

The Critique of the Principle of Uniformitarianism and the Analysis of High School Earth Science Textbooks

Ho Jang Song and Hui Soo An

Department of Earth Science Education, Seoul National University

Although uniformitarianism is widely recognized as the basic principle upon which the structure of historical geology has been erected, a closer investigation on the basis of present scientific knowledge and the philosophy of science reveals some of its invalid aspects.

The concept of uniformitarianism was developed in a dual concept in Lyellian days. Substantive uniformitarianism (a testable theory of geologic change postulating uniformity of rates or material conditions) is false, ambiguous and stifling to hypotheses formation. Methodological uniformitarianism (a procedural principle asserting that former changes of the Earth's surface may be explained by reference to causes now in operation) belongs to the definition of science and is not unique to geology. Moreover, it also has some methodological defects in forming bold and novel working hypotheses. Methodological uniformitarianism today should take the form of a much older and more general scientific principle: Occam's Razor, the principle of simplicity.

Accordingly, substantive uniformitarianism, an incorrect theory, should be abandoned. Methodological uniformitarianism, now a superfluous term, should be best confined to the historical roles in geology. In this connection, the presentation of uniformitarianism in high school textbooks was analyzed. It was revealed that text books were riddled with false and misleading statements as to what uniformitarianism means. Since uniformitarianism, as presented in many textbooks, is in direct contradiction to the philosophy of inquiry learning, it is important to rethink the direction of uniformitarianism presentation in Earth Science curriculum development.

I. Introduction

There is widespread agreement among textbook writers that the whole mental process involved in the reconstruction of an ancient history is based on the cornerstone of geologic philosophy, the principle of uniformitarianism. As a matter of historical fact, the use of the concept has been fundamental in the working out of the history of the Earth, and in the evolution of geologic science itself (Hubbert, 1967). But the problems surrounding the concept are not so simple. If the question be asked, however, just what precisely is uniformitarianism, a variety of nonequivalent answers such as the following are likely to be received (Hooykass, 1959):

- a. The present is the key to the past.
- b. Former changes of the Earth's surface may be explained by reference to causes now in action.
- c. The history of the Earth may be deciphered in terms of present observations, on the assumption that physical and chemical laws are invariant with time.
- d. Not only are physical laws uniform, that is invariant with time, but the events of the geologic past have proceeded at an approximately uniform rate, and have involved the same processes as those which occur at present.

These diverse definitions of uniformitarianism are, however, very ambiguous in perspective of the present geological knowledge and the philosophy of science. In the 1960s, the ambiguities and even fallacies of uniformitarianism were implied by some geologists and philosophers (Hooykaas, 1963; Gould, 1965; Goodman, 1967; Hubert, 1967; Simpson, 1967; Kitts, 1967; Krynine, 1956). But it seems that these definitive analyses of what uniformitarianism means today, as opposed to what it meant in the Lyellian days, have not been widely read by earth science curriculum developers. Even more surprising is the fact that, judging by its almost total lack of citation, these studies seem to have been virtually ignored.

In this context, the objectives of this investigation have the

following two levels:

- a. First is to investigate the concept of uniformitarianism in the light of modern scientific knowledge and the modern philosophy of science, with the view of evaluating the extent of its validity.
- b. Second is to analyze some recent high school earth science textbooks (6th national curriculum) on the basis of those findings of the preceding investigation.

II. The Concept of Uniformitarianism

The origin and the development of uniformitarianism

An understanding of uniformitarianism can best be achieved in the historical context in which it originated. Limited in their interpretation of nature by rigid exigencies of the Mosaic chronology, 19th century catastrophists postulated a succession of great upheavals culminating in a general Flood which swept away all extinct life from the continents, tore up the solid strata, and reduced the surface to ruins. Their world view extends beyond a simple theory of geologic changes. It encompassed a methodological procedure, excluded from the modern definition of science, which permitted direct Providential control of Earth's history. Thus a catastrophist such as Buchland, chief architect of the catastrophist synthesis, speaks of the direct agency of Creative Interference, with his conclusion to regard geology as the efficient auxiliary and handmaid of religion to which the uniformitarianists could not agree (Park, 1990)

Hutton stated:

“Therefore, there is no occasion for having recourse to any unnatural supposition of evil, to any destructive accident in nature, or to the agency of any supernatural cause, in explaining that which actually appears” (Hubbert, 1967)

This world view of Hutton's represents one of the earlier formations of what later became known as uniformitarianism.

