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Darwin the geologist: Between Lyell and von Buch

Darwin le géologue : entre Lyell et von Buch

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ABSTRACT

Upon returning from his voyage on the *Beagle*, Darwin prepared reports of his geological observations. Together, these reveal Darwin's approach to reasoning about geology. Darwin argued that successive terraces prove a very gradual elevation of the coast that lagoon islands show a reciprocal sinking of the oceanic floor. Hence, Darwin reinforced Lyell's uniformitarian, or steady state theory. Unlike lagoon islands, the movement of erratic boulders onto the plains is evidence of forces, which do not now exist. Darwin and Lyell attributed this movement to floating icebergs. However, mountain formation remained difficult for them to explain with reference to contemporary causes. Lyell discovered uplifts in Scandinavia, which resulted from epirogenesis, whereas mountain formation is an orogenesis, which involves both folding and uplift. Darwin was more impressed by uplift than by folds. However, when in Cordillera he saw strata overturned by masses of injected rock, proving successive periods of violence, Darwin took a position, which was closer to the plutonic theories of von Buch and Humboldt than it was to Lyell's uniformitarian views.

Mots-clés :
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RÉSUMÉ

À son retour du voyage sur le *Beagle*, Darwin prépara le compte rendu de ses observations géologiques, lesquelles composent la thèse suivante. Tandis que les terrasses superposées prouvent l'élévation graduelle de la côte, inversement les îles coralliennes témoignent d'un abaissement du plancher océanique. Ainsi, Darwin conforta-t-il la thèse de Lyell, nommée uniformitarienne ou *steady state theory*. Cependant, le transport de blocs erratiques jusque dans les plaines prouve l'existence de forces qui n'existent plus. Darwin et Lyell les supposent venus des icebergs véhiculés par la mer. Pourtant, la formation des montagnes demeure difficile à expliquer par des causes actuelles. Lyell découvre le soulèvement du continent scandinave. Mais celui-ci est une épirogenèse, alors que les montagnes se forment par une orogénèse comprenant soulèvement et plissement. Darwin fut plus attentif au soulèvement qu'au plissement. Néanmoins, il vit dans la cordillière des couches renversées par l'injection de roches qui montraient des périodes de violence, qui le rendaient proche des théories plutoniques de von Buch et Humboldt.

1. Introduction

After reading Sandra Herbert's wonderful book, one might ask: should Darwin have pursued the career in

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geology, which he began with such promise [1]? We know he brought the first volume of Charles Lyell's *Principles of Geology* [2] with him on the *Beagle*. The editors of *The Voyage of the Beagle* said that the ship's captain, FitzRoy, "had a special interest in geology, and it was FitzRoy who had given Darwin a copy of Lyell's first volume" [3]. And "during the actual period of the voyage", writes John W. Judd, geology, "certainly engrossed most of his time and attention" [4].

Upon returning, Darwin published the first edition of *Voyage*, entitled *Journal and remarks* (*1832–1836*). This comprises the third volume of FitzRoy's *Narrative of the surveying voyages*... [5]. Later, it was issued separately as *Journal of Researches* [6].

During the same period in which the *Voyage* appeared, Darwin prepared his geological observations for publication. These were released in three parts: "The structure and distribution of Coral Reefs" (1842) [7]; "Geological observations on the volcanic islands..." (1844); [8] and "Geological observations on South America" (1846) [9]. In addition, a few of Darwin's papers were read at The Geological Society of London, starting in November, 1837 [10]. Together, these papers and publications reveal an approach to reasoning about geology that the following six points summarize.

2. Elevation of the coast

Darwin experienced the earthquake of February 20, 1835 in Valdivia. Previously, he had noticed that much of land along the Pacific coast of South America was uplifted. In the elevated places, Darwin observed "numerous marine remains amongst which a gryphaea is the most abundant, likewise shells, resembling turritellae, terebratulae, and an ammonite. It is an old story, but not the less wonderful, to hear of shells, which formerly were crawling about at the bottom of the sea, being now elevated nearly 14,000 feet above its level" [3: p. 245; also 9]. In Patagonia, he had already remarked that "there are proofs, that the whole coast had been elevated to a considerable height within the recent period; and on the shores of the Pacific, where successive terraces likewise occur, we know that these changes have latterly been very gradual. There is indeed reason for believing, that the uplifting of the ground during the earthquakes, in Chile, although only to the height of two or three feet, has been a disturbance which may be considered as a great one, in comparison to the series of lesser and scarcely sensible movements which are likewise in progress" [3: p. 159], also [1: p. 160 sq].

3. Theory of lagoon islands

Prior to Darwin, travelers had long been struck by lagoon islands. These are madrepore coral atolls that circumscribe lagoons in the middle of the ocean. To what do the coral anchor themselves where the sea is at least hundreds of meters deep? Why do their reefs form a ring around the lagoon, which lacks any coral at all?

