Charles Lyell: The Man Who Unlocked the Earth's Sprawling History*

C P Rajendran

Charles Lyell, born in 1797, and Scottish by birth was one among the last generation of British polymaths who contributed much to the development of geology as a scientific discipline. He laid the foundation of modern geology and outlined his geological vision supported by global examples in a treatise called the *Principles of Geology*. This book that became popular with the scholars and the reading public inspired many contemporary researchers, most prominently Charles Darwin to think in new ways about the evolutionary pathways of the Earth and its constituents. Lyell, a heretical thinker in geology in his time was given due recognition by the establishment as he was knighted in 1848 and made a baronet. His lasting legacy lies in providing scientific underpinnings to the study of Earth's history, centered on the foundational principle of uniformitarianism that views all the geological features of the Earth's surface as a product formed in a gradualistic manner, mediated through deep time. And, that the geologic processes acted in the same manner and intensity in the past as they do in the present, summarized in a maxim: "the present is the key to the past".

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Keywords
Lyell, geology, uniformitarianism.

Early Life and Career

Bill Bryson in his book *A Short History of Nearly Everything* says geology excited the 19th century Europe in a way no science ever had [1]. Those were the days, he says, the men of learning especially in Britain would venture into the countryside to do a little "stone-breaking" as they called it, and self-styled scholars

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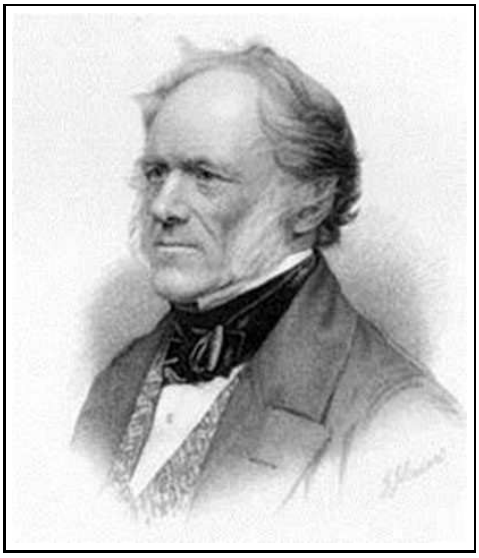
Industrial Revolution must have given an economic impetus to the new-found interest in geology among the academics. And, influential than all others combined was Charles Lyell, who was born in 1797 in Kinnordy, Forfarshire, Scotland. Coincidently, it is the same year James Hutton, the author of a 1795 geology classic, *A Theory of the Earth* that practically inaugurated the science of modern geology, died. Both were Scottish by birth, but Lyell grew up in the far south of England, in the New Forest of Hampshire.

took an interest in everything, from mineralogy to metaphysics, and from the botanical origin of mosses to notional content in the works of poet Dante. Among all the fields of enquiry, geology alone captured the zeitgeist of 1800s that attracted many contemporary extraordinary minds. The interest from the entrepreneurial class in mining and public works that require the understanding of the subsoil conditions in the backdrop of the ever-increasing need for raw materials with the onset of the Industrial Revolution must have given a economic impetus to the new-found interest in geology among the academics. And, influential than all others combined was Charles Lyell, who was born in 1797 in Kinnordy, Forfarshire, Scotland. Coincidently, it is the same year James Hutton, the author of a 1795 geology classic, *A Theory of the Earth* that practically inaugurated the science of modern geology, died. Both were Scottish by birth, but Lyell grew up in the far south of England, in the New Forest of Hampshire on insistence by his mother who seemed to hold the Scots in somewhat low esteem for their drinking habits and called them 'feckless drunkards' [1]. Eldest of 10 children, Lyell is said to have imbibed the interest in natural history from his father Charles, and not much on the attributes of his mother is available. The patriarchal Victorian England never cared much about mothers' interests, anyway; they are there to bear children and take care of them. The remarks of a snobbish character named Miss Caroline Bingley in Jane Austin's novel *Pride & Prejudice* sum up this prevailing societal attitude: "it was important for a well-educated girl to soften her erudition with a graceful and feminine manner". In that respect, Lyell's mother must have been 'un-Victorian' who seemed to be holding strong opinions, judging from her insistence on moving out of a Scottish neighborhood.



