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EARTH SCIENCE IN THE SCIENTIFIC REVOLUTION 1600-1728

by

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SUMMARY

Although recent historians of Earth science have attempted to show that the geological achievements of the seventeenth century provided the basis for the nineteenth-century development of geology, they have tended to regard seventeenth-century ideas mainly as constructive elements in the preparation of the nineteenth century's approach to the Earth and have failed to treat them as being legitimate in their own right. My approach here is different from my predecessors not only in that I end my arguments by the mid-eighteenth century but also in that I attempt to illuminate the development of Earth science in seventeenth-century England as an integral part of the Scientific Revolution. Standard textbooks on the Scientific Revolution have discussed the development of physics, chemistry and biology, but not Earth science. This thesis discusses an aspect of the Scientific Revolution which has not previously been fully recognized.

In the early seventeenth century the study of the Earth was not a distinctive discipline, but the formation of the Royal Society of London later in the century provided a forum where different approaches to the Earth could come into contact. The Society's plan for natural history facilitated the introduction of each programme, and eventually, by the mid-eighteenth century, created a basis for geology. I suggest here that the "internal" development of Earth science was conditioned by "external" factors such as the formation

of the Royal Society and the ensuing interaction between scientists. I challenge the internalist historian's conviction that the "internal" development of science is autonomous and absolute. I even claim that the large-scale pursuit of Earth science was stimulated and motivated by "cultural values". Unlike the externalists, however, I do not intend to show any relation between the science and the value-orientation of a society as a whole, because such an approach does not explain why conflicts at various levels occurred within a scientific community and eventually created a basis for geology. Therefore, this thesis is an attempt to synthesize the "internal" and "external" approaches to the history of science.

PREFACE

My research into the history of Earth science originates from the suggestion of Dr. A.C. Crombie, Trinity College, Oxford, to write a biography of Thomas Burnet. Because of lack of sources, however, I have found it difficult to acquire further information on Burnet himself, and consequently I have extended my research into other fields. In the course of my work Professor R.S. Westfall, Indiana University, advised me to consider the influence of Robert Hooke on his contemporaries, and I have realized that the activities of Hooke may not be ignored even in the development of Earth science. It is, however, Professor R.W. Home who has supervised almost all my research. His weekly supervision has been the best a student could ever hope for. I have been financially supported by a Melbourne University Postgraduate Scholarship and a Grant-in-Aid which made it possible to conduct my research in Britain and Ireland in 1982.

I owe so much of my training as a geologist to the late Professor Kotora Hatanaka, Professor Shin Kitamura and Professor Tamio Kotaka, and as a historian to Professor Nobuyoshi Kito and the late Professor Kwan Chiyoda. I was stimulated to study the history of science by Professor Masao Watanabe, Niigata University, Professor Shuntaro Ito, Tokyo University, Professor Zenji Suzuki, Yamaguchi University and Professor Masakazu Yoshinaka, Tohoku University.

In writing the thesis I have benefited from the help of variuos people. Hazel Maxian translated, from Latin, a part of Burnet's <u>Telluris Theoria Sacra</u> (1681). Maria

Dominguez-Ridley translated, from French, sections of Descartes' Philosophiae Princiae and most of Leibniz' Protogaea, and read and corrected an early draft of the thesis. Her excellent English has been a great help to me. Many people read parts of this thesis, and I should like to thank Professor J. Ben-David, University of Chicago, Professor G.L. Davies, Trinity College, Dublin, Dr. H. Le Grand, University of Melbourne, Dr. D.R. Oldroyd, University of New South Wales, Dr. R. Porter, Wellcome Institute for the History of Medicine, London, R. Ridley, University of Melbourne, and Professor K.L. Taylor, University of Oklahoma, for comments and offering bibliographical advice. I am deeply indebted to Ingred Barker for a splendid typing of the final draft. My wife has aided and sustained me through various labours.

The staffs of many libraries have assisted me, especially those of Baillieu Library, Melbourne, the State Library of Victoria, the Parliamentary Library of Victoria, the British Library, the Library of the Royal Society of London, Edinburgh University Library, Trinity College Library, Dublin, the Bodleian Library, Oxford, Cambridge University Library and Trinity College Library, Cambridge. I wish to extend my appreciation to the secretaries of the Department of History and Philosophy of Science in the University of Melbourne, especially Valerie Cribbes and Lynne Padgham have assisted me over the last several years.

