



Reviewing the term uniformitarianism in modern Earth sciences



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ARTICLE INFO

Article history:

Received 16 September 2014

Accepted 9 May 2015

Available online 22 May 2015

Keywords:

Uniformitarianism

Catastrophism

Actualism

Gradualism

Lyell

Whewell

ABSTRACT

Uniformitarianism is a classical term of the geological sciences, coined in 1832 by Whewell to indicate a specific part of Lyell's hypothesis. However, over the years uniformitarianism has been used with different meanings, finally becoming synonymous with the entire theoretical system proposed by Lyell in his *Principles*. The popularity of this term and its frequently kaleidoscopic usage in the literature may be due in large part to the apparent simplicity of the "principle" of uniformitarianism. This is often summarized by the classical adage "the present is the key to the past", a reductionist motto that has been passed through many generations of Earth scientists. In the text that follows, the major revisions of the term by Gould, Mayr and Rudwick are discussed in detail. These revisions are used as solid epistemological basis for understanding the countless "shades of meaning" attributed to the term over time, and the main reasons that led to the overgrowth of a semantic chaos; one that poorly fits a modern scientific discipline.

Apart from the "invariance of natural laws" in space and time (the basic assumptions made in all scientific disciplines), all remaining "principles" historically related to, or imbedded within uniformitarianism, have been definitively falsified. Even the "Uniformity of process", which is essentially coincident with the term "actualism", can be applied only to certain categories of products and processes (or to some particular stages in the evolution of our planet). In many cases, an extension of a current process to the past and *vice versa* is not warranted, in view of the crucial importance played by "configurational causes" during the evolution of our planet.

On the whole the analysis carried out highlights a real need to reconsider and investigate the epistemological underpinning of the Earth sciences, with one main effort aimed at solid preparation of young geologists, beginning with the basic courses of university education.

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1. Introduction

Uniformitarianism is a classical term of the geological sciences, a term that has frequently been the subject of heated debate since the time of its first appearance in literature, in 1832. Though uniformitarianism is traditionally associated with the name of one of the founders of geology (e.g. Zittel, 1901), Charles Lyell (1797–1875) and

superficially only to his "predecessor" James Hutton (actually several concepts embedded in the term 'uniformitarianism' had been pioneering developed as early as the fifteenth century by prominent naturalists such as Leonardo da Vinci and Agostino Scilla; see Romano, 2013, 2015), the word was originally coined in 1832 by William Whewell (Fig. 1), in an anonymous review of Volume 2 of Lyell's *Principles* (Marvin, 1999). Whewell identified uniformitarianism as one of the fundamental principles on which the Lyell theoretical system is based, particularly that relating to the uniformity of rates and intensities in the natural processes, rejecting the possibility that major changes in

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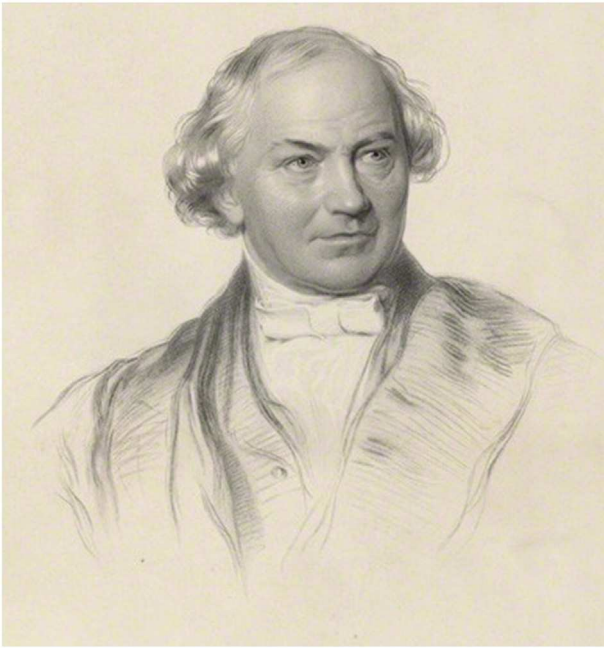


Fig. 1. William Whewell (1794–1866), by William Holl Jr, after Anthony de Solomé stipple engraving (from © National Portrait Gallery, London).

the structure of our planet have been concentrated in particular convulsive periods (the latter essentially representing the concept embraced by “catastrophism”). In discussing the work of Lyell, Whewell (1832, p. 126) posed the question: “Have the changes which lead us from one geological state to another been, on a long average, uniform in their intensity, or have they consisted of epochs of paroxysmal and catastrophic action, interspersed between periods of comparative tranquillity?” For Whewell these two viewpoints would divide Earth scientists into two opposing factions, “the Uniformitarians and the Catastrophists” (Whewell, 1832, p. 126), thus giving rise to a fundamental dichotomy destined to endure in the geological literature to this day.

Over the years, the concept of uniformitarianism has extended well beyond a dichotomy of perspectives, instead becoming equivalent to the entire theoretical system proposed by Lyell. Thus, as already stated by Camardi (1999, p. 537) “Charles Lyell is celebrated as the scientist who formulated the uniformitarian synthesis, opposed deists and catastrophists”. This led to a new and kaleidoscopic conception of the term, which is sometimes used as a synonym for uniformity of rates; sometimes as a synonym for actualism (understood in its original definition, see below), invariance in time and space of natural laws; and sometimes as a synonym for the so-called Steady-state Principle, *i.e.* the denial of any directional change in the Earth’s history.

In addition to the several meanings with which the term itself is used, there are also numerous and diverse qualifiers that may accompany the term. Examples include “behavioural uniformitarianism”, “biological uniformitarianism”, “classic uniformitarian model”, “ecological uniformitarianism”, “environmental uniformitarianism”, “evolutionary uniformitarianism”, “modern uniformitarianism”, “phylogenetic uniformitarianism”, “physical uniformitarianism”, “physiological uniformitarianism”, and “taxonomic uniformitarianism”. In many cases, the qualifiers associated with the term indicate only a single aspect of “uniformitarianism”, without considering either its original definition (Whewell, 1832), or the major revisions of the term provided in the course of time (in particular those by Gould, 1965, 1987; Rudwick, 1972; Mayr, 2011).

It follows that uniformitarianism, considered by Marriner *et al.* (2010, p. 43) as “the dominant paradigm in modern geology”, has

been affected over the years by equivocation processes, resulting in different and not always reconcilable meanings.

In the text that follows, I review the principal meanings that the term uniformitarianism has assumed, and discuss the possible reasons behind the semantic chaos that resulted. Given the extensive literature on the subject, and the brevity of this treatment, I confine my remarks to the main conceptual issues, in an effort to open this important topic for discussion and debate.

2. Principal reviews of the term uniformitarianism

To understand how the nuances of meaning for the term under study have changed through the years, it is useful to consider the major revisions of the uniformitarian concept, and the influence that such analyses have had on the common use of the term in the literature pertaining to the Earth sciences.