Lyell's *Principle of Geology* was devoted almost exclusively to the deciphering of the history on the basis of his own

modification of the Huttonian thesis that the former changes of the Earth's surface may be explained by reference to causes which are now in operation (Laudan, 1987). Since this involved the assumption of "uniform" operations in geological processes, the Huttonian-Lyellian philosophy later become known as uniformitarianism. To become a science, they affirmed geology need not only be an empirical theory unencumbered by Divine Interference, but also a methodology which affirmed the potential natural explanation of terrestrial development and relegate intrinsic mystery to the proper theological realm. The uniformitarian assault was launched from two logically distinct platforms, and the cardinal geologic principle arising from its victory is a dual conception (Gould, 1965).

First, the uniformitarian camp strove to replace the catastrophist theory with a notion of cumulative slow changes produced by natural processes operating at relatively constant rates. Thus uniformitarianism, in the first sense, is a testable theory of geologic changes (substantive uniformitarianism of Gould, 1965). But Lyell was even more firm in controverting the catastrophist methodology which affirmed that geology should be an auxiliary of religion,

Lyell stated:

"Many appearances, which for a long time were regarded as indicating mysterious and extraordinary agency, are finally recognized as the necessary results of the laws now governing the material world; and the discovery of this unlooked for conformity has induced some geologists to infer that there has never been any interruption to the same uniform order of physical events. The same assemblage of general causes, they conceive, may have been sufficient to produce, by their various combinations, the endless diversity of effects, of which the shell of the Earth has preserved the memorials, and, consistently with these principle, the recurrence of analogous changes is expected by them in time to come.

.....

By degree, many of the enigmas of the moral and physical world are explained, and, instead of being due to extrinsic and

irregular causes, they are found to depend on fixed and invariable laws. The philosopher at last becomes convinced of the undeviating uniformity of secondary causes (Hubbert, 1967).

Thus, Lyell's major view was embodied in the statement, "the philosopher at last becomes convinced of the undeviating uniformity of secondary causes." The term "secondary causes" pertains, in the philosophy and theology of that period, to events subsequent to the "first causes" which ordinarily is synonymous with "Divine Creation". Hence Lyell's understanding of uniformity of secondary causes appears to be equivalent to asserting the permanency of physical laws and any form of supernaturalism or interferences by Divine Providence. He thus postulated another, very different, type of uniformity that asserted the invariability of natural laws in space and time, a necessary condition to his condition that reference need only be made to observable processes in explaining past changes. Once accepted, this uniformity ended the dichotomy between a contemporary world operating under constant and verifiable natural laws and a past incapable of purely scientific explanation. The entire geologic record, with all its evidence of vast upheaval and mass extinction, was for the first time integrated within the sphere of empirical investigation. Thus, uniformitarianism, in the second sense, is a statement of proper scientific procedure in general, regardless of any particular substantive theory (Gould, 1965).

These two things have been confused in discussions about uniformitarianism. They can remain logically distinct because we may formulate a theory of natural catastrophic changes that denies the first point but which affirms the procedural points. Consequently, catastrophism has often been misrepresented as scientifically absurd and impossible from the methodological point of view. In fact, catastrophists like Cuvier, Sedwick, and Buckland have never propounded the idea that physical laws have changed through the ages (Hugget, 1990). It seems that where the dichotomy between substantive and methodological was not made, the ambiguities and fallacies about uniformitarianism start.

Geologic critique of uniformitarianism as substantive theory

The critique of the meaning of uniformitarianism is given here in two ways. It is based on both the nature of geology as historical science and geological knowledge. History may be defined as configurational changes through time, i.e., a sequences of real individual but interrelated events. Therefore, historical science may thus be defined as the determination of configurational sequences, their explanations and the testing of such sequences and explanations (Shimpson, 1967). Past configurations were never quite the same as they are now and were often quite different. The actual state of the material universe or of any part of it at a given time is constantly changing. Within those different configurations, the physical laws have worked at different scales and rates at different times, sometimes combining into complex processes different from those in action today. This point helps to explain the fact that history is not uniform. Only to the extent that past configurations resemble the recent in essential features could past processes have worked in a similar way.

