Second Bibliography and Index for the Philosophy of Geology[1]

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Introduction and Acknowledgments

The body of writings on the philosophy and history of geology has grown in a remarkable way since the end of the Second World War. There is no obvious explanation for this quickening of interest in what are surely the most academic aspects of a science best known for its practical applications. Influences arising both from within and from outside the geological profession have probably been responsible.

It is a matter of record that many departments of geology, upon resuming full-time operations after the war, decided not to go on moving in the old curricular ruts. The new courses, even those in the classical geological disciplines, became more analytical, relying less and less upon the memorization of factual material. This trend has called for a rethinking of the basic principles of geology. There has even been some pecking and scraping around that mossy Victorian cornerstone of historical geology, the principle of the uniformity of nature—and some of us have been astonished to find that the shape of the moss is not the shape of the stone.

Meanwhile philosophers and historians of science have discovered geology. C. C. Gillispie's *Genesis and Geology* and W. F. Cannon's articles on uniformitarianism and catastrophism are examples of historical writings that have disclosed something of the interplay between the geological thought and the social opinion of the last century. The volumes of writings on evolutionary thought attending the centennial celebration of Darwin's *Origin of Species* likewise have focused attention upon geology, not only because of Darwin's own substantial contributions to geologic thought, but also because of the bearing of fossils and geologic time upon evolutionary theory. One of the most glowing appreciations of James Hutton's work, for example, is found in Loren Eisley's popular *Darwin's Century*.

Most philosophers of our century have taken little notice of geology, preferring to draw their illustrations from mathematics and

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physics. Hugh Miller was one of the earlier exceptions; his *History and Science,* published in 1939, made a strong case for the synthesis of historical and theoretical principles through historical sciences such as geology and paleontology. More recent support for this view is given in T. A. Goudge's writings on causal and genetic explanations. In one of his two works cited in this bibliography, S. E. Toulmin actually argues that geology was the first of the natural sciences to demonstrate how its subject matter has evolved down through the ages, and hence was the first science to "grow up."

There is little evidence, however, that the geologists, philosophers, historians and others who are writing about the philosophy of geology are in close communication with one another. In any case the literature on the subject is widely scattered through books and professional journals addressed to very different audiences. One purpose of my first bibliography for the philosophy of geology[3] was to bring many different scholarly and scientific viewpoints to bear upon the subject. The inevitable misunderstandings and disagreements that appear in such a collection point the way to an array of problems, some of which have philosophic substance.

This supplementary bibliography cites 125 works, most of which were published after 1959 by British or American authors. Mrs. Robert R. Wheeler graciously assisted with the searching for titles. Through the Reference Department of The Science Information Center in Dallas, Mrs. Nadine George was able to obtain microfilm and photocopy of writings that are not in our collections. Mrs. Jacquelyn Newbury typed the manuscript and assisted with the proofreading.

CONTENT OF THE BIBLIOGRAPHY

The writings cited in the bibliography fall into one or more of the categories listed in the following table.

A. STUDIES OF GEOLOGY AND CLOSELY RELATED DISCIPLINES, WITH REGARD TO:

1. *Principles, laws, and maxims.*—Includes: (1) Studies of the content, logical status and application of the principles of uniformity, indeterminacy, association, etc.; (2) considera-

[3] Published in *The Fabric of Geology* (C. C. Albritton, Jr., ed.), Addison-Wesley Publishing Co., 1963; Reissued in 1964 by Freeman, Cooper & Company of Stanford, California.

tions of the validity and usefulness of propositions that have been called geological laws or historical laws; and (3) analyses of the meanings of maxims such as, "The present is the key to the past."

2. *Methodology.*—Includes: (1) evaluations of the use and misuse of natural, theoretical and mathematical models in attacking geological problems; (2) analyses or examples of the use of multiple working hypotheses; and (3) comparisons of the rational and empirical methods of investigation.
3. *Theory.*—Includes: (1) analyses of the formal characteristics of theoretical propositions; (2) comparisons of strengths and weaknesses of rival theories offered as explanations of geologic phenomena whose origin remains uncertain, and (3) investigations of the role played by theory in the development of certain geological sciences.
4. *Systems of classification.*—Includes: (1) discussions of various procedures for ordering and classifying strata, faults, fossils and other geologic phenomena, and (2) comparisons of relative merits of descriptive and genetic schemes of classification.
5. *Explications of terms and concepts.*—Includes analyses of the meanings of geologic and paleontologic terms such as "unconformity" and "species."
6. *Symbols and the communication of information.*—Includes analyses of the tools of geologic communication, and of the geologic map as a vehicle for conveying geologic fact and interpretation.
7. *Psychological impediments to development.*—Includes discussions of the difficulties in forming concepts of the length of geological time; and of the tendency to find in nature whatever one is looking for.
8. *Scientific philosophies of individual geologists or schools of geologists.*—Includes analyses of the scientific methods and habits of thought of James Hutton, Charles Lyell, Charles Darwin and G. K. Gilbert.
9. *Evolution of ideas.*—Includes discourses on the sequence of events leading to the formulation of the hypothesis of continental glaciation, the Huttonian theory of the Earth, and the theory of organic evolution.

10. *Current trends in development.*—Includes discussions of trends toward quantification, empiricism, authoritarianism, vitalism, determinism, indeterminism, etc.
11. *Major intellectual contributions.*—Includes appraisals of geologic contributions to general thought—as, for example, the idea of the antiquity of the Earth, the idea of incessant change in the configurational aspects of nature through time, and the idea that the courses of physical and organic evolution may be deciphered from the spatial relationships of rocks and fossils.
12. *Scope, interrelations and distinguishing characteristics.*—Includes: (1) identifications of the various geological specialties (physical, historical and applied), and their relationships to each other and to non-geological sciences; (2) analyses of the scope, method, and contributions of special fields, such as forensic mineralogy; and (3) identifications of the distinguishing features of geology as an historical science.