In his *Principles of Geology*, Lyell hypothesized that "The circular or oval forms of the numerous coral isles of the Pacific, with the lagoons in their centre, naturally suggest the idea that they are nothing more than the crest of submarine volcanoes, having the rims and bottoms of their craters overgrown by corals" [2].

Darwin brilliantly linked these coral formations to slow coastal uprising. He surmised that the reefs were signs of a deepening of the sea floor, which resulted from geological movements reciprocal to those that elevated the coasts. Darwin called this kind of sinking "subsidence", borrowing a term Lyell used to describe some of the effects of earthquakes. Volcanic craters were thus no longer necessary to explain the presence of the coral lagoons. According to Darwin, any island the elevation of which peaked near its center could produce such a lagoon, which would form somewhere below the summit [11]. Darwin found a plausible mechanism for the formation of lagoon islands in the progressive transformation of fringe reefs into barrier reefs into a atolls. In subsequent editions of his book, Lyell took up Darwin's view, given that it offered a theory of lagoon islands that was more Lyellian than Lyell's own theory.

4. Uniformitarianism

In his review of the second volume of *Principles of Geology,* William Whewell contrasted what he called "geological uniformity" to "geological catastrophe". The former described processes of slow, gradual geological change. Lyell's theory thus came to be called uniformitarian [12], also [13]. Darwin reinforced Lyell's uniformitarian theory. In a passage of the first volume of *Principles*, which Darwin must have read very carefully, Lyell noted that "on the 19th of November 1822 the coast of Chili was visited by a most destructive earthquake. The shock was felt simultaneously throughout a space of 1200 miles from north to south" [2]. After having observed the region himself, Darwin wrote to the Geological Society on January 4, 1837 that ever since the earthquake happened, "the land on the coast of Chili has risen though insensibly, since 1822 (...)". Hence, he concluded that "the earthquakes, volcanic eruptions, and sudden elevations of the coast line of the Pacific, ought to be considered as irregularities of action in some more widely extended phenomenon" [14]. Likewise, the subsidence of islands that become coral atolls is gradual and continuous. Far from appealing to such islands as evidence for phenomena that are even more intense than earthquakes, Darwin pointed to them as extreme examples of the results of much more continuous processes. One could say that the Beagle's naturalist was a hyper-uniformitarian.

5. Steady-state theory

Whewell's uniformitarian label represents only one aspect of Lyell's theory. The other aspect of the theory is that it supposes that the earth is basically stable, equilibrating through changes. Lyell thus held a steady state theory, according to astronomical vocabulary [15] "There can be no doubt, that periods of disturbance and repose have followed each other in succession in every region of the globe, but it may be equally true, that the energy of the subterraneous movements has been always

uniform as regards the whole earth. The force of earthquakes (...) may then have gradually shifted its position" (2: I, 64). Lyell correctly attributed this view to Hutton, but it could just as well be ascribed to Aristotle. Darwin also took it up when he observed that "when beholding more than one hemisphere divided into symmetrical areas, which within a limited period of time had undergone certain known movements, we obtain some insight into the system by which the crust of the globe is modified during the endless cycle of changes" [16].

6. Past revolutions of the globe

The mountains that reveal signs of geologic upheaval, and the erratic boulders that have been transported to plains provide evidence for geological forces far greater than those we are familiar with today. They support the catastrophe theory, which posits that the earth has undergone a series of climatic revolutions, of which Noah's flood was only the latest. It would be unfair to undercut the catastrophe theory on the grounds that it interprets the Bible literally and assumes that the earth is only 6 million years old. In fact, some of Lyell's catastrophist adversaries thought that the earth was millions, or even quadrillions of years old [17]. They did not invoke cataclysms in order to reconcile geological facts with an erroneous belief that the earth is very young. Rather, they did so because they realized that contemporary waterways simply were not capable of eroding the valleys though which they run. The valleys were carved by ancient glaciers, the existence of such things had only begun to be recognized in Darwin's time. Their role in transforming geology was first championed by the glaciologists Playfair (1802), Agassiz (1836 sq.), Venetz (1821) and Charpentier (1834) [18]. Darwin accepted their arguments that erratic boulders were inexplicable without reference to glaciers. However, Darwin did not accept the idea that continental glaciers had transported boulders to incongruous locations. Instead, he believed that they had carried the boulders over seas, in the form of icebergs [19,20]. Thus, Darwin's views remained close to those of Lyell, who only accepted Charpentier and Agassiz's theory of glaciers with great difficulty [21]. It is important to remember here that the idea of a glacial period, with its affinity to diluvianism, did not conform to uniformitarianism, which rejected claims of drastic global climate change [22]

Before leaving the subject of Darwin's uniformitarianism, it is important to attend to a controversy in which "Darwin lost a key exemplar for his original simple geology". Darwin wrote to Lyell about this, stating that he had been "smashed to atoms". The affair began during the voyage of the Beagle. In the 3rd volume of his *Principles*, Lyell wrote about the parallel roads of Coquimbo in Chili, which are ancient marine beaches, noting: "the theory proposed by Captain Hall to explain these appearances is the same as that which had been adopted to account for the analogous parallel roads of Glen Roy in Scotland" [2].