Charles Lyell

Lyell attended Exeter College in Oxford and obtained a bachelor's degree in 1819 and studied law and earned a master's in 1821. He worked as a lawyer for a few years but never abandoned his passion for geology. Lyell's interest in natural history logically developed into a life-long devotion for geology when he came under the mentorship of Reverend William Buckland at the Oxford University. Buckland was one of the influential geologists of his time and was the University's first Reader in Geology. Lyell found Buckland, with all his eccentricities, inspiring and found himself joining his mentor for a fieldwork mission in Scotland. The field tour with Buckland turned out to be decisive in Lyell's career, which until then had been stuck with law as a barrister. Between 1822–1832, Lyell was busy touring various sites of geological interest in Europe and North America, and thus began what could be considered as a preparatory phase for writing his book, *The Principles of Geology*. In 1831, he was appointed as the Professor and Chair of Geology at King's College in London. Soon, his theories on the evolution of the Earth were found to be at odds with the prevalent Christian creationist beliefs beholden to the college management of those days, which made his professorship untenable, resulting in his resignation in 1833. But Lyell

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continued his geological explorations in all earnestness, and like his influential predecessor James Hutton, he was able to develop his geological concepts far from the scholarly ambience of the universities [2]. Apart from the understanding gained from occasional forays into geological fieldwork, Lyell was benefitted by the emerging avant-garde cultural ambience that promoted interaction with contemporary scholars in professional meetings and a sudden spurt of scientific publications that provided intellectual resources and stimulus. Further, his knowledge of European languages helped him make use of the vast West European geological literature. His training as a barrister stood him in good stead as it enhanced his felicity with words and argumentative reasoning skills much useful in the exposition of ideas in a deductive science like geology. Mary Honner, who he married in July 1832, shared his geological interests and was helpful in many of his field explorations. The social and family settings provided Lyell the right conditions for his intellectual pursuits. He was, by and large, a product of his time. like so many of his contemporaries—who like him by virtue of living in a 'fanatically inquisitive' age, made exceptional contributions in ushering in modern science and its unique methodologies.

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Beginning of a New Geological Vision

When Lyell became single-mindedly interested in geology, there were two contrasting theoretical models of Earth's processes available for him to make sense of the empirical material that was to come in his way, [3]. The first was the Huttonian principle of uniformitarianism that believed in gradual change, and the second was catastrophism, mostly molded by biblical stories of cataclysmic events, allowing its adherents like Reverend Buckland to incorporate 'Noah's flood' into their theories. Lyell's eventual break with his mentor Buckland's theories of geological deluges initially started with his analyses of published materials and later by his first-hand field observations [3]. The emerging social trends of liberalism and anti-religiosity must have also influenced Lyell to free the geological concepts from liturgical entan-

glements [3]. Lyell became a consistent defender of the Huttonian contention that the Earth's shifts are essentially uniform and repetitive, continuing in an almost infinite time frame. Shorn of liturgical implications, there was also yet another theoretical formulation that viewed the Earth as a product of complex contingent history—a theory mainly spearheaded by French paleontologist Georges Cuvier, who argued for the realities of mass extinctions occasioned by catastrophic events at some periods of the Earth's history [3].

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Lyell's 1823 visit to Paris was motivated primarily by Cuvier's secularized theories of catastrophism that culminated in an extensive fieldwork in the region. He wanted to explore the Paris sedimentary basin from where Cuvier had reported some events of mass extinctions. Teamed up with a French geologist Louis-Constant Prévost, his study of the Tertiary of the Paris basin, helped him gain the understanding of the sedimentation characteristics during the Eocene, Miocene, and Pliocene time intervals [3]. Lyell and Prévost argued that the alternating facies of marine-fresh water was best explained by steady changes without taking recourse to sudden changes and they believed that all those processes were comparable to present-day processes. A large chunk of European literature that contained reports from various sedimentary basins elsewhere, helped him to assess his own conclusions from a regional perspective and gave further evidentiary material to argue his case for piecemeal faunal changes rather than sudden unprecedented changes, as proposed by Cuvier. We could trace the beginnings of the idea of uniformitarianism from these initial forays.

