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Book review

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Book Review

The Epochs of Nature by Georges-Louis LeClerc, le comte de Buffon, translated and edited by Jan Zalasiewicz, Anne-Sophie Milon and Mateusz Zalasiewicz, 2018. The University of Chicago Press, Chicago and London, 190 pp, ISBN 978-0-226-39543-2, hardback, £34.00, https://doi.org/10.7208/Chicago/9780226395579.001.0001

Users of Google Scholar will be familiar with the phrase 'Stand on the shoulders of giants'. Georges-Louis Leclerc, le comte de Buffon, was one of these, but although copies of his works appear frequently in Antiquarian and second-hand book sales, because they were written in French his ideas have been less well known. Jan Zalasiewicz, Anne-Sophie Milon and Mateusz Zalasiewicz set out to redress this imbalance and to draw attention to Buffon's wide-ranging contributions to geological thought. The translation seems excellent, preserving both the original, albeit repetitive, precision and what we would now regard as the 'mannered' language of the day. Few items jarred: the use of 'vitrescible' and 'monuments' in particular. It was necessary to look up the former but it seems to mean any *mineral* matter that forms glass when sufficiently heated. At times this is justified but we now take it for granted that most sand will consist of just such material and in this it seems redundant, confusing what would otherwise be clear statements. The use of 'Monuments' seems just too literal a translation. There are very few typographical errors and the book is well produced.

The Introduction (22 pp.), by Jan Zalasiewicz, Sverker Sörlin, Libby Robin and Jaques Grinevald, provides an enlightening history of le comte de Buffon, and views on the significance of his work today. Born in 1707, Buffon died at the age of 80 of natural causes, narrowly missing the French Revolution that claimed the life of his son. The family were not hereditary aristocrats, and may have come from labouring stock, but hard work, education, judicious marriages and the purchase by his father of the rights to the Buffon estate, were reflected in a steady progression and, as Director of the Royal Botanic Gardens in Paris for almost 50 years, Buffon became a pillar of society. Although he had set out to study law, he developed an interest in what was then natural philosophy. His father disapproved, regarding this as less than a profession, but his biographer, Jaques Roger, is quoted as describing him as one of the greatest naturalists produced by France, where the following generation included Jean-Baptiste Lamark, Etienne Geoffroy Saint-Hilaire and Georges Cuvier. His work was characterized by careful analysis, but the clarity of his writing, making it easily understood, set him apart from many contemporaries who regarded it as 'dumbing down'. In this respect he can be seen as pioneering 'popular science', standing comparison with the works of Stephen Jay Gould or Carl Sagan today. It is one of the first attempts to create a geological history of the Earth, introducing the term Epochs. Publishing throughout his life his monumental *Histoire Naturelle* runs to 36 volumes, several published posthumously.

This book, written late in his life, in 1778, was his most widely read and was reportedly 'devoured' by Catherine the Great, influencing luminaries that included James Hutton, Alexander von Humbolt, Charles Lyell, Charles Darwin, Vladimir Vernadsky and Thomas Jefferson. He wrote about minerals, plants and animals but also philosophy and in the latter is compared to his contemporaries Voltaire (François-Marie Arouet) and Jean-Jaques Cuvier. He developed concepts of geological succession, stratigraphy and species, bringing order to ideas that had been only loosely defined in the previous 200 years. Of greater significance was his approach, regarded as having more in common with modern Earth systems science than the categorization of strata and fossils, advocated by British icons like William Smith, Adam Sedgewick, Roderick Murchison and others. The reasoned approach of the 'Discourse', prefacing descriptions of the various Epochs, summarizes much that was then known about the Earth but he viewed Earth's origins in natural processes that had evolved and might one day come to an end. His Earth was ancient and dynamic and although his estimate of the age, of only 75 000 years since it began as a molten ball, was wrong, it was better than others and he feared that it was too short. He was religious, defending the biblical account of the origin of the Earth over five pages of discussion but, in contrast to many contemporaries, argued that the biblical timescale could *only* be metaphorical, regarding interpretations like those of Bishop Ussher as based on a doubtful premise that could not explain observed events. His advocacy of a holistic approach to Earth systems was prescient. The planetary scale of environmental changes currently affecting the Earth may be seen as echoes of his Seventh Epoch, defined as 'the state in which we today see Nature is as much our work as its own'. The translators' Introduction suggests that this lies close to the concept of the Anthropocene, first proposed by Paul Crutzen and Eugene Stoermer and now taken seriously enough to be considered by the International Commission on Stratigraphy. In an atmosphere in which climate change – widely accepted by science – is hotly denied by others, it has ethical and personal implications for us all.