A significant revision of the “uniformitarian tradition” in the modern era is that made by Gould (1965). Gould views equivalence of “uniformitarianism” with the famous maxim “the present is the key to the past” as overly simplistic, and suggests a more complex, dualistic concept of the term (Table 1). The first concept, which he called “substantive uniformitarianism” assumes that natural processes operate (and have always operated) at uniform rates, producing slow, cumulative changes. The second, called “methodological uniformitarianism”, represents the *a priori* assumption that natural laws are invariant in time and space. Thus, in the analysis of the term provided by Gould, the concept of uniformitarianism is considerably broader than the original definition provided by Whewell, in that includes other (though not all) aspects of Lyell’s theoretical system (specifically, the invariance of natural laws in time and space). According to Gould (1965), substantive uniformitarianism is an anachronistic hypothesis that cannot be sustained in light of available evidence. The theory that all natural phenomena act at slow and uniform rates is in fact an *a priori* assumption that inhibits the construction of alternative hypotheses, even in the presence of clear empirical evidence to the contrary. The second concept contained within the term uniformitarianism—the methodological one—represents, according to Gould, an assumption which is not unique to geology, but is the basis of all empirical sciences. Methodological uniformitarianism, in fact, “...is a statement of proper scientific procedure in general, independent of any particular substantive theory” (Gould, 1965, p. 224). Gould concludes his analysis by stating that substantive uniformitarianism represents an outdated assumption that is contradicted (or falsified) by new empirical evidence. According to Gould, methodological uniformitarianism, as applied to geological processes *per se*, represents an obsolete usage that is too narrowly confined. In fact, the claim that the principle of methodological uniformitarianism is valid with respect to geology is equivalent to the observation that geology is a science. As Gould (1965, p. 227) states, “...we need no longer take special pains to affirm the scientific nature of our discipline”. Historically, the dichotomy identified by Gould (1965) can arguably be traced back to early debates on uniformitarianism, as highlighted by the following conclusion of Prestwich (1895, p. 28) in response to a paper by Wallace (1895): “Volcanic action, therefore, does not seem to me to be in any way in contradiction to the conception of uniformity of kind or law, and to non-uniformity on the question of degree”. Despite the clarity and mastery with which Gould (1965) used to weave his conceptual framework, the basic message of his work has been often not fully understood (in particular by non-geologists) and in some cases has been completely misrepresented.

Rudwick (1972) reanalyses the concept of uniformitarianism in Lyell (Fig. 2), identifying four distinct meanings in the *Principles*, an interpretation accepted and taken up by Gould (1987) in his famous “Time’s Arrow, Time’s Cycle: Myth and Metaphor in the Discovery of Geological Time” (Table 1). The first concept, termed “uniformity of law”, asserts the invariance in time and space of natural laws (defined as the “weak principle of uniformitarianism” in Balizshov, 1994), and therefore can be made to coincide essentially with the “methodological uniformitarianism” of Gould

Table 1

Summary sketch of “causal schemes” by Gould (1965, 1987), Rudwick (1972) and Mayr (2011). Elements in common between the different analyses are indicated with the same colour. In white, conceptual areas that have no unique correspondence between the various schemes.

Gould (1965)	(I) Substantive Uniformitarianism	Natural processes operate and have always operated at uniform rates, producing slow, cumulative changes.
	(II) Metodological Uniformitarianism	The <i>a priori</i> assumption that natural laws are invariant in time and space.
Rudwick (1972) and Gould (1987)	(I) Uniformity of law	Coincident with point (II) in Gould (1965)
	(II) Uniformity of process	The extension to the past of currently observable processes and products. Gould (1987) considers this point essentially synonymous with “actualism”
	(III) Uniformity of rate or gradualism	Essentially equivalent to point (I) in Gould (1965).
	(IV) Uniformity of state	Earth's history followed no vector of progress or change, with a general aspect and conditions always and entirely similar to that observable nowadays.
Mayr (2011)	(I) Naturalism	Subsequent to an initial creative act of God (primary cause), geological processes acted according to secondary causes (essentially a deistic conception).
	(II) Actualism	The same laws of physics have always operated as causal effects during planetary history. Thus differing from “actualism” in Gould (1967) and essentially coincident with point (II) in Gould (1965) and point (I) in Rudwick (1972) and Gould (1987).
	(III) Intensity of the causal forces	Coincident with point (I) in Gould (1965) and point (III) in Rudwick (1972) and Gould (1987).
	(IV) Configurational causes	Different configurations of the same factors at different times can lead to significantly different processes and products.
	(V) Gradualism	Coincident with point (I) in Gould (1965) and point (III) in Rudwick (1972) and Gould (1987).
	(VI) Directionalism	Comparable to point (IV) in Rudwick (1972) and Gould (1987).

(1965), a principle that is currently accepted and acclaimed by all Earth scientists (Gould, 1987).

The second is represented by the “uniformity of process”, a principle that extends the currently observable processes and products to the past. Gould (1987) considers this point essentially synonymous with “actualism” in the sense of products and processes observable today—but not in the English sense of “actual” in reference to “real”. With the latter meaning, in fact, actualism would substantially indicate invariance of natural laws, obliterating the initial shade of meaning.

The third is identified as “uniformity of rate, or gradualism”, and states that all geological phenomena and their products are the result of a slow, gradual rhythm of change that occurs through insensible variations that operate over vast expanses of geologic time (“strict uniformitarianism” in Donaldson et al., 2002). This meaning is, of course, equivalent to “substantive uniformitarianism” described by Gould (1965) and represents a point that gave birth to some of the most heated debates in Earth sciences. As already highlighted by Gould (1987), Lyell himself did not exclude the possibility of isolated catastrophic phenomena in the past (such as major earthquakes observed today). Basically, what Lyell fought was the idea that, in the past, the Earth was subject to large-scale but short-lived periods of intense, globally evident changes, with highly energetic “convulsive” episodes concentrated in relatively short periods of planetary history. It is precisely on this central point that Whewell (1832) built the initial dichotomy between uniformitarianism and catastrophism, and that encloses and crystallizes the real meaning of the term when it was conceived for the first time. In Bak and Paczuski (1996), “gradualism” is considered synonymous with uniformitarianism, though in describing the dichotomy with the catastrophist “faction” the authors are quite close to the original definition of Whewell.