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INTRODUCTION

Charles Lyell claimed in his Principles of Geology (1830) that the identification of the objects of geology with those of cosmogony had been the most common and serious source of confusion in the science of geology. Referring to James Hutton, Lyell wrote that

> The first who endeavoured to draw a clear line of demarcation between these distinct departments, was Hutton, who declared that geology was in no way concerned "with questions as to the origin of things." ...geology differs as widely from cosmogony, as speculations concerning the creation of man differ from history.[1]

Lyell declared that geology is the science which investigates the successive changes that have taken place in the organic and inorganic kingdoms of nature. In tracing the history of geology from the close of the seventeenth to the end of the eighteenth century, however, he claimed that we must expect to be occupied with accounts of the retardation, as well as the advance of the science:

> A sketch of the progress of Geology is the history of a constant and violent struggle between new opinions and ancient doctrines, sanctioned by the implicit faith of many generations, and supposed to rest on scriptural authority. The inquiry, therefore, although highly interesting to one who studies the philosophy of the human mind, is singularly barren of instruction to him who searches for truths in physical science.[2]

Lyell criticized "the familiar association in the minds of philosophers, in the age of Newton, of questions in physics and divinity",[3] wishing to "free the science from Moses."[4]

Lyell's interpretation of the history of geology before Hutton was long accepted by historians of science. Joseph Needham suggested that the basic principles of Huttonian geology are a notable landmark in the progress of the science.[5] C.C. Gillispie maintained that Hutton was "perhaps the first student of the earth who may properly be called a geologist."[6] Geology, wrote D.B. McIntyre, did not exist prior to Hutton, and "the science was created in the fifty years between 1775 and 1825."[7] F.D. Adams criticized the early theories of the Earth on the ground that they were absurd, and regarded Buffon's theory in his Histoire Naturelle (1749) and Epoques de la Nature (1778) as the end of a long period of imaginative effort.[8] A.H. Hagner claimed that natural philosophy was based more on speculation than observation before James Hutton's Theory of the Earth appeared in 1788, and that it was not until the publication of Lyell's Principles of Geology (1830-33) that the revolution in this science became widespread and effective.[9] All these views dismiss the centuries before Hutton as "unscientific". The development of Earth science had been retarded, so it was said, because ancient cosmogony had placed a major obstacle to the progress of the "scientific" study of the Earth.

Martin J.S. Rudwick has criticized this kind of approach on the grounds that it divides the figures of the past into those who had been correct and those who had been erroneous. "To historians of science today," he has claimed, "this kind of historiography is a dead horse that is no longer worth flogging."[10] Besides Rudwick's Meaning of Fossils (1972), in fact, recent works on the history of Earth science such as Gordon L. Davies' Earth in Decay (1969) and Roy Porter's Making of Geology (1977) have shown that Earth science of the seventeenth century cannot be regarded as entirely fruitless. In tracing the history of British geomorphology, Davies claims that between 1578 and 1878 "geologists were seeking to understand the processes which have given the Earth its present configuration."[11] Rudwick's work contains "episodes" of paleontology from the sixteenth to the nineteenth century. Porter suggests that seventeenth-century achievements contributed to the creation of geology in the nineteenth century.[12]

Davies and Porter, however, tend to treat "geological" activities of the seventeenth century mainly as constructive elements in the preparation of the nineteenth century's approach to the Earth. As a result, they are inclined to consider "geological" activities of the eighteenth century as imperfectly-harmonized mixtures of old and new.[13] A similar interpretation can also be found in Rudwick's work.[14] Such an approach is inherently unsatisfactory, because although seventeenth-century achievements were connected in some ways to the later emergence of geology, they were in fact based upon a fundamentally different outlook. It is not a proper historical attitude to approach the past mainly from the point of view that it provided the grounds for what came afterwards. The former period and its concerns ought to be treated as being legitimate and worthy of study in their own right.

Not only do these recent works on the history of Earth science not fully consider the context of the seventeenth century Scientific Revolution, but also the standard works on the Scientific Revolution dismiss the development of Earth science at that time. In his standard textbook on the Scientific Revolution, Richard S. Westfall discusses the influence of the intellectual revolution on physics, chemistry and biology, but does not refer to the field of Earth science.[15] The neglect of Earth science exemplified in Westfall's work may originate in the fact that the study of the Earth did not have a solid disciplinary identity in the seventeenth century. As Porter has suggested, the study of the Earth was not a distinctive discipline at this stage, but was scattered among various other subjects such as cosmogony, history, cosmography, geography, topography, natural history, chemistry, mineralogy and meteorology.[16] The study of the Earth was not specialized as it is today, and nobody devoted his life entirely to geological research. It does not necessarily follow, however, that Earth science was unattended to and unaffected by the considerable intellectual changes that occurred at this period.

In late seventeenth-century England there appeared some popular geological works such as Thomas Burnet's