The body of the text, 130 pp., is divided into the First Discourse (although there is no other), descriptions of Seven Epochs, and a further 45 pp. of what are essentially 'footnotes', justifying the statements previously made.

The Discourse begins by contrasting Human History, largely document based, and Natural History,

> where one must rummage through the Earth's archives and pull ancient monuments from the entrails of the Earth

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> and assemble their remains … in a body of … evidence of physical change that can allow us to reach back into the different ages of Nature.

Although the language is colourful, this is not a bad description of how to go about geology: the assembly of evidence based on observations of the Earth. He regards this as more reliable than civil history, 'that becomes increasingly uncertain with time', and sets out a series of basic tenets, of which the first: 'Use facts that allow us to get close to nature', may be the most important, but is followed by observations used as evidence of the early history of our planet.

Five 'facts' define the Earth: internal heat; independent of that of the Sun; materials; that can all be reduced to 'glass' (reflecting experiments on their response to heating); and the fact that 'immense quantities of shells may be found' on mountains 3000–4000 m high. The primitive Earth was liquefied by fire but all materials formed subsequently required water, because they consist of or include shells and other products of the sea, forming sands, clays and limestones.

The 'Monuments of Nature' are 'evidence' and Buffon draws particular attention to fossils. He may have been first to recognize that species represent populations capable of interbreeding and was aware that rocks across Europe and in continental interiors contained remains that included a large proportion of species of fish and plants not present in adjacent seas, noting that: 'these species either no longer survive, or are only found in more southerly seas' whereas others 'have no living analogues' and 'seem to be lost and destroyed … through causes that are as yet unknown'. In 'Siberia and … northern countries of Europe and Asia, [remains] of elephants, hippopotami, and rhinoceri, are present in large enough [numbers] to be assured that … these animals, which today … propagate only in … southern areas … [formerly also occurred] in … northern' countries. He notes that elephant bones and hippopotamus teeth found in northern North America, are of species found at shallow depths and no longer present in the New World, whereas shells and other marine debris are more deeply buried.

The disappearance of exotic species of mammals is seen as reflecting a 'change in climate', but he rejects suggestions that they were fleeing from a great flood and died of the cold! Among alternative explanations, suggestions 'by physicists' that climate change reflected 'changes in the obliquity of the elliptic' (a hundred years before James Croll (1867)!) were also rejected, in the belief that northern latitudes had been warmer because they retained heat from the primeval Earth, 'proof' that the Earth began in a fiery state. These examples illustrate the tone of the discussion and the evidence used to order events that separate six epochs, or ages of Nature. The discussions that follow are long and detailed and it seems appropriate here to summarize only a few observations from each.

The First Epoch: When the Earth and the Planets Took Their Form

The planets, including Earth, were originally molten and of similar form, flattened at the poles by their individual speeds of rotation. All rotate in the same direction and orbit in almost the same plane. They were formed by a single impact between a comet and the Sun. The 400–500 comets recorded between 1101 and 1766 provide an estimate of total numbers in the Solar System, and it is argued that heating within the Sun may reflect internal friction generated by the gravitational attraction of these bodies. Planets with satellites like the Earth/Moon pair, might be similarly heated, although to a lesser degree. Finally, planets would have been luminous, like the Sun, while they remained liquid, but the light faded as they solidified. Regarding this as 'a very probable hypothesis', Buffon expected to find planets around other stars, only invisible because of their great distance from us.