Accordingly, interpretations that are based on the present state of materials or processes and attempt to assign them as obligatory properties of a configuration of the past are logically erroneous. The history of nature illustrates this point. The operation of a great system of processes through appreciable intervals of geologic time has had great effects. Historical geology demonstrates that things were different in the past. A familiar example involves the origin and evolution of life. It seems certain that the presence of life as it exists today, and the present state of the biological environment, are inimical to the repetition of many kinds of evolutionary events that have occurred in the past. In other words, the operation of a process alters the configuration, and subsequent operation of the process must necessarily occur in a new configurational context.

Geologic and geophysical knowledge may reveal another poor point of uniformitarianism. The energy input into the Earth's surface environments consists of radiation from outer space—overwhelmingly from sun-tidal energy; from the kinetic and potential energy of the Earth-moon-sun system; and from thermal, chemical, and mechanical energy from the Earth's

interior. In view of the approximate constancy of the Earth's surface temperature when averaged over a year or more, it followed that the outward flux of energy from this system must be very nearly equal to the inward flux. Because of the temperature increase with depth, thermal energy from the outside can penetrate only to shallow depths beneath the Earth's surface. Hence, the outward flux must be by means of radiation from the Earth into outer space.

In the process, solar energy is used principally to produce a continuous circulation of the atmosphere and the oceans which dissipate, by erosion continuously, into heat the potential energy of the Earth's topographic configuration. Thermodynamic erosion and transportation of sediments are irreversible processes in which the initial mechanical energy is conveyed by friction into low-temperature heat. This heat is added to the thermal input of the surface environment of the Earth which it leaves by long wave radiation. Thus topography of the Earth represents a large reservoir of mechanical energy which the erosional process continuously dissipates. The energy of one orogeny, therefore, can never be used to produce another, since that energy is completely dissipated and discharged from the Earth. Hence after peneplanation of any area of the Earth, new mountains can be formed only from a new source of energy from inside the Earth.

Because there have been repeated orogenies and episodes of vulcanism throughout the earth's history, these can only have occurred at the expense of a diminution of the Earth's initial supply of energy.

In addition to the energy lost from the Earth by orogenies, there is also the energy transported to the Earth's surface from its interior by heat conduction in virtue of the geothermal gradient, and that convected by mass transport resulting from the activities of volcanoes and earthquakes. It is for this reason that uniformitarianism on which the same processes have been and always will be operative, and at about the same rate, is equivalent to a perpetual motion mechanism and a physical impossibility. Because of its involvement in thermodynamically irreversible processes, the Earth's history, despite the long time scale, can only be in the long run a unidirectional progression from some initial state characterized by a large store of available

energy to a later state in which this energy has been discharged from the earth (Krynine, 1956). In this later state, if the earth continues in the planetary orbit around the sun, and if the solar energy has not been exhausted by that time, we may anticipate the continuations of atmospheric and oceanic circulation, which may lead the ultimate cessation of diastrophic and volcanic activities, with a corresponding permanent peneplanation of the land areas.

There is now much reason for suspecting that conditions in the solar system have undergone important changes, and since the earth participates in the evolution of that system, the force acting upon the earth from outside, may well have differed very materially, not only in degree but also in kind, from anything observable at this particular time. There are abundant indications that some of the most potent causes of geological changes must be sought outside of the earth (Heylmum, 1971)

Now it is appropriate to ask to what degree we may still regard this uniformitarian principle as valid. According to the preceding analyses, it is certain that uniformitarianism as a substantive theory has not withstood the logic of geology as historical science and the test of scientific data and can no longer be mentioned in any strict manner.

In conclusion, although substantive uniformitarianism may often be a guarantee against pseudo-scientific fantasies and loose conjectures in Lyellian days, it makes one easily forget that uniformitarianism is not a law, not a rule established after comparison of facts, but prior principle preceding the observation of facts.

Philosophical critique of uniformitarianism as methodology

The principle of uniformitarianism includes two things in relation to methodology in historical genesis.

- a. Former changes of the earth's surface may be explained by reference to causes now in operation.
- b. The physical laws now in operation have always been in operation.