Darwin visited Coquimbo in May, 1835 as part of his voyage: "I spent 2 or 3 days in examining the step-formed terraces of shingle first described by captain Basil Hall, in his work, so full of spirited descriptions, in the west coast of America. Mr Lyell concluded from the account, that they must have been formed by the sea during the gradual rising of the land. Such is the case: on some of steps which sweep round from within the valley, so as to front the coast, shells of existing species both lie on the surface, and are embedded in a soft calcareous stone. This bed of the most modern tertiary epoch passes downward into another, containing some living species associated with others now lost. Amongst the latter may be mentioned shells of an enormous perna and an oyster, and the teeth of a gigantic shark, closely allied to, or identical with the Carchiarias Megalodon of ancient Europe" [3: p. 261].

However, two observers at Glen Roy – Mac Culloch, in 1816 (published in 1817) and Lauder, in 1821 (published in 1823) – concluded that the parallel roads were in fact lake beaches. After returning to England, Charles Darwin visited Glen Roy from the 28th June to the 5th July 1838. His observations there were published under the title "Observations on the Parallel Roads of Glen Roy, and of Other Parts of Lochaber in Scotland, with an Attempt to Prove that They Are of Marine Origin" [23]. They began with discussion of the "buttresses of alluvium" at the upper end of Loch Dochart. About these Darwin concludes that "Rivers could not have deposited it. Barrier of lake very lofty, and no trace of it; to the Sea more probable" [1,p. 266].

Unfortunately for Darwin, Louis Agassiz determined the origin of the roads to be glacial just 2 years after Darwin posited that they were of marine origin. Rudwick et al. [24] and Herbert [1] have told the story of this controversy. The final arbitration was provided by Jamieson, who visited Glen Roy in 1861. Jamieson concluded that a lack of good evidence in favor of the marine hypothesis, combined with good evidence in favor of Agassiz's hypothesis rendered Darwin's theory completely untenable. Two decades latter, Darwin recalled that he subsequently "had given up the ghost with more sighs and groans than on almost any other occasion in my life" [25].

Is this "great failure" responsible for Darwin having abandoned geology?

7. Mountain-building

Another problem for uniformitarianism was that mountain formation remained difficult to explain in terms of gentle, gradual causes. Lyell discovered the process of uplift in his works about Scandinavia. Like Leopold von Buch before him [26], he understood that despite what Linneus and Celsius thought, Baltica does not sink. On the contrary, the continent is rising. On Lyell's position before his conversion, see [2]; on his conversion, see L. Wilson [27].

However, the elevation of Scandinavia is an example of epirogenesis, to use modern vocabulary. This differs from mountain formation, which is orogenesis. Orogenesis has two phases: tectogenesis (folding) andorogenesis sensu stricto (uplift) [28].

Darwin was more impressed by elevation than by folding. It was easier for an uniformitarianist to explain elevation with reference to gradual movement than with reference to a shortening of the earth's crust. However, during his travels in Cordillera, he saw "great pile of strata

(...) penetrated, upheaved, and overturned, in the most extraordinary manner, by masses of injected rock, equaling mountains in size" [3: p. 245]. And in a communication to the Geological Society, Darwin claimed that "the conclusion that mountain-chains are formed by a long succession of small movements, may, as it appears to me, be rendered also probable by simple theoretical reasoning" [29]; see also S. Herbert [1], particularly a figure showing Hopkin's sketches, p. 228.

To this, Darwin added: "We shall be deeply impressed with the grandeur of the one motive power, which, causing the elevation of the continent, has produced, as secondary effects, mountain-chains and volcanoes". And when he explained earthquakes in South America by "the interjection of liquefied rocks between masses of strata", "proving by their intersections, successive periods of violence (...) (along) great lines of dislocation" [3: p. 245], he came closer to the plutonic theories of von Buch and Humboldt than to the ideas of Charles Lyell. Adhering to the views of von Buch and Humboldt, Darwin thought Saint. Helena and other islands were craters of elevation [8]. Moreover, he adopted the new idea of metamorphic actions [9] to which the names of both Lyell and von Buch were associated. Lyell coined the term "metamorphic", while von Buch held that rising pyroxene porphyry magma explains the formation of dolostones by chemical transformation of limestone [30].

According to Sandra Herbert, Darwin wrote in his *Red Notebook* that "With regard to Humboldt, the phrase 'Humboldt's Fragmens' holds the clue." This is a reference to Alexander von Humboldt's *Fragmens de géologie et de climatologie asiatiques*, published in two volumes in Paris in 1831 [31]. On 18 August 1832, his brother Erasmus wrote to Charles that he had acquired the book, "which I suppose was the one you want"; the flyleaf of the second volume is inscribed "Chas Darwin Monte video Novem: 1832", so the month in which Darwin received the book is known [1: p. 199].

Can we thus conclude that Charles Darwin's approach to reasoning about geology was something between Lyell's and von Buch-Humboldt's?

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