Experiments with heated iron balls suggested that the planets cooled from the surface inwards, and he assigned 2936 years for the Earth to consolidate to its centre. Volatile components were reduced to vapour and dispersed, and he used observations during a solar eclipse to argue that the Sun has an extensive 'atmosphere' that includes a sphere of 'aqueous material' and may reach as far as the Earth. However, Buffon felt that his estimate of age might be too short because construction of the great works of Nature 'could be made only by a slow succession of regulated and constant changes'.

The Second Epoch: When Matter, Being Consolidated, Formed the Interior Rock of the Globe and the Great Vitrescible Masses That Are at Its Surface

Buffon's estate included deposits of sedimentary iron ore and a foundry and he would have been familiar with the processes of smelting that appear to have informed his interpretation of the cooling Earth. He directly compares the solidification of the Earth with that of molten metal and glass, describing the formation of irregular cavities, 'caves', within it and 'mountains' on the surface as a natural result. Similar imagined subsurface caverns appeared in Jules Verne's *Journey to the Centre of the Earth* published in 1864. Buffon regarded the present highest mountains, 6000–7000 m high 'consisting of vitrescible matter', as remnants of this primitive state, but is careful to note that they remain small relative to the diameter of the Earth. Explanations for the positions of mountain ranges within continents are unrecognizable today when we have very different models for their formation.

During the initial cooling of the Earth, elements (here meaning air and water) separated and volatile components were driven out. 'Many centuries elapsed before the formation of limestone mountains became possible'. In the first 37 000 years, the Earth's surface would have been marked by fissures and veins in which metallic ores formed by fusion or sublimation. Secondary lodes were produced below these by the action of water, and flakes of gold or silver, derived from primary deposits, could be concentrated to form new ores. Generalizations relating ores to specific regional climates and the sizes of mountains were held to reflect progressive stages in the cooling process.

The Third Epoch: When the Waters Covered Our Continents

Before the oceans formed, the Earth's surface would have consisted entirely of 'vitrescible' rocks, lacking sedimentary

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deposits. 'Thirty or thirty-five thousand years after the formation of the planets, the Earth had cooled enough to receive … waters'. The atmosphere became organized and volatile components condensed and filled depressions in the primeval surface. With this surface covered, the mountains were then subject to erosion and the lower peaks were 'covered by glass scoria, sands, muds and all the debris of the products of the sea'. 'There is clear proof that the seas covered the continent of Europe up to (3000 m) above present' sea-level. Shells and other products of the seas can be found in the Alps, in the Pyrenees, and in Asia, Africa and America. In the latter, shells occur up to 4000 m, implying that the entire globe was covered in water up to 4 km deep! The mountains had to be covered in water in order to deposit the shells, leading to the expectation that those at the highest levels would be oldest.

Because the sea was initially boiling (*sic*) and remained relatively hot, the first fish and other aquatic animals 'regarded as the first inhabitants of the globe' were heat-tolerant. Buffon imagined repeated distillation of waters and violent winds that 'began to carve valleys more deeply, open subterranean passages and destroy caverns'. It is not clear how this would happen at a depth of 4 km but 'As caverns collapsed' water apparently 'filled these new depths and 'sea level gradually reduced'.

Nature was driving the spread of animals and plants to the land as well as the sea. Mines of coal and slate (but not as we know it!) indicate that 'the ancient species of marine animals and terrestrial vegetation were destroyed, or rather ceased to multiply, once the land and sea lost the great heat necessary for their propagation'.