Another phase of his geological exploration was centered on the sedimentary basin in Sicily. This fieldwork helped him evolve a mollusc-based stratigraphy for the Tertiary Period (65 to 1.8 million years) with new nomenclature and additional units of epochs, which are now in vogue and the bulk of Lyell's last volume of Principles consisted of detailed study of Tertiaries. He presented this study as a template to show how the geo-history should be reconstructed [3]. His primary intention was to demonstrate that

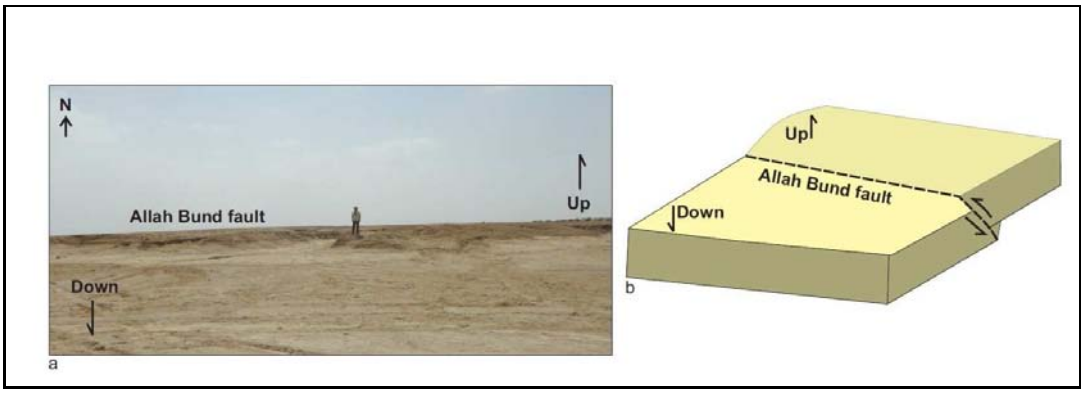

Figure 1. **(a)** Land-level changes during the 1819 earthquake. The northern side of the Rann was uplifted and the southern side subsided [5]. The photograph was taken on June 16, 2019 when the author attended a field workshop to commemorate the 200th anniversary of the earthquake. **(b)** A cartoon showing vertical displacement of the land during the earthquake faulting.

throughout the Tertiary geo-history processes with the same intensities as of the present had been in operation [3]. Most importantly, Lyell could re-establish the fact that the transition between stratigraphic contacts are continuous, representing a gradual change in sedimentary environment and are not marked by any abrupt catastrophic episodes of violent uplifts of the seabed and rising sea level. These sedimentary basin studies helped Lyell to introduce additional time units called epochs or series to cover the Tertiary Period, the time-interval since the age of dinosaurs to the present (since 65 million years ago).

During 1828–1829, Lyell reached Central France, a region that remained volcanically active throughout the Tertiary and Quaternary periods, to inspect the lava flow stratigraphy and the morphology of the valleys [4]. Later he made an adventurous trip to the top of Mt Etna, an active volcano in southern Italy to find further support for his argument that such volcanic activities, repetitive with some time lag are a process continuing to the present [4]. In his travels to America, in the lower valleys of the Mississippi and Ohio, he found a landscape that he correctly considered analogous to the forests and mangrove swamps of the Carboniferous Period (that existed 359 to 299 million years ago), in which bituminous coal and lignite ('coal measures') were formed. These observations provided further confirmatory details for Lyell in further developing his methodological principle to understand the Earth's history: "the present is the key to the past" [2].

Lyell was also fascinated with the casual links of level changes with that of block movements during the earthquakes (*Figure* 1). He considered earthquakes and volcanoes as constructive forces. Many 19th century earthquakes including the 1819 Rann of Kutch (Gujarat) earthquake find place in book. This earthquake made an impression because of the sharp elevation changes up to 6 m in a low-lying tidal flat area of radius of 80 km [5] (*Figure* 2). To make this clear, he included the pre- and post-woodcut prints of Sindri Fort situated in the Rann in his book, which had subsided during the earthquake (*Figure* 3). Although, Lyell's concept of the physical basis of earthquakes and fault displacement lacked any major insight on their causality [6], he was probably the first geologist to see earthquake as a 'quantum' in building a mountain.