Rudwick’s (1972) fourth meaning, identified as “uniformity of state,” assumes that the Earth’s history followed no vector of progress or change, with a general aspect and conditions always and entirely similar to that observable nowadays. This would imply gradual and continuous change—though this change does not lead to any particular state, nor does it follow any particular direction (see also the dichotomy between the “steady-state” model of Lyell and the strictly “historical” model of William Daniel Conybeare, highlighted in Rudwick, 1967). This dynamic

steady-state was extended by Lyell also to organic life, with the initial denial of progressive development (*i.e.* evolution), accepted belatedly only in the tenth edition of the *Principles* published in 1872. As already pointed out by Gould (1987), the fourth point can be considered a direct legacy of the cyclical conception found in the “machine of the world” analogy that characterizes the thought of James Hutton (Fig. 3). The assumption of a steady-state condition, even in the context of life (an hypothesis challenged by clear trends observable in the fossil record), was a source of criticism by Lyell’s contemporaries (see the classic cartoon of the “Professor Ichthyosaurus” drawn by Henry Thomas De la Beche as metaphorical critics of this aspect of Lyell’s system, carefully interpreted and illustrated by Rudwick, 1975; see also the letter to Lyell from Conybeare in Rudwick, 1967). According to Ospovat (1977) the steady-state, non-directional concept present in Lyell’s *Principles* may be traced to a “shocked” reaction at the reading of the “Philosophie zoologique” by Lamarck, which also placed the human species within progressionist theory (see also Bartholomew, 1976; Corsi, 1978). In this context, according to Coleman (1962, p. 329) “A major aim of the Principles of Geology was to destroy totally the theory of the successive development of organic creation”.

An even more complex subdivision of meanings contained by the term uniformitarianism is the one proposed by Ernst Mayr (2011; first edition published in 1982). In the interesting discussion about the relationship of Lyell’s system to the evolutionary ideas of Lamarck, Darwin and Agassiz, Mayr (2011) identifies six concepts or “causal schemes” into which “uniformism” can be subdivided (Table 1):

- 1) “Naturalism”, *i.e.* the persistence of natural theology in the interpretation of geological phenomena (see also Ospovat, 1977). Subsequent to an initial creative act of God (primary cause), geological processes acted according to secondary causes, without the need

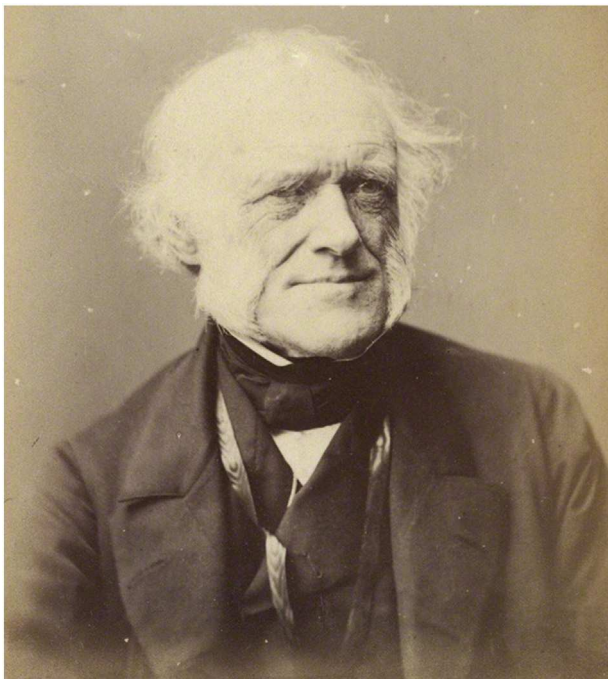


Fig. 2. Charles Lyell (1797–1875), by John & Charles Watkins albumen print (from © National Portrait Gallery, London’).



Fig. 3. James Hutton (1726–1797), by John Kay etching (from © National Portrait Gallery, London’).

- for direct intervention of God (essentially a deistic conception). This point does not find any direct equivalent in the conceptual schemes of Gould (1965, 1987) and Rudwick (1972).
- 2) "Actualism", the principle that the same laws of physics have always operated as causal effects during planetary history, since the immanent characteristics of the world have always remained the same (Mayr, 2011). In this case, actualism is deprived of its original meaning, i.e. the study of present phenomena and possible extension of these latter to the geological past, becoming synonymous with "methodological uniformitarianism" of Gould (1965) and of "uniformity of law" in Gould (1987) and Rudwick (1972). The same concept of actualism is found, among other, in Camardi (1999), Donaldson et al. (2002), and Shea (1982a).
 - 3) "Intensity of the causal forces", typical of Lyell and of "radical" uniformitarianists, which postulates the same intensity in processes and geological forces throughout time. In this case, the magnitude of geologic time would easily explain even major changes of our planet (Mayr, 2011). This point can be made to correspond essentially to the "substantive uniformitarianism" of Gould (1965) and to the "uniformity of rate, or gradualism" of Gould (1987) and Rudwick (1972), although Mayr (2011) considers it necessary to include a separate point for gradualism (point six below).
 - 4) "Configurational causes", a concept based on the premise that different configurations of the same factors at different times can lead to significantly different processes and products. The term was introduced by Simpson (1970) in reference to phenomena such as the passage from a reducing to an oxidizing atmosphere, or the effects of plate tectonics on the size of the continental masses and the role of continental shelves in the course of geological time (Mayr, 2011). This point is not reflected in the dichotomy recognized by Gould (1965); it is inherent in part to the "uniformity of state" of Gould (1987) and Rudwick (1972), although it is antithetical to the dynamic steady-state envisaged by Hutton and Lyell.
 - 5) "Gradualism", according to which the changes that occurred during Earth history have been—generally gradual in nature. This point falls basically in the "substantive uniformitarianism" category of Gould (1965) and in the "uniformity of rate, or gradualism" concept of Gould (1987) and Rudwick (1972).
 - 6) "Directionalism", or in the case of Lyell, anti-directionalism, i.e. the concept of a stationary world envisaged earlier by Hutton and summarized in the famous aphorism "no vestige of a beginning and no prospect of an end", a concept which thus denies any directionality or "evolution" in Earth history and in the processes occurring in the course of geological time (Mayr, 2011). This point, not mentioned in Gould (1965), can be made to coincide essentially with the "uniformity of state" of Gould (1987) and Rudwick (1972).

As the foregoing reviews show, uniformitarianism is a multifaceted, complex concept that cannot be simply summarized by the aphorism "the present is the key to the past", so often used in textbooks and peer-reviewed research contributions alike. Despite this complexity of the concepts underlying the term, and the impossibility of reconciling some of the nuances of meaning (see the difference between the causal schemes of Rudwick, 1972; Gould, 1987 with those proposed by Mayr, 2011), "uniformitarianism" has been often used in the literature with a partial meaning, highlighting, following or heatedly criticizing from time to time only a particular aspect of the term.