These two things have even been confounded in discussion about uniformitarianism (Gould, 1965). Consequently

catastrophism has often been misrepresented as scientifically absurd and impossible from the methodological point of view. However, it ought to be stressed that catastrophists like Cuvier, Sedwick, and Buckland never propounded the idea that physical laws have changed in the course of ages (Hugget, 1990).

The practical and real problem centered around the first point. The second point is only tautology. The first point proposes that geology be an inductive science. That is to say, its reasoning is from effect to cause. It starts with observational data and ends with inference which is more or less probable (Popper, 1959). The essentials of the inductive method applied to the apprehension of a case, in general, are:

- a. finding of facts by observation and experiment;
- b. multiple hypotheses, the product of imagination and invention;
- c. arrangement of hypotheses in the order of their agreement with facts;
- d. invention of critical tests, where possible, to discriminate between residual hypotheses.

The result of this inductive process is the determination of the relative probability of hypotheses in terms of logical empiricism. The philosophical analysis of the induction shows that it falls short of certitude. And this analysis is doubtless theoretically sound (Charmers, 1989). In practice, however, the degree of probability attained frequently approaches certainty so closely as to exclude reasonable doubt. The discussion of various geological hypotheses in the past years (particularly since the 1920s) clearly indicates that the considerable hostility and prejudice has arisen from the clash between free thinking and long established geological belief, the principle of uniformitarianism (Pyne, 1978). But Lyellian uniformitarianism, seemingly reasonable enough in its days, soon took on dogmatic qualities which may be well enough in theology, but not in science.

Uniformitarianism may, of course, often be a guarantee against fantasies and mere speculations. But it puts a limit to the many available working hypotheses possible, by proposing that there is only one way in which ancient causes are equal to

present ones. There is, however, an infinity of ways in which ancient and present causes could be supposed different. So this methodological attitude easily degenerates into a narrow dogmatism.

In this negative aspect, it can lead to a denial of unknown causes. To say that throughout the time covered by the geological record no causes have acted, other than those that are in operation at the present, is to make a hazardous and unwarranted assumption which, by its very nature, is incapable of proof. It should therefore not be inculcated as geological principle to the detriment of hypotheses that may have more support. Thus the principle of uniformitarianism would discourage, if not wholly prevent, the correct interpretation of the effects of causes which were once operative, but which are *not now in existence*. For imagination must be free to follow whenever logic leads. It seems to be a good policy in science to adjust theories to the data of observation instead of adapting these data to prejudices of any kind whatsoever. The uniformitarian position, at its worst, forces past phenomena into a preconceived frame built upon events occurring in our epoch. It seems, therefore, that the principle of uniformity should be abandoned when a better interpretation of the phenomena of the past could be attained by doing so.

Imagination controlled by logic is one of the most precious and productive attributes of the human mind. It is the soul of invention and resourcefulness. It is also applied everyday in many fields in diagnosis, using that word in its broadest sense. For the good of science, imagination must know no other limitations than those of logical reason in the inductive process. The more hypotheses the better. Contrary to this essential of the inductive process, the principle of uniformitarianism leads to poverty in hypotheses where riches are desired. As a methodological principle, uniformitarianism is now also largely superfluous. In the inductive science of geology uniformitarianism should be recognized as, at best, only partly true, and not be permitted to be either the invention, or the subsequent consideration, of hypotheses for the purposes of inductive logic.

Futhermore, saying the principle again is, at worst, confusing since it leads to the inference that geology has a powerful and

unique guiding principle on its own. The unity of procedural assumptions, which binds the empirical science together, therefore, should not be obscured by terminology specific to one discipline, geology.

As a special term, methodological uniformitarianism was useful only when science was debating the status of the supernatural in its realm. For if God intervenes, the laws are not invariant and induction becomes invalid. It was useful for those who, like Lyell, needed a guide to combat what we now consider the unscientific notion of Divine Intervention and resultant discordance of past and present modes of changes. In other words, uniformitarianism must be evaluated only in its historical context. As far as the science of geology is concerned, the term uniformitarianism today is an anachronism.