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Lyell was keener to use these surface-faulting earthquake examples to strengthen the theory of uniformitarianism that mountains and valleys were formed in prehistoric times by omnipresent geological forces, and not by 'one-time' cataclysmic events. For example, in the southern coast of Italy, somewhat reminiscent of the afore-mentioned Sindri Fort in the Rann of Kutch in northwest India, he surmised, in his *Principles*, that the stone pillars of the Temple of Serapis (an Egyptian deity worshipped by the Romans) had submerged in water, and later pushed above ground by the internal forces of the Earth (http://articles.adsabs.harvard.edu//full/1998HisSc..36..299D/0000303.000.html). After describing the columns as "smooth and uninjured at the height of about twelve feet above their pedestals", Lyell records this inference in his book: "Above this is a zone, about nine feet in height, where the marble has been pierced of a species of marine perforating bivalve, *Lithodomus* (a marine genus of clams)". Thus, as these claims cannot live above the low-tide level, Lyell makes a deductive inference that the lower part of Serapis columns had at one time been underwater (https://ncse.ngo/temple-serapis). Through such examples, Lyell was able to elevate a field-based inquiry to an epistemological level—as a methodological protocol that is heavily focused on outdoor observations, measurements,

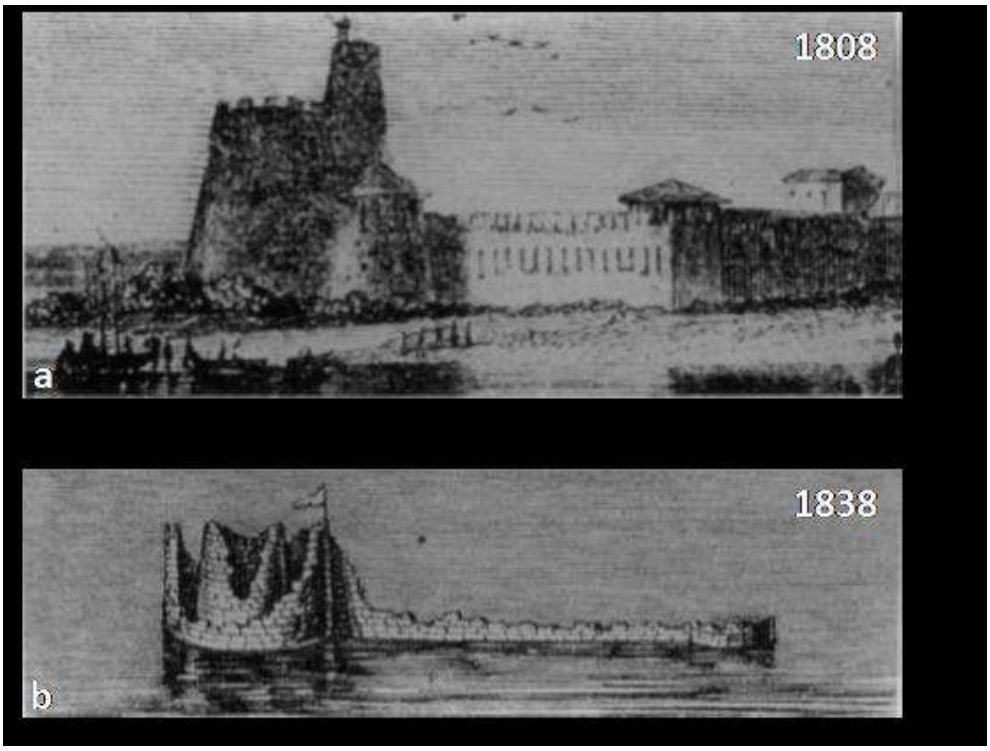

Figure 2. The sketches, published in Lyell's book (1857) [9], depicting the 19th century built Sindri Fort in the Rann of Kutch as it appeared in 1808 **(a)** and 1838 **(b)** The post-1819 earthquake depiction of the fort (located on the down-faulted block), as shown in 'b' informs how it was subsided during the earthquake.

and interpretation of natural geological features and their time-dependent evolutionary relations, as different from the laboratory-based methods followed in experimental sciences.