3. Modern usage of the term

The most widespread example of partial use of the meaning embodied in the term "uniformitarianism" is, without doubt, the equivalence between uniformitarianism and actualism, often regarded as perfect synonyms in the light of the motto "the present is the key to the past". Beyond the fact that this aphorism captures only a fraction of the

meanings historically associated with the term, the famous sentence can be misleading and allows for alternative interpretations. For example, the "study of the present" in modern Earth sciences (analysis of current processes and associated inferences with respect to the fossil record) provides substantial evidence that a steady-state interpretation is inapplicable to Earth history, that catastrophic events in the past have played important roles in the history of the planet and of organic life, that rates of various geological processes vary widely, and that some processes which are currently operating cannot be extended to the geological past and *vice versa*. Ultimately, all elements that convincingly falsify the "uniformitarianism" understood in the essential points discussed by Gould (1987) and Rudwick (1972). Hence, if "the present is the key to the past" is considered synonymous with actualism, which in turn is considered synonymous with uniformitarianism, then the term may be logically self-falsifying. On the other hand, if the famous phrase refers only to invariance of natural laws in time and space (a usage adopted by some authors), actualism and uniformitarianism (considered in this case synonyms) are superfluous terms, as already noted by other authors and elsewhere herein.

A second possible source of multiple meanings is the frequent use of uniformitarianism in palaeoecological studies, and even in areas of knowledge external to geology *sensu stricto* (both in scientific and humanistic fields). For example a widely-used term characterizing the palaeoenvironmental and palaeoecological literature is "taxonomic uniformitarianism". Taxonomic uniformitarianism has been used or cited in the reconstruction of past environments essentially as a synonym for actualism (in the meaning of the term embraced in the present paper), either explicitly or implicitly (Gray, 1988; Bosence and Allison, 1995; Bottjer et al., 1995; Schultze, 1995; Haunold et al., 1997; Poyato-Ariza et al., 1998; Sponheimer et al., 1999; Taylor et al., 2004; Schubert et al., 2006; Dominici et al., 2008). Although the phrase was originally coined with respect to extending presently observable characteristics (habitat preference, behaviour, physiology, and so forth) of living taxa to those of fossil forms (with resultant data then forming the basis for more synthetic palaeoenvironmental reconstructions), taxonomic uniformitarianism has been used in quite different areas—such as the study of palaeosols (Retallack, 1998)—contributing additional shades of meaning to the word uniformitarianism. In the same context, another term found in the literature is "physiological uniformitarianism" (Tiffney, 2008). As this phrase refers to invariance over time of the physiological tolerances characterizing a group of organisms under study, it can be considered more-or-less equivalent to "taxonomic uniformitarianism".

In biology, an example of the use of the term with reference to invariance of biological processes over time is given by Boyd (2001, p. 160) which states: "The interpretation of stable isotope ratios often assumes uniformitarianism, where present day biological processes are considered to be similar to those that have acted in the past...". Erwin (2011, p. 1) writes, "Evolution has been implicitly viewed as a uniformitarian process where the rates may vary but the underlying processes, including the types of variation, are essentially invariant through time. Recent studies demonstrate that this uniformitarian assumption is false, suggesting that the types of variation may vary through time". This case exemplifies the problem of applying a term rooted in the geological sciences to other disciplines such as biology. The "invariant types of variation" may fall within the "uniformity of the process" of Gould (1987) and Rudwick (1972). However, the term uniformitarianism has also been used with respect to a "steady-state" condition (which is incompatible, by definition, with evolution) and "gradualism" or "uniformity of rate, or gradualism". This last usage is completely incompatible with the passage cited from Erwin (2011), wherein both rate and process of evolution may be subject to change. Other examples of the use of the term in biology *sensu lato* (zoology, botany, anthropology, etc.) can be found in Bleiweiss (2009), Cope and Lacy (1992), and Roksandic and Armstrong (2011).

In other cases, only the “gradualist” aspect of uniformitarianism is criticized, assuming the “principle” of uniformitarianism as an *a priori* negation of catastrophic phenomena. In fact, as already noted, Lyell himself—widely regarded, in geological mythology, as a paladin of uniformitarianism (e.g., Zittel, 1901) accepted occurrence of past and present catastrophic phenomena. In such a case, the description of a single catastrophic event such as a meteorite impact or a mega-flood, does not falsify the doctrine of uniformitarianism as a whole—whether following the modern treatments of Gould (1965, 1987) and Rudwick (1972), or in the original sense of Whewell (1832). In particular, falsification of Whewell’s concept would require substantial data documenting the concentration of catastrophic “convulsive” periods that are both temporally restricted and that involve major restructuring on a global level (see Marriner et al., 2010 for a clear definition of “catastrophism”). Catastrophism, in the original definition of Whewell and in the vision supported by Adam Sedgwick (Fig. 4), contemplated a greater overall magnitude of geological forces and processes in the past. Subsequent lessening intensity, largely tied to the secular cooling of the planet, was as explanation for the major discontinuity observed in the geologic record. In addition, the original vision included a general evolution of the Earth “from a crude primitive (perhaps molten) state to its present peaceful condition” (Cannon, 1960, p. 39; see also Cannon, 1961).

As mentioned briefly above, the term uniformitarianism has also been borrowed and used in fields completely outside the Earth sciences *sensu lato* (that is, the development of life and its decisive influence on many processes and products that make up the geologic record). For example, the word uniformitarianism has been used in the field of social philosophy (in discussing whether “men and women enjoy the same status in life politically, sexually and in numerous derivative respects;” Machan, 1992, p. 77), in archaeology (Cameron, 1993), and anthropology (Bailey, 1983).



Fig. 4. Adam Sedgwick (1785–1873) by Samuel Cousins, after Thomas Phillips mezzotint (from “© National Portrait Gallery, London”).

4. What remains of uniformitarianism in the modern understanding of the Earth sciences

Keeping in mind the analyses of uniformitarianism and its multiple implications provided by Gould (1987) and Rudwick (1972) it is worthwhile considering the four principal points highlighted by these authors in the context of current knowledge in geology.

The “uniformity of law”, *i.e.*, the invariance in time and space of natural laws as an *a priori* postulate, is an assumption basic to all scientific endeavours (Gould, 1965, 1987; see also Hubbert, 1967). Despite broad acceptance of this point dating back to the time of Lyell, Shea (1982a, p. 458) considers that “the original statement about the laws of nature being constant is empty; it is a tautology”. Similarly, Goodman (1967, p. 94) asserts: “On the other hand, the thesis that some laws hold for all time is an empty truism”. However, according to Popper (2000, p. 150) natural laws are conjectures about the hidden properties of nature and have as their most important feature to be “the same throughout the world, at any place and at any time: they are omnipresent.” Virgili (2007, p. 575) notes that “The uniformity of the laws of Nature cannot be demonstrated, it is a postulate or ‘the rules of the game’, in the same way as ‘the rationality of the real world’, or the fact that our reason is adequate to understand and explain the world that surrounds us. If we do not accept this, then science is impossible and everything must be left to the whims of the gods”. In this regard, Balizshov (1994, p. 935) states: “It can reasonably be argued that the constancy of laws is an indispensable assumption of scientific method in general, since no simple generalization of experience is possible without it” (however see Balizshov, 1994, for caveats). Ultimately, at least the Earth history should fall completely within the so-called “perfect cosmological principle” (PCP, see Balizshov, 1994) which postulates large-scale uniformity of the universe in space and time. This would ensure the invariance of natural laws in the time-slice of interest, thereby providing logical basis for study of earth’s geological phenomena.