Immediately after 'the establishment of the waters', acids were formed that converted scoria and sand into clays, rapidly at first because the water was hot, but continuing today more slowly. 'Sands are only the detritus of granites, of sandstones, and of vitreous rock … of which rain, ice and other external agents … detach small parts … every day'. The first shells formed a few centuries later with the transport of their remains almost immediately forming limestones.

Shales, slates, coals and bituminous matter date from about the same time because these materials are 'generally associated with clays at some depths'. 'Below [~39 m] of clay of which the beds contain belemnites, horns of Ammon [ammonites], and other ancient shell debris' … are

> seams of coal of which the formation is a little more ancient than that of the external beds of clayey earth. This is proved by these veins of coal being almost all inclined, while … (beds) of clay, like all … other external layers of the globe, are ordinarily horizontal.

Inclined beds are explained as having 'been brought in by a current upon a sloping terrain'. Buffon seems to have understood the origins of coal, considering that it represented the 'first vegetation formed by the Earth'. He was impressed by 'the immense quantity of plant debris that these coal seams indicate', citing the great numbers of trees presently 'carried by rivers such as the Mississippi and the Amazon'. However, based on experiments with vegetable oil and acid, he suggests that 'acid from the decomposition of … sand by fire, air, and water … finally entered into the composition of bitumen'.

The first shells and their detritus formed calcareous rocks, while plant detritus formed bitumen and coal and 'at the same time the waters, by their movements and by their sediments, composed the organization of the surface of the Earth into horizontal beds'. As the water that had formerly been so deep was progressively lowered, the emerging land 'was strewn with marine products'. 'The time during which the waters covered our continents was very long'. But his estimate of 20 000 years might be too short because, by analogy with modern-day growth of oysters (before Charles Lyell's axiom: 'the present is the key to the past' that appeared in *Principles of Geology* (1830–33)) implies that the 'immense number' of shells would require

> centuries of centuries … so that marine products were not just reduced to powder, but transported and deposited by the waters, in a manner that could form the chalks, the marls, the marbles, and the calcareous rocks.

Because the Earth is not a perfect sphere the Sun heated the tropics while the polar regions cooled and hence were first to be covered by water. (This begs the question of how deep water could be present at the poles and simultaneously absent at the Equator.) However, the Antarctic cooled the most, and more water and greater water movement eroded the southern extremities of the continents that taper and are separated as a result. 'It is certain that the … continents were not separated toward (the) north' (because) … 'elephants existed at the same time in Siberia and Canada. This proves unarguably the continuity of Asia or Europe with America'. However,

> it seems equally certain that Africa was separated from America since the first times, since not one of the animals of the ancient continent has been found in this part of the New World.

Accompanying this speculation is a clear statement following Nicholas Steno's law of superposition (1669).

> During this long interval of time, when the sea rested on our lands, the sediments and the deposits of the waters formed horizontal beds of the Earth: the lower ones of clay, and the upper ones of calcareous rock. It is in the sea that petrifaction of marbles and of stone took place. At first, these materials were soft, having been successively deposited one above the other, in proportion to how the sea carried them in and how it let them fall in the form of sediments. Then, they were little by little hardened by the force of affinity of their constituent parts, and at last they formed all of the masses of calcareous rock.

Equally interesting were his views on erosion: 'The rains have loosened and entrained earth … and the hills have been lowered little by little, while the valleys have been filled with earth moved by rainwater or flowing water'. Wells in Bicêtre, near Paris, recovered 'human worked' wood at [22.5 m] depth, indicating that the valley of the Seine had been filled to this depth 'since humans existed'. 'One can … be assured

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that the mountains are still being lowered day by day, and that the valleys are filling about in the same proportion.'

'Upheavals' of the Earth were confined to the beginning of the third Epoch and in particular to the tropics.

> The waters that covered our continents were lowered and receded, flowing in great streams towards the lands of the south of which they filled the depths … One can envisage the immense quantities of matter of all kinds that were then transported by the waters. How many sediments of different natures were then deposited, one above another? … one can believe that the Earth has nearly arrived at a state quiet enough for the inhabitants to no longer fear the disastrous effects of these great convulsions.