III. Analysis of Uniformitarianism in National High School Earth Science Textbooks

Then how do the national textbooks of high school earth science (in the 6th national curriculum) present uniformitarianism. The second objective of this investigation is to analyze the textbooks in detail on the basis of the results of preceding investigation. This analysis was made in the order of: conceptual categories, meanings, and misconceptions in relation to uniformitarianism. All kinds of textbooks for analyzing in which

Table 1

Author	Textbook	symbol
Na Il Sung et al.	Earth science II	A
Choi Suk Eun et al.	Earth science II	B
Paek Kwang Ho et al.	Earth science II	C
Jung Chang Hee et al.	Earth science II	D
Jung Jae Sup et al.	Earth science II	E
Jung Jin Woo et al.	Earth science II	F
Jung Hae Moon et al.	Common science	G
Lee Min Sung et al.	Earth science II	H
Lee See Woo et al.	Earth science II	I
Woo Jong Ok et al.	Earth science II	J
Woo Yung Kyun et al.	Earth science II	K

Table 2

Textbook	Categories	Textbook	Categories
A	Law, principle	F	Theory
B	Principle	G	Law
C	Principle	H	X
D	Law, principle	I	Law principle
E	Law, principle	J	X
		K	Law principle

uniformitarianism is presented are listed as follows. Table 1 lists those textbooks alphabetically by authors.

Conceptual categories

Table 2 is a list of different categories to which uniformitarianism is said to belong. Almost all authors, except two, make comments on uniformitarianism, as seen in table 2. Diverse vocabularies with respect to uniformitarianism are presented in them: principle (7 textbooks), law (6 textbooks), and theory (1 textbook). Many textbooks also use two or more kinds of categories at the same time to mention uniformitarianism. These results can be thought of as revealing the following facts.

First, it is not difficult to see why a number of analyses of uniformitarianism have advocated dropping the term. An analogous situation would be where geologists were so uncertain as to the nature of quartz that they identified and referred to it by several dozen different names, and placed it in an even greater number of general categories (such as mineral, rock, metal, glass, liquid, soil, etc, Laudan, 1987) and were in general uncertain just exactly what quartz is and to which general classes of substances it belonged.

Second, it is apparent that many textbooks make a mistake of placing uniformitarianism under the category of law or theory. Certainly uniformitarianism was not a law or a rational theory as was discussed earlier.

Third, it could be admitted that the term "principle" was used in the same meaning as Lyell's "the principle" of geology when Lyell adopted "the principle" in geology, he meant the principle of reasoning methodologically (Laudan, 1987). But Lyell's principle of reasoning was to reconcile phenomena with his rigorous uniformitarianism as a theory. In fact, Lyell's principle

of reasoning and uniformitarianism as a theory, however, were not unrelated in his mind (Hooykaas, 1963). Yet they are logically distinct. Lyell was misleading and confusing. Many textbooks are also very confusing in the same respect. As a result they are using the anachronistic term equivocally.

Judging from the fact that almost all textbooks are using the terms (law, principle, theory) in a substitutive manner of one another in the same textbooks, it is certain that they also make Lyell's mistake.

Meanings

Uniformitarianism has a dual meaning. Substantive uniformitarianism is a testable theory of geologic changes postulating uniformity of rates or material conditions. Methodological uniformitarianism is a procedural principle of inductive reasoning assigning spatial and temporal invariance of causes and natural laws. The former is clearly false. The latter is not only, at best, partly true, but also is, at worst, largely superfluous as was discussed. Here substantive uniformitarianism may be divided into two kinds. The one is a strict uniformitarianism which postulates that the processes on Earth were the same as today in kind and rate. The second is a less strict uniformitarianism which postulates that they were the same as today in only kind. Actualism, in methodological inference, what is called, has meaning to the effect that the course of nature has been uniform from earliest ages, and causes now in action have produced the former changes of the earth's surface. Its meaning can be usually epitomized in the maxim "The present is the key to the past methodologically"

As can be seen in table 3, almost all textbooks except a few, are confounded in discussion about the just meaning of uniformitarianism. They accept and teach uniformitarianism with little further thought since it is considered to be one of those basic "laws" that forms the very foundation of geology. In addition, they also present uniformitarianism as a principle of reasoning methodologically. They clearly confound "methodological" with "substantive".

