and in its way as apocalyptic a reimagining of the earth's history as Burnet's *The Sacred Theory of the Earth* or Hutton's *The Theory of the Earth*. Between 1915 and 1929 Wegener revised his *Origin* three times to take into account advances in geology, but he was

still ignored by the geological establishment. In 1930 he led another meteorological expedition to Greenland. Three days after his fiftieth birthday he and his team were caught in a severe Arctic blizzard, in which temperatures dropped to –60°F. Wegener became separated from his companions, and froze to death in the private wilderness of a white-out. His body was found by his colleagues when the storm receded. They entombed Wegener inside a mausoleum built of blocks of ice, topped with a twenty-foot iron cross. Within a year, the structure and its contents had disappeared into the interior of the glacier on which it was built – a means of burial that would no doubt have met with Wegener's approval.

It was not until the advent of the so-called New Geology during the 1960s that it was realized that Wegener had been at least half-right. As advances in bathysphere technology permitted the more systematized exploration of the ocean floor, it was discovered that the continents did indeed move and had indeed spun apart from a vast ur-continent. But the continents weren't – as Wegener had thought – independent entities drifting over a sea of basalt, like icebergs in water. In fact, the surface of the globe was discovered to be composed of some twenty crustal segments or plates. The continents were simply the portions of the plates which were sufficiently elevated to protrude from the sea.

These plates were named by the New Geologists. There was the African Plate, the Cocos Plate, the North American Plate, the Nazca Plate, the Iran Plate, the Antarctic Plate, the Juan de Fuca Plate, the Australian Plate, the Arabian Plate and the decidedly unfragile China Plates. Driven by convection currents or 'cells' within the semi-liquid mantle of the earth, and pulled by their own weight, these plates move around relative to each other. Where their edges meet beneath the ocean, either a mid-ocean ridge or a subduction zone is formed. At mid-ocean ridges the boundaries of two plates are continually being pushed apart by action in the mantle. Magma rises into the gap, and cools to form sea-floor basalt. Mid-ocean ridges are therefore raised above the surrounding ocean floor, like the seam on a cricket ball. A subduction zone, by contrast, is where the edges of two plates are forced together, and the less buoyant plate slides underneath the other. There, the rock of the subordinate plate is pushed down into the mantle, where it melts and comes bubbling back up in liquid form, causing super-heated wounds in the crust. These subduction zones form the oceanic trenches: the Aleutian Trench, the Java Trench, the Marianas Trench. At the bottom of these trenches – the Marianas Trench is deeper than Mount Everest is high – the atmospheric pressure is so enormous that, were you to materialize at that depth, your body would instantly be compacted to the size of a tin can.

Most of the world's mountain ranges have been thrown up by the jostling and collision of the continental plates. Thus, for example, the Alps were created when the Adriatic Plate (which carries Italy on its back) was driven into the Eurasian Plate. The oldest mountains are those which are now the lowest, for erosion has had time to reduce them. The blunted, rubbed-down spine of the Urals, for instance, speaks of great age. So too do the rounded forms of the Scottish Cairngorms. Perhaps surprisingly, among the youngest mountains on earth are the Himalaya, which began to form only 65 million years ago, when the Indian Plate motored northwards and smashed slowly into the Eurasian Plate – ducking underneath it and then butting it five-and-a-half miles upwards into the air. Compared to the earth's venerable ranges, the Himalaya are adolescents, with sharp, punkish ridges instead of the bald and worn-down pates of older ranges.

Like adolescents, too, they are still growing. Everest – which became the world's highest mountain less than 200,000 years ago – shoots up by a precocious five millimetres or so a year. Give it a million years – the blink of an eye in geological terms – and the mountain could have almost doubled its height. Except of course that won't happen, because gravity won't tolerate such a structure. Something will give: the mountain will collapse under its own weight, or be shaken apart by one of the huge earthquakes which rack the Himalaya every few centuries.

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For years now I have gone to the mountains and been astonished by deep time. Once, halfway up the mica-rich peak of Ben Lawers in Scotland on a sunlit day, I found a square chest of sedimentary rock, hinged at its back with an overgrowth of moss and grass. Stepping back and looking at it from the side, I could see it was composed of hundreds of thin layers of grey rock, each one no thicker than a sheet. Each layer, I reckoned, was a paraphrase of 10,000 years – a hundred centuries abbreviated into three millimetres' depth of rock.

Between two of the grey layers I noticed a thin silvery stratum. I pushed the adze of my walking axe into the rock, and tried to lever the strata apart. The block cracked open, and I managed to get my fingers beneath the heavy top lid of rock. I lifted, and the rock opened. And there, between two layers of grey rock, was a square yard of silver mica, seething brightly in the sunlight – probably the first sunlight to strike it in millions of years. It was like opening up a chest filled to the brim with silver, like opening a book to find a mirror leafed inside it, or like opening a trapdoor to reveal a vault of time so dizzyingly deep that I might have fallen head-first into it.