The Fourth Epoch: When the Waters Retreated and the Volcanoes Became Active

As sea-level fell the highest mountains emerged and became fertile, with the entire globe 'a kind of archipelago'. 'Nature established itself and spread with great vigour; because of the heat and humidity ….' The land was

> covered by great trees and vegetation of all kinds, the worldwide sea was filled everywhere with fish and shellfish: it was also the universal repository for all that became detached from the lands that overlooked it.

In the latter are included sands, muds, shale and slate, together with the first seams of coal, of salt and of bitumen and sedimentary iron ores.

'No volcanoes … existed before the waters had become established' and they could not become active until the water level lowered. Terrestrial and marine volcanoes differ because the latter, 'at the instant that their fire is ignited by effervescence of pyrite and combustible materials [*sic*] it is immediately extinguished by the water that covers them'. Terrestrial volcanoes 'have an action that is durable and proportional to the quantity of materials that they contain' but they need

> a certain quantity of water to enter a state of effervescence, it is only by the shock of a large amount of fire meeting a great volume of water that they can produce their violent eruptions.

For this reason, volcanoes active today 'are on islands or near the sea's coast'. Extinct volcanoes reflect the retreat of waters that become too distant to react.

These statements might have been based on observations of the reactions between lava flows and the sea. However, there are other possibilities: 'It seems to me that electricity plays a very great role in earthquakes and in volcanic eruptions'. Experiments suggested that 'the basis of electrical matter is the inherent heat of the terrestrial globe'; some produce 'a very bright fire and powerful explosions'. He surmised that subsurface caverns contain fire, air and water. 'The action of this first element must produce violent winds, loud storms and subterranean thunder … compared to lightning in the air' and related to earth tremors.

> A volcano is a vast oven, in which the bellows, or rather ventilators, are sited in the interior cavities, to the side and below their centre … These are the same cavities, since they extend to the sea, that serve as suction pipes to carry upward not just vapours but even masses of water and air.

Lightning is produced by this transport and the explosions that follow produce 'clouds of ashes and stones, (and) boiling torrents of lava … extending beyond the convulsive movements in the entrails of the Earth.' Most mountains are situated above cavities that contain 'materials that become inflamed solely by effervescence or that are set alight by sparks from the internal heat of the globe'.

Earthquakes are attributed to the collapse of the vast caverns formed within the primeval Earth but give rise to several effects: (1) water was 'forced to race in great floods to fill this new deep'; (2) 'shaking of the neighbouring ground … made the mountains tilt … detaching landslips'; and (3) 'raised far-off ground and water' and 'changed the course of rivers. We have thus to cease being surprised to see … the horizontal uniformity of the work of the waters broken and cut by inclined fissures'. We can now suppose that these were faults.

In a curious segue Buffon concludes that 'up to the time when volcanoes became active, there existed only three types of matter on the globe'. Those produced by primitive fire, calcareous matter produced by water, and the detritus of plants and animals. A new fourth class comprises materials brought up and expelled from volcanoes, and appearing to include mixtures of primitive matter. Each of these can be attributed to a specific Epoch.

In another foray into geomorphology Buffon concludes that it is only water 'that, as a general cause subsequent to that of primitive fire, managed to construct and shape the present-day surface of the Earth', but notes that 'The particular work of the currents was subsequent to the general work of the sea'. In a study of the mountains of Langres, the source of both the Seine and the Saône, he compares large valleys to 'trunks that throw off branches as other valleys' that in turn 'throw off twigs as other little valleys'. He refers to successive valleys as first order, second order etc., an idea reprised by R. E. Horton (1945). He suggests that 'the floors of the lower valleys were formerly much deeper than those of the upper valleys today and have been gradually filled by debris' deposited by currents. Unfortunately, he regards much erosion not as the work of rivers but of 'the seas that formerly covered the Earth'.