This ambiguity might have been avoided had Lyell named his conception. The term uniformitarianism, however, was coined by Whewell in a review of Lyell's principle:

"Hence the changes which lead us from one geological state to another have been, on a long average, uniform in their intensities, or have they consisted of epoch of paroxysmal and catastrophic action interposed between periods of comparative tranquility? These two opinions will probably for some time divide the geological world into two sects, which may perhaps be designated as the uniformitarianists and catastrophists" (Gould, 1965).

It seems that Whewell speaks here of substantive uniformitarianism. Nevertheless many great 19th century geologists, realizing that a strict uniformity of rates was untenable, began to apply this term to Lyell's methodological principle. From then on, the term uniformitarianism has been in chaos. The pseudo controversy over uniformitarianism has continued to the present day as debunkers of it attack the substantive theory while supporters uphold the methodological principle. This situation can clearly also be found in the major comments about uniformitarianism across all the textbooks.

Furthermore, the explanation of uniformitarianism with the maxim "The present is the key to the past," is as ambiguous as the original term itself. The maxim has the same limitations as uniformitarianism has. Surely the maxim deserves the same critical examinations. Frequently, however, uniformitarianism is used fruitfully to explain the anti-catastrophist viewpoint of history. In fact, it has been successful in explaining some of the geologic record, perhaps because the sample of natural processes with which we are present today is somewhat representative of the universe of processes which have operated in the past, and because the present configurations are similar to those of the past for many parameters. It would be a mistake, however, to count on such a close correspondence. It seems unfortunate that uniformitarianism, a principle which has so important a place in the history of geology, should continue to be misrepresented in almost all textbooks by, "The present is the key to the past," a maxim yet without much credit.

Misconceptions

The preceding investigation of uniformitarianism reveals that the national textbooks of earth science are replete with fallacies

Table 3

textbook	major statements	substan- -tive	method -ological
A	1) Geological changes are not only very slow, but also repeated without interruption. 2) The law of uniformity controverts catastrophism. 3) The earth is very old, beyond our imagination.	O	X
B	1) Uniformitarianism is the principle that the history of the earth may be deciphered in terms of detailed observations of the present aspects of changes. 2) The present is the key to the past. 3) Uniformitarianism is the most basic principle in the interpretation of geologic history.	O	O
C	1) Uniformitarianism is the idea that changes on the earth's surface are invariant with time. 2) The present is the key to the past. 3) But it seems that the present changes are not strictly the same as the past changes in scale and aspect.	O	O
D	1) The present is the key to the past. 2) Uniformitarianism controverts catastrophism.	O	O
E	1) The slow change now in action had occurred in the past at a similar rate. 2) Uniformitarianism means the uniformity of process. 3) The present is the key to the past.	O	O

Table 3 (Continued)

textbook	major statements	substan- -tive	method -ological
F	1) The geological processes of change now in action are similar to those of the past in tempo. 2) Former changes in the earth's surface may be explained by reference to those of the present.	O	O
G	Processes of geological changes now in operation are the same as those of the past in both rate and scale.	O	X
H	No statement.		
I	1) These diverse changes now in action have always acted and will also act in the future. 2) The present is the key to the past. 3) With the recent advent of catastrophism such as meteorite impact theory, uniformitarianism could not be interpreted literally.	O	O
J	No statement.		
K	1) Although Hutton's ideas were correct in general, the direct interpretation of the present changes can not be applied to the past changes.	O	O

Table 4

-
- | |
|--|
| a. Uniformitarianism is a law established empirically. |
| b. Uniformitarianism is unique to geology. |
| c. Uniformitarianism was first conceived by James Hutton. |
| d. Uniformitarianism was established by Charles Lyell. |
| e. Only currently active processes operated during geologic time. |
| f. The rates and intensities of processes are constant through time. |
| g. Geologic processes of the past are the same as today in only kind, but not in rate. |
| h. Only gradual non-catastrophic processes have occurred during earth history. |
| i. Uniformitarianism holds that the earth is very old. |
| j. Uniformitarianism controverts catastrophist methodology. |
-

and misconceptions. Table 4 lists what can be considered to be the most common misconceptions, explicit or implicit, across the national textbooks

The investigations into uniformitarianism were likely to reveal an astonishing array of vague conceptions, half-truths, and outright fallacies. Similarly, geological textbooks of high school Earth Science are riddled with misconceptions and fallacious statements of uniformitarianism. It is certain that most textbooks don't understand the nature and correct meaning of what is said to be the basic principle of geology.