The Book and the Impact

Lyell's *Principles of Geology* is the most significant work in the early days of modern geology. The third and the last volume the book was completed and released by April 1833. The book though dealt in an exotic subject of geology whose accessible writing style and the fact that the subject matter had bearing on a raging controversy on the Christian thoughts on creation caught the attention of the reading public. The success of Lyell as a communicator of science comes through this commentary on his last book *Antiquity of Man* by A. R. Wallace (in *Nature*, Vol.8, pp.462–464, 1873.):

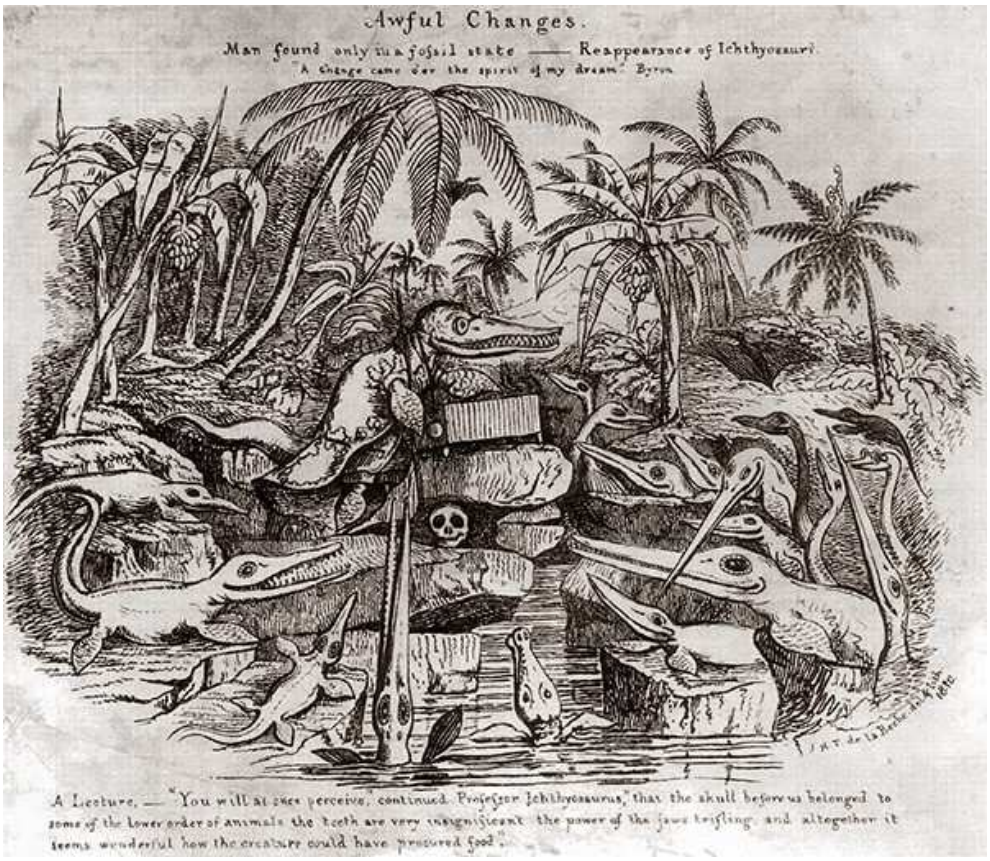

Figure 3. A humorous cartoon (1830) lithographed by Henry De La Beche showing a Professor Ichthyosaurus lecturing on a human skull to a group of Jurassic reptiles. This was created to make fun of Lyell's idea of a cyclic pattern of the Earth's history. Lyell initially propounded that the past geologic events would repeat in the post-human future, which he abandoned later (Adapted from Rudwick, 1998) [3].

Since the first volume of "The Principles of Geology" appeared—now more than forty-three years ago—Sir Charles Lyell has put forth an uninterrupted series of new works or new editions, and we have now arrived at the 11th edition of the "Principles," the 7th of the "Elements of Geology," and the 4th of the "Antiquity of Man." A most striking feature of these works is, that they give the fullest and most accurate scientific details, and the most philosophical discussion of principles and results, without for a single page ceasing to be interesting to any well-educated and thoughtful man. Perhaps no author has attained in so perfect a degree the art of making science popular without ever attempting to popularise it or has produced a series of works which are equally acceptable to the experienced geologist and to the general reader.