The Fifth Epoch: When the Elephants and Other Animals of the South Lived in the North

Life could only begin *c.* 36 000 years after the formation of the Earth but is expected to come to an end after 132 000 years. Fixated on the idea of a gradually cooling Earth, Buffon reconsiders the recent fossil record.

> All that exists today in living nature could equally have existed since the temperature of the Earth came to be the

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> same … The northern countries of the globe long enjoyed the same degree of warmth as… southern countries

do today. However, at the beginning of this period, 'terrains towards the south were still burning and remained as deserts … uninhabitable long after the lands of the north became populated'. The Equator was hot 'because of the greater thickness of the Earth' rather than heat from the Sun, and water from the atmosphere arrived much later here than at the poles where 'continual rains' accelerated cooling. The remains of plants and shell fish in coal seams and slates are of organisms less sensitive to heat that were destroyed by cooling. The first terrestrial animals were born less than 15 000 years ago when elephants, rhinoceri and hippopotami and others were present in great numbers in Russia and Siberia and when 'the northern countries of Europe, Asia and America' were contiguous. They are likely to have appeared first in more elevated regions because these 'would have cooled first'.

The first terrestrial animals were 'larger than … today', but larger elephants 'of which the species no longer survives' (were these dinosaur bones?) are grouped together with large ammonites. As the northern lands cooled, the elephants and others moved south and their remains are found in Poland, Germany, England, France and Italy. In the Americas, migration was halted by the mountains of the Panama Isthmus and none of the larger animals of the eastern continents are found in South America. The larger species all came from the north and the region of the Equator produced only a few 'inferior species'. Living Nature, and particularly terrestrial animals, was established independently in South America.

Buffon's views on the origins and spread of Man reveal an important belief.

> We agree that the human species does not essentially differ from other species by its bodily faculties … One cannot say that humans, such as those of the Marianas Islands, or … Tahiti and other islands … in the middle of the seas and at such great distances from all inhabited land, are not nevertheless humans of our species, because they can reproduce with us … the small differences that we see … are slight variations caused by the influence of climate and of nourishment.

Ahead of its time, this view has yet to be universally acknowledged. The spread of Man 'happened after all our epochs' and the fact that Man cannot 'defend himself … against too great a heat' suggests that his creation came after that of the great animals and that, like them, he lived first 'in the high lands of Asia'.

Sixth Epoch: When the Separation of Continents was Made

'The … separation of continents was … later than the times when … elephants lived in the lands of the north, as their species then subsisted equally in America, in Europe, and in Asia.' 'This separation … seems to have been made in two places, by … stretches of sea, that extend from (the) northern countries … becoming wider, as far as the most southern countries.' This is seen as proof that 'the waters' originally came from the poles.

'Separation' was not as we would now understand it, by a lateral movement, but is closer to the ideas of 'Undation', vertical crustal movement, associated with Reinout van Bemmelen (1931), that preceded the acceptance of Plate Tectonics (Continental Drift) in the 1960s. The Buffon view was that

> If Europe is today separated from Greenland, that is probably because there was a considerable subsidence between the lands of Greenland and Norway and the tip of Scotland, of which the Orcades, the island of Shetland, those of the Faroes, of Iceland and of Hola, now reveal to us only the summits of submerged terrains.

Similarly, if 'Asia is no longer contiguous with … America … this is doubtless a consequence of a similar effect'. This 'subsidence … was later … than the birth of the great terrestrial animals in the northern countries'. Buffon infers continuity of land from Canada to Spain via Newfoundland, suggesting that this might be the origin of the legend of Atlantis, 'passed to us' by 'the ancient Egyptians'. Alternative connections are examined, but a northern American–Asian connection is favoured, at least in part, because peoples in the two areas 'resemble each other so strongly'.