B. STUDIES OF NATURAL SCIENCE THAT HAVE A PARTICULAR BEARING UPON GEOLOGY.—Includes selected writings on general principles, methods, and problems of science—*e.g.*, discussions of the principles of simplicity, microreduction, connectivity and verification; studies of the structure of scientific theories and of the nature of scientific explanation; and analyses of the problems of induction, prediction and retrodiction.

BIBLIOGRAPHY

Ager, Derek Victor, 1963, Principles of paleoecology; an introduction to the study of how and where animals and plants lived in the past: New York, McGraw-Hill, ix and 371 pp. ". . . uniformitarianism has its limitations when applied to the fossil record."

Albritton, Claude Carroll, Jr., 1961, Notes on the history and philosophy of science; 1. A conference on the scope and philosophy of geology: J. Graduate Research Center, vol. 29, no. 3, pp. 188-192.

2. 1963, Philosophy of geology: a selected bibliography and index, pp. 262-363 *in* Albritton, Claude C. Jr., ed., The fabric of geology: Reading, Mass., Addison-Wesley, x and 372 pp. Con-

tains references, with brief annotations, to some four hundred writings which reflect upon the scope, methods, and contributions of the geological sciences.

Allison, A. C., 1962, Natural selection in human populations: Univ. Kansas Sci. B., Supp., vol. 42, pp. 5-32. ". . . natural selection has in fact continued in human populations with only slightly reduced intensity to the present day, when its effects can still very easily be demonstrated."

Alonso del Real, Carlos, 1962, Comments on "Epistemology and archaeological theory," by Gordon R. Lowther: Current Anthropology, vol. 3, no. 5, p. 502. ". . . an understanding of the past as a function of the present and the problem of going from the better known to the lesser does not seem to me only important in a didactic sense but moreover . . . in an epistemological or gnoseological sense . . ."

Anderson, Charles Alfred, 1963, Simplicity in structural geology, pp. 175-183 *in* Albritton, Claude C. Jr., ed., The fabric of geology: Reading, Mass., Addison-Wesley, x and 372 pp. "The geologic history becomes more complex as we build up a storehouse of 'verifiable elements,' even though each succeeding historical account does not introduce entities beyond necessity."

Ardley, Gavin, 1950, Aquinas and Kant, the foundations of the modern sciences: London, New York, Toronto; Longmans, Green and Co., vii and 256 pp. "The exact science of physics belongs to the 'stern judge' class. A descriptive science like geology or botany . . . belongs predominantly to the 'receptive pupil' class. To find a common method in these two is a hopeless task."

Bailey, *Sir* Edward, 1962, Charles Lyell: London, Thomas Nelson and Sons, x and 214 pp. Lyell "consistently taught that all geological events, but not the origin of species, have been governed by laws of nature which are open to investigation at the present day."

Barth, Paul, ed., 1907, Raum und Zeit in Geographie und Geologie; naturphilosophische Betrachtungen von Dr. Friedrich Ratzel: Leipzig, Johann Ambrosius Barth, Natur- und kulturphilosoph-

ische Bibliothek, vol. 5, viii and 177 pp. "Die Beschränkung, die Lyell der Wissenschaft von der Erde auferlegte, indem er den Grundsatz aussprach, dass Geologie nichts mit Kosmogonie zu tun habe, steht in einem schreienden Widerspruch zu seinen Zeitforderungen. Denn wo können wir die Erfahrung dieser gewaltigen Zeiträume machen als in unserer kosmischen Umwelt?"

Bemmelen, Reinout Willem van, 1952, Prognose en diagnose in de geologie: Geol. en Mijnbouw, vol. 14, pp. 401-409. "Die natuurwetenschap veklaart nimmer; zij beschrijft de natuur in symbolische termen . . ."

Bernal, J. D., 1961, Origin of life on the shores of the ocean; physical and chemical conditions determining first appearance of biological processes, pp. 95-118 *in* Sears, Mary, ed., Oceanography: Am. Assoc. Adv. Sci., Pub. 67, xi and 654 pp. "The general principles I have tried to use in working out the origin of life are those which have been used with success in all the previous attempts at establishing *origins* at different levels of organization from galaxies to human societies. The first of these is essentially the same as the uniformitarian principle used . . . by Lyell . . ."

Betz, Frederick, Jr., 1963, Geologic communication, pp. 193-217 *in* Albritton, Claude C. Jr., ed., The fabric of geology: Reading, Mass., Addison-Wesley, x and 372 pp. "Perhaps the best way for scientists to attack the 'information problem' is to become more expert with the tools of communication, which we often use indiscriminately and badly."

Bradley, Wilmot Hyde, 1963, Geologic laws, pp. 12-23 *in* Albritton, Claude C., Jr., ed., The fabric of geology: Reading, Mass., Addison-Wesley, x and 372 pp. "Some day we may grow old and have more laws; right now we are busy exploring, experimenting, and trying to understand more of the 'how' of those processes that have produced the features of the earth, its crust beneath, and all it contains."

Breddin, Hans, 1962, Die naturwissenschaftliche Methodik in der Geologie: Geologische Mitteilungen (Aachen), vol. 3, no. 1, pp. 23-32. "Die naturwissenschaftliche Methodik—basierend auf

Chemie, Physik und Mathematik—spielt für die Geologie . . . eine besondere Rolle."

Brouwer, Aart, 1962, Past and present in sedimentology: Sedimentology, vol. 1, no. 1, pp. 2-6. "There is no apparent reason to suppose that ancient causes differed from present ones, but the tectonical and morphological state of the earth, in short its whole physiognomy, is constantly changing."

Brown, Bahngrell Walter, 1964, The influence of Avicenna and geology on philosophy: Southern Quarterly, vol. 2, no. 3, pp. 179-189. ". . . the practice of geological, mineralogical, and metallurgical arts in Avicenna's Arabia widened the philosophic horizons, because these arts demanded a deeper probing of the laws of nature."

Brown, G. Burniston, 1956, Have we abandoned the physical theory of Nature?: Science Progress, vol. 44, no. 176, pp. 619-634. ". . . a recent philosopher of science has declared (that) it is no use even beginning to look at things until you know exactly what you are looking for. . . . The result of this attitude is a great temptation to find what you are looking for."