Lyell's success as a writer who secularized geology, however, cannot be seen in isolation from James Hutton's landmark treatise, *Theory of the Earth*, where he had already set forth the principle of uniformitarianism: 'the present is the key to the past'. For example, in a major departure from theological thoughts, Hutton had proposed that the crystalline rock formations that include granite, basalts, etc. were solidified from ancient magma and underscored the fact that the Earth's history goes back in time that does not fit with Biblical estimates.

The huge popular endorsement saw *Principles* going through 12 editions in the author's own lifetime. Lyell's success as a writer who secularized geology, however, cannot be seen in isolation from James Hutton's landmark treatise, *Theory of the Earth*, where he had already set forth the principle of uniformitarianism: 'the present is the key to the past'. For example, in a major departure from theological thoughts, Hutton had proposed that the crystalline rock formations that include granite, basalts, etc. were solidified from ancient magma and underscored the fact that the Earth's history goes back in time that does not fit with Biblical estimates. Hutton dispensed with the need to invoke divinely ordained catastrophes and was the first to 'secularize' all geological processes of past and present, deriving their energy from gravity, the Earth's rotation, and heat produced internally as well as from the Sun. Lyell, while admitting his debt to Hutton's ideas, extended this theory to gain insights into the ubiquitous Earth processes that included erosion, weathering, sedimentation, and topographical changes. Besides his exceptional reasoning and deductive capabilities, Lyell's genius lies in making the exotic geological concepts hugely popular and succeeded in competing with Biblical creationist assertions.

Based on direct field observations from Britain and elsewhere in Europe, Lyell was able to lay out his theory in such clarity—establishing the fact that the processes active in the past are also active today. It was Lyell who first put this principle of "the past is the key to the present" on a strong observational foundation and, therefore, it is correct to affirm that scientific geology began with the work of Lyell. None of Lyell's writings, including his *Principles*, ever mentioned the word 'uniformitarianism' *per se*. It was William Whewell (1794–1866), an influential historian of science while reviewing the second edition of *Principles*, who formally coined the terms 'uniformitarians' and 'catastrophists' as adherents of two opposing schools in geology [3].

The *Principles of Geology* placed Lyell among the recognized leaders of his field. In 1838, he published *Elements of Geology* as a sequel; it described European rocks and fossils from the most

recent to the oldest then known. Like the *Principles of Geology*, this well-illustrated work was periodically enlarged and updated. Lyell was befriended by many prominent scientists of his time such as naturalist Charles Darwin and physicist Michael Faraday. Lyell's work was highly regarded by the researchers across disciplines, and with the publication of *Principles*, Lyell became the cynosure of literati and intellectuals of London. Their acceptance of him as a leading scholar saw his elevation as the president of the prestigious Geological Society of London and later as its foreign secretary.

Preparing the Way for Charles Darwin: Lyell as a Mentor

Lyell theorized that everything that has happened on the Earth was gradually incubated within the cusp of immense amounts of time. He detested 'catastrophism', as a theory that requires sudden cataclysmic events such as floods (mostly alluding to the biblical flood of Noah) to shape the surface of the Earth. On catastrophism, Lyell has been quoted as saying: "Never was there a dogma more calculated to foster indolence, and to blunt the keen edge of curiosity". Lyell's theorizing on 'deep time', in contrast to the biblical teachings of a young Earth, is what probably attracted Charles Darwin, a contemporary naturalist to delve into geological findings detailed in *Principles*. Darwin took this volume with him during his *Beagle* cruises across the globe in search of biological evidence for natural selection. Darwin admits later that Lyell's book "was of highest service to me in many ways". In the initial leg of the cruise, Darwin took the first edition with him that puts in perspective the Earth's past in terms of the processes that are taking place presently following the dictum, "the present is the key to the past". He managed to procure the second volume of the book when the Beagle anchored at Montevideo for the second time, in which Lyell added discussion on whether the succession of fossilized organisms preserved in the rock strata represents a process of 'transmutation' or if they indicate independent events of successive creations and extinctions. Darwin regarded the process of evolution as a form of "biological uniformitarian-

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ism", and posited that evolution happens gradually through random inherited variations in populations of organisms leading to natural selection and survival of the fittest.