The “Uniformity of process”, considered basically synonymous with “actualism” (*sensu* Gould, 1987) or extension of the present operating processes (and products) to the geological past, requires further reflection in the light of current knowledge. Donaldson et al. (2002) have discussed the use and meaning of the term actualism in the geological literature, coming to the conclusion that all geological processes and their related products fall within the concept of actualism. For this reason, the term non-actualistic should be avoided, since it “deals with ‘parallel worlds’ that are inhabited, for instance, by unicorns” (Donaldson et al., 2002, p. 11). Following this interpretation of the term, then, actualism becomes synonymous with the invariance of natural laws (e.g., mechanics, chemistry, fluid dynamic)—which, as we have already seen, is an *a priori* assumption both common and necessary to all sciences. By equating the meaning of actualism with invariance of natural laws (at least after the Big Bang), Donaldson et al. (2002) logically exclude the possibility of non-actualistic processes or products, and claim “We further contend that actualism should be accepted as the fundamental premise of the geosciences (as well as the other natural sciences) which serves to amplify the principle of uniformitarianism” (2002, p. 11). However, if actualism as invariance of natural laws serves to amplify the principle of uniformitarianism, it logically follows that it does not coincide with uniformitarianism itself. Further, considering that all the other points (save the invariance of natural laws) of uniformitarianism are falsified by current knowledge, it is then difficult to appreciate which sort or aspect of “uniformitarianism” should be amplified.

Therefore, with the meaning just discussed, actualism is a superfluous term, equivalent to saying, for example, that intermolecular forces of attraction are operative in geological phenomena. By contrast, the terms actualistic and non-actualistic make sense in reference to individual processes and products that may or may not have analogues among processes that are currently observable (therefore not merely considering physical and chemical laws, but the changeable configurationally

causes which affect, in a contingent and often unique manner, processes and products recorded in the fossil record). Simple reflection upon planetary history before and after the appearance of life—and the determining influence of life on atmospheric composition (Kleidon, 2002), land surface characteristics, and sedimentation (to name only a few)—suggests that usage of the term “non-actualistic” is well-justified. In fact, in agreement with the well-known and widely accepted Gaia Hypothesis, life and the planet Earth are intimately connected, with complex feedback between organisms and their environments which “can shape the evolution of both” (Kirchner, 2002, p. 391). It is clear that all these processes, self-regulated by continuous feedback, are logically unthinkable before the appearance of life on our planet. In discussing the term actualism as a synonym for invariance of natural laws, Donaldson et al. (2002, p. 4) argue that the evolution of the Earth is “constrained by invariant physical, chemical and biological laws”. As we have seen, however, within the realm of biology alone it has been shown (Erwin, 2011, p. 6) that evolutionary processes are not invariant, but have changed through the history of life. The increase of biological complexity has taken place through eight major evolutionary transitions “each of which involved new ways of packaging and transmitting information between generations”. The “non-invariance” of biological “laws”, therefore, is a simple example of why the use of the terms actualistic and non-actualistic could still have meaning in modern Earth sciences *sensu lato*. The fact that, in these three eight major transitions, the laws of chemistry have been met is of no interest to the biologist or palaeontologist who studies evolution at the level of the population, species or even family. Numerous other examples that justify the use of the terms actualistic or non-actualistic—in the sense of contingent processes, products and conditions that are specific to a particular developmental stage of our planet (and therefore not extensible to the past, or *vice versa*, from past to present)—are found in all major fields of Earth sciences, including (for example) sedimentology, atmospheric studies, palaeoclimatology, and plate tectonics (e.g., Kasting, 1993; Macnaughton et al., 1997; Hamilton, 1998a, 1998b, 2010; Rasmussen and Buick, 1999; Nisbet, 2002; Stern, 2005, 2008; Dornbos, 2006; Evans, 2006; Eriksson et al., 2007).

Use of the terms actualistic and non-actualistic, following the meanings embraced in this present paper, can be found for example in Albritton (1967), Baker (2002), Bernoulli and Jenkyns (2009), Cannon (1976), Dominici and Zuschin (2005), Dornbos (2006), Hamilton (1998a, 2010), Hildebrand (2005), Lawrence (1978), Macnaughton et al. (1997), Marriner et al. (2010), Nisbet (2002), Ospovat (1977), Pflüger and Gresse (1996), Romano (2013), and Rudwick (1967, 1975). In all these examples, the terms are used as stand-alones and not as reductionist synonyms of uniformitarianism.

The “Uniformity of rate, or gradualism”, essentially the substantive uniformitarianism of Gould (1965), has been definitively falsified in Popperian terms by the overwhelming evidence that important catastrophic events have repeatedly affected the history of our planet, consistently affecting both the inorganic world and the evolutionary history of the organic one.

One of the most discussed catastrophic events is represented by a bolide impact at the K–Pg boundary, which may have played a decisive role in the mass extinction that took place about 66 Ma ago (Alvarez, 2009; Schulte et al., 2010; Pievani, 2014). Regardless of the magnitude of extinctions resulting directly from the impact (see Keller et al., 2009), most scientists agree that a giant extra-terrestrial body collided with Earth at the K–Pg boundary, and that the Chicxulub Crater on the Yucatán Peninsula of Mexico represents the impact site (Marvin, 1999). Over the years a large body of evidence has been accumulated in favour of the impact hypothesis, including the dramatic iridium peak in the clay marking the K–Pg boundary in the Scaglia Rossa Formation at Bottaccione Gorge (Gubbio, Italy; a similar Iridium spike is seen in many other units worldwide; see Alvarez, 2009); glass spherules derived from the impact melt (Smit and Klaver, 1981; Smit et al., 1992; Arenillas et al., 2006; Schulte et al., 2006), quartz grains deformed by the shock collision (Bohor et al., 1984), impact glasses from a drill core

beneath the Yucatán crater floor dated at 64.98 ± 0.05 Ma (Swisher et al., 1992), tsunami deposits and crater ejecta around the Gulf of Mexico (Marvin, 1999), Ni-rich spinels found in many K–Pg boundary deposits (Schulte et al., 2010), and the multi-ringed shape of Chicxulub crater revealed by seismic reflection (Morgan et al., 1997). At present, the impact theory best explains the coexistence of peculiar evidence in the geological record at the K–Pg boundary.