To account for the formation of the Mediterranean and the Black Sea, Buffon reunites Asia, Europe and Africa as a single continent (shades of Gondwana!). Before the straits of Gibraltar formed, the Mediterranean would have been smaller (was this the Messinian salinity crisis?), whereas the Caspian Sea was much larger (perhaps as large as the present Mediterranean), accommodating the drainage of much of northern Europe. When the Bosphorus was breached, water flooded into the Mediterranean, drowning adjoining low-lying areas of Greece, Spain, Italy and north Africa. A second deluge followed the opening of the Gibraltar straits, with waters rising to their present level.

> These events, although later than the establishment of terrestrial animals in the countries to the north, perhaps preceded their arrival in the lands of the south, of which the excessive heat then did not permit sensitive creatures to become accustomed to it.

'The Sun was still the enemy of Nature in these regions, [that were] still burning from their own heat.' 'The lands of this torrid zone have been inhabited for perhaps only five thousand years.' The high mountains, 'although situated in the hottest climes, were cooled perhaps as quickly as those in the temperate countries'. 'At times … the only places that would be suitable to living Nature were the summits of the mountains and other elevated regions.'

About 10 000 year ago, Europe separated from America, at 'the same time that England was separated from France, Ireland from England, Sicily from Italy, Sardinia from Corsica, and both from the continent of Africa'. The Antilles, the Dominican Republic and Cuba were separated from America. Great upheavals in the Indian Ocean were driven 'by earthquakes, the collapse of caverns … and the actions of volcanoes, but also by the continual … general movement of the seas … from east to west' (the South Equatorial

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Current?). Vast lands around New Guinea, the Marianas Islands, Japan and the Philippines were invaded by the sea.

Great rivers like the Nile, the Mississippi, the Amazon, and Guyana (Essequibo?) formed new land near their mouths and Buffon describes vegetation sequences in Guyana reflecting decreasing salinity. Noting that the 'great thickness of vegetable earth, found as far as the summits of the hills, demonstrates the recent formation of all of this country'. The 'people … seem to be the newest in the universe, later than the establishment of the human species in the high countries of Mexico, Peru and Chile'. Originating in Asia they would have followed the same migration route as the elephants but would easily have crossed the high ground to move beyond the Panama isthmus. He believes that the only animals in South America are pygmies, but also that parts of America are inhabited by giants that were 'formerly so common in Asia' and no longer exist there.

People gradually left the lands north of Greenland, Spitzbergen and Novaya Zemla, and Buffon uses Russian maps to suggest a very recent desertion of the northern coast. 'Formerly warm enough to allow elephants and hippopotami to multiply', the northern lands 'cooled to the point of supporting only white bears and reindeer', and 'in a few thousand years', will be 'entirely denuded and deserted … by the effects of cooling'. Glaciers in the Alps are additional evidence, 'growing and extending', providing further 'proof of the progressive cooling of the Earth'.

The Seventh and Last Epoch: When the Power of Man Has Assisted That of Nature

The first men were 'witnesses of convulsive movements of the Earth' and occupied their lives running from floods, volcanoes, and wild animals. Driven by 'a common feeling of baleful terror' they 'quickly seek to unite, first to defend themselves in numbers, then to help each other and work in concert to make dwellings and weapons'. These weapons are the first records of the art of Man. They discover fire and use it to cleanse and purify (*sic*) the terrains they wish to inhabit. Earth became the domain of Man who 'took possession by his work of cultivation; and attachment to a fatherland … quickly followed'. 'Individual interests being part of national interest, order, police, and laws soon followed and society assumed its solidity and its force.'

Fears of floods, volcanoes and earthquakes are preserved as a racial memory from which superstitions and theologies have been derived … and are

> barely reassured today by the passage of time, by the calm that followed centuries of storms, and ultimately by knowledge of the actions and operations of Nature: a knowledge that could be acquired only after the establishment of some great society in these peaceable lands.
>
> It was not in Africa, nor in the lands of Asia that are farthest to the south that the great societies could first form. These countries were still burning and deserted … It was not in America.