Lyell, however, had initially refused to admit the relatedness of organisms and evolution in general. For some time, Lyell believed that mammals could be found in the oldest fossiliferous beds and mammals, reptiles, and others living forms co-existed together from the beginning of time and refused to believe in the extinction of animals and plants. Later, when his thoughts matured and after reaching a conclusion contrary to Lyell's, Darwin confided his theory of transmutation of living forms to his friend Dalton Hooker almost like confessing a murder. But the only gap in Darwin's argument during his time was the absence of transitional species in the geological columns. Darwin rationalized that it was due to imperfection of the geological record, which later fossil findings proved his foresight correct.

Lyell continued to believe that geological and biological history were cyclical and that ancient life forms would reappear on the Earth. Lyell much to Darwin's chagrin believed that if the climatic conditions of the previous geological era were to repeat, the great reptiles would reappear as if stretching the uniformitarianism theory to its breaking point [2]. This made Lyell initially write in his book: "*The huge iguanodon might reappear in the woods, and the ichthyosaur in the sea, while the pterodactyl might flight again through umbrageous groves of tree-ferns*". This prompted Henry Thomas De la Beche (1796–1855), the first director of the British Geological Survey to poke fun at Lyell. He produced a cartoon (*Figure* 3), showing an ichthyosaur (a large extinct marine reptile) 'Professor' lecturing on a fossilized human skull: You will at once perceive this professor lectures on, "that the skull before us belonged to some of the lower order of animals; the teeth are very insignificant, the power of the jaws trifling, and altogether it seems wonderful how the creature could have procured food" [3].

Lyell later regretted his convoluted sense of geological time. This came about mostly through prolonged discussions with Darwin.

Lyell's initial skepticism gave way to his acceptance of his protégé's arguments in the book *Origin of Species*. This conversion as an evolutionist compelled Lyell not only to make amends in the *Principles of Geology* in 1865, by fully adopting Darwin's conclusions, but also resulted in the publication of another book, *The Geological Evidence of the Antiquity of Man*, published in 1863 [2]. Lyell probably did not realize that the book itself would be considered as a harbinger of modern anthropological research. Darwin made light of Lyell's late acceptance of the theory of natural selection thus, "Considering his age, his former views, and position in society, I think his action has been heroic." The whole episode says much for the intellectual and human qualities of an already illustrious scholar who was ready to make amends in the face of evidence—a characteristic that defines a genuine seeker of truth. The *Principles*, which ran into 12 editions in his time is a testament to his intellectual honesty, and in each of the editions Lyell added revisions if new convincing evidence was made available to him that challenged his earlier held views.

Legacy

Lyell's vision maintained that the time the Earth had required to evolve to its current state was enormous and 'incalculable'. In his time, there was no way of quantifying it as the 'clock' of radioactivity was discovered much later. The concept of 'deep time' probably is the enduring legacy of Lyell. He hypothesised that changes on the surface of the Earth take place gradually over long periods of time. He intuitively realized that the Earth's internal energy is long-lasting enough to sustain the surface processes *ad infinitum*. The later discovery of deep radioactive processes would prove his intuitions correct. As discussed earlier, Lyell's initial insistence on lack of directionality in Earth's history (geological events as unique parts of history) and his mechanical rejection of the role of any cataclysmic events (not in any liturgical sense) in the past had been criticised even during his time. His method of theorizing made it difficult for the geologists during his time to grasp the full significance of the Pleistocene glacia-

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The debate on the universal applicability of uniformitarianism initiated during Lyell's time continues to this day and becomes more intense with the availability of new pieces of evidence. Huge meteoritic impacts and sustained periods of volcanism, though rare and unique have impacted the Earth's past and the species distribution. Further, the current 'Anthropocene Era', characterized by the changes wrought to the natural environment by humans is also an unprecedented geological development, and the 'past' may not give us any clue for the 'present' or *vice versa*.

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