It seems that a substantial part of the problems has deep historical roots. But, even so, there is little justification for continuing the error of the past after those errors have been repeatedly and convincingly exposed.

IV. Conclusion

This investigation into uniformitarianism attempted to reveal that although it played a useful role in the historical context in which it originated, today the concept of it is an anachronism. Because the question of divine intervention is no longer an issue in science, reference to it is superfluous. In addition to this fact, methodological uniformitarianism's inductive logic is stifling the free imagination necessary to multiple-hypotheses thinking.

Uniformitarianism, at best, dissolves into a principle of simplicity (Occam's Razor) that is not peculiar to geology but

pervades all science. Geologist work under no uncommon handicaps and enjoys no special privileges merely because their work may be historical or descriptive. Geologist can now forget the obsolete controversy over uniformitarianism and cease defending them selves for practicing what may not be a genuine science. Geology has long since come of age.

In this connection, it was revealed that these negative aspects of uniformitarianism were reflected in the national high school Earth Science textbooks. Many textbooks present uniformitarianism with little further thought. Even substantive uniformitarianism is still presented in many textbooks. They present it in such a way to leave the students with the impression that it is an indisputable "law". It is possible that at the present time the influence of this principle is largely a subconscious one, still persistent, in students' minds. Against its insidious effects, students should be warned. And particularly the earth science curriculum developers who are interested in the broader problem of geology and those who are likely to be perplexed at finding that modern discoveries and explanations appear to conflict with the principle long held as true, should also be warned.

As a matter of fact, many textbooks dismissed the possibilities of global catastrophism altogether, whereas some others ridicule and scoff at the early ideas. But all textbooks and curriculum developers implore their students to think scientifically and to develop the principle of multiple-working hypotheses.

In conclusion, one of the most significant things this investigation demands would be to reach a clear understanding of the nature of uniformitarianism in pertinent respects and to eliminate all-to-common misconceptions and fallacies from textbooks. This proposal would be, in particular, important in relation to the student's building of bold and novel hypotheses in "learning through inquiry" of which the recent national curriculum materials make so strong a point.

References

- Charmers, A. F., 1989, *What is This Thing Called Science?* St. Lucia, Queensland: Uni. of Queensland Press.
- Gould, S. J., 1965, "Is Uniformitarianism Necessary?", *American Journal of Science*, Vol.263, p.223-28.

- Hallam, A., 1989, *Great Geological Controversies*, Oxford: Oxford University Press, p.30-60.
- Heylman, E. B., 1971, "Should We Teach Uniformitarianism?", *Journal of Geological Education*, V.19, p.35-37
- Hooykass, R., 1959, *Natural Law and Divine Miracle: Leiden*, E. J. Brill, p.327. 1963, "The Principle of Uniformity in Geology, Biology, and Theology", *Faith and Thought*, Vol.88, p.101-116.
- Hubbert, M. K., 1967, "Critique of the Principle of Uniformity", in Albritton, C. C., ed., *Uniformity and Simplicity*, Geo. Soc. Amer. special paper 89, p.3-33
- Hugget, R., 1990, *Catastrophism*, A division Hodder & Stoughton, p.4-38.
- Kitts, D. B., 1967, *The Theory of Geology*, Geo. Soc. Amer. p.49-67.
- Krynine, P. D., 1956, "Uniformitarianism is a Dangerous Doctrine", *Journal of Paleontology*, Vol.30, p.1003-4
- Laudan, R., 1987, *From Mineralogy to Geology*, Chicago: University of Chicago Press, p.20-27, Ch9.
- Park, Y. O., 1990, *Geology and Mineralogy of William Buckland (1784-1856) Dissertation*, Ch2.
- Popper, K. R., 1959, *The Logic of Scientific Discovery*, New York: Harper & Row p.31.
- Pyne, S. J., 1987, "Methodologies for Geology: G. K. Gilbert and T. C. Chamberlin", *Isis*, 69 (No. 248), p.413-424.
- Shimpson, G. G., 1967, "Historical Science", In: Albritton, C. C., ed., *The Fabric of Geology*, Geo. Soc. Amer. p.24-47.