The discovery of the Chicxulub Crater and many other crater-forming impacts (Grieve and Pesonen, 1992; Marvin, 1999; Montanari and Koeberl, 2000; Haines, 2005; Keller, 2005) indicates that collisions with large extra-terrestrial bodies is an important catastrophic process in Earth history affecting our planet on multiple occasions, with different magnitudes and effects on the inorganic and organic world. According to Eriksson et al. (2007), bolide impacts and tsunamis caused by them were likely the main regulatory factors of global tractive currents in the Archean (between 4.4 and 3.7 Ga ago). These cataclysmic events thus represented the major regulatory factors of sedimentary patterns on Earth, at a time when terrestrial loess and biochemical planktonic sedimentation were absent (Eriksson et al., 2005). In conclusion, according to Marvin (1999), the unpredictable, catastrophic and multi-megaton impacts with extra-terrestrial bodies must now be considered as major geological process.

Another well documented example which falsifies “substantive uniformitarianism” (Gould, 1965) is represented by the catastrophic erosion and deposition that resulted from high-energy, mega-flooding events in the Channelled Scabland region (east-central Washington state) (Baker and Milton, 1974; Baker, 1978, 2009). The super floods were caused by the cataclysmic collapse, onto the Columbia Plateau, of Pleistocene ice dams (Bretz, 1923), giving rise to peculiar deposits and landscape including loess island, gigantic gravel bars, and a complex system of anastomosing channels (Baker, 2009). First proposed by J. Harlen Bretz in the 1920s (Baker, 1978, 2009), the hypothesis of cataclysmic mega flooding was viewed with scepticism for a long time (Orme, 2002), betraying an obvious uniformitarian (in the sense of uniformity in rates and intensity; gradualism in Rudwick, 1972; Gould, 1987) preconception that was directly inherited from the Lyellian tradition. In fact, speaking of the “intensity of aqueous forces at remote periods”, Lyell (1850, p. 151) writes “it was still supposed that denudation, or the power of running water, and the waves and current of the ocean, to strip off superior strata, and lay bare the rocks below, had formerly operated with an energy wholly unequalled in our times. These opinions were both illogical and inconsistent, because deposition and denudation are parts of the same process, and what is true of the one must be true of the other”.

In recent years, however, cataclysmic mega-flooding and its attendant deposits and landscape remodelling, have been documented in North America (Kehew and Lord, 1986), Asia (Baker et al., 1993; Rudoy and Baker, 1993; Grosswald et al., 1994; Carling et al., 2002), the English Channel (Gupta et al., 2007) and, speaking in planetary context, even on Mars, thus becoming a well-documented morphogenetic process (Baker and Milton, 1974; Baker, 2002, 2007).

“Uniformity of state” is an aspect of uniformitarianism that was rejected in part by Lyell himself in the tenth edition of the *Principles* (Rudwick, 1998), when he finally accepted the possibility of organic evolution, while at the same time continuing to advocate a steady-state view of geological processes in general (a solution that allowed him minimal retreat according to Gould, 1987). Considering what has been said above for the uniformity of processes (and hence for “actualism”), it is clear that the evolution of the Earth (in particular the development of configurational causes and then of geological processes and products) makes uniformity of state logically unacceptable in the interpretation of the geological history. In this regard, the following statement of Balizshov (1994, p. 936) is enlightening: “The whole geological scene is nothing but a local superstructure over the basic level of the physico-chemical laws. The evolution of the ‘scene’ can proceed against the unchanging background of the underlying laws”. On

the other hand, among Lyell's contemporaries, the steady-state interpretation of geological history was already one of the most challenged and least accepted aspects of uniformitarianism. As stated by Lawrence (1978, p. 116) "The results of current research in 1830 were decidedly in favour of a directional interpretation of geological history". Strangely, the uniformity of process (actualism) and the uniformity of state were not directly and explicitly linked by Gould (1987), although, as seen above, the two points are necessarily and inextricably interrelated and thus conceptually interdependent.

5. Discussion and conclusion

It may seem curious that uniformitarianism, one of the classic and most-cited principles of geology—if not "the most fundamental paradigm of modern earth science" (Kennedy, 2006, p. 8)—ranks among the most ambiguous terms of our discipline. As noted by Ghiselin (1984, p. 104), however, "equivocation" [i.e., the use of a term with two or more meanings] "... is among the commonest of logical fallacies, and it sometimes does have unfortunate consequences". In practice, then, the most often used-terms in a discipline are also those most subject to discussion and different interpretations, resulting in highly ambiguous and equivocal meanings. A classic example is the multitude of meanings attributed to the term "character" in the science of systematics. In discussing the definitions of the term "character" in use until 1985 (and thus not considering the enormous number of subsequent works treating the subject matter), Colless (1985, p. 229) opened by observing that "[to] an uninformed outsider, taxonomy must seem a most extraordinary discipline: one of its basic terms, 'character' is regularly used in several different (albeit related) ways." In light of the foregoing account, similar reasoning is applicable to the term uniformitarianism and to its kaleidoscopic usage in the Earth sciences.

The term "uniformitarianism" is probably susceptible to equivocation for several reasons. First of all, in many cases, authors have forgotten or overlooked the original meaning of the term coined by Whewell, whose purpose was to identify a fundamental dichotomy between two opposing views of geological process and Earth history, namely "uniformitarianism" and "catastrophism". The central point of this dichotomy does not hinge on the existence of isolated catastrophic phenomena (which were accepted by Lyell himself). Rather, it lies in the denial by "uniformitarians" (in the original definition of Whewell) that major changes and structures (such as sedimentary basins, denudation or mountain ranges) of our planet are mainly the result of "convulsive" paroxysmal events, relegated to short periods of time of the geological past (this dichotomy was already fully appreciated by Cannon, 1960, before the major revision by Gould and Rudwick). This fundamental issue has been overlooked in most of the criticisms to "traditional" uniformitarianism, based on current observation or on the reconstruction for the past of single catastrophic phenomena. The existence of highly energetic, individual catastrophic phenomena, does not falsify uniformitarianism in the original definition of Whewell, which admits catastrophic events but denies their condensation into short "convulsive" periods that define major changes or features of Earth history.

A second category of problems—one that triggered, in turn, further confusion and misinterpretations—has been the attribution of the term (but not the concepts or the alleged "principles" later associated with the term itself) uniformitarianism to Lyell or to his "predecessor" James Hutton, when in fact the term was coined by Whewell and was never used or mentioned by Lyell. This point has been made by Laudan (1982, p. 216), who states: "To think of Lyell's main aim as being that of establishing a 'principle of uniformity' or 'uniformitarianism' in geology is to introduce categories that were only applied retrospectively to his work by Whewell". However, over time, uniformitarianism has been completely attributed to (and made synonymous with) the work of Lyell—an attribution codified in early historical analyses of geological sciences and in the "canonical mythicization" of the 'eponymous heroes of geology', in particular the influential work of Zittel (1901). A typical example can be found

in the criticism of Bushman (1983) to the revision of the term uniformitarianism carried out by Shea (1982a), where the former states: "We need to clearly state that it was Lyell who perverted the concept of uniformitarianism by restricting it to constant rates and a limited pattern of change. We should refer to this error as Lyellism and eliminate it as being part of uniformitarianism" (Bushman, 1983, p. 313). Lyell in no way perverted the meaning of "uniformitarianism," in part because he never used the term himself, and in part because that term was not coined or recognized by one of his 'predecessor', Hutton, to crystallize his thoughts. Indeed, Hutton died thirty-five years before the coining of the term. It is also worth pointing out that the "thought" of Hutton that comes to us through the majority of textbooks is actually one filtered and reworked by John Playfair (Fig. 5).