Brown, Harrison, 1958, The physical sciences, pp. 122-129 *in* Hutchings, Edward, Jr., ed., Frontiers in science: New York, Basic Books, vi and 362 pp. "Stars, like people, are born, live, and die. And the life which is supported by an individual star similarly must one day die."

Cardwell, D. S. L., 1962, Science and technology in the eighteenth century, pp. 30-43 *in* Crombie, A. C. and Hoskin, M. A., eds. History of science; an annual review of literature, research and teaching, vol. 1; Cambridge, W. Heffer and Sons, vii and 133 pp. ". . . we meet with another instance of the cross-fertilization between technology and science in the work of William Smith, the civil engineer whose observations during the course of his professional work led him to make fundamental contributions to the science of palaeontology."

Charlesworth, John Kaye, 1957, The Quaternary Era, with special reference to its glaciation: London, Edward Arnold, 2 vols., 1700 pp. ". . . much of Quaternary geology is still in the stage

of multiple hypotheses, and the fate that has overtaken so many geological fictions awaits some which are widely current or held to be impregnable at the present day."

Chenoweth, Philip Andrew, 1962, Comparison of the ocean floor with the lunar surface: Geol. Soc. Am., B., vol. 73, pp. 199-210. "There are two principal theories of origin of the lunar features—volcanic and meteroritic. Both theories lead to the conclusion that the agent which produced the structures was more active in the past and may have been essentially dormant since the Archeozoic era."

Chorley, Richard J., 1962, Geomorphology and general systems theory: U.S. Geol. Survey, Prof. Paper 500-B, 10 pp. To "operate within an appropriate general systematic framework" is to "increase the scope of the study, make possible correlations and associations which would otherwise be impossible, generally liberalize the whole approach to the subject and, in addition, allow an integration into a wider general conceptual framework."

2. 1963, Diastrophic background to Twentieth Century geomorphological thought: Geol. Soc. Am., B., vol. 74, pp. 953-970. "In the earth sciences . . . the most notable advances are almost invariably associated with the construction of a theoretical model which, in a particularly symmetrical and harmonious manner, seems to embrace a large part of observed reality."

Cloud, Preston Ercelle, Jr., 1961, Paleobiogeography of the marine realm, pp. 151-200 *in* Sears, Mary, ed., Oceanography: Am. Assoc. Adv. Sci., Pub. 67, xi and 654 pp. "Uniformitarianism is not to be confused with gradualism, or thought of as properly incorporating purely static analogy, a misconception that has led to uncritical rejection of this fundamental operational principle, without which geology cannot be thought of in scientific terms. It does not exclude catastrophic processes or unusual events, but only *ad hoc* reasoning."

Coleman, William, 1962, Lyell and the "reality" of species: Isis, vol. 53, pp. 325-338. "Perhaps Darwin himself gained his first acquaintance with the principle of selection, although not, of course, selection as a creative process, from reading Lyell . . ."

Conant, James Bryant, 1951, The study of the past, Chapt. 10, pp. 258-259, *in* Science and common sense: New Haven, Yale Univ. Press, xii and 371 pp. "Geology expounded as earth history almost invariably takes on a dogmatic cast."

Daber, Rudolf, 1963, Beispiele für paläontologische Gesetze und gesetzmässige Erscheinungen: Wiss. Zs. Humboldt-Universität (Berlin), vol. 12, no. 3, pp. 451-452. "Der Schritt zum Indeterminismus einerseits, aber auch zum Vitalismus andererseits ist für viele Paläontologen sehr nah."

de Beer, *Sir* Gavin, 1964, The world of an evolutionist (Essay review of George Gaylord Simpson's "This view of life":) Science, vol. 143, no. 3612, pp. 1311-1317. "The last word on the credibility and course of evolution lies with the paleontologists."

Durham, John Wyatt, 1959, Palaeoclimates, pp. 1-16 *in* Ahrens, L. H.; Press, Frank; Rankama, Kalervo; and Runcorn, S. K., eds., Physics and chemistry of the earth, vol. 3: New York, Pergamon Press, viii and 464 pp. "Inferences about past climates are based on certain assumptions and limitations. The first and most significant of these assumptions is of course the 'Principle of Uniformitarianism' . . ."

Edelman, Nils, 1962, Mathematics and geology: Geol. Fören. Stockholm, Förh., vol. 84, no. 4, pp. 344-349. "Mathematics should be used neither for hiding defects in the primary field observations nor as a loose ornament to give the investigation the appearance of being more exact and more scientific than it really is."

Engel, Albert Edward John, 1963, Geologic evolution of North America: Science, vol. 140, no. 3563, pp. 143-152. "The classic view—that geologic events of the past may be explained by observable, contemporary earth processes and products—requires some modification. The formation of the earth 4.5 billion years ago was a cataclysmic event. So in lesser degree may have been the formation of a first granitic crust."

Fairbridge, Rhodes Whitmore, 1961, Eustatic changes in sea level, pp. 99-185 *in* Ahrens, L. H.; Press, Frank; Rankama, Kalervo; and Runcorn, S. K., eds., Physics and chemistry of the earth,

vol. 4: New York, Pergamon Press, 317 pp. ". . . since for geologists the Lyellian philosophy that the present is the key to the past is one of the fundamental tenets, it is highly desirable to study such contemporary processes as sedimentation and erosion."

Feuer, Lewis Samuel, 1963, The scientific intellectual; the psychological and sociological origins of modern science: New York and London, Basic Books, Inc., xii and 441 pp. "A new species of young scientist is said to be arising in America. He has no use for the hopes of the 'new philosophy' of the seventeenth century. He has no philosophy; a few scraps of managerial ideology suffice for him."

Gilluly, James, 1963, The scientific philosophy of G. K. Gilbert, pp. 218-224 *in* Albritton, Claude C. Jr., ed., The fabric of geology: Reading, Mass., Addison-Wesley, x and 372 pp. ". . . in the nature of geologic evidence, a geologic concept, even if it survives enough tests to have the rank of theory, can never be *proved*. On the other hand, a single definite negation is enough to disqualify it."