'It is not even in Europe … but in the northern countries of Asia that the stem of human knowledge grew … the more he knew, the more he could do.'

> All this assumes active peoples in a happy climate, under a pure sky for observing, upon fertile Earth for cultivation, in a privileged country, sheltered from floods, distant from volcanoes, higher, and consequently temperate for longer than the others. All these conditions, all these circumstances, were united in the centre of the continent of Asia … It was in this privileged country that arose the first people worth to bear this name, worthy of all our respect, as creators of the sciences, the arts, and all useful institutions.

Science was not born in China or in India and Buffon takes as evidence early astronomical observations of the six-hundred-year lunisolar period, noting that much of this early work was lost, and not rediscovered until Giovanni Cassini (1625–1712).

> The loss of the sciences, this first wound made upon humanity by the axe of barbarism, was without doubt the effect of an unfortunate revolution, which would have destroyed, perhaps in a few years, the work and the works of several centuries.

It seems

> that when the lands to the north of this happy land cooled too much, the men who lived there, still ignorant, wild and barbaric, would have streamed toward the … country that was rich, fertile and cultivated in the arts. It is even somewhat astonishing that they seized it and that they … destroyed not only the origins but even the memory of all science.

Religious metaphysics spread to all parts of the world. Man

> plunged back into the shadows of ignorance … The useful arts were retained (and) became more necessary as men became more numerous … All the arts implied by the construction of edifices, the fabrication of idols and of weapons, (and) the weaving of fabrics survived.

It is

> only since around 30 centuries that the power of man has been united with that of Nature, and has extended over the greater part of the Earth: the treasures of its fertility were until then buried, and man placed them in bright daylight. Its other riches, still more profoundly buried, could not hide from his researches, and have become the price of his work. Everywhere, where he conducted himself with wisdom, he followed the lessons of Nature, profited from its examples, employed its means and chose in its immensity all the objects that could service him or please him … The entire face of the Earth today carries the imprint of the power of man, which, though subordinate to that of Nature, often created more than did she, or at least marvellously assisted, so it is with the help of our hands that she developed in all her extent, and that she arrived by degrees to the point of perfection and magnificence that we see today

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We would now see this differently.

> It took six hundred centuries for nature to construct her great works, to cool the Earth, to shape its surface and arrive at a tranquil state. How many centuries will be needed for men to arrive at the same point and cease to trouble, to agitate, and to destroy themselves? When will they recognize that the peaceful working of the lands of their fatherlands suffices for their happiness? When will they be wise enough to reduce their pretensions, to renounce their imagined dominance, relinquish their foreign possessions, often ruinous or at least more burden than use?

His hope is for

> an equilibrium between the powers of the civilized peoples … that can be maintained, leading to a world at peace … Is there a single Nation that can boast to have arrived at the best government possible, which would make all men not equally happy, but less unequally unhappy?

Man's effects on Nature are illustrated by examples in France and Germany, where one had 'cut down the forests, drained the swamps, contained the torrents, directed the rivers and cleared … the lands', and in Guyana where changes in microclimate are also attributed to forest clearance. He regards the proliferation of domestic animals as good, suggesting that

> the first trait of man as he starts to become civilized is the empire that he learns to take over animals, and the first trait of his intelligence then becomes the greater character of his power over Nature. Because it is only after having subjugated them that he has, through their help, changed the face of the Earth, converted the deserts into ploughed land and the heaths into cornfields.

Improvements in cereals, fruits and vegetables, and even flowers are the result of work by Man, not Nature.

The Translators have succeeded in making this work available to all and Buffon would have approved! Although some of his interpretations were erroneous they were based on observations, many of which showed remarkable insight. He understood much about the Earth that others had failed to see and was able to view it as a system with a chronology. Those interested in the history of our science and indeed in the philosophy of Buffon's time will find much to stimulate them.

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