All the texts, books and manuals that carry out the 'canonical mythicization' starting from influential works such the one by Zittel (1901) actually narrate just a part of the story. The immediate success of Lyell and his ideas was not so sensational and shared outside England, as we learn from the words of another prominent personality, Sir Archibald Geikie (Fig. 6), who, in his "Founders of Geology" states: "*He (Lyell) became the great high priest of Uniformitarianism—a creed which grew to be almost universal in England during his life, but which never made much way in the rest of Europe, and which in its extreme form is probably now held by few geologists in any country.*" (non-italicized word added, Geikie, 1897, p. 281).

Nevertheless, once the term was made synonymous with the thought of Lyell, uniformitarianism lost its original meaning as expressed by the dichotomy of Whewell, instead becoming equivalent to the entire theoretical underpinning of Lyell's work. Viewed in this light, the work of Gould (1965, 1987), Mayr (2011), and Rudwick (1972) can be boiled down to equation of the term uniformitarianism to the whole theoretical system of Lyell, with the respective identification of two, four, and six conceptual points that cannot be easily and unequivocally traced back to the original definition of the term. Paradoxically, these refined and modern analyses enclose more meanings



Fig. 5. John Playfair (1748–1819) by R. Cooper, published by T. Cadell & W. Davies, after Sir Henry Raeburn stipple engraving (from © National Portrait Gallery, London).



Fig. 6. Sir Archibald Geikie (1835–1924) by James Valentine albumen carte-de-visite (from © National Portrait Gallery, London’).

than does the original definition, and ironically, none of the highlighted points can be clearly and unambiguously identified with the term indicated by Whewell, who coined it to emphasize a fundamental dichotomy in geological interpretation, thereby distinguishing uniformitarianism from catastrophism.

The term uniformitarianism is also bedevilled by misrepresentation at the other end of the spectrum. The detailed, point-by-point analyses of Gould (1965, 1987), Mayr (2011), and Rudwick (1972), lie in sharp contrast to the more common, ultra-reductionist usage (see Albritton, 1967) embodied by the phrase “the present is the key to the past”, a maxim that is unfortunately taught and learned during the first year of geological curricula, and that is wrongly identified as the key principle of the geological sciences. In this case, the meaning of the term not only departs from that set forth by its progenitor, Whewell, but it also represents (in a cryptic and non-unique way) only one of the points highlighted by Gould (1987) and Rudwick (1972).

Another category of problems results from the application of a term with purely geological origin and meaning to other fields of investigation, such as biology, evolution, or even sociology. In these cases, it seems that (reader interpretation is often needed, as meaning is rarely made explicit) uniformitarianism is generally equated with uniformity or gradualism of processes. Such usage does not reflect the dichotomy in world view that led to the coining of the term, or the shades of meaning that the word has taken on the course of time.

A final source of possible equivocation comes from the urge to seek, at all costs, a “modern” conception of uniformitarianism (e.g. Windley, 1993), with the result that the term may assume but one of the many identities it has had through the course of time. Often this meaning is not made explicit (it being assumed, apparently, that any geologist should know what is meant by the term today) or, when it is expressed clearly, it is simply presented as the “rule of simplicity” or invariance of natural laws (e.g. Shea, 1982a, 1982b). In this extremely reductionist form of meaning, the term is not only superfluous (see Goodman, 1967), but is misleading or confusing to anyone familiar with the various meanings of the term.

Considering the highly confusing semantic state of the classic term “uniformitarianism,” it is legitimate to wonder what role the word plays in modern Earth sciences. As noted above, apart from the invariance of natural laws in space and time (in other words, the basic assumptions made in all scientific disciplines), all remaining “principles” into which the meaning of uniformitarianism has been divided by Gould (1987), Mayr (2011), and Rudwick (1972), have been definitively falsified, either by evidence observable today or that which can be inferred from the study of Earth history. Even the “Uniformity of process” of Gould (1987) and Rudwick (1972), which is essentially coincident with “actualism”, can be applied only to certain categories of products and processes, or to some particular stages in the evolution of our planet. In many cases, an extension of a current process to the past and *vice versa* is not warranted, with an understanding of the crucial importance played by the “configurational causes” (*sensu* Simpson, 1970) during the evolution of our planet. In discussing his twelve alleged fallacies of uniformitarianism, Shea (1982a, p. 459) considers the “modern” meaning of the term as essentially synonymous with the “law of simplicity,” affirming “that uniformitarianism today consists only of the scientific approach to the study of nature” (this is essentially the concept of “strict uniformitarianism” in Alvarez et al., 1989, which considers the modern form of uniformitarianism equivalent to the principle of Occam’s Razor.) Shea (1982a, p. 459) concludes that “[t]he use of the term ‘uniformitarianism’ and all of its synonyms for some special content or assumption or methodology of geology should be abandoned as fallacious, fruitless, and confusing”. In a similar vein, Shea (1982b, p. 702) states: “In short, the time has surely come for sedimentologists to free themselves of all remaining traces of constraining dogmas of uniformitarianism and to become true scientists free to go where observation, experimentation, and reasonable theory take us”.

It is now beyond any doubt that cataclysmic and catastrophic phenomena have had a major impact on Earth history and the evolution of its biota (see Pievani, 2014). Marvin (1999, p. 112) astutely noted that “Newton’s umbrella is closed. Today we understand that we must incorporate sudden, unpredictable, cataclysmic impacts from space into our inventories of geologic processes”. However, as is the case for uniformitarianism, the terms “neo-catastrophism” (see Schindewolf, 1963; Palmer, 2003; Marriner et al., 2010; Pievani, 2014) and “catastrophism” should be reconsidered and analysed in detail. Almost half a century ago, Newell (1967, p. 66) anticipated this need for analysis, observing that neo-catastrophism “like catastrophism, is a term with an emotional connotation that implies calamity and destruction, and as such it is not appropriate in any scientific context”. Misunderstandings or misinterpretations of the proper meaning of these classic terms could lead to the incorrect conclusion that all of the major processes affecting Earth’s history were catastrophic in nature (following the original definition of catastrophism in Whewell); or even worse, could lead to a resurgence of metaphysical, non-scientific and super naturalistic hypotheses. According to Donaldson et al. (2002, p. 6) “As now used by earth scientists, catastrophism is applied without the Divine Intervention rider. Examples of geologically recognized catastrophic events include: bolide impacts; hurricanes, cyclones and tornadoes; tsunamis; flash floods; landslides and avalanches; earthquakes, volcanic eruptions and lahars”. A central point of this contribution is the interpretation of these processes as individual catastrophic events rather than a warp thread that binds together Earth history under the term “catastrophism” (as originally defined).

Finally and more broadly speaking, Earth sciences (like other sciences), are advanced by the formulation of hypotheses that are based on empirical data that are rich in content and are characterized by high predictive and explanatory powers. Modern Earth sciences must take into account not only the wide range of present and past processes, but also the ranges of intensity and pace with which these processes have operated, operate today, and will operate in the future. Explanatory theories of the geologic record must be able to reconcile, for example, the slow-but-steady sedimentation owing to fallout of nannoplankton

with the emplacement, in a few hours, of enormous turbidite bodies. Similarly, in the terrestrial realm, slow, gradual erosion and modelling of landscape must be considered together with cataclysmic and high-energy mega flooding events. Each interpretation and theory must be firmly based on the congruence of available evidence, without any ideological bias provided by the rigid cages of uniformitarianism (in its original definition), actualism, or catastrophism. As noted by Scharnberger (1983; in a comment on the paper by Shea 1982a) the term uniformitarianism should be understood in its original meaning, and therefore considered that, for historical analysis, it falls into the same category as do the classic terms “Neptunist” and “Plutonist”. In this regard Scharnberger (1983, p. 312) states “A problem arises only when one starts with the fixed notion that the word ‘uniformitarianism’ must refer to some fundamental principle of geology, whatever that principle might be. But because the fundamental principle of geology is not different from the fundamental principle of the other natural sciences... there is really no need for a special term to describe it”. This conclusion is, in my opinion, the most useful of the literature analysed on the subject. Yet that conclusion was made more than thirty years ago, and despite the substantial and fundamental advances made in Earth sciences since that time, the term uniformitarianism remains entrenched in current literature, as a broadly-conceived “straw man” fallacy to be dismantled or falsified the light of newly-acquired knowledge. A new boom in the use of the term uniformitarianism may also be related to the growing popularity of studies dealing directly or indirectly with catastrophic processes and phenomena. This trend, which rose to prominence in the 1980s, was reviewed recently by Marriner et al. (2010). It is basically linked to the profound impact (psychological as well as physical) that catastrophic processes have: loss of human lives, damage to infrastructure, and ultimately to modern civilization’s vulnerability to natural hazards (also see Marriner et al., 2010, for other possible factors that may account for the burgeoning literature on with natural disasters). In parallel with the increase of contributions dealing with catastrophic phenomena, an increase in use of the term uniformitarianism is entirely predictable, insofar as it is often considered and understood to be a synonym for “gradualism”—and hence is dogmatically antithetical to any event that is catastrophic in nature.

In the light of the foregoing discussion on “Uniformity of process”, terms such as actualistic or non-actualistic might still find a place in modern Earth sciences, remarking the historic, contingent, and often system oriented nature of ideographic science such as geology (Dodick and Orion, 2003), understood in a holistic and multidisciplinary sense. Moving beyond this point of view, refined and detailed analyses such as those conducted by Eriksson et al. (2005) and Eriksson et al. (2007) show how the terms actualistic and non-actualistic may even prove reductionist. In fact, considering the evolution of the processes at work on the Earth and of configurational conditions, the present can (and in demonstrable ways is) different from the past, and, further, individual “slices” of the past may differ from each other and from conditions or processes observable today. Along these lines, processes and products characteristic and peculiar for the Archean, Palaeoproterozoic, and Mesoproterozoic (e.g. see Hamilton, 2010 for major changes in tectonic styles) have been identified. Their comparison with present conditions, dictated by a dogmatic adherence to actualism (basically the legacy of Hutton and Lyell) is completely superfluous. This, I believe, is the way that modern Earth sciences should take in approaching a high historical discipline such as geology.

In conclusion, the preceding review highlights the fact that widespread semantic chaos surrounds classical terms and concepts of geology. This example indicates a real need to reconsider and implement epistemological reflection in the Earth sciences, beginning in the basic courses of university education. Very often the definitions and concepts underlying the major historical debates in the Earth sciences (and perhaps other disciplines as well) are taken as “law” from traditional textbooks or dictionaries, skipping the crucial step of reading the original texts. Any historical analysis of a subject, as far as can be conducted

with seriousness and impartiality, will always be affected by a certain degree of subjectivity, inextricably connected to the specific attitudes of the writer, to the general preconceived view of the topic and, to particular idiosyncrasies. Following a careful analysis, the early history of geology illustrated by Lyell in his *Principles*, as represented and acclaimed by many later historians, is decidedly partial in some respects and in several cases it is even cleverly “distorted” or skilfully presented so as to support a particular thesis (McCartney, 1976). In this context, after a meticulous analysis of the original texts (in particular of the historical analysis illustrated by Brocchi in his “Conchiologia fossile subappenninica”), McCartney (1976, p. 179) came even to the conclusion that “Lyell’s historiography is therefore very much an apologia-pro geologia sua”. Similarly, Oldroyd (2002, p. 2) states that the history presented by Lyell “served, for him, the polemical purpose of garnering support for his geo-philosophy”.

Therefore, in order to dispel any doubt, and to have a less distorted picture of the genuine thought of an author from the past, the best way is undoubtedly to analyse in detail the original works, always keeping in mind the specific “Zeitgeist” i.e. the “spirit of the time” that characterized the scientific but also socio-cultural environment in which the author conceived his ideas (see also Romano, 2015), so as to avoid the pitfall of unmerited criticism or useless ridiculing of outdated theories in the light of current knowledge.

Terms such as “uniformitarianism” and “catastrophism” can be fully understood only following a serious reflection of the meaning that such terms can assume in light of the current state of knowledge (and not simply the reductionist definition listed in dictionaries of geology). Similarly, only a careful analysis of the meanings that those words have taken over time, and the different schools of thought underlying the words themselves, can really make clear the importance that historical terms such as “uniformitarianism”, “catastrophism”, “neo-catastrophism” and “actualism” have assumed in the structuring and development of our discipline, avoiding a stereotypical use of these words in current scientific publications as mere slogans or useless cliché.

Acknowledgements

Thanks to William Cavazza, Carlo Doglioni, Ruggiero Matteucci, and Gian Battista Vai for their helpful and constructive comments on an earlier version of this paper. Rich Cifelli and Umberto Nicosia are warmly thanked for invaluable suggestions and for correcting and improving several versions of the manuscript. Comments and suggestions by the Editor and two Reviewers have significantly improved the initial draft.

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