Goguel, Jean, 1962, Tectonics (English translation from the French edition of 1952, by Hans E. Thalmann): San Francisco, W. H. Freeman and Co., viii and 384 pp. "As is characteristic of geology in general, tectonics is principally a historic science, inasmuch as its object is the reconstruction of past phenomena."

Goodman, Nelson, ———, Uniformity and simplicity: Geol. Soc. Am., Spec. Paper (in press) ". . . the Principle of Uniformity dissolves into a principle of simplicity that is not peculiar to geology but pervades all science and even daily life."

Green, Jack, 1962, The geosciences applied to lunar exploration, pp. 169-257 *in* Kopal, Zdenek and Mikhailov, Zdenka Kadla, eds., The Moon (Symposium 14, Internat. Astronomical Union): London and New York, Academic Press, xiii and 571 pp. ". . . in order to apply geophysics and geochemistry effectively, one must begin with a geological model."

Gruber, Howard Ernest and Gruber, Valmai, 1962, The eye of reason; Darwin's development during the *Beagle* voyage: Isis,

vol. 53, pp. 186-200. "As a theoretical model . . . Darwin's theory of the formation of coral reefs displays *formal* characteristics strikingly similar to the theory of evolution through natural selection."

Guntau, Martin, 1963, Bemerkungen zum Determinismus in der Geologie: Wiss. Zs. Humboldt-Universität (Berlin), vol. 12, no. 3, pp. 431-434. "Die Forschungsergebnisse der modernen Geologie zeigen jedoch, dass die Entwicklungsgeschichte der Erde nicht in ewig gleichbleibenden Gesetzen gefasst werden kann."

Hagner, Arthur Feodor, 1963, Philosophical aspects of the geological sciences, pp. 233-241 *in* Albritton, Claude C. Jr., ed., The fabric of geology: Reading, Mass., Addison-Wesley, x and 372 pp. "Because geology rests in part on physics, chemistry, and biology, in addition to being a science in its own right, the geologist is in an excellent position to appreciate attempts to unify science and to contribute to them."

Haldane, John Burdon Sanderson, 1956, Time in biology: Science Progress, vol. 44, no. 175, pp. 385-402. "Only the Hindus among pre-scientific thinkers had dared to postulate stretches of time comparable to those revealed by geology, and for this reason . . . the emotional attitude to the universe resulting from . . . an acceptance (of the length of geologic time) will in some respects resemble the Hindu attitude."

Hamilton, Edwin Lee, 1961, Stratigraphy of the deep-sea floor, pp. 51-84 *in* Sears, Mary, ed., Oceanography: Am. Assoc. Adv. Sci., Pub. 67, xi and 654 pp. ". . . the study of the stratigraphy of the deep-sea floor will yield the last, missing data which will permit the writing of a first valid geologic history of the whole world."

Hanson, Norwood Russell, 1963, Some philosophical aspects of contemporary cosmologies, pp. 465-482 *in* Baumrin, Bernard, ed., Philosophy of science; Delaware Seminar, vol. 2 (1962-63): New York, Interscience Publishers, xviii and 551 pp. "The creation of the universe is, in any physically intelligible context, tantamount to the creation of Time—since in the absence of physical processes there is (simply and dogmatically) no such thing as Time."

Harrison, James Merritt, 1963, Nature and significance of geological maps, pp. 225-232 *in* Albritton, Claude C., Jr., ed., The fabric of geology: Reading, Mass., Addison-Wesley, x and 372 pp. ". . . the geological map, although in part objective and a record of actual facts, is also to a very large degree subjective, because it also presents the geologist's *interpretation* of these facts and his observations."

Hawkins, Herbert Leader, 1934, Fossils and men: South-East. Naturalist and Antiquary, vol. 39, pp. 1-13. ". . . the only true rigidity in the organic world is '*rigor mortis*'."

Hedberg, Hollis Dow, 1961, The stratigraphic panorama; an inquiry into the bases for age determination and age classification of the Earth's rock strata: Geol. Soc. Am., B., vol. 72, pp. 499-518. ". . . when we fully know the crust of our earth, both on the continents and under the oceans, the chances are that in one place or another the gaps in the rock record will be filled."

Hill, Mason Lowell, 1963, Role of classification in geology, pp. 164-174 *in* Albritton, Claude C., Jr., ed., The fabric of geology: Reading, Mass., Addison-Wesley, x and 372 pp. "To stimulate advancements in their science, geologists must be as willing to revise their classifications as they are to make new observations and new interpretations."

Hölder, Helmut, 1962, Geologie als historische Naturwissenschaft: Geologische Mitteilungen (Aachen), vol. 3, no. 1, pp. 11-21. "Wenn wir . . . heute, wie vermutlich in langen Zeiten der Erdgeschichte, kein irdisches Eis hätten, so wäre auch die Enträtselung der glazialen Erscheinungen des Quartärs auf dem üblichen aktualistischen Wege nicht möglich."

Hubbert, Marion King, 1963, Are we retrogressing in science?: Geol. Soc. Am., B., vol. 74, pp. 365-378. ". . . we appear to have lost sight of our intellectual foundations and to have reverted to authoritarianism."

Hull, Lewis William Halsey, 1959, History and philosophy of science; an introduction: London; Longmans, Green, xi and 340 pp. "The really reliable evidence of great change in the past is geological: we can only shrewdly guess that the Galaxy was

once a cloud of incandescent gas; but we can scarcely doubt that the earth itself is very different from what it was once."

Hutchison, Eric, 1964, Science and responsibility: Am. Scientist, vol. 52, no. 1, pp. 40A-50A. "Only the most bigoted scientists would assert . . . that the natural historian and the field naturalist do not carry out perfectly *scientific* activities, even though these latter scientists have little to do with pointer readings."

Hutten, Ernest Hirschlaff, 1962, The origins of science; an inquiry into the foundations of western thought: London, George Allen and Unwin, 238 pp. "Every theory must contain some error if it is to be true. If it did not, it would be impossible to correct it by later experience and more advanced theories. Such a theory would . . . belong to a closed system. It would be a pseudotheory, constructed as a defense against paranoid anxieties."

Huxley, *Sir* Julian Sorrell, 1963, The human crisis: Seattle, Univ. Washington Press, 88 pp. "Scientific laws and philosophical ideas, religions and moral codes are man-made products and evolve like everything else."

Huxley, Thomas Henry, 1897, Geological reform, Chapt. 10, pp. 305-339 *in* Discourses biological and geological, vol. 8: New York, D. Appleton and Co., xv and 388 pp. "The attempt to limit, at a particular point, the progress of inductive and deductive reasoning from the things which are, to those which were—this faithlessness to its own logic, seems to me to have cost Uniformitarianism the place, as the permanent form of geological speculation, which it might otherwise have held."

Imbrie, John, 1956, Biometrical methods in the study of invertebrate fossils: Am. Mus. Nat. Hist., B., vol. 108, art. 2, pp. 211-252. ". . . every species description is an act of faith based on the assumption that from the characteristics of the specimens actually at hand it is possible to draw useful inferences concerning the original population."

Jobert, Antoine Claude Gabriel, 1847, The philosophy of geology, 2d ed.: London; Simpkin, Marshall and Co.; Paris, A. and W. Galignani and Co., xiv and 184 pp. ". . . in examining the

phenomena of the established order, science has discovered monuments of the past, hitherto unknown or misunderstood, and . . . has begun to reconstruct the series of events which have succeeded each other on the earth, ascending from monuments to monuments, until it has reached the limits of a beginning and a creation, as taught *à priori* by the cosmogonic annals of all nations."

Jourdain, Philip Edward Bertrand, 1919, The logical significance of "Ockham's Razor": Monist, vol. 29, pp. 450-451. ". . . the principle of parsimony appears . . . to be simply the maxim that logical analysis is to be carried as far as possible; and this is no more than Dedekind's maxim that what *can* be proved *is* to be proved."

Kaiser, H. E., 1962, Beispiele für die Anwendung und Grenzen aktualistischer Betrachtungsweise in der Geologie: Acta Biotheoretica, vol. 14, pp. 99-120. "Der Aktualismus ist die vergleichende Methode, die es erlaubt, gewisse Vorgänge der Erdvergangenheit durch Beobachtungen der Gegenwart nachzuprüfen und zu erklären."

Kirk, Edwin, 1928, Fossil marine faunas as indicators of climatic conditions: Smithsonian Inst., Ann. Rept., 1927, pp. 299-307. "We may now fairly ask the question whether marine animals are dependable indicators of the climates of the past. I think this can safely be answered in the negative."

Kitts, David B., 1963, The theory of geology, pp. 49-68 *in* Albritton, Claude C., Jr., ed., The fabric of geology: Reading, Mass., Addison-Wesley, x and 372 pp. "The theory of geology is . . . the theory of physics and chemistry. The geologist, however, unlike the chemist and the physicist, regards this theory as an instrument of historical inference."

Kuhn, Thomas Samuel, 1962, The structure of scientific revolutions: Chicago, Univ. Chicago Press, xv and 172 pp. "Scientific education makes use of no equivalent for the art museum or the library of classics, and the result is a sometimes drastic distortion in the scientist's perception of his discipline's past."

Legget, Robert Ferguson, 1963, Geology in the service of man, pp.

242-261 *in* Albritton, Claude C., Jr., ed., The fabric of geology: Reading, Mass., Addison-Wesley, x and 372 pp. "It is exceedingly clear . . . that geology will be applied in the works of the engineer in steadily increasing measure as far into the future as the mind can foresee."

Leopold, Luna Bergere and Langbein, Walter Basil, 1963, Association and indeterminacy in geomorphology, pp. 184-192 *in* Albritton, Claude C., Jr., ed., The fabric of geology: Reading, Mass., Addison-Wesley, x and 372 pp. "General physical laws are necessary but not sufficient to determine the exact shape of each land form."

Liebenberg, W. R., 1961, Forensic mineralogy, with special reference to the Erfdeel inquiry: Geol. Soc. S. Africa, Pr., vol. 64, pp. ix-lviii. Describes the scope and methodology of forensic mineralogy.

Lindsay, Robert Bruce, 1963, The role of science in civilization: New York, Harper and Row, ix and 318 pp. ". . . if history as a whole is an ingredient of culture in our civilization, the story of the evolution of science is an essential component and its absence necessarily leads to distortion."

Lowther, Gordon R., 1962, Epistemology and archaeological theory (with discussion): Current Anthropology, vol. 3, no. 5, pp. 495-509. "Now, 'explanation' can only be explanations of relations; phenomena, if discretely identified, are not 'explained.' It would be invalid to ask that, for example, an artifact be explained."

Lyell, *Sir* Charles, 1881, Life letters and journals of Sir Charles Lyell, Bart. (Edited by his sister-in-law, Mrs. Lyell): London, John Murray, 2 vols. "The difficulty which men have of conceiving the aggregate effects of causes which have operated throughout millions of years, far exceeds all other sources of prejudice in geology, and is yet the most unphilosophical of all." (Lyell to Whewell, March 7, 1837.)

McIntyre, Donald B., 1963, James Hutton and the philosophy of geology, pp. 1-11 *in* Albritton, Claude C., Jr., ed., The fabric of geology: Reading, Mass., Addison-Wesley, x and 372 pp.

"Analogy of microcosm and macrocosm, analogy of celestial spheres and atmosphere, analogy of heart and sun, analogy of blood and rain: this is the heredity of Hutton's Theory—of our theory."

2. 1963, Precision and resolution in geochronometry, *Op. cit.*, pp. 112-134. "Geology is rapidly becoming quantitative and it seems worth while to draw attention to the importance of presenting data so that the precision of measurement is clear, for it is this precision that determines the resolving power and hence, in large measure, the utility of the method."

McKelvey, Vincent Ellis, 1963, Geology as the study of complex natural experiments, pp. 69-74 *in* Albritton, Claude C., Jr., ed., The fabric of geology: Reading, Mass., Addison-Wesley, x and 372 pp. "Geology offers almost unique opportunity to observe the results of processes that not only involve interplay of more variables and larger masses than can be handled in the laboratory, but that also extend over much greater periods of time and hence reveal the effects of reactions too slow to observe under ordinary conditions."

McKenzie, Arthur Edward Ellard, 1960, The major achievements of science: Cambridge, Cambridge Univ. Press, vol. 1, xvi and 368 pp. "Geological facts were beginning to outrun theory, and the time was ripe for some comprehensive principle to co-ordinate them. Hutton provided the principle, whose importance in geology is comparable with that of evolution in biology: 'the present is the key to the past'."

Mackin, Joseph Hoover, 1963, Rational and empirical methods of investigations in geology, pp. 135-163 *in* Albritton, Claude C., Jr., ed., The fabric of geology: Reading, Mass., Addison-Wesley, x and 372 pp. ". . . if the objective is an understanding of the system investigated, and if that system is complex, then the empirical method is apt to be less efficient than the rational method."

Malik, S. C., 1962, Comments on "Epistemology and archaeological theory," by Gordon R. Lowther: Current Anthropology, vol. 3, no. 5, pp. 506-507. "In any inductive argument one statement

about the past is used to justify another; but still there are no independent means of justifying them all."

Mantell, Gideon Algernon, 1839, The wonders of geology, 1st American ed: New Haven, A. H. Maltby; London, Relfe and Fletcher, 2 vols. "What, then, is the result of our inquiry into the ancient state of our globe?—That, so far as our present knowledge extends, all the changes produced by mechanical, chemical, or vital agency . . . have been taking place from the earliest periods revealed by geological research; and, as like causes must produce like effects, will continue to take place so long as the present material system shall endure."

Mead, Hunter, 1958, Science and society, pp. 214-221 *in* Hutchings, Edward, Jr., Frontiers in science: New York, Basic Books, vi and 362 pp. ". . . the narrow, strictly technical view of the philosophy of science will be broadened, or else a new field will come into existence (perhaps called 'Science and Society,' or 'The Sociology of Science')."

Merrill, George Perkins, 1924, The development of the glacial hypothesis, Chapt. 13, pp. 615-642 *in* Merrill, George Perkins, The first one hundred years of American geology: New Haven, Yale Univ. Press, xxi and 773 pp. "His (Louis Agassiz's) method of procedure . . . consisted in applying what one of our prominent geologists has slightingly referred to as the principle of prolonging the harmless and undestructive rate of geological change of today backward into the deep past."

Moore, John Alexander, 1962, The development of evolutionary thought: Univ. Kansas Sci. B., Supp., vol. 42, pp. 33-43. ". . . Darwin was much closer to the truth than he had any right to be . . . only a genius could have analyzed in so penetrating a manner the meager amount of data available in 1858."

Moore, Leslie Rowsell, 1950, Geology and man (Inaugural Lecture delivered May 3, 1950): Sheffield Univ., 17 pp. "The human mind shows an instinctive parsimony in matters where time is concerned, and it is doubtful whether any other simple fact has so retarded the acceptance of the results of geological science."

Moore, Raymond Cecil, 1952, Orthography as a factor in stability of stratigraphic nomenclature: Geol. Survey Kansas, B. 96, pt. 9, pp. 363-372. Rules are given for procedure judged best suited for stabilizing stratigraphic nomenclature.

Newell, Norman Dennis, 1963, Crises in the history of life: Sci. American, vol. 208, pp. 77-92.

2. ———, Revolutions in the history of life: Geol. Soc. Am., Spec. Paper (in press). "There is nothing in the record to give support to catastrophism, as Cuvier understood it, nor to the uniformitarianism of Lyell which emphasized slow and uniform instead of episodic changes. Yet the record of past revolutions in the animal kingdom is understandable by application of basic principles of modern science. In this sense, the present is the key to the past."

Newmark, Philip, 1962, Biochemical evolution: Univ. Kansas Sci. B., Supp. vol. 42, pp. 99-111. "It would appear that—at least during the billion or two years of the fossil record—nature has been obtaining all the diverse proteins from the same group of 20 to 25 amino acids."

Nicol, David, 1958, Taxonomy versus stratigraphy: J. Washington Acad. Sci., vol. 48, no. 4 pp. 113-114. "Nomenclatural designations should serve to clarify, not obscure, taxonomic relationships, and the practical needs of stratigraphers should in no way hinder this goal."

Oakeshott, Michael Joseph, 1933, Experience and its modes: London, Cambridge Univ. Press, viii and 359 pp. "The 'uniformity of nature' is not established by observation, it is not even an hypothesis to be verified, it is, for scientific experience, a postulate, a *conditio sine qua non* of scientific thought. Uniformity is secured to nature by definition."

Oparin, Aleksandr Ivanovich, 1961, Origin of life in the oceans, pp. 119-128 *in* Sears, Mary, ed., Oceanography: Am. Assoc. Adv. Sci., Pub. 67, xi and 654 pp. ". . . many of the phenomena which took place in the past do not now occur, but new processes have arisen which did not exist on the surface of the lifeless earth."

Pompeckj, Josef Felix, 1928, Is the earth growing old?: Smithsonian Inst., Ann. Rept., 1927, pp. 255-270. "Into whatever class of geological activity we probe, in no case are we led to the conclusion that evidence from the expressed movements indicates an on-coming senility of the earth."

Pospelov, G. L., 1960, O kharaktere geologii kak nauki i ee meste v estestvoznanii (Geology as a science and its position among other sciences): Akad. Nauk, Isv., S.S.S.R., Geol. Ser., 11, pp. 3-19. To the criticisms that geologic generalizations are temporally and geographically limited (making geology more historical and descriptive than mathematical and logical), and that the twentieth century has added nothing to geological principles, the author counters that information originating in the more exact sciences of physics and chemistry must be interpreted geologically before it can be applied to geological problems, and that in the twentieth century the method of actualism has been supplemented by a new historic concept—the principle of spiralling evolution.

Prestwich, Joseph, 1895, Collected papers on some controverted questions of geology: London and New York, Macmillan, xi and 279 pp. ". . . we would not for a moment contend that the forces of erosion, the modes of sedimentation, and the methods of motion, are not the same in *kind* as they have ever been, but we can never admit that they have always been the same in *degree*. The physical laws are permanent; but the effects are conditional and changing, in accordance with the conditions under which the law is exhibited."

Quine, Willard van Orman, 1963, On simple theories of a complex world: Synthese, vol. 15, no. 1, pp. 103-106. ". . . the maxim of the uniformity of nature is of a piece with" the maxim of the simplicity of nature, "uniformity being a species of simplicity."

Rodgers, John, 1950, The nomenclature and classification of sedimentary rocks: Am. J. Sci., vol. 248, pp. 297-311. "Classifications of sedimentary rocks serve a number of purposes, and no one can serve all; we need both descriptive and genetic classifications, but the need for the former is at present the greater."

Roller, Duane Henry Du Bose, 1963, Galileo and modern science: Texas J. Sci., vol. 15, no. 4, pp. 365-380. "Modern historical studies seem to be steadily denying the importance of the accumulation of data by scientists who engage in significant scientific work. In case after case . . . vast amounts of data have *failed* to produce scientific advances, in case after case major discoveries have been produced with nearly no data collecting."

Romer, Alfred Sherwood, 1962, Darwin and paleontology: Univ. Kansas Sci. B., Supp., vol. 42, pp. 53-61. ". . . work in paleontology without belief in evolution is unthinkable."

Rudwick, M. J. S., 1962, The principle of uniformity (essay review of "Natural law and divine miracle," by Reijer Hooykaas), pp. 82-86 *in* Crombie, A. C. and Hoskin, M. A., eds., History of science; an annual review of literature, research and teaching, vol. 1: Cambridge, W. Heffer and Sons, vii and 133 pp. "It is generally acknowledged that geology provided an essential background to evolutionary theory, and that the enormously lengthened time-scale which it postulated has had a profound effect on thought in general. Yet most books on the history of science give it the most perfunctory treatment . . ."

Rutten, Martin Gerard, 1953, Topographie sous-marine et sedimentation actuelle: Internat. Geol. Cong., 19th, Algiers, sec. 4, fasc. 4 pp. 119-125.

2. 1954, Continental origin of fossil salt layers: Geol. en Mijnbouw, vol. 16, pp. 61-68. Illustrates the use of natural models in the reconstruction of geologic history.
3. 1957, Remarks on the genesis of flints: Am. J. Sci., vol. 255, pp. 432-439. ". . . actualism does not mean that processes now active have always been as active in geological history. Also, processes, possible now, but relatively inactive, might have been far more active formerly."
3. 1962, Strata, movement and time—a dialogue: Cong. Avanc. Études Stratig. et Géol. Carbonifère, 4th, Heerlen, C. R. vol. 3, pp. 603-608. "One might safely say that the stratigrapher likes facts best, the tectonician theories."

Sandage, Allan, 1958, The birth and death of a star, pp. 188-199 *in* Hutchings, Edward, Jr., ed., Frontiers in science: New York,

Basic Books, vi and 362 pp. "We on this planet are lucky. The rate of aging of our sun is slow. We have another 6 billion years to live."

Schlesinger, George, 1963, Method in the physical sciences: New York, Humanities Press, vii and 140 pp. An analysis of supplementary principles within science, *e.g.*, the principles of simplicity, microreduction, connectivity, and verification.

Schwarzbach, Martin, 1963, Climates of the past; an introduction to paleoclimatology: London, D. Van Nostrand, xii and 328 pp. "Throughout the history of paleoclimatology, there has never been a proper balance between observation and hypothesis."

Scott, G. H., 1963, Uniformitarianism, the uniformity of Nature, and paleoecology: New Zealand J. Geol. and Geophys., vol. 6, no. 4, pp. 510-527. ". . . the possibility of doing paleoecological research does not depend upon the present being the key to the past."

Semper, Max, 1914, Die geologischen Studien Goethes, Beiträge zur Biographie Goethes und zur Geschichte und Methodenlehre der Geologie: Leipzig, Veit and Co., xii and 389 pp.

Shantser, Ye. V., 1961, Contemporary geology and its place in the natural sciences: Akad. Nauk, SSSR, Ser. Geol., 1961, no. 10, pp. 14-21 (English trans., Am. Geol. Inst.) "For geologists the mere framework of the earth's crust is too narrow; already the subject of geology includes the structure and development of the globe as a whole."

Shoemaker, Eugene Merle and Hackman, Robert J., 1962, Stratigraphic basis for a lunar time scale, pp. 289-300 *in* Kopal, Zdenek and Mikhailov, Zdenka Kadla, eds., The Moon (Symposium 14, Internat. Astronomical Union): London and New York, Academic Press, xiii and 571 pp. "The geological law of superposition is as valid for the Moon as it is for the Earth . . ."

Sidorenko, A., 1962, Geologie und technischer Fortschritt: Zs. angew. Geol., vol. 8, pp. 561-565. ". . . Wissenschaft und Praxis sind wahrscheinlich nirgends so miteinander verflochten wie in der Geologie."

Simpson, George Gaylord, 1963, Historical science, pp. 24-48 *in* Albritton, Claude C., Jr., ed., The fabric of geology: Reading, Mass., Addison-Wesley, x and 372 pp. "Historical science may . . . be defined as the determination of configurational sequences, their explanation, and the testing of such sequences and explanations."

2. 1964, This view of life—the world of an evolutionist: New York; Harcourt, Brace and World, ix and 308 pp. "Biology . . . is the science that stands at the center of all science. . . . And it is here, in the field where all the principles of all the sciences are embodied, that science can truly become unified."

Sokal, Robert Reuven, 1962, Some stages in the development of the concept of natural selection: Univ. Kansas Sci. B., Supp. vol. 42, pp. 129-151. ". . . now, as 50 years ago and also in the time of Darwin, the preponderance of the evidence is deductive rather than observational."

2. 1963, (and Sneath, Peter Henry Andrews), Principles of numerical taxonomy: San Francisco, W. H. Freeman, xvi and 359 pp. "In paleontological studies, the importance of exact and numerical methods is even greater than it is with living material, since in extinct forms there can be no appeal to genetic data . . ."

Spaulding, Albert Clanton, 1962, Comments on "Epistemology and archaeological theory," by Gordon R. Lowther: Current Anthropology, vol. 3, no. 5, pp. 507-508. "We do indeed see the world through a glass darkly; the view is distorted and sometimes obscured by our own reflections, but nevertheless we can see something and we can verify our observations with greater or lesser credibility by comparing them with those of others."

Tikhomirov, V. V., 1963, Some laws in the development of science, based on an analysis of geology during the first half of the Nineteenth Century: Archives internationales d'Histoire des Sciences, vol. 16, no. 63, pp. 143-153. ". . . the development of science is a directed process, which follows definite laws . . ."

Tomkeieff, Sergei Ivanovich, 1963, Unconformity — an historical study: Geologists' Assoc., London, Pr., vol. 73, pt. 4, pp. 383-

417. Traces the history of the idea of unconformity. Four types of unconformity are recognized: angular, parallel, non-depositional, and heterolithic.

Toulmin, Stephen Edelston, 1962, Historical inference in science: geology as a model for cosmology: Monist, vol. 47, no. 1, pp. 142-158. ". . . it could . . . be argued that a fully-fledged science must display a proper grasp of the historical development of its subject matter, and succeed in demonstrating how this has evolved down the ages. Using this criterion, we shall end up by ordering the sciences differently: by this standard, geology came of age first, zoology second, and the physical sciences have been 'growing up' only during the twentieth century."

2. 1963, The discovery of time: Manchester Lit. and Phil. Soc., Mem. and Pr., vol. 105 (1962-63), pp. 100-112. ". . . this drastic expansion of our time-scale constitutes as dramatic and significant an intellectual revolution as the earlier expansion of Man's ideas about the size and layout of the universe."

Weaver, Warren, 1964, Scientific explanation: Science, vol. 143, no. 3612, pp. 1297-1300. "Why is it that the universe furnishes so many paired instances of useful isomorphism as long as the scale of events lies, roughly, between 10^{-8} centimeter and a few hundred thousand light years but recedes into completely special and unique abstractness when the scale is roughly 10^{-13} centimeter or smaller or is as large, say, as a billion light years?"

White, John Francis, 1962, The study of the Earth, pp. 1-9 *in* John Francis White, ed., Study of the Earth; readings in geological science: Englewood Cliffs, N. J., Prentice-Hall, viii and 408 pp.

White, Walter Stanley and Wright, James Clifton, 1954, The White Pine copper deposit, Ontonagon County, Michigan: Econ. Geol., vol. 49, no. 7, pp. 675-716. The principle of simplicity is used in making a choice among rival theories of copper deposition. See pp. 714-715.

2. 1960, The White Pine copper deposit: Econ. Geol., vol. 55, pp. 402-409. ". . . Dr. Sales seems to argue . . . . that an explanation that is simple and understandable is ipso facto more credible. The merits of associating simplicity and credibility are certainly dubious."

Williams, L. Pierce, 1962, The physical sciences in the first half of the nineteenth century: problems and sources; pp. 1-15 *in* Crombie, A. C. and Hoskin, M. A., eds., History of science; an annual review of literature, research and teaching, vol. 1: Cambridge, W. Heffer and Sons, vii and 133 pp. "There exists . . . a singular hypocrisy in the writings of the nineteenth century men of science. The origins of the new scientific ideas are attributed to induction from factual observations whereas, in many cases, they really arose from flights of speculative fancy entirely worthy of the epithet 'poetic'."

Wilson, Albert George, 1958, Astronomy and eschatology; what the astronomer finds when he studies the cosmic disasters which could end the existence of mankind, pp. 205-213 *in* Hutchings, Edward, Jr., Frontiers in science: New York, Basic Books, vi and 362 pp. ". . . the modern Jeremiahs and Daniels . . . do not get their source material from handwriting on walls, but from the data science has accumulated concerning the evolutionary processes of stars, rocks, and living organisms."

Wilson, Edgar Bright, 1952, An introduction to scientific research: New York, McGraw-Hill, xi and 375 pp. "Prediction and control are important aims of science. This is true even in such sciences as geology, where little can be done at present to control the larger forces molding the earth, but where progress is being made in learning to predict their consequences."

Wilson, Leonard Gilchrist, ———, The origins of Charles Lyell's uniformitarianism: Geol. Soc. Am., Spec. Paper (in press). ". . . while the assumption of uniformity made it imperative for the geologist to look closely at geological evidence, it was also an assumption which was indispensable if geological evidence were to have any meaning. It was the *sine qua non* without which geology could not be a science."

Wilson, Robert Warren, 1962, The significance of the geological succession of organic beings, 1859-1959: Univ. Kansas Sci. B., Supp. vol. 42, pp. 157-178. ". . . although an ordered succession of fossils would not necessarily prove descent with modification, a completely random record in an orderly succession of rock layers would disprove it."

Woodford, Alfred Oswald, 1963, Correlation by fossils, pp. 75-111 *in* Albritton, Claude C., Jr., ed., The fabric of geology: Reading, Mass., Addison-Wesley, x and 372 pp. "The fossils of the units in the standard column and of other units in other columns are still our principal guides in stratigraphic correlation, although we cordially welcome the statistical calibration of the standard column, in years, from radiometric data."

Young, Keith, 1960, Biostratigraphy and the new paleontology: J. Paleont., vol. 34, no. 2, pp. 347-358.

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