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Catastrophism in geology,

its scientific character in relation to actualism and uniformitarianism

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I. Introduction *

The history of geology has often been expounded, in the fashion of a fairy tale, as a battle between good and evil. Neptunism is black, Plutonism white; Catastrophism is black, Uniformitarianism white. In the 18th century darkness reigned until, through Hutton, suddenly all became light. In the beginning of the 19th century Cuvier, Buckland, c.s. fell back again upon deluges and catastrophes, until Lyell dispelled the clouds and definitively established uniformitarian orthodoxy.

Catastrophists are accused of giving free play to their phantasy, of rashly resorting to extraordinary events and supernatural causes, and of mixing up independent geological research with metaphysical beliefs.

In this paper [1] we will listen to the other side too. And the conclusion will be that, though there have been catastrophists who answer to the description just given, uniformitarians could be as metaphysical and perhaps even more dogmatical than their opponents, and that, quite apart from the resulting theoretical *system*, at least the *method* of the Catastrophists was a legitimate one.

II. Classification of geological methods and systems

In geological literature the 'anglosaxon' term 'uniformitarianism' and the continental term 'actualism' are generally used as perfectly synonymous, and both are put forward as the opposite of 'catastrophism'.

Uniformitarianism implies that ancient changes in the earth's crust were effectuated by causes of the same *kind* as those working

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* The paragraphs I–III, IV *b* and *c*, VI *a*, *b*, *c* and *e*, contain the text of a lecture delivered before the Geological Society of Krakow on October 30th, 1967. Russian transl. in: Istorija Geologii, Acad. Sci. Armenian SSR, Erevan 1970, pp. 33–57.

[1] Reactions on my "The Principle of Uniformity in Geology, Biology and Theology" (Leiden 1959 [1]; 1963 [2]), urged me to further research on this topic.

The paragraphs II–V (pp. 5–25) replace the pp. 1–4 and 13–14 of the first and second editions of the book; par. VI (pp. 25–35) is an addition to pp. 33–42 of P.U.; par. VII, *a* and *c* (pp. 35–42) is an addition to pp. 11–12 of P.U.; par. VII, *b* an addition to pp. 90–92 of P.U.; par. VIII (pp. 42–45) an addition to p. 179 of the book.

As in discussions on actualism the relevant texts of Buffon sometimes are chosen onesidedly, and as Razumovsky and Dolomieu are never mentioned in this connection, we here give full quotations from their works. Also other geologists not dealt with in my earlier publications (Élie de Beaumont, Frapolli, Conybeare, Cotta, Bronn, Prestwich) have been brought to the fore. For authors already commented upon in "The Principle of Uniformity" we cannot but send back the reader to that book.

at present and that these causes had about the same *intensity* as their modern equivalents. Existing geological causes work rather slowly, so that strict uniformity of geological events requires an immensity of time: all past changes on the globe have been brought about by the *slow* agency of still existing causes (Lyell, 1830) [2].

That is to say, that uniformitarianism is antagonistic to catastrophism, which holds that causes now in operation (ice, water, winds, volcanism), if active with the now prevalent intensity, are not sufficient to explain the geological events of the past. Catastrophists, therefore, resorted also to the operation of extraordinary, violent causes: sudden elevations of whole continents, paroxysmal volcanic eruptions, and inundations of large areas of dry land by the ocean.

The usual contradistinction of uniformitarianism or actualism (by which a *method* as well as its resulting *system* was meant) and catastrophism (which is a geological *system* and not a method) has caused many misunderstandings.

In British and American literature the term "uniformitarianism" is always used. This term fits well to the methods and systems of Hutton and Lyell, who supposed a perfect similarity between the geological causes and effects of the past and the present,—a uniformity not only as to their kind but also as to their intensity.

In continental European languages, however, though the term "actualism" is considered as synonymous with the anglosaxon "uniformitarianism", it often has somewhat wider implications. For this term *in itself* implies only that the present (modern or actual) causes are sufficient to explain the events of the past; it does not necessarily include the idea that they operate with the same energy in the present as they did in the past. One could imagine that the geological causes of the past were of the same kind as the actual causes, but that they were much more powerful, so that they sometimes led to cataclysmic effects. In such a case they would be in the literal sense of the word "catastrophic" as well as "actualistic"; the *system* (the resulting historical description) would be catastrophist, whereas the *method* of constructing it would be actualistic.

Moreover, the quietness and slowness of change, which seem so characteristic of uniformitarianism over against catastrophism, are not sufficient to guarantee that a system is based on an "actualistic" method. It might be that totally different causes of change

[2] Ch. Lyell, Principles of Geology, being an Attempt to explain the former changes of the Earth's surface by reference to causes now in operation. sec. ed. London 1832, vol. I, pp. 72–73.

were active in the past and that they worked equally in a slow, non-catastrophic tempo: the result then would be neither "catastrophic" nor "actualistic".

The current division into catastrophistic and "actualistic" (or uniformitarian) *systems* or theories does not give an adequate representation of the present situation in geological science. It should be replaced by the more fundamental division in "conceptions based on an actualistic *method*" (strict uniformitarianism and actualistic catastrophism included) and "conceptions based on a non-actualistic *method*" (i.e. those recognizing ancient causes, whether catastrophal or not in their effects). This division, then, is determined in the first place by the extent to which the actualistic *method* is applied, and *not* by the uniformity or non-uniformity of the resulting descriptive *systems*.

Roughly speaking, then, at least four (or five) different conceptions of the history or the historiography of the earth may be distinguished.

a. *Non-actualistic conceptions*

1. The causes of some geological changes of the past *differ in kind and energy* from those now in operation.

This is catastrophism in the traditional sense (*non-actualistic catastrophism*), implying that forces which are not in operation at present, caused revolutions of an intensity much greater than that of the causes working now (Cuvier). Especially in paleontology, sometimes supernatural causes are introduced.

2. The causes of some geological changes of the past *differ in kind but not in energy* from those now in operation; their effects were not more violent, and the changes resulting from ancient causes occurred in the same slow tempo as is prevalent now.

b. *Actualistic conceptions*

3. The causes of geological changes in the past *differ not in kind*, though they may sometimes *differ in energy*, from those now in operation. This is actualism, though no uniformity of activity is assumed.

3*a*. In general, the background of this conception is the belief that the energy of geologic forces has gradually diminished, as the earth is cooling down (Hooke, Ray, von Buch, Breislak, and even the non-catastrophist actualists Scrope and Von Hoff). Therefore, when the earth was younger, the causes of change must have been more powerful and their effects more violent.

3*b*. A series of discontinuous outbursts of geological activity is assumed, and superposed upon the continuous changes. This

conception (Élie de Beaumont, Sainte-Claire Deville) is an *actualistic catastrophism* as to the resulting historic-descriptive *system*; it is a catastrophist *actualism* as to the *method* used, as it tries to interpret past phenomena as much as possible in terms of actually existing causes.

4. The geological forces of the past *differ neither in kind, nor in energy* from those now in operation. This is "*actualism*" or rather "*uniformitarianism*" in the current sense. In this case the method largely determines the resulting theoretical system.

4*a*. When using an actualistic method admitting strict uniformity in kind and energy throughout the ages, one may arrive at a geological system describing the situation of the earth in successive epochs in which the same circumstances and events are repeated with a large measure of uniformity.

The term *uniformitarianism* should be restricted to this subdivision. It may refer to a uniformitarian *system* or theory, propounding uniformity of material conditions and rates of change, as well as to a uniformitarian *method* (a subdivision of the actualistic method), asserting that the past should be reconstructed on the assumption that *all* geological causes (and not only the petrogenetical or even only the physical causes) of the past were of the same kind and intensity as those now in operation.

4*b*. However, *uniformity* might refer not so much to uniformity of the *situation itself* as to uniformity of *change of the situation*. When a small rate of progressive or directed change prevailing now, is assumed to have prevailed always, a situation that is non-uniform throughout the ages is uniformly changed. In biology, the darwinistic protagonists of practically uniformly, or at least continuously, increasing complicatedness of animal structure, believed that they kept themselves to strict uniformitarianism. The resulting *system*, however, is *evolutionism* [3].

Perhaps one could say that both Lyell and Darwin used a uniformitarian *method*, but that Lyell (1830) arrived by its help at a uniformitarian geological *system*, whereas Darwin's theory of descent with modification is not a uniformitarian, but an *evolutionist system*.

5. If the appearance of *new* causes in the course of the history of the earth is admitted, not *all* "actual" (present) causes could be used to explain past events. It would depend on the epoch concerned what part of them ought to be chosen. The *method* of explanation

[3] Cf. R. Hooykaas, The parallel between the history of the earth and the history of the animal world. Arch. Internat. Hist. Sc. 10 (1957), pp. 1–18. Also: R. Hooykaas, Geological Uniformitarianism and Evolution. Arch. Intern. Hist. Sc. 19 (1966), pp. 3–19.

then would be actualistic (or perhaps even strictly uniformitarian), but the descriptive *system* would not be uniformitarian (cf. Johannes Walther's "Wüstenbildung")[4].

The above classification does not cover all differences of system and method and interpretation in geology. How far can we go back into the past in order to be able to speak of uniformity of the situation, or – less stringently –, of the applicability of "actual causes" in the explanation thereof? How long ought to be the period of change one takes into account for deciding whether a change is catastrophic or continuous?

Moreover, as to the identity of kind or the identity of energy of geological causes, a wide range of interpretation seems to be possible. It is difficult to establish what is meant by *geological* causes in contradistinction to *physical* causes. A good deal of confusion may arise through the ambiguity of the term "actual cause". It might be that a coincidence of fundamental primary physical causes (nuclear, atomic and molecular forces, gravitation etc.) in their combination gave rise to effects which were acting in their turn as causes of geological change (sedimentation, geochemical and petrogenetical phenomena), but that these ancient combinations or coincidences do not occur at present. In that case one might speak of *ancient* geological causes (dependent on an ancient geological situation and therefore only possible in the circumstances of the ancient world), and yet maintain that these are to be explained in an actualistic way, that is by physical forces similar to those active now. Thus actualism may be maintained on the level of physics, whereas, under the pressure of the evidence of geological observation, it is taken less strictly on the geological level.

When, however, the notion of "actual geological cause" has been widened then so far that it is practically considered as equivalent to "*physical* cause", systems based on a non-actualistic method become virtually non-existent. Only theories introducing supernatural, that is non-physical, causes would be non-actualistic then.

III. Catastrophism

According to a widespread opinion, pre-scientific speculative systems, denoted as "catastrophism", prevailed in geology until, with Hutton's and Lyell's uniformitarianism and the overthrow of Cuvier's catastrophism, truly scientific geology triumphed.

It should, however, be borne in mind that uniformitarianism did

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[4] R. Hooykaas, The Principle of Uniformity in Geology, Biology, etc. pp. 52–53.

not arise in a "catastrophic" way in the decades before and after 1800. Uniformitarianism and catastrophism already existed alongside each other in the 18th century. The cosmogonic systems of Burnet, Woodward and Whiston bore a strongly catastrophist character. Neither the kind, nor the energy of actual causes were considered sufficient to explain former changes. Moreover, these systems did not restrict themselves to changes in the *crust* of the earth, but embraced the genesis of the whole planet.

Over against them, less speculative, more scientific, systems, which were based on *observations* of the crust of the earth (the only part of the globe accessible to direct investigation), were put forward already in the late 17th and in the 18th century. Cuvier stated in 1821 that "since long it has been believed to be possible to explain past revolutions by actual causes" [5]. As a rule, those geologists who abstained from geogenic speculations and restricted themselves to explaining those changes the traces of which are still accessible to observation, tried to do so as much as possible with the help of causes they actually saw at work before their eyes.

a. *Buffon*

Buffon (1707–1788), having supposed the earth as detached from the sun by collision with a comet and then cooling off gradually, had no further use for this hypothesis. In his explanation of changes in the surface of the earth, he always referred to the actually existing causes.

In this "Théorie de la Terre" (written in 1744; published in 1749), he said that in the recent period (2000–3000 years) geological change was very small in comparison with "the revolutions which must have taken place in the first time after the creation", when the crust was much less solid than now [6]. So he had catastrophist ideas about the most ancient epochs, but at the same time he left no doubt about his actualistic conceptions, for he added that "consequently, the same causes which at present produce almost insensible changes in several centuries, must *then* have caused very great revolutions in very few years" [7].

On the other hand, when reconstructing the past situation of

[5] G. Cuvier, Discours sur les révolutions de la surface du globe, et sur les changemens qu'elles ont produits dans le règne animal. Paris 1826, p. 14.

[6] Buffon, Théorie de la Terre. Histoire Naturelle générale et particulière, Tome I, Paris 1749, p. 77.

[7] "... par conséquent les mêmes causes qui ne produisent aujourd'hui que des changemens presqu'insensibles dans l'espace de plusieurs siècles, devoient causer alors de très-grandes révolutions dans un petit nombre d'années; en effet il paroît certain que la terre actuellement sèche et habitée, a été autrefois sous les eaux de la mer, et que ces eaux étoient supérieures aux sommets des plus hautes montagnes ..." Buffon, o.c.p. 77.

what is at present dry land (but which for a long time has been covered by the sea), he starts from the assumption that it underwent "the same changes that the land *now* covered by the sea actually undergoes". "Therefore, in order to find what happened formerly on this earth, let us look at what is happening today at the bottom of the sea" [8]. The origin of the Atlantic Ocean may have been sudden (e.g. by the breaking down of a huge subterraneous cave and a subsequent universal deluge), or by slow action, but at any rate it was a *natural* event; "for deciding what has occurred and even what will occur, we have only to examine what is occurring" [9].

As "historians" we have, according to Buffon, to refuse to enter into vain and gratuitous speculations about the origin of the earth by the approach of a comet, etc. In order to have a firmer starting point, he intends himself "to take the earth as it is, to exactly observe all its parts and to conclude by inductions from the present to the past". He will not be affected by "causes whose effect is rare, violent and sudden", as "they do not belong to the ordinary course of nature", but he will use as "causes and reasons" only "effects which occur every day . . . constant and always reiterated operations" [10]. Nevertheless, he recognizes that "sudden and rapid changes took place by inundations and earthquakes" [11], and he contrasts such "particular causes" (which produce upheavals, inundations and sinkings) with the continual and slow changes by the "general causes" (fire, air and water) [12].

In his later geological work, "Les Époques de la Nature" (1778),

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[8] ". . . la partie sèche du globe que nous habitons a été longtemps sous les eaux de la mer; par conséquent cette même terre a éprouvé pendant tout ce temps les mêmes mouvemens, les mêmes changemens qu'éprouvent actuellement les terres couvertes par la mer. Il paroît que notre terre a été un fond de mer; pour trouver donc ce qui s'est passé autrefois sur cette terre, voyons ce qui se passe aujourd'hui sur le fond de la mer . . ." Buffon, o.c., p. 81.

[9] "ce changement a donc pu se faire tout à coup par l'affaissement de quelque vaste caverne dans l'intérieur du globe, et produire par conséquent un déluge universel; ou bien ce changement ne s'est pas fait tout à coup, et il a fallu peut-être beaucoup de temps, mais enfin il s'est fait, et je crois même qu'il s'est fait naturellement; car pour juger de ce qui est arrivé et même de ce qui arrivera, nous n'avons qu'à examiner ce qui arrive". Buffon, o.c., p. 96.

[10] ",, , il faut le prendre tel qu'il est, et bien observer toutes les parties, et par des inductions conclure du présent au passé; d'ailleurs des causes dont l'effet est rare, violent et subit, ne doivent pas nous toucher, elles ne se trouvent pas dans la marche ordinaire de la Nature, mais des effets qui arrivent tous les jours, des mouvemens qui se succèdent et se renouvellent sans interruption, des opérations constantes et toujours réitérées, ce sont là nos causes et nos raisons". Buffon, o.c., pp. 98–99.

[11] Buffon, o.c., p. 605.

[12] Buffon, o.c., p. 609.

there is the same ambiguity. He emphasizes that the course of Nature is "not absolutely uniform", but that it undergoes "successive alterations, and is liable to new combinations", so that at present Nature is very different from what she was at the beginning and in the first periods [13].

Nevertheless, Buffon keeps to the actualistic method. In his opinion, when penetrating into the "night of time", one has to go back "only from existing facts to the historical truth of bygone facts"; one has to evaluate "not only the recent past, but also the most ancient past, by the present alone" [14].

The picture Buffon gives of the beginning of the Third Epoch is far from uniformitarian. He speaks of the "first moments of shock and agitation, of upheavals, irruptions and changes, which have given a second form to the greater part of the surface of the earth" [15]. "Nature was then in its first energy, and wrought the organic and living matter with a more active power and a higher temperature" [16]. Clay was produced in a shorter time than now, as the water was hotter, and, though this decomposition is still going on today, it is slower and less. [17]

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[13] Buffon, Histoire Naturelle des Époques de la Nature. Histoire Naturelle, générale et particulière, Supplément V, Paris 1778, p. 3." . . . en l'observant de près, on s'apercevra que son cours n'est pas absolument uniforme; on reconnoîtra qu'elle admet des variations sensibles, qu'elle reçoit des altérations successives, qu'elle se prête même à des combinaisons nouvelles, à des mutations de matière et de forme: . . . et si nous l'embrassons dans toute son étendue, nous ne pourrons douter qu'elle soit aujourd'hui très-différente de ce qu'elle étoit au commencement et de ce qu'elle est devenue dans la succession des temps: ce sont ces changemens divers que nous appelons ses époques . . .".

[14] "ce n'est donc que de cet instant l'on peut commencer à comparer la Nature avec elle-même, et remonter de son état actuel et connu à quelques époques d'un état plus ancien. Mais comme il s'agit ici de percer la nuit des temps; de reconnoître par l'inspection des choses actuelles l'ancienne existence des choses anéanties, et de remonter par la seule force des faits subsistans à la vérité des faits ensevelis; comme il s'agit en un mot de juger, non seulement le passé moderne, mais le passé le plus ancien, par le seul présent . . .". Buffon, Époques, p. 5.

[15] "Quels mouvemens, quelles tempêtes ont dû précéder, accompagner et suivre l'établissement local de chacun de ces élémens! Et ne devons-nous pas rapporter à ces premiers momens de choc et d'agitation, les bouleversemens, les premières dégradations, les irruptions et les changemens qui ont donné une seconde forme à la plus grande partie de la surface de la Terre?". Buffon, Époques, p. 96.

[16] "La Nature étoit alors dans sa première force, et travailloit la matière organique et vivante avec une puissance plus active dans une température plus chaude . . .". Buffon, Époques, p. 99.

[17] "La décomposition des poudres et des sables vitrescibles, et la production des argiles, se sont faites en d'autant moins de temps que l'eau étoit plus chaude: cette décomposition a continué de se faire et se fait encore tous les jours, mais plus lentement et en bien moindre quantité". Buffon, Époques de la Nature, p. 103.

At any rate, in spite of his actualism, it goes too far to say that Buffon was "in advance of his time" by admitting only "actual and *slow* causes" [18]. There is always analogy, but not always identity of ancient and modern phenomena in his descriptions. His wavering attitude gives warning of the difficulties one meets when trying to classify geological theorists.

IV. Non-actualistic catastrophists (ad 1)

a. *G. Razumovsky*

In the ideas of the Russian geologist Count Gregor Razumovsky (1759–1837) we meet with another example of ambiguity. He was a neptunist and a catastrophist, that is, from the Huttonian standpoint he was as unorthodox as possible. But he was also an "actualist" in using physical and chemical *causes* which still are at work now for the explanation of "ancient" phenomena, whereas he was a non-actualist as well, in that he believed that these *phenomena* do no longer occur in nature today.

His catastrophism becomes evident e.g. when he says (1789) that the facts demonstrate that the environment of Lausanne has formerly been covered by waters, and that "the power of these waters is hardly conceivable by our imagination, as it was much superior to that of our most terrible modern waters in their effects" [19]. There are found there enormous boulders, which have a composition different from that of the surrounding rocks and similar to that of the most ancient Alpine rocks. This shows that they have been brought there by a strong torrent of water: "one cannot think of any power in nature today that would have been able to lift and to transport such large pieces so far from the place of their first formation" as has been done by those "ancient waters" [20]. The

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[18] Cf. J. Roger, Mém. Mus. Hist. Nat. nouvelle série C, X (1962), p. 271. According to J. Staszewski (Kwartalnik Historii Nauki i Techniki IX (1964), p. 40) the actualistic principle was "a mere rudimentary conception in Buffon". The claim is then made that Hugo Kollontaj (1750–1812) was "the first actualist in geological history". Though it is recognized that he often depends on Buffon, the actualistic principle is said to be his "own, original creation". It is evident that Staszewski's under-estimation of Buffon's actualism matches the over-estimation by J. Roger and J. Piveteau.

[19] Cte G. de Razoumowsky, Histoire Naturelle du Jorat et de ses environs. Tome II, Lausanne 1789, p. 25. ". . . cette contrée . . . a été couverte par les eaux, . . . la puissance de celles-ci à peine concevable pour notre imagination, étoit bien supérieure à celle de nos eaux modernes les plus terribles dans leurs effets".

[20] ". . . on ne conçoit aujourd'hui aucune puissance dans la nature qui aye pu soulever et transporter des fragments de cette taille, si loin du lieu de leur première formation . . ., on ne peut douter qu'elles ne se trouvent là encore à la place même où elles ont été déposées par les eaux anciennes". Razumovsky, o.c., p. 26.

environment of the Jorat unmistakably shows "incontestable monuments of the most astonishing catastrophes" [21].

In a later publication (1791) Razumovsky tackled the problem of the origin of the primitive rocks. In his opinion, granite was a product of crystallization from an "aqueous" fluid [22]. In order to find out from which solvent it has been crystallized, we have to take recourse either to the examination of the actions of still existing natural aqueous fluids on quartzeous matter, or to reasoning from analogy [23]. The only natural waters we know today (viz. fresh and salt water), do not dissolve quartz. Therefore, only the second way is open: chemistry teaches us that only "spar acid" [24] possesses this dissolving power. It seems, then, plausible that the globe originally was wholly covered by a sea containing this acid, whereas in more recent epochs salt water seas, resembling our modern seas, took its place. From the combination of the earthy, saline and acid principles, "according to the immutable laws of gravity, attraction and affinities", took rise this first crystalline kernel of the earth as well as the ancient fluid surrounding it [25].

Razumovsky, then, clearly states that the physical and chemical laws are immutable (and from this general viewpoint he could be called even a uniformitarian). In order to reconstruct the past, he starts from the *present* situation and from *actual* phenomena: he asks whether there are *now* causes active in nature that might give an explanation of an ancient event, and—when the answer turns out to be negative—he tries whether *now* experiments can

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[21] "l'Histoire Naturelle du Jorat comme celle de toutes les Montagnes grandes ou petites, nous offre les traces non équivoques des révolutions successives des siècles les plus réculés. Chaque pas, nous y présente ces médaillons, ces monuments incontestables des catastrophes les plus étonnantes". Razumovsky, o.c., p. 228.

The interpretation of erratic blocks by Catastrophists and Uniformitarians will be dealt with in a forthcoming article.

[22] Comte de Razoumowski, Idées sur la Formation des Granites. J. de phys. **39**, (1791), p. 251.

[23] "Pour résoudre ce problème important d'une manière satisfaisante, nous ne concevons que deux voies: l'examen de l'action des fluides aqueux naturels que nous connoissons de nos jours sur la terre vitrifiable ou quartzeuse, qui forme la majeure partie des granits, et l'*analogie*." Razumovsky, l.c., p. 252.

[24] "Acide spathique", i.e. hydrofluoric acid. [24a] Razumovsky referred to the presence of fluor compounds in "primary" rocks as an argument in support of his hypothesis. As late as 1820 the Netherlandish scientist. H. C. van der Boon Mesch, in his "Disputatio geologica de Granite" (Lugd. Batav. 1820, p. 100) accepted Razumovsky's theory.

[25] "c'est . . . de la combinaison . . . de ces divers principes (terreuses, salines, acides) entre eux, selon les lois immuables de la pesanteur, de l'attraction et des affinités, qu'ont résulté cette première coagulation cristalline qui dès-lors a formé le noyau du globe, et ce fluide le plus ancien de tous qui ait jamais enveloppé notre globe". Razumovsky, l.c., p. 253.

be made in the laboratory which, by analogy, may reveal what possibly could have happened in the past. That is, he follows a truly *actualistic method.*

Nevertheless, he is also decidedly non-actualistic. Why do not we find remnants of this hypothetical fluid? The answer is: "one cannot compare the causes and the effects of such remote epochs, as one cannot compare their products; such rests do not exist and can no longer exist today, as neither granites nor fluor-spars are formed nor could be formed any longer, whatever may have been contended, ungroundedly, by a small number of naturalists" [26].

In this connection it is of no importance whether Razumovsky's hypothesis seems phantastic or not. What matters is, that he uses an actualistic method (comparison with phenomena occurring now; recognition of the immutability of physical and chemical laws), and that this leads him to conclusions that are decidedly non-actualistic. Moreover, the absence of any appeal to supernatural causes shows that catastrophism is not necessarily connected with "metaphysics".

b. *D. Dolomieu*

According to the system put forward (1791) by Déodat de Dolomieu (1750–1801) there has been a very slow sedimentation of the primitive rocks from the primeval ocean [27], during "thousands of centuries" [28]. After that period there occurred a worldwide catastrophe, which disturbed the horizontal layers by "a force of extraordinary violence" [29], and which gave rise to the primitive moun-

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[26] "Que si l'on nous demande d'où vient qu'on ne trouve plus aujourd'hui des restes d'un fluide tel que nous le supposons, tandis qu'on trouve encore partout ceux qui ont formé les montagnes à couches? nous répondons qu'on ne peut pas plus comparer les causes et les effets d'époques si éloignées les unes des autres que leurs produits, que ces restes même n'existent ni ne peuvent plus exister de nos jours, puisque ni les granits, ni les fluors ne se forment ni ne peuvent plus se former, quoi qu'en aient prétendu, sans fondement, un petit nombre de naturalistes". Razumovsky, l.c., p. 253. Cf. p. 254.

[27] Commandeur Déodat de Dolomieu, Mémoire sur les pierres composées et sur les roches. In: Observations sur la Physique, etc. 39 (1791), p. 382: "Quel qu'ait pu être ce dissolvant, c'est avec M. de Saussure et M. de Luc que j'admets la précipitation comme première cause de la formation et de la consolidation des plus anciens matériaux de nos montagnes . . . la précipitation s'est faite assez lentement . . .".

Like Razumovsky, Dolomieu thought that the solvent which kept the siliceous matter that gave rise to the primitive rocks, in solution, finds no counterpart in nature now. In contradistinction to Razumovsky, however, he found no equivalent of it in the laboratory either. pp. 378–380.

[28] Dolomieu, o.c., p. 404.

[29] "La régularité du premier travail a été dérangée; une rupture a été produite par une cause quelconque, mais sûrement d'une force ou d'une violence extraordinaire . . .". Dolomieu, o.c., p. 390.

tains [30]. After a long interval, an epoch of the formation of "couches de transport" started, in which enormous periodical inundations disturbed the regularity of the deposits of the first epoch. "No great antiquity" is supposed for "the actual order of things" [31].

Dolomieu energetically rejected the idea that during a very long period and with extreme slowness the sea could shape the surface of the earth: "When shaping the earth as we inhabit it, Nature has not spent time with such a prodigality as some famous authors did suppose" [32]. It seems probable that this is a thrust at Buffon, who—according to many contemporaries—was too lavish with thousands of years.

To Dolomieu, however, geological *facts* seem to point out the necessity of a catastrophist explanation: "Getting convinced that it is impossible that the sea, in its present circumstances, might operate anything similar to what exists on our continents . . . the naturalist must imagine more powerful circumstances, capable of greater effects, in which, however, the sea must intervene, as there are certain proofs of its cooperation" [33]. "It is not by weak currents that I would open our valleys, but by all the power that the waters can receive from the uniting of the weight of a very large mass" increased by the acceleration through the impetus of their fall [34]: "it is not time that I will invoke, but it is force; one only relies on the first, when one does not know where to find the other" [35].

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[30] Dolomieu, o.c., p. 404.

[31] ". . . je ne supposerois pas une bien grande antiquité à l'ordre actuel des choses". Dolomieu, o.c., p. 404.

[32] "Que l'on ne me dise pas que la Nature ne compte pas avec le tems, que l'histoire des hommes est bien nouvelle; et que, dans le long période qui l'a précédée, la mer, quoiqu'avec une extrême lenteur, a pu faire tout ce qu'on lui attribue. Je conviendrai que le tems n'est rien pour la nature, mais cependant elle a placé au milieu de ses créations quelques bornes qui fixent différentes époques dans sa durée, et qui doivent modérer les élans de l'imagination. Tout me porte à croire qu'en façonnant la terre telle que nous l'habitons, la nature n'a pas dépensé le tems avec autant de prodigalité que quelques écrivains célèbres l'ont supposé". Dolomieu, o.c., p. 394.

[33] "En acquérant la conviction de l'impossibilité où est la mer d'opérer, dans ses circonstances présentes, rien de semblable à ce qui existe sur nos continens, il (le naturaliste) ne peut plus supposer qu'elle y ait résidé long-temps; il doit imaginer des circonstances plus puissantes et capables de plus grands effets, où la mer doit cependant intervenir, puisqu'on a des preuves certaines de son concours". Dolomieu, o.c., p. 403.

[34] "Ce n'est donc point la mer reposant tranquillement dans les bassins où elle est fixée par le centre de gravité de la terre, que j'appelle à la formation de nos couches, mais ce sont ses eaux dans le plus violent état d'agitation où elles puissent se trouver. Ce ne sera pas par de débiles courans que j'y ferai ouvrir nos vallées, mais par toute la puissance que l'eau peut recevoir de la réunion du poids d'une trèsgrande masse à une chûte précipitée". Dolomieu, o.c., p. 398.

[35] "Ce n'est pas le tems que j'invoquerai, c'est la force; on ne place en général sa confiance dans l'un que lorsqu'on ne sait où trouver l'autre". Dolomieu, o.c., p. 399.

In a letter to H. B. de Saussure, for whom he had a great admiration, Dolomieu wrote that he would not have the slightest objection to abandoning his "hypothesis", if a more probable one could be put forward. He insisted, however, that this should present then "a cause sufficiently active for producing the required effects" [36].

The geological changes of the past, so he says, evidently are "outside the ordinary course of nature" [37], and therefore they cannot be explained by what is actually going on. It is precisely the comparison of the ancient phenomena with what the *actual* operations would effect if working in the past under the same circumstances as are prevailing now, which led him to the conclusion that actual causes are insufficient for explaining them: "At present the sea does not form similar strata; it does not excavate valleys; it does not bury lava currents under banks of calcareous rocks; it does not deposit salt mines, etc." He thinks that this will not be doubted by anybody who is free from "ancient prejudices" [38]. This dubbing the actualistic principle (according to which present causes must be sufficient for explaining past changes) an "ancient prejudice", demonstrates convincingly that at the end of the 18th century the actualistic method was not considered as something new.

To Dolomieu "the ideas of those who attribute an age of more than a hundred thousand years to our continents" [39] represents another prejudice, but this one he considers as of less importance, as it touches the system only and not the method.

c. *G. Cuvier*

Cuvier (1769–1832) was of the opinion that amongst those who have endeavoured to explain the present state of the globe, "hardly any one has attributed it entirely to the agency of slow causes, and still less to causes operating under our eyes" [40]. But, though approving of their non-actualism, he blamed these predecessors because this necessity of seeking causes different from those which we see acting at the present day, has made them "imagine so many extraordinary suppositions and lose themselves in so many erroneous and contradictory speculations, that the very name of their science

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[36] Dolomieu à de Saussure, 26–4–1792. In: A. Lacroix, Déodat de Dolomieu, T. II, Paris 1921, p. 41.

[37] Dolomieu, l.c., p. 41.

[38] "Or, la mer ne forme point maintenant de couches semblables aux nôtres, ne creuse pas de vallées, n'ensevelit pas des courants de laves sous des bancs de pierre calcaires, ne dépose pas de mines de sel gemme, etc., etc. Je crois que pour ceux qui savent se défendre d'anciens préjugés, il ne doit rester aucun doute à cet égard". Dolomieu, l.c., p. 41.

[39] Dolomieu, l.c., pp. 42–43.

[40] G. Cuvier, Discours, etc., p. 21.

has long been a subject of ridicule" [41]. He deemed these early catastrophists too speculative and too ambitious, because they dealt with events (like the origin of our planet, or changes in the interior of the earth) of which, in his opinion, no trace has been left.

Accordingly, precisely like the uniformitarians before and after him, Cuvier rejected the cosmogonic systems of his predecessors, and he dated scientific geology from the moment that "it preferred the positive data furnished by observation, to fanciful systems, contradictory conjectures regarding the first origin of the globes" [42].

Evidently, the catastrophists of the school of Cuvier agreed with the uniformitarians of the Lyellian school in that they rejected the catastrophism of the cosmogonists, because it had not been built upon observations. But, for the same reason Cuvier and his disciples rejected uniformitarianism as well. They propounded their own theories not because of some prejudice in favour of catastrophes, but because they held that *observation* led to them.

Cuvier restricted his theory to those changes in the *crust* of the earth of which visible traces remain, and he was so successful, that, when Lyell in 1830 entered upon the scene, uniformitarianism had to fight its way with great difficulty.

In Cuvier's opinion the sudden transition of one kind of layer to another, and, in particular, the fossils they contain, testify to the revolutionary rapidity of certain changes which characterize the beginning of new geological and paleontological epochs. Consequently, the energy of these forces must also have been extremely great, "as no cause acting slowly could have produced sudden effects" [43].

Of course, the "ordinary" changes of the surface of the globe, caused by weathering, sedimentation and volcanic eruptions, were supposed to be common to all epochs. But geologists like Cuvier, Murchison and Élie de Beaumont deemed it impossible that any amount of these small agencies, though continued for millions of years, could have produced such results as the disruption and overturning of the mountain masses of the Alps, enormous dislocations which belong "distinctly to former epochs". The facts, according to Murchison, announce in emphatic language "how ordinary operations of accumulation were continued tranquilly during very lengthened epochs, and *how such tranquillity was broken in upon by great convulsions*" [44].

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[41] Cuvier, Discours, p. 21.
[42] Cuvier, o.c., p. 145.
[43] Cuvier, o.c., p. 21.
[44] R. I. Murchison, Siluria, The history of the oldest known rocks containing organic remains. London 1854, p. 505.

That is to say, even in the past the more energetic causes were not always at work, but only during the relatively short periods of the catastrophes. Murchison and Sedgwick in England, and Élie de Beaumont in France, took their proofs of the greater *intensity* of former causation especially from the geological phenomena of the Alps, which, in their opinion, showed signs of former catastrophes, inexplicable by any reference to those puny oscillations of the earth which can be appealed to during the times of history [45].

But not only the *energy* of the causes of past geological changes was supposed to have been different from that of the causes now in operation,—these causes were sometimes also supposed to have been of a *different kind*. As Cuvier wrote: "It is in vain that we search among the powers which now act at the surface of the earth, for causes sufficient to produce the revolutions and the catastrophes, the traces of which are exhibited by its crust" [46]. . . "The thread of operations is broken; the march of Nature is changed, and none of the agents which she now employs, would have been sufficient for the production of her ancient works" [47].

But even Cuvier believed that, if not identity, at least some *analogy* with the physical phenomena of the present is indispensable for the reconstruction of the past. He deemed it the error of the cosmogonists that, inventing systems built upon "phenomena, which, having no resemblance to those of our actual physics, could find in it, for their explication, neither materials, nor touchstone"; "the geologists of whom I speak, neglected precisely the posterior facts which could alone have reflected some light upon the darkness of preceding times" [48].

And, finally, even catastrophists like Deluc and Cuvier distinguished between ancient causes which have ceased to act in the crust of the earth, and other causes, which have continued their activity up to the present day. Cuvier fully recognized the right of the actualistic method to be used for explaining phenomena which had occurred *between* the catastrophes or *after* the last revolution.

V. Actualistic catastrophists (ad 3*b*)

a. *L. Élie de Beaumont*

Élie de Beaumont (1798–1874) was of opinion that those who would refuse to believe that the causes now in operation could ever have produced the great geological phenomena, would reason like

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[45] Murchison, o.c., p. 476.
[46] Cuvier, Discours, p. 20.
[47] Cuvier, o.c., p. 14.
[48] Cuvier, o.c., p. 145.

people who, while having no experience of cold below the freezing point, would deny that water could ever become a solid body. According to his fundamental hypothesis, the irregularities of the crust of the earth, in its outward form as well as in its structure, result from the disappearance of part of the heat that the earth contained when its crust was still in a state of fusion. The "slow and continuous" phenomenon of cooling of the earth causes a slow and progressive diminution of its volume, from which ensues the rise of the mountains [49]. This cooling, which acts as a slow and gradual cause, has as its effects violent and sudden cataclysms, – "of a very short duration, and, as it were, instantaneous". Consequently, there are long periods of quietness, alternating with short periods of revolution [50].

Evidently, though being a catastrophist, Élie de Beaumont did not recognize ancient causes that are *essentially* different from the causes now in operation. The slow tectonic effects of the present day result from the same fundamental cause as the sudden and violent effects of the past. These latter, moreover, are not even essentially *ancient effects*, for it is possible that in the future a new catastrophe will strike the surface of the earth.

In Élie de Beaumont's system, however, this does not imply an eternal repetition of revolutionary and gradual effects in perfectly similar cycles. In his opinion, the effects of the causes presented by the phenomena of the past often differ from the phenomena of the present. He speaks even of the "gradual enfeeblement of the chemical agents which have been active on the surface of the globe" [51].

Petrogenesis

Élie de Beaumont established relations between the geochemical data and the sequence of events, thus indicating the way modern geochemistry would follow. He thought that in the formation of granite "extremely ancient phenomena, which must have been

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[49] L. Élie de Beaumont, Notice sur le système des montagnes. Paris 1852. T. III, p. 1329.
Élie de Beaumont had already put forward his catastrophism in his "série de recherches sur quelques-unes des révolutions de la surface du globe", in Ann. sciences naturelles **19** (1829–'30).

[50] Élie de Beaumont, Notice, III, p. 1329.

[51] Élie de Beaumont, Note sur les émanations volcaniques et métallifères. Bull. Soc. géol. France [2], T. IV (1846–'47), p. 1331: "L'affaiblissement graduel des agents chimiques qui ont agi à la surface du globe, comparé à l'ordre suivant lequel y ont apparu les différentes classes d'êtres organisés, laisse apercevoir dans l'histoire de la nature un plan aussi harmonieux que celui qu'on admire dans la constitution de chaque être en particulier".

different from those occurring today on the surface of the globe", have been involved. There is an "enormous difference" between the phenomena characteristic of the epoch when granite was formed, and what happened later on in the formation of the other crystalline rocks. A large part of the chemical elements has been chemically bound in this first epoch, so that it could never reappear afterwards, and this fact alone indicates a gradual change in the course of geological phenomena [52]. In his petrogenetical conceptions, then, Élie de Beaumont was decidedly non-actualistic.

Summarizing, we may conclude that Élie de Beaumont's geology admits that there is a general decrease of the energy of geological causes, together with a gradual decrease of temperature and of the number of elements that participate in the formation of rocks. And, besides this qualitative and quantitative change of a continuous character, there are the cataclysms.

It goes without saying, that Uniformitarianism is energetically rejected by this catastrophist: if everything had always happened in the same way in perpetual geological cycles without essential change, in all mineral deposits the same elements would be found, so he says [53], whereas, in his opinion, this is not so in fact.

b. *L. Frapolli*

In the same year (1846–'47) L. Frapolli took over this distinction between *periods of tranquillity* (slow upheavals) and *epochs of*

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[52] "... la concentration du *silicium*, du *potassium* et d'une classe nombreuse de métaux dans les granites ... remonte nécessairement à des phénomènes extrêmement anciens qui ont dû être différents des phénomènes qui se passent aujourd'hui sur la surface du globe; que lors de la coagulation de la première enveloppe du globe terrestre, il doit avoir existé une cause quelconque pour qu'un grand nombre de corps fussent retirés de la circulation; qu'il y a eu une énorme différence entre les phénomènes propres à l'époque où le granite s'est formé et ce qui s'est passé plus tard, lors de la formation des autres roches cristallines; d'où il résulte que les phénomènes qui se sont accomplis sur la surface du globe ont suivi une *certaine gradation*". Élie de Beaumont, Note, p. 1330.

[53] "Quelle qu'ait été la nature des premiers phénomènes géologiques, une grande partie des corps simples ont été alors séquestrés de manière à ne plus reparaître ailleurs, et ce fait seul indique un changement graduel dans la marche des phénomènes géologiques. On voit combien cela est contraire à certains systèmes dans lesquels on suppose que tout s'est constamment passé de la même manière sur la surface de la terre, et que l'origine du globe se perdrait dans la nuit d'une période indéfinie, pendant laquelle les phénomènes géologiques auraient tourné perpétuellement dans le même cercle. Si tout s'était toujours passé de la même manière, sans aucun changement essentiel, on trouverait dans tous les gisements de minéraux la même série de corps simples, et non pas une série plus nombreuse dans les gîtes formés les premiers que dans ceux formés les derniers". Élie de Beaumont, Note, p. 1330.

agitation (sudden upheavals, ruptures, inundations) [54]. In his opinion the problem of drawing an exact borderline between the products of the cataclysmic periods and those due to the "ordinary agents of the physical forces" and the activity of air and water during the periods of tranquillity, has been thrown into a regrettable confusion by "the substitution of phantastical agents for the real and actual causes" [55].

Evidently, with Frapolli a catastrophistic *system* does not exclude an actualistic *method*. He says that in the periods that are analogous to the present one, "similar causes produced effects resembling those we may observe in our time". There is, however, one restriction: the greater power of the chemical agents and the meteorological influences, which especially in the first epochs must have been modified by the higher temperature and by the different composition of the atmosphere, "must have made some difference" [56].

It goes without saying, that this difference from contemporary phenomena is more evident in the case of periods of agitation. But even for that case there is nothing to indicate that Frapolli would have resorted to "ancient" causes.

c. *Ch. Sainte-Claire Deville*

In the long run, through Lyell's triumph, Élie de Beaumont's system, which had been the orthodox one at least in France, became ridiculous in the eyes of the Uniformitarians. Nevertheless, he has had devoted partisans amongst later geologists, e.g. Charles Sainte-Claire Deville (1814–1881) [57] and, more recently, G. Simoens [58] (1907).

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[54] L. Frapolli, Réflexions sur la nature et sur l'application du caractère géologique. Bull. Soc. géol. France [2], IV, pp. 623–625.

[55] "Malheureusement la substitution *d'agents fantastiques* aux *causes réelles et actuelles* a jeté dans ces derniers temps cette partie de la géologie dans une si déplorable confusion, qu'elle est à peu près encore à refaire". Frapolli, l.c., p. 626, note 1.

[56] (*"périodes de tranquillité"*:) "Dans ces périodes, espaces de temps analogues à celui où nous vivons, des causes semblables produisaient des effets pareils à ceux que nous pouvons observer de nos jours. Une plus grande puissance des agents chimiques, et les influences météorologiques modifiées, surtout dans les premiers temps, par la plus grande uniformité d'une température plus élevée, par la composition des eaux et de l'atmosphère de l'époque, par la disposition des mers et des continents, par l'existence probable d'une plus grande quantité de sources minérales et thermales, ont dû seules y apporter quelque différence, et réagir surtout puissamment sur la vie des végétaux et des animaux, en leur imprimant en général un cachet de contemporanéité respective; 2° des *époques d'agitation*, moments de soulèvement brusque et de *rupture*, marqués par l'arrivée des matières intérieures à la surface". Frapolli, l.c., pp. 624–625.
See below the paragraphs on Cotta and Bronn, showing similar conceptions.

[57] Ch. Sainte-Claire Deville, Coup d'oeil historique sur la Géologie. Paris 1878.

[58] G. Simoens, La Théorie de l'Évolution cataclysmique et de l'Évolution alternante. Paris-Bruxelles, 1936.

In his lectures delivered in the Collège de France in 1875, Sainte-Claire Deville is an actualist, though not a uniformitarian. He says that the opinion which Lyell wrongly imputed to the geologists (viz. that ancient causes are wholly different from those that are behind the gradual changes we see today)[59], is a "geological heresy"[60], accepted only in *geogeny* and not in *geology*, with the exception "perhaps" of Cuvier[61]. Everybody agrees that the great geological causes, like the great astronomical causes, "cannot any longer be supposed to have ceased to exist at a certain moment"[62].

Even, in spite of Lyell's protests against Cuvier's wording, Sainte-Claire Deville thinks that one cannot reasonably suppose, that – when he spoke of "actual causes" –, Cuvier could have meant that there are two categories of forces of an essentially different nature, for such a proposition "would strike us by its absurdity"[63] Cuvier evidently meant that no agent "in its actual force and expression could have caused these ancient phenomena; he did not wish to say that the same agents, moved by incomparably superior forces, could not have produced the observed effects[64].

Sainte-Claire Deville himself, too, though recognizing with Lyell that "the ancient causes were the same as those we see active before our eyes", is not willing to admit that "the *intensity* of those forces has always, in all periods . . . been identical with that of the present time"[65]. Consequently, the final aim of geology precisely is to see how "essentially identical *causes*" could produce "exceedingly variable effects"[66].

Almost inevitably, such a conception must lead Deville into a non-actualistic direction (except for the elementary physical processes), as these effects in their turn become geological causes. And also, to Sainte-Claire Deville an actualistic *method* leads to a decidedly non-uniformitarian system.

The variability of effects goes so far, in his opinion, that there are phenomena that do not come back: mineral waters in the past deposited substances which are not (or almost not) formed in more recent deposits; the atmosphere has lost the substances that are harmful to the development of living beings[67/68]. The chemical

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[59] Deville, o.c., p. 251.
[60] Deville, o.c., pp. 578, 208.
[61] Deville, o.c., p. 252.
[62] Deville, o.c., pp. 218–219.
[63] Deville, o.c., p. 218.
[64] Deville, o.c., p. 218.
[65] Deville, o.c., p. 250.
[66] Deville, o.c., pp. 379–380.
[67/68] Deville, o.c., p. 269. Élie de Beaumont had already made a similar remark on the more recent rocks, when saying that these are less harmful to the growth of plants and animals: "Cette marche graduée, suivant une

conditions of volcanic emanations have totally changed; modern lavas have no equivalent in the granite epoch [69].

A whole chapter [70] of Deville's book is devoted to an answer to the problem of "variation of the intensity of geological phenomena". In the Carboniferous period there has been in the atmosphere an enormous production and consumption of carbon-bearing gases, which finds no analogon in the recent period [71]; in some ancient periods the glaciers were larger than the present ones [72]; the causes remained, but their effects diminished.

Moreover, Sainte-Claire Deville, repeating an old catastrophist argument [73], is of opinion that we should emphasize over against Lyell, that a weak force would not always be able to perform in much time what a greater force can do in a short time. Consequently, "the explanations of gigantic phenomena by means of relatively microscopic forces that are still active before our eyes" crumble down [74]. And then Deville assumes exactly the same methodological position as Conybeare had taken 45 years earlier: "instead of torturing the facts in order to make them fit in with those preconceived ideas" (scil. of Lyellian uniformitarianism!), it would be better to "follow the really scientific way and to find out which are the phenomena of different order . . . and which are the variations their effects seem to have undergone, from ancient times of the earth up till the present time" [75].

Like Cuvier and Élie de Beaumont before him, Sainte-Claire Deville divides the *effects* of geological causes into two categories: *slow and continuous effects* (sedimentation, gradual elevation of continents), and *sudden and violent effects* (upheaval of mountains) [76]. He thinks that the slow and continuous causes have a tendency to lose intensity and that their effects, therefore, are becoming smaller: organic sedimentation is now practically restricted to tropical

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progression décroissante, des phénomènes chimiques, est une des merveilles de la nature . . . Le globe terrestre était destiné aux êtres organisés qui ont peuplé sa surface, et l'ordonnance général des phénomènes inorganiques dont il a été succesivement le théâtre, était étroitement liée au plan général de la nature organique . . . les corps simples, qui, par leur nature, auraient pu exercer une action délétère sur les êtres organisés, ou qui devaient rester étrangers à leur composition, ont été retirés, en grande partie, de la circulation dès les premiers âges du monde". Élie de Beaumont, Bull. Soc. géol. 2, IV, p. 1331.

[69] Deville, o.c., pp. 256–257.

[70] Deville, o.c., pp. 241 ff.: Neuvième leçon: Y-a-t'-il eu variation dans l'intensité des phénomènes géologiques?

[71] Deville, o.c., p. 253.

[72] Deville, o.c., p. 254.

[73] See below § VI*b* on Greenough, Cuvier and Conybeare.

[74] Deville, o.c., p. 259.

[75] Deville, o.c., p. 260.

[76] Deville, o.c., p. 264.

regions; the gradual movements of the continents took place on a much larger scale when the solidified crust was thinner; volcanic eruptions and earthquakes are less energetic and less frequent today than in the past [77].

But, if, "attributing a greater importance to actuality in geology", one goes back to the great phenomena of elevation of mountains, one recognizes that the mountain chains that arose most recently, stand out in highest relief [78]. The more the thickness of the crust grew, the greater became the force necessary for breaking it. Consequently, the phenomena of dislocation have acquired a greater violence and the periods that separate them have grown longer [79]. That is to say, that there is a tendency of divergence between the ordinary geological phenomena and the cataclysms [80].

In our classification of geological methods, Sainte-Claire Deville's catastrophism, which admits nothing but *actual* causes, (causes which still are in operation), would be a kind of actualism. Sainte-Claire Deville himself, however, kept to the general use of terms. When speaking of the "actualistic method [81], or „the theory of actual causes" [82], he meant Lyell's strict uniformitarianism which he energetically combated.

VI. The methodological difference between catastrophists and uniformitarians.

a. *Physical causes. W. Conybeare*

We have distinguished non-actualistic from actualistic catastrophists, both standing in opposition to uniformitarianism. There is no hard and fast dividing-line between these two categories of catastrophists. The choice will depend on what kind of causes one takes into consideration: the more elementary causes, or the more complicated ones that are themselves the effects of the primary causes. It depends also on the willingness to regard difference of tempo as non-essential.

In general, both groups were actualists at least in so far as they supposed that the same *physical* causes as those prevalent today, were also behind the phenomena of the most ancient epochs and that the same physical laws describe the slow changes as well as the cataclysmic ones [83].

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77 Deville, o.c., pp. 267–270.
78 Deville, o.c., p. 268.
79 Deville, o.c., p. 269. Cf below Conybeare, l.c., p. 361.
80 Deville, o.c., p. 268.
81 Deville, o.c., pp. 253, 252.
82 Deville, o.c., p. 571.
83 This has been emphatically declared by catastrophists of the English school: Conybeare, Sedgwick, and Buckland.

Perhaps, one may even say that secondary, „geological", causes too were to a large extent considered to have been always essentially the same. From the beginning of the controversy between uniformitarians and catastrophists there was a misconception about the catastrophist position on this issue.

In 1830, immediately after the publication of Lyell's work, William Conybeare pointed out that Lyell's frequent use of the phrases "existing causes" and "uniformity of nature" seemed to imply that the catastrophists speculate on causes of a different order from any with which we are acquainted, and even on the supposition of different laws of nature. In his opinion, however, "both parties equally ascribe geological effects to known causes, viz to the action of water, and of volcanic power" [84].

After this actualistic statement, however, Conybeare immediately added that the catastrophists maintain that much which has resulted from aqueous action, e.g. the excavation of many valleys, "indicates the violent action of mighty diluvial currents" rather than effects "which do or can result from the present draining (of rain water) by the actual rivers . . . to which Mr. Lyell looks exclusively" [85].

That is to say, Conybeare referred to geological causes which are *not* actually working now ("diluvial currents"), though he maintained that it is the power of water (an *actual* cause) which was then and now in operation.

Whether one would call Conybeare c.s. actualists or non-actualists, then depends on how far one is willing to go back in the series running from highly complicated combinations of causes up to simple, primary causes. With Conybeare the two most primitive steps—primary mechanical forces (of collision and gravitation of matter), manifesting themselves in the more special impact of water on rocks—, function in an actualistic way. From that point on, however, his and Lyell's ways part: one, in a non-actualistic way, refers to "combinations of forces" not occurring now (viz. "diluvial currents"), whereas the other, in an actualistic way, keeps to the still existing "slow excavation".

It depends on where one puts the accent, whether one would call Conybeare's geology actualistic or not. Dolomieu and Conybeare assumed about the same position on extraordinary catastrophes in the remote past, but Dolomieu,—thinking of the debacles—, spoke of a "different order", whereas Conybeare, referring to the

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[84] W. D. Conybeare, An examination of those Phenomena of Geology, which seem to bear most directly on theoretical Speculations. Phil. Mag. 8 (1830), p. 360.

[85] Conybeare, l.c., p. 360.

activity of water and heat in general, could maintain that the "same order" is still reigning.

b. *Multiplication of small effects*

The argument in favour of the non-actualistic aspect of the catastrophist explanation, is that a cause not powerful enough to have a certain effect (e.g. imparting of movement to a boulder) in a short time, is neither able to do so in a long time. Dolomieu did not observe even a small beginning in the present of some effects of the past and, therefore, he supposed a different order of events (greater intensity of operations) for the most ancient periods. *G. B. Greenough* (1819) attacked the plutonists because they think that slow action during a long time may perform the same thing as violent action during a short time: "What profit can a man expect from putting zeros out to interest?", he asked. "If seas and rivers do not tend to produce within the period of human experience, any such effect as that which we are endeavouring to account for (scil. mountain formation), they will evidently produce no such effect in a million of years" [86].

In the same way Cuvier, when speaking of species transformation, pointed out that what is produced on this issue in a *short* time, – to wit *nothing*—, yields *nothing* in a long period [87]. Even Hutton recognized the legitimacy of such a reasoning, when saying that *no* change, when multiplied, remains no change. He added, however, that a *small* change then becomes a large one! [88].

The question is: where is the „*nothing*" that cannot be multiplied? The most basic causes (gravitation, e.g.) are active always and everywhere, but certain combinations of them are less general the further one goes in the series running from general and simple component causes to their complicated combinations. These latter do not occur in all times and places. Consequently, being absent, they cannot be "multiplied". But if we emphasize that finally *all* phenomena have as their *primary* causes such fundamental and immutable ones as gravitation, collision, etc., the controversy between uniformitarians and catastrophists becomes meaningless, as *all* geologists would admit the immutability of physical laws as a working hypothesis.

Dolomieu stressed that certain causes and effects (violent outbursts of geological activity) do not occur now and, consequently,

[86] G. B. Greenough, A critical Examination of the First Principles of Geology. London 1819, pp. 148–149. Greenough resorts to one universal deluge, whereas earlier geologists (Pallas, James Hall) had invented a plurality of partial debacles.

[87] Cuvier, o.c., p. 63. Cf The Principle of Uniformity, p. 71.

[88] R. Hooykaas, The Principle of Uniformity, pp. 94–95.

he could consider himself a non-actualist. Conybeare, on the other hand, looking to more general causes (water, heat), which are still active now, could maintain that he was true to the actualsitic method. Nevertheless, their methodological positions do not essentially differ.

Secondly, when the present causes are not deemed sufficient to explain ancient phenomena, one may try to find "ancient" causes of a different kind. But this difference is in general reduced to a simple difference in activity for causes still in operation today. *Identity* may be abandoned, but *analogy* remains. The catastrophists were willing enough to accept as much uniformity in nature as seemed warranted by observation, and to go as far as possible with the actualistic method, but they were of opinion that hard facts forced them to abandon, at a certain level, the uniformity of energy of causes or tempo of actions. It was because he judged it impossible to reconcile his *observations* with the uniformitarian hypothesis that Dolomieu resorted to ancient violent actions: "Getting persuaded that the cause of all he sees does not belong to the actual order of events, the naturalist will be authorized to seek it in a different order" [89]. He declared to be willing to give up his own theory as soon as it would be contradicted by reliable observations, but he was unwilling to stick to the methodological necessity of explaining past phenomena by what is actually going on [90].

Conybeare too emphasized that "the only question appears to be whether we prefer embracing an adequate or an inadequate cause" [91]. He tried to demonstrate that violent currents *must* have swept over our continents at several periods, and to him there can be "nothing unphilosophical in supposing that volcanic agency might have been capable of acting with greater energy" at the beginning of the formation of the crust of the earth, "than

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[89] ". . . car, lorsqu'il (le naturaliste) sera persuadé que la cause de tout ce qu'il voit n'est point dans l'ordre actuel des événemens, il sera autorisé à la chercher dans un ordre différent". Dolomieu, Mémoire, etc., p. 403.

[90] "Mais comme les faits valent mieux que les systêmes les plus séduisans, je renoncerai au mien aussitôt que quelques observations bien faites y seront directement contradictoires". Dolomieu, Mémoire, p. 407.

In his letter to de Saussure, after having rejected the prejudice against ancient causes, he continues: "Je crois que pour ceux qui savent se défendre d'anciens préjugés, il ne doit rester aucun doute à cet égard. Autant donc que je crois devoir insister sur cette première partie de mes opinions, autant je tiens peu à l'hypothèse à laquelle j'ai dû recourir pour expliquer des faits en apparence contradictoires et qui sont certainement hors du cours ordinaire de la nature . . . Si un système plus vraisemblable m'est présenté, je l'adopterai volontiers . . .". Dolomieu à Saussure, Lacroix, o.c., p. 41.

[91] Conybeare, o.c., p. 361.

at present, when the whole weight and resistance of the actual crust opposes it" [92].

The present, then, to him turns out not to be a mere repetition of the past. Even Hutton's supporter, *James Hall*, though maintaining the cyclical, a-historical conception of the uniformitarian theory, felt himself urged by observation of the geological situation, to introduce periods of violence and revolution [93].

c. *Sedgwick on method*

On the 18th of February 1831 the Rev. Professor Adam Sedgwick retired from the President's chair of the Geological Society of London with an address animated by the same spirit as Rev. W. Conybeare's article.

Sedgwick emphasized that "geology is a science of observations" [94], and his main objection against Hutton and Lyell is that they put forward arbitrary dogmas (the repetition of similar cycles) and *a priori* principles, already enounced on the title page of Lyell's book, which says that it is "an attempt to explain the former changes of the earth's surface, by reference to causes now in operation". Nevertheless, Sedgwick himself put forward also an a priori principle, viz. the constancy of the primary laws of physics (law of gravitation, laws of atomic affinity) [95]. This a priori belief, however he gave a more legitimate status when affirming at the same time that it is an empirically established fact [96].

The fundamental primary processes, then, are combined in "results of indefinite complexity . . . which are removed far out of the reach of any rigid calculation". Volcanic forces, e.g., are the "irregular secondary results" of masses of matter obeying the primary laws of atomic action; in their turn they act as secondary, "geological" causes [97]. It seems to Sedgwick a "merely gratuitous hypothesis . . . unsupported by the direct evidence of fact", that they have acted at all times and in each period with equal intensity.

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[92] Conybeare, l.c., p. 361.

[93] R. Hooykaas, The Principle of Uniformity, pp. 20–23.

[94] Rev. Prof. Sedgwick, Address to the Geological Society, delivered on the evening of the 18th of February 1831. Phil. Mag. 9 (1831), pp. 281–317; p. 298.

[95] "I believe that the law of gravitation, the laws of atomic affinity, and, in a word, all the primary modes of material action, are as immutable as the attributes of that Being from whose will they derive their only energy". Sedgwick, o.c., p. 301.

[96] "We show by the help of records, not to be misinterpreted, that during this vast lapse of time, in the very contemplation of which our minds become bewildered, the law of gravitation underwent no change, and the powers of atomic combination were still performing their office". Sedgwick, o.c., p. 300.

[97] Sedgwick, o.c., p. 301.

Such a theory confounds the immutable primary laws of nature with the mutable results arising from their irregular combination, and it assumes that no elements have ever been brought together, which we ourselves have not seen combined [98]. In Sedgwick's opinion this is the prejudice of limiting the possibilities of nature by our own daily experience or by our own understanding [99].

Evidently referring to Lyell's parallel of the repetition of astronomical constellations and geological cycles, Sedgwick denied that the great phenomena of geology, "where the combinations are mutable and indefinite", where we have "no vestige of returning periods", and where the fixed elements of force are imperfectly known, could be compared with celestial movements which return in themselves and can be calculated. As in morals, so in physics, "the continued action of immutable (primary!) causes may and does coexist with mutable phenomena" [100]. Thus Sedgwick clearly pointed out the historical, non-repeatable aspect of geological events, which become the more historical the more complicated they are.

The limits of geological changes, so he went on, "may be studied in the records, but cannot be fixed by any a priori reasoning, based upon hypothetical analogies" [101]. This refers to the *kind* of geological causes, but Sedgwick protested also against their *energy* being submitted to apriori limitations [102]. If Lyell's principles be true, "there can be no great violation of continuity" [103], and this is again an unwarrantable prejudice.

Sedgwick wanted first of all to register facts and to build up his theory aposteriori: "We must banish all *a priori* reasoning from the threshold of our argument"; theory should only appear "as the simple enunciation of those general facts, with which, by observation alone, we have at length become acquainted" [104]. In his opinion, Lyell's "Principles of Geology" violates this proposition; the great objection against this book is that it *starts* from a hypothetical assumption and then interprets the phenomena in accordance with it: "from the very title page of his work, Mr. Lyell seems to stand forward as the defender of a theory" [105]. In this way he "vitiates all the great results of our observations", excluding beforehand a general cooling down of the earth, alternate periods of violence

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98 Sedgwick, o.c., p. 301.
99 Sedgwick, o.c., p. 302.
100 Sedgwick, o.c., p. 302.
101 Sedgwick, o.c., p. 303.
102 Sedgwick, o.c., p. 303.
103 Sedgwick, o.c., p. 306.
104 Sedgwick, o.c., p. 303.
105 Sedgwick, o.c., p. 303.

and tranquillity, difference of mineral genesis in subsequent epochs, origin of new animal and vegetable types, and admitting only those interpretations in which "operations now going on, are not only the type, but the measure of intensity of the physical powers acting on the earth at all anterior periods" [106]. Thus Lyell in the general statement of his results has sometimes been warped by his hypothesis: instead of describing the history of nature, he has been defending his hypothesis; "in the language of an advocate, he sometimes forgets the character of an historian" [107].

Now Sedgwick, speaking for all catastrophists (Conybeare and Buckland included) [108], fully recognized that we have to apply an *actualistic method* of interpretation of geological phenomena in that we assume that the fundamental laws of physics did never change, and in that the present yields as it were the coordinates for the description and interpretation of the past:

"For we all allow, that the primary laws of nature are immutable — and that we can only judge of effects which are past, by the effects we behold in progress" [109].

But we cannot say *apriori* in how far the secondary combinations are the same in different periods:

"But to assume that the secondary combinations arising out of the primary laws of matter, have been the same in all periods of the earth, is ... an unwarrantable hypothesis with no *a priori* probability, and only to be maintained by an appeal to geological phenomena" [110].

Lyell's error, then, is in his opinion, that he did not decide *aposteriori*, from the phenomena themselves, which secondary combinations, and to what extent, were active in the past, but that he decided beforehand that *all* secondary combinations of the present were the same as those of the past and were working with the same intensity then. That is, Lyell's extremely actualistic *method* (putting forward the uniformity of kind and energy of secondary causes as a methodological principle) inevitably led to a *system* that was uniformitarian too, a system in which "all we now see around us is only the last link in the chain of phenomena arising out of a uniform causation, of which we can trace no beginn-

106 Sedgwick, o.c., p. 304.
107 Sedgwick, o.c., p. 303.
108 Rev. W. Buckland, Geology and Mineralogy considered with reference to Natural Theology, vol. I. London 1836, p. 11: "Geology has already proved by physical evidence, ... that the ultimate atoms of the material elements, through whatever changes they may have passed, are, and ever have been, governed by laws, as regular and uniform, as those which hold the planets in their course".
109 Sedgwick, o.c., p. 305.
110 Sedgwick, o.c., p. 305.

ing and of which we see no prospect of an end" [111]. If Lyell's principles be true, the earth's surface ought to present "an indefinite succession of similar phenomena". Sedgwick, however, would enounce the inverse proposition and affirm that the earth's surface "presents a definite succession of dissimilar phenomena" [112]. As we know nothing of the secondary causes but by the *effects* they have produced, "the undeviating uniformity of secondary causes" [113] and other Lyellian phrases of like kind, only enunciate the proposition of a hypothesis, but do not "describe the true order of nature". We may, as Lyell does. *imagine* indefinite cycles and the indefinite succession of phenomena, but these things "do not belong to inductive geology", and "all I now contend for is, that in the well-established facts brought to light by our investigations, there is no such thing as an indefinite succession of phenomena" [114].

What, then, are those facts established by "inductive geology"?

d. *Sedgwick on the geological system*

Over against "one of the arbitrary dogmas of the Huttonian theory", viz. the doctrine of geological cycles, Sedgwick puts that there are indications of a primeval fluidity of the earth before the commencement of the typically geological phenomena, and of a great diminution of temperature before the earth was fitted for the habitation of organized beings [115]. Though the records show the constancy of the primary physical laws [116], the "evidence of fact" points out the non-uniformity of e.g. volcanic forces. Moreover, "inductive geology" demonstrates that there is no indefinite repetition of the same events: "in the well-established facts brought to light by our investigations, there is no such thing as an indefinite succession of phenomena". Between successive formations there is a mineralogical distinction as well as one of animal and vegetable forms, many types of which are now not living any more [117].

In particular the paleontological record shows, according to Sedgwick, "a series of proofs the most emphatic and convincing—, that the existing order of nature is not the last of an uninterrupted succession of mere physical events derived from laws now in daily operation: but, on the contrary, that the approach to the present system of things has been gradual, and that there has been a progressive development of organic structure subservient to the

111 Sedgwick, o.c., p. 304.
112 Sedgwick, o.c., p. 305.
113 Cf. Lyell, Principles of Geology, vol. I, sec. ed., p. 86.
114 Sedgwick, o.c., p. 305.
115 Sedgwick, o.c., p. 299.
116 Sedgwick, o.c., p. 300.
117 Sedgwick, o.c., p. 305.

purposes of life". The recent appearance of man is "by itself absolutely subversive of the first principles of the Huttonian hypothesis" [118].

Not only equality of the average situation of the earth's surface, but also continuity of local change belonged to Lyell's system: "In the speculations I am combating, all great epochs of elevation are, and I think unfortunately, excluded", says Sedgwick [119]. Over against this exclusion apriori, he puts that structure and position of successive formations prove that there have been "enormous violations of geological continuity", produced by forces adequate to these effects [120]. Small wonder, then, that Sedgwick welcomes Élie de Beaumont's catastrophist theories as "little short of physical demonstration". He shares Beaumont's idea that "comparatively short periods of violence and revolution", during which the continuity was broken and elevation took place, were followed by changes in many of the forms of organic life, whereas they were separated by long periods of "comparative repose" [121].

It should be stressed that Sedgwick did not believe that catastrophes made the assumption of a very long geological time unnecessary: "in the phenomena of geology we are carried back . . . into times unlimited by any narrow measures of our own, and we exhibit and arrange the monuments of former revolutions, requiring for their accomplishment perhaps all the secular periods of astronomy" [122].

Sedgwick did not vote for Élie de Beaumont and against Lyell, in order to reduce geological time, but because the former's theory was in his opinion more conformable to geological data and sounder in its methodological basis: "because his conclusions are not based upon any *a priori* reasoning, but on the evidence of facts; and also, because, in part, they are in accordance with my own observations" [123]. With Élie de Beaumont, Sedgwick shared the conviction that facts demonstrate that not in all periods all geological events were of the same kind and intensity.

e. *Conybeare on method*

The question at issue between Uniformitarians and Catastrophists was only in the second place one of geological *systems* (uniformity

[118] Sedgwick, o.c., p. 306.
[119] Sedgwick, o.c., p. 307.
[120] The Scandinavian boulders found, even in Holland, can be explained, according to Sedgwick, as one of the effects of a period of intensive volcanic violence, (sudden elevation of the Scandinavian chain, enormous rush of retiring waters transporting these boulders), i.e. by a cause commensurate to the effects observed. Sedgwick, o.c., p. 306.
[121] Sedgwick, o.c., pp. 308–311.
[122] Sedgwick, o.c., p. 299.
[123] Sedgwick, o.c., p. 311.

and slow change, over against catastrophes); fundamentally it was one of difference of *method*: shall we start from the assumption that the geological causes at work in the past were precisely the same in kind and energy as those now in operation, or shall we try to make an unbiassed investigation of the relics of the past (under the supposition that the laws of physics have not changed), in order to find out in how far the secondary combinations of the physical causes (i.e. the so-called "geological causes,,) that are at work now, are sufficient to explain the phenomena of the past? As Conybeare put it:

"We may commence with the effects actually resulting from the causes still in operation and acting within their present power, and thus taking our departure from circumstances with which we are familiarly acquainted, we may proceed to the consideration of the geological changes produced at former periods".

This, according to Conybeare, is Lyell's method. But, alternatively we may choose the other method, that is:

"we survey the geological phenomena, in what may be called a chronological order . . . finally, comparing the whole together, with the view of observing whether they all indicate a uniform and constant operation of the same causes, *acting with the same intensity*, and *under the same circumstances*; or rather evince that there has been a gradual change in these respects, and that the successive periods have often given rise to such new circumstances as must have in a very great degree modified the original forces" [124].

The second method appears to him "more strictly philosophical", and he rejects the imputation that it implies that he and other catastrophists resort to unknown causes. One might add, that it is "more philosophical" from the methodological point of view, in that it does not exclude beforehand that the result might be a *uniformitarian* system.

Lyell, on the other hand, though recognizing that he had a *bias* towards uniformity, was of the opinion that the system *based* upon this assumption was "more philosophical" than a catastrophist one [125].

But his opponent William Whewell deemed it equally presumptuous to call in *time* to protect us from *force*, as to do the reverse; both are to him "superstitions": "the effects must themselves teach us the nature and intensity of the causes which have operated" [126].

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[124] Conybeare, l.c., p. 360.

[125] Lyell to Whewell, 7-3-1837. In: Lyell's Life and Letters, vol. II, London 1881, p. 7.

[126] W. Whewell, History of the Inductive Sciences, 3d ed., London 1857, vol. III, p. 513. For Whewell's penetrating criticism of Lyell, cf. R. Hooykaas, The Principle of Uniformity, pp. 42–47.

This criticism of Lyell's method by his contemporaries underlines that what should be only a methodological principle of research, anticipated in fact part of a concrete theory (viz. the tenet of *strict uniformity*), which should at best have been a *result* of the method. The principle of actualism should be an empty form; Lyell's "principle of uniformity", however, possessed already concrete contents, i.e. it was also a working hypothesis. A methodological principle, may have a cogent (and at the same time, indefinite) character within a science, while a working hypothesis has only a tentative one. In its legitimate use, it should not force the results into conformity with itself. On precisely this point (that of giving the authority of a methodological principle to what legitimately should be but a working hypothesis), the arguments of Lyell's opponents were, more or less explicitly, concentrated.

It should be recognized, then, that the *method* of the catastrophists was a scientifically legitimate one. They emphasized that Uniformity, however "logical" and economical it may be, should not be maintained a priori, but that field research should be the basis of geological science. The method of explaining things in the simplest manner imaginable (uniformity!), should be subservient to, and not overrule the duty of "following Nature to whatever abysses it may lead you".

The method of the Catastrophists may be sound, quite apart from the question whether *their* method or that of the Uniformitarians led to the better geological theoretical *system*. Their merit remains that they refused to let their results be determined beforehand by the dogma of uniformity of the system of the earth, or that of uniformity of tempo and mode in geological change.

VII. Non-catastrophist actualism (ad 3 *a*)

It was, however, *not essential* for the catastrophists' conception of the actualistic method, that the resulting theory would be "catastrophism". It might as well be that geological investigation on this same methodological basis would lead other people to a non-catastrophist theory of slow changes of the surface of the earth as well as the organic world. Even a complete uniformity in the Lyellian sense should not be excluded a priori.

The theory of gradual decrease of temperature of the earth was not necessarily connected with catastrophism (Cf. Buffon, von Hoff, Poulett Scrope, Prévost) [127]. In its non-catastrophist version

[127] On von Hoff and Scrope, cf. R. Hooykaas, The Principle of Uniformity, pp. 4–12. About the non-catastrophist progressionism of Constant Prévost (1787–1856) in 1825, see R. Hooykaas, Geological Uniformitarianism and Evolution, Arch. intern. hist. sc. **19** (1966), pp. 12–17.

it was held that there is a rather slow and continuous change of character of mineral formation and surface building, and that gradually and slowly new types of plants and animals have developed.

a. *B. Cotta*

The Freiberg professor Bernhard Cotta recognized valuable elements in Élie de Beaumont's elevation theory as well as in Lyell's uniformitarianism [128], but he deemed both standpoints onesided and wanted to unite them in a medium way [129]. Élie de Beaumont's theory was in his eyes an "artificial system", whereas against Lyell's tenet of the always uniform transformation of the earth's crust, he adduced the arguments that in ancient times volcanic action bore a different character and also that the most ancient eruptive rocks have not the same composition as the more recent ones [130]. Lyell assumes, "in contradiction to experience", that organic life did not develop by degrees, but was complete from the beginning. He was right in contending that the forces and laws of nature have always been the same, but it should be added that their effects are different in subsequent eras; they continually change with their objects; there is a "developmental history" (Entwicklungsgeschichte) of the earth and not only a sequence of changes of always the same energy [131].

As Cotta believed that the original state of the earth was that of a hot fluid mass which gradually cooled down [132], and that the original atmosphere contained much more carbonic acid than the present one, he had to hold also that the organic world underwent essential changes in the course of time [133]. In a mysterious way

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[128] B. Cotta, Der innere Bau der Gebirge. Freiburg 1851, p. 16; B. Cotta, Grundriss der Geognosie und Geologie (zweite Auflage der "Anleitung zum Studium der Geognosie und Geologie, 1842) Dresden, Leipzig 1846, p. 375.

[129] Cotta, Der innere Bau, etc., p. 16.

[130] Cotta, Grundriss der Geognosie und Geologie, pp. 378, 387, 376; Der innere Bau, etc., p. 60.

[131] Cotta, Grundriss der Geognosie und Geologie, p. 376: "Gern wollen wir ihm zugeben, dass die Naturkräfte und Gesetze von Anfang an dieselben waren, und es dankbar anerkennen, dass er diese Idee lebhaft angeregt hat; aber die Wirkungen dieser Gesetze und Kräfte haben offenbar den gegenwärtigen Zustand, der kein ursprünglicher sein kann, erst aus einem früheren herausgebildet und sind sich folglich nicht durch alle Zeiten gleich geblieben, sondern haben sich mit ihren Objecten fortwährend verändert. Diese Hauptidee ist es, welche unserem Systeme zu Grunde liegt. Ich behaupte, dass man eine Entwicklungsgeschichte des Erdkörpers nachweisen kann, und nicht blos beständige Umänderungen von sich stets gleichbleibender Energie".

[132] Cotta, Grundriss, p. 385.

[133] ". . . es entstanden Organismen, angemessen jener hohen Temperatur, jener dichten Atmosphäre, welche beide auf der Erde damals noch alle klimatischen Unterschiede unbemerkbar machten". Grundriss, p. 391.

higher organisms arose, as is evident from the paleontological record [134].

In Cotta's system, then, there is, mainly attributed to the cooling down [135], an irreversible historical development (Entwicklung) of the earth (ancient eruptive rocks different from more recent ones; before the condensation of water, erosion was different; the rise of organic beings went together with decrease of carbonic dioxide in the atmosphere, etc.).

Cotta clearly saw that the results of geological change in their turn act as causes, so that a real change of the earth's crust leads to an accumulation of results, which inevitably introduces different and more complicated causes of further change, even when the degree or energy of geological activity would remain the same [136].

The basis of his geological theory he put forward (1850, 1858) as the "law of gradual development by summation of particular operations": "The multiplicity of the phenomenal forms is a necessary consequence of the summation of the results of all particular events" [137]. This law is, in his opinion, no hypothesis, but a logical necessity [138].

With the cooling down of the earth, then, goes together a growing diversity (at first only gaseous, afterwards also liquid, and finally solid bodies). In the earth's crust there has been an increase of

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134 "Es muss nothwendig auffallen, dass in diesen ersten Gebilden Reste von auf der Stufenleiter der Organisation ziemlich tief stehenden Geschöpfen gefunden werden, während in späteren Zeiten nach und nach immer höhere auftreten . . .". Grundriss, p. 392.

135 Cotta, Grundriss, p. 388.

136 "Hier erlaube ich mir nur eine ganz allgemeine Bemerkung gegen das Extreme dieser Ansicht. Vorausgesetzt, es sei wirklich nicht nur das Wesen, sondern auch der Grad (die Energie) aller geologischen Vorgänge von je her derselbe gewesen wie jetzt, so würde dennoch ihr Erfolg, ihr Resultat sich nothwendig beständig geändert haben, immer complicirter, mannichfaltiger geworden sein, da eine stete Summirung dieser Resultate stattfindet und nothwendig stattfinden muss, eine Summirung der Resultate, deren jedes auf das nachfolgende einwirkt. Alle Veränderungen der Erdoberfläche sind von dauernden Folgen begleitet, diese aber summiren sich, und jede frühere wirkt auf die spätere ein, macht dieselbe weniger einfach. Zu irgend einer Zeit müsste doch ganz gewiss ein erstes Gebirge erhoben worden sein. Dieses wurde durch keinerlei schon gegebene Unregelmässigkeiten seiner Art modificirt, sobald aber nachher ein zweites in der Nähe des ersten, wenn auch nur durch genau dieselben Kräfte, entstand, musste dessen Bau unbedingt durch das schon vorhandene erste beeinflusst werden . . . Das gilt aber keineswegs bloss für Gebirgsbildung, sondern für alle erdgeschichtlichen Vorgänge und ganz besonders auch für die Entwicklung des organischen Lebens, in welchem immer eine Form die andere bedingt". Cotta, Der innere Bau der Gebirge, pp. 4–5.

137 B. von Cotta, Die Geologie der Gegenwart. 4 Aufl. Leipzig 1874, p. 185: "Die Mannigfaltigkeit der Erscheinungsformen ist eine nothwendige Folge der Summirung von Resultaten aller Einzelvorgänge, die nach einander eingetreten sind".

138 Cotta, o.c., p. 186.

diversity of rocks and of texture [139], though it is not yet possible to find the chronological order of the first appearance of particular rocks and though it is not yet certain whether some of them do not take rise any longer (as is the case with extinct animals) [140]. The rise of organisms is a further step also in *geological* development: new materials are absorbed from the atmosphere and deposited afterwards. Moreover, there is a series of development of organic forms themselves [141]. No alteration has been completely reversible: every change left behind some permanent trace, and thus modified the next stage [142]. Especially the growing diversity of climate had a diversifying influence on the earth's surface and on the organic world [143]. Though, generally speaking, greater multiplicity goes together with higher forms (and greater complication), this ascent is no necessary consequence [144].

Cotta made efforts to prove the exaggeration (Ueberschwenglichkeit) of Lyell's proposition that always the same transformations took place as are now in operation, and that the degree of the transformations has always been the same as it is now. Nevertheless, he was of the opinion that Lyell liberated us from a hypothetical and miraculous primitive world (Vorwelt), by explaining all past change by natural laws still at work now [145].

In general, Cotta's sympathy for Lyell seems to have been greater than that for Élie de Beaumont, and he depicted the old catastrophists as phantastic miracle-mongers [146]. This demonstrates how soon Lyell's superficial and partial exposition of catastrophism was accepted, even by those who did not share his rigid views on uniformity.

b. *H. G. Bronn*

In one of his earlier works the German paleontologist H. G. Bronn made the idea of "development" the basis of his "history of nature". The "physiological" series of attraction (Attractions-Leben), affinity (Affinitäts-Leben), organic life (Organisches Leben) and mind (Vernunft-Leben) was to him also a chronological series. These subsequent degrees do not take rise suddenly, but imperceptibly and gradually: it is impossible to indicate the borderlines [147].

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139 Cotta, o.c., p. 192.
140 Cotta, o.c., p. 194.
141 Cotta, o.c., p. 199.
142 Cotta, o.c., p. 203.
143 Cotta, o.c., p. 204.
144 Cotta, o.c., p. 208.
145 Cotta, Der innere Bau, p. 5.
146 Cotta, Der innere Bau der Gebirge, p. 4.
147 H. G. Bronn, Handbuch einer Geschichte der Natur, Bd I, Stuttgart 1841, pp. 5–6.

Bronn accepted the theory of the gradually cooling down of the earth [148]. Consequently, he rejected (with reference to Conybeare's critique) Lyell's tenet of the equality of intensity of geological forces and phenomena [149]. The plutonic forces diminished as the temperature decreased [150]. The chronological geological progression consists in the growing multiplicity of rocks, the increasing tectonic complication of the earth's crust [151] and the growing diversity of climate, soil and waters, and (dependent on these) animal and plant life [152].

In a later work, Bronn held the view that there has been a development of organisms from imperfect to more perfect forms. He assumed an "independent force of production" (eine selbstständige Produktions-Kraft), an "inner necessity" (eine innere Notwendigkeit), a law of inherent progressive development of the organic world, and at the same time a (more powerful) law of progression of external circumstances, in general running parallel to the former in its effects. Organisms that could not exist (bestehen) in certain circumstances, did not take rise (entstehen): "The conditions of creation and those of preservation. . ., then, must coincide to a certain extent" [153]. But the creative force of progression from lower to higher forms is continuous, whereas the progression of the external circumstances conditioning the existence of plants and animals, is sometimes rapid and at other times slow. The inherent law of development (progressive creation) would produce a continuous ladder of nature; as a result, however, of the external circumstances, in many cases only parts of such a series are to be seen [154]. Nevertheless, as the effects of the two causes run more or less parallel, there must be a rectilinear development also of external conditions. In fact, the main influence here is (in Bronn's opinion) the slowly cooling down of the earth (and the consequent change of the atmosphere), which causes a universal change of

[148] H. G. Bronn, Handbuch einer Geschichte der Natur, I, pp. 75, 393.

[149] "Wir bestreiten hiermit Lyell's Behauptung vom Gleichbleiben der Intensität geologischer Erscheinungen, sofern sie von astronomischen Kräften bedingt werden, eben so wohl als jene, die von geologischen Kraften selbst abhängen, welches letzte auch schon Conybeare (Jahrb. 1832, 324) u. A. gethan haben". H. G. Bronn, Handbuch, I, p. 62.

[150] Bronn, Handbuch, I, p. 136.

[151] Bronn, Handbuch, I, p. 246.

[152] Bronn, Handbuch, I, p. 447.

[153] H. G. Bronn, Untersuchungen über die Entwicklungs-Gesetze der organischen Welt während der Bildungs-Zeit unserer Erd-Oberfläche. Stuttgart 1858, p. 86; (cf. p. 352): "Die Schöpfungs-Bedingungen müssen daher mit den Erhaltungs-Bedingungen, die Schöpfungs-Kraft muss mit der Erhaltungs-Kraft in *gewissem Grade* zusammenfallen oder identisch seyn, obwohl die erhaltenden Bedingungen nicht immer nothwendig auch produzirende sind".

[154] H. G. Bronn, Entwicklungsgesetze, p. 87.

population "*in one direction*" [155]. Thus the gradual change of geological conditions goes together with a gradual development towards higher forms of organic life [156].

Bronn thus, like Lamarck, introduced two main factors of development, but, in contradistinction with Lamarck, the ascending series is only a sequence of forms that are not necessarily connected by descent. Moreover, the change of external circumstances (gradual cooling of the earth; change of climate; alteration of composition of the atmosphere) [157], does not cause a change in animal forms *in response* to them. The external conditions sift out the viable forms and modify them [158].

In geology Bronn was actualistic, but not in the Lyellian uniformitarian sense: "the changes are still going on, but, as their result, the situation has become radically different "[159].

Though he did not put forward world catastrophes, but rather accentuated that there is a gradual cooling down of the earth, the effects of the latter are not wholly uniform: the rate of refrigeration and the intensity of plutonic eruptions is diminishing; some of the effects are continuous, others are periodical. In connection herewith, the changes of the animal world are, as a rule, not abrupt and not simultaneous over the whole world [160].

Bronn frankly confessed his ignorance about the way in which the rise of new species takes place. Like Lyell, he supposed that old species still continue becoming extinct, whereas cognate new ones arise [161]. But, in contradistinction to Lyell, he recognized that this goes together with a "development" towards more complicated forms.

Bronn's theory differed from catastrophism and progressionism

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155 Bronn, o.c., p. 237.
156 Bronn, o.c., p. 115.
157 Bronn, o.c., p. 114.
158 Bronn, o.c., p. 354.
159 "Alle diese Bewegungen und Veränderungen dauerten mehr und weniger lange Zeit fort und dauern noch jetzt; ihre Wirkungen häuften sich daher immer mehr, und die Folgen jeder Art werden um so beträchtlicher und augenfälliger, in je späterer Zeit man sie zu summiren versucht; die Zustände der Erdoberfläche, der Wasser, der Atmosphäre sind von den anfänglichen um so verschiedenartiger, je weiter sie in der Zeit davon entfernt sind;—und so muss es auch die Bevölkerung der Erde seyn". Bronn, Untersuchungen über die Entwicklungs-Gesetze, etc., p. 114.
160 Bronn, o.c., p. 121, p. 114. "Die fortschreitende Vervollkommnung der organischen Welt ist daher in diesem Falle bloss eine Folge der fortschreitenden Vervollkommnung der äussern Lebens-Bedingungen und insbesondere der Wohnstätten der Organismen. Und wie die physische Ursache nur *allmählich*, Stück-weise und örtlich eintritt, so müssen auch die Folgen, muss auch das Fortschreiten der Bevölkerung im Einzelnen und im Ganzen *allmählich* geschehen . . .". Bronn, o.c., p. 129.
161 Bronn, o.c., p. 227.

as put forward by the British paleontologists (Buckland, Sedgwick, etc.) in that it rejected special periods of creation of new species in which a renovation of the whole animal world would have taken place. The extinction and rise of species took place at all times, dependent on the external circumstances, gradually or suddenly, locally or everywhere [162]. He called this doctrine "the theory of progressive development or systematic evolution" [163] (Theorie der progressiven Entwicklung oder der systematischen Evolution), and he considered it a result of induction. He wrote his book (in answer to a competition arranged by the Paris Academy of Sciences in 1855) under the motto: "Natura doceri" [164].

The theory of Étienne Geoffroy St. Hilaire, (which had been propounded many years before), was also "progressionist", but decidedly catastrophist at the same time. In periods of geological catastrophe, the rapidly changing external conditions (particularly of the atmosphere) cause saltatory change in animal types. In times of gradual and slow geological change, there has also been a gradual change of animal forms [165].

In Geoffroy's case, as in that of Bronn, there is "actualism" as to the method (Geoffroy even believed that the breeding of artificial monstrosities would give the clue to natural saltatory transformation). But in neither case there was "uniformitarianism" as to the resulting theoretical system.

On the other hand, there is more *uniformity of change* in Bronn's than in Geoffroy's theory. Bronn did not connect the components of the series of species by a hypothesis of descent. Yet, his ideas about the relation of the environment with the animal forms shows some affinity with Darwin's theory of natural selection, so that it does not seem strange that he introduced the "Origin of Species" in Germany.

c. *Evolutionism* (ad. 4*b*)

After Darwin, *Evolutionism* was put forward as a third way (at least in paleontology) beside *Catastrophism* and *Uniformitarianism* [166]. Now Darwin was strongly influenced by Lyell's *geological* uniformitarianism, but the *paleontological* basis of his

[162] Bronn, o.c., p. 237.
[163] Bronn, o.c., p. 355.
[164] Bronn, o.c., p. IV.
[165] For Étienne Geoffroy St. Hilaire, cf. The Principle of Uniformity, pp. 80–88, 117–118. Also: R. Hooykaas, The parallel between the history of the earth and the history of the animal world, Arch. intern. hist. sc. **10** (1957), pp. 9–13.
[166] Lamarck's theory was founded on the "ladder" of still existing animals and not on the paleontological record. Cf., The Principle of Uniformity, pp. 73–80, 88–89; R. Hooykaas, The parallel, etc. pp. 5–9.

theory he could only find with the progressionists of the catastrophist school (Buckland, Sedgwick, Conybeare, Murchison, etc.) or with those of the more gradualistic type (Chambers, Bronn) [167]. That is to say, that, in contradistinction to progressionists of all kinds (catastrophist as well as non-catastrophist), he did not propound a parallel development of the earth and the animal world. In the organic world of Darwin's system, there is development, whereas in the inorganic world there is uniformity throughout geological time. Darwin borrowed from Lyell the idea of slow and imperceptibly small changes adding up to larger transformations in the course of very long periods; saltatory transformation of the kind advocated by Geoffroy St. Hilaire, was and is an arch-heresy to all orthodox darwinists [168].

But the uniformity in his *evolutionism* is a uniformity of *becoming* and not (as with Lyell) a uniformity of *being*. His organic world is on the move in a certain direction.

VIII. Catastrophism, uniformitarianism and metaphysics.

Again and again the accusation of introducing non-physical, supernatural, causes has been levelled against the Catastrophists. It is said that they rejected the large geological time scale of uniformitarianism because they held that the Biblical story of Creation tells against it. This is one of the arguments supporting the misconception that uniformitarianism is the only scientific position over against the unscientific attitude of the catastrophists.

As far as geology proper is concerned, this charge is unjustified: for the periods of quiet change between the catastrophes (i.e. for the formation of sediments) many catastrophists too had recourse to a long time. As a rule, when religion influenced their conceptions, this happened rather by a general conception (e.g. that of "purpose" in nature) than through the exegesis of a particular biblical text. Dolomieu (and probably Razumovsky too) was an 18th-century "philosophe", Cuvier a liberal protestant. Even so orthodox a Low Church Anglican clergyman as Adam Sedgwick, when openly disavowing in 1831 his former interpretation of "diluvial gravel", said that he agreed with Francis Bacon [169] that one should not

[167] On Darwin, cf. The Principle of Uniformity, pp. 100–107; The parallel, etc. pp. 15–16, and R. Hooykaas, Natuur en Geschiedenis, Mededelingen Kon. Ned. Ak. Wetensch. afd. Letterkunde, nw. reeks 11, nr. 9, Noord-Hollandse Uitgeversmij, Amsterdam 1966, pp. 46–50. On Robert Chambers, cf. The Principle of Uniformity, pp. 90–92, and "The parallel, etc." pp. 13–15.

[168] This becomes evident in the controversy about saltatory evolution between H. G. Schindewolf and E. Mayr. (Cf. The Principle of Uniformity), pp. 121–133.

[169] F. Bacon, "Of the Advancement of Learning", Bk II: "For to seek heaven and earth in the Word of God . . . is to seek temporary things amongst eternal: and as to seek divinity in philosophy is to seek the living amongst

seek for scientific data in the Bible [170]. His Oxford colleague, the Rev. Prof. William Buckland, in his Bridgewater Treatise (1836) abandoned the diluvial theory [171] which he had put forward in his famous "Reliquiae Diluvianae" (1823) [172].

It must be recognized, however, that in *paleontology* the embarrassing problem [173] of the creation of new faunas was either referred to some mysterious creative power God had laid into matter (Bronn, Cotta) [174], or to special divine interventions (Buckland, Miller). Especially in the latter instance there evidently was a mixing up of metaphysical and physical considerations [175].

With uniformitarians, however, no less metaphysical preconceptions and intrusions occurred. Hutton's "Theory of the Earth" (like his other works) is steeped in them, and even with Lyell they are not wholly absent. But, these two great geologists were soberminded enough not to propound an *eternal* repetition of cycles. They only declared that we *find* no vestige of a beginning and we *see* no prospect of an end in the cyclical course of events presented by the geological record.

Some uniformitarians, however, went much farther and made Uniformity into a kind of religious dogma. G. H. Toulmin (1780) dogmatically excluded the possibility of a beginning or an end of the earth. He tied uniformitarianism to the metaphysical belief in the eternity of Nature [176].

The geologist and mineralogist Otto Volger (1822–1897) wrote a book (1857) "Earth and Eternity" (Erde und Ewigkeit), the main

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the dead, so to seek philosophy in divinity is to seek the dead amongst the living".

[170] He now recognized that not all the gravel that he had formerly attributed to the Noachian deluge, could stem from one and the same, so-called Diluvial period, and that the Noachian deluge, as far as we know, did not leave any geological traces. Having been a propagator of what he now called "a philosophical heresy", he showed the courage in this Presidential Address, as he said himself, "publicly to read my recantation". Sedgwick, o.c., p. 314.

[171] W. Buckland, Geology and Mineralogy considered with reference to Natural Theology, vol. I. London 1836, p. 95.

[172] W. Buckland, Reliquiae Diluvianae; or, Observations on the Organic Remains contained in caves, fissures, and diluvial gravel, and on other geological phenomena, attesting the action of an Universal Deluge. London 1823.

[173] Embarrassing not only to the catastrophists, but also to the uniformitarian, Charles Lyell.

[174] H. G. Bronn, Untersuchungen über die Entwicklungs-Gesetze der organischen Welt (1858), p. 81; B. Cotta, Die Geologie der Gegenwart, 4 Aufl. (1874), p. 270; B. Cotta, Grundriss der Geognosie und Geologie (1846), p. 408.

[175] R. Hooykaas, The Principle of Uniformity, pp. 199–206.

[176] On Toulmin, cf. R. Hooykaas, James Hutton und die Ewigkeit der Welt. In: Gesnerus 23 (1966), pp. 55–66 (on Toulmin and Hutton). Also Arch. intern. hist. sc. 19 (1966), pp. 10–12.

thesis of which is revealed by the subtitle, "The Natural History of the Earth as a circling development, in contrast with the unnatural Geology of Revolutions and Catastrophes" [177]. He unblushingly made gratuitous statements on "Eternity": the new formations once will be perfectly similar to those we now consider "ancient"; "who could doubt, that Nature always goes through the same course, from all eternity behind us to all eternity we are going to meet" [178]. As to the organic world, "here too we look backwards into infinity; here too the prospect of eternities opens itself to us" [179]. There is no indication of a cooling down of the earth from which we might conclude that the original and the future state of the earth would be different from the present one; there is always absorbed as much heat by the earth as is lost by her: "so it is now, so it has been always, so it will be in all future" [180]. The world will "in all eternity" be in destruction and reconstruction [181], the same minerals are formed and destroyed in all periods; all species of minerals we now find did exist in former periods wherever and whenever the circumstances were favourable; they come back like planetary constellations [182].

The "primitive" mountains require, according to Volger, the existence of animals and plants: without chalk no feldspar, no granite, – without plants and animals no chalk [183]. There has been no time in which inorganic nature was without organic nature; if no traces of living beings are found, this is because they have disappeared [184]. Though species died out and other species took rise, as a whole the same set of forms stayed on [185]. All types of animals existed always, though their fossil rests may not have been found as yet [186]. There is no progressive development of species, neither in the mineral, nor in the botanical or zoological world, but an eternal cycle [187]: the same species come back when the same conditions are fulfilled [188].

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177 G. H. Otto Volger, Erde und Ewigkeit. Die natürliche Geschichte der Erde als kreisender Entwicklungsgang im Gegensatz zur naturwidrigen Geologie der Revolutionen und Katastrophen. Frankfurt a.M. 1857.

178 "Wer könnte zweifeln, dass die Natur stets den gleichen Gang gehe von aller Ewigkeit, die hinter uns liegt, bis in alle Ewigkeit der wir entgegenwalten!" Volger, o.c., p. 137.

179 Volger, o.c., p. 148.

180 Volger, o.c., p. 162.

181 Volger, o.c., p. 474.

182 Volger, o.c., pp. 497, 573.

183 Volger, o.c., pp. 521, 526.

184 Volger, o.c., p. 526.

185 Volger, o.c., p. 537.

186 Volger, o.c., p. 555.

187 Volger, o.c., pp. 559, 573.

188 Volger, o.c., p. 574.

In Toulmin's and Volger's theories, then, not only the dogmatic but also the a-historic character of Uniformitarianism has reached its extreme.

IX. The historical character of geology.

Uniformity of geological *causes* on all levels, inevitably leads to uniformity of geological *effects*. If a change has occurred, this causes a different situation which will modify the secondary combinations that act as causes of further change. But when it is a priori held that the geological situation does not essentially change, this implies that the effect of change is compensated by reverse changes in other localities, so that a permanent equilibrium would be maintained, which establishes a global uniformity of causes as well as effects.

To the fathers of uniformitarianism, Hutton and Lyell, these two aspects were inextricably woven together. Quite apart from his geological theory, Hutton was strongly preoccupied with the idea of natural cycles. With him, the principle of uniformity and the uniformitarian system are hardly distinguished from each other; uniformitarianism is a method as well as a theory ensuing from it. He does not admit any causes in the past but those that are of the same kind and degree as those that are in operation now, and at the same time he confesses to find "no vestige of a beginning and no prospect of an end" of the geological cycles. As far as we can know, according to him, the geological situation (as well as the organic world) has been always the same and will remain always the same as it is now.

With Lyell, too, the uniformitarian method and the uniformitarian system are closely knit together. Even in paleontology (before his conversion to darwinism) he assumed that species may disappear, but similar ones will replace them; no "development" is admitted.

This cyclical and a-historic conception of the past, Sedgwick rightly called "one of the arbitrary dogmas of the Huttonian theory" [189]. It was dogmatically asserted for the mineral, vegetable and animal world by all true Uniformitarians (Toulmin 1780; Hutton 1785; Lyell 1830; Volger 1857).

From the methodological point of view, we made above the distinction between non-actualistic and actualistic methods, and,—within the latter—, between actualistic-empirical and uniformitarian-dogmatical methods. As to the resulting *systems*, then, one could make a distinction between *historical* and *a-historical systems*.

An a-historic system is cyclical; its actualism consists in the

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[189] A. Sedgwick, o.c., p. 299.

events as well as in their elements. A historical system admits a sequence of unique events [190].

Catastrophism bears a *historical* character. If there would be a monotonous repetition of similar alternating periods of geological activity and tranquillity, there would be at least within such a cycle a kind of history. In general, however, catastrophists went even further: they did not put forward identical cycles. The idea of a continuously diminishing geological activity was one of their fundamental assumptions. This continuous course is interrupted now and again by outbursts of geological activity, and each of them bears its own individual character. Moreover, it is held that not all rocks have been formed at all times.

In paleontology catastrophism was almost always combined with organic progressionism, that is, with the idea that sudden geological outbursts run parallel with the rise of new (and also higher) animal types.

And even when the adherents of the gradual cooling down of the earth did not resort to catastrophes, they propounded a rectilinear development of the inorganic and the organic world, that is, a real, irreversible, *history* of the earth and the organic beings. Cotta (1842; 1846) contrasted the new geological theories, based on Lyell's supposition of continual equality of transformation and ever equal energy of forces—, the so-called "continuity theories" (Stetigkeitstheorieen)–, with the "development theories" (Entwicklungstheorieen), which start from a formerly different situation of the earth [191]. In his opinion "the essence of things is not known but when their coming-to-be is found therein" [192]. Geology, so he said, concludes from the structure of the earth's crust to the *history* of its formation [193]. As in the history of the development of organic beings a distinction is made between ancient and recent faunas and floras, there is also a series of ancient and recent mountains. These latter, too, have been "developed" (entwickelt); they show the "history of their becoming" by their structure [194].

[190] R. Hooykaas, Nature and History. In: Organon 2 (1965), pp. 5–16; R. Hooykaas, Natuur en Geschiedenis. Amsterdam 1966.

Perhaps one could say that among the historical systems, Darwinism shows strongly a-historic tendencies, whereas among the a-historic, uniformitarians, Lyell at least admitted two historical interventions in the ordinary course of nature: the rise of life and that of Man. Besides, though the "level" of the inorganic world did not change, the different epochs have in his system their individual characteristics, whereas on climate he held views that did not go far enough in the eyes of the uniformitarian diehard Rev. John Fleming (Principle of Uniformity, pp. 27–30 and 112–117).

[191] B. Cotta, Grundriss der Geognosie und Geologie (1846), p. 377.

[192] "Das Wesen der Dinge hat man erst dann erkannt, wenn man darin auch ihr Werden findet". B. Cotta, Der innere Bau der Gebirge, p. 1.

[193] B. Cotta, Der innere Bau der Gebirge, p. 1.

[194] B. Cotta, Der innere Bau der Gebirge, p. 10.

Finally, *Evolutionism*, as put forward by Charles Darwin, stressed, at least for the organic world, an upward movement from lower to higher forms. The uniformity in this system rather consists in the *rate of change* than in the resulting final effects, which form a sequence of unrepeatable unique phenomena. Thus, evolutionism may be methodologically close to uniformitarianism, but from the systematic point of view it is closer to catastrophism in that it is a *historical* system. As a system the evolution theory owes its historical aspects to the catastrophists and its uniformitarian aspects (slow changes, extremely long periods) to Lyell. The remarkable fact is, that, because of Lyell's (rather reluctant) conversion to Evolutionism, and Darwin's adherence to geological uniformity, evolutionism has wrongly been considered as necessarily connected with uniformitarianism [195].

X. Epilogue

a. *J. Prestwich's criticism*

Lyell's able advocacy, together with the triumph of Darwinism, gave to uniformitarianism, especially in Britain, "the charm of an infallible faith" [196]. On the European Continent, though catastrophism was generally abandoned, a moderate form of actualism (and, together with it, a more *historical* conception of geology) prevailed.

Yet, even Britain had its critics of Uniformitarianism. The London geological professor Joseph Prestwich (1812–1896) recognized the dogmatical character of the prevalent doctrine of uniformity, which, in his opinion, barred the advance of geology [197]. Though fully accepting the uniformity of *kind* of geological causes, he rejected the uniformity of *degree* [198]. In his opinion "Nature had

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[195] In our article on "Geological Uniformitarianism and Evolution" (Arch. intern.hist. sc. **19** (1966), pp. 3–19) we opposed this thesis.

[196] "The argument in favour of uniformity of action has been put before us with so much skill and ability, and possessing as it does the charm of an infallible faith, that Uniformitarianism has become the accepted doctrine of the dominant school of geology". J. Prestwich, Collected Papers on some controverted questions of Geology. London 1895, p. 3.

[197] Prestwich, o.c., p. 1.

[198] Prestwich, o.c., p. 5. "In contradistinction to *kind* or *law*, where we are on common ground, no common scale on the question of *degree* is possible in judging of the past by comparison with the present" (p. 6). "The doctrine of uniformity in all time . . . still remains the creed of the majority, though I believe, in many cases, this arises from confounding *degree* with *kind*" (p. 6, note 1). "We would not for a moment contend that the forces of erosion, the modes of sedimentation, and the methods of motion, are not the same in *kind* as they have ever been, but we can never admit that they have always been the same in *degree*. The physical laws are permanent, but the effects are conditional and changing, in accordance with the conditions under which the law is exhibited" (p. 14).

greater forces at her command . . . than is admitted by Uniformitarians" [199]. As the shifting positions of uniformitarians show, their measures of time and change stand on an insecure basis and "they have probably done as much to impede the exercise of free inquiry and discussion as did the catastrophic theories which formerly prevailed" [200].

But not only did they shift the measure of time, they took also the freedom of lengthening the whole time scale at will. Sometimes, the protagonists of slow change (uniformitarian or evolutionist) made a virtue of this elasticity. Cotta (at that time an evolutionist), rather naively expressed his satisfaction about that "time was the only thing about which a geologist could dispose wholly freely, whereas in every other respect he is bound to natural laws, observations and experiences" [201].

It was precisely this freedom which Prestwich would not allow to the geologists, whereas, on the other hand, he criticized in them the lack of freedom they gave to change the degree of activity.

Whereas, in Prestwich's opinion, catastrophism found its own cure in the more accurate observation of geological phenomena, uniformitarian theories "hedge us in by dogmas which forbid any interpretation of the phenomena other than that of fixed rules which are more worthy of the sixteenth than of the nineteenth century. Instead of weighing the evidence and following up the consequences that should ensue from the assumption, too many attempts have been made—not unnaturally by those who hold this faith—to adjust the evidence to the assumption" [202].

Evidently, Prestwich, who certainly was no catastrophist, repeated the *methodological* objections to Uniformitarianism put forward by the Catastrophists half a century earlier, and he even recognized that, from the methodological point of view, the latter were more sound. He stressed how unfortunate it would be for any science to have free discussion and inquiry barred by assumed postulates, and not by the ordinary rules of evidence as established by the facts, however divergent the conclusions to which those facts lead may be from the prevailing belief [203]. The fact that he wanted to apply these remarks mainly to questions connected with the more recent geological periods, is the more remarkable because

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199 Prestwich, o.c., p. 2.
200 Prestwich, o.c., p. 12.
201 "Die Zeit ist vielmehr das Einzige über welches der Geolog ganz frei zu verfügen hat, während er in jeder anderen Beziehung an Naturgesetze, Beobachtungen und Erfahrungen gebunden ist". B. v. Cotta, Die Geologie der Gegenwart, 4 Aufl., Leipzig 1874, p. 205.
202 Prestwich, o.c., p. 14.
203 Prestwich, o.c., p. 18.

even the catastrophists had always recognized the value of the uniformitarian approach for recent epochs. Prestwich hoped, that also the phenomena of these later periods would be judged "by the evidence of facts rather than by rules", so that the interpretation might "escape the dwarfing influence of Uniformitarianism" [204].

b. *Actualistic Method and Uniformitarian system*

As the matter stands now, geologists quite sensibly follow the catastrophists and other protagonists of the *historical* interpretation of nature in trying to be *as actualistic as possible*, but they do not push their actualism to the extreme of an almost absolute uniformity of causes. The principle of "uniformity", or actuality in general, serves as the methodological principle of trying to be as economic as possible with causes and notions in scientific explanation. Consequently, the conceptions of the scope and contents of the Principle of Actuality (Aktualitätsprinzip) are widely divergent: they run from strict uniformity of all geological causes (in the Lyellian sense) to such a trivial general verdict as that of the "immutability of the laws of physics".

Nevertheless, however much geologists are forced to adapt their contentions to the facts, generally speaking they all rally around the "Fetish of uniformity" [205], as adherence to it has become a token of scientific respectability. The holy names of Lyell and Darwin are connected with it, and, however widely one may deviate from its original meaning, one has to pay at least lip service to it. Catastrophism, on the other hand, remains the bugbear to the geologist.

Perhaps much confusion could be avoided if the anglosaxon term "uniformitarianism" were no longer translated by "actualism" in the continental European languages. The term "actualism" (Aktualitätsprinzip) has become automatically associated with the Lyellian system and method.

The term "uniformitarianism", however, should be restricted to theoretical *systems* like those of Hutton and Lyell, *and* to the rigid conception of the actualistic *method* as applied by those fathers of geology, that is, connected with the hypothesis of an almost perfect equality of causes at all times.

Actualism, on the other hand, covers a wide range of theories (from extreme catastrophism to uniformitarianism) that go together with the methodological principle of being as "actualistic" as the geological facts admit: a principle which finds a more rigid applica-

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[204] Prestwich, o.c., p. 18.
[205] Prestwich, o.c., p. 8.

tion in a uniformitarian system than in that of catastrophism or in the systems of other protagonists of the "historical" conception of geology: a principle, however, that never should have its contents dogmatically fixed a priori [206].

Theses

1. The battle of Catastrophism versus Uniformitarianism, though revealing itself as that of two different geological systems, is essentially a controversy on method. Catastrophism held that the interpretation ought to be adapted to geological facts; Uniformitarianism tended to interpret data in conformity with the assumption of the immutability in kind and degree of all geological causes.

2. The Principle of Uniformity in the Lyellian sense implies the theory of the *identity* of the causes operating in past and present.

A moderately actualistic method implies the actualistic principle of being as uniformitarian as possible (i.e. as the *facts allow*); it admits the *analogy* of causes in past and present. That is, in itself it is "an empty form" [206], the contents of which depend on geological research.

3. The uniformitarian method leads to *a-historic* theories; the actualistic method (as defined above in the second thesis) may lead to *historical* theories of development of the inorganic and the organic world (either catastrophist or non-catastrophist). Evolutionism owes its historical character to the development theories.

4. Catastrophist theories may be based on actualistic or on non-actualistic principles; uniformitarian theories are based on an extremely actualistic "principle of *uniformity*".

5. The statement that the contrast between Catastrophism and Uniformitarianism is fundamentally one between explanations by supernatural and natural causes—though true in some cases—greatly oversimplifies the real situation. It overlooks the basic methodological controversy and the fact that many uniformitarians used metaphysical arguments and many catastrophists did not use them at all [207].

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[206] R. Hooykaas, The Principle of Uniformity, p. 161. One could compare this, perhaps, with the principle of economy of causes (or that of the simplicity of explanation): no more different causes should be assumed than is strictly necessary for explanation (or: explanatory systems should be as simple as possible). As soon as such a principle is transformed into the thesis that Nature *is* economic and simple (and this economy and simplicity get, moreover, a concrete formulation), it has acquired an ontological, instead of a purely methodological character.

[207] The Principle of Uniformity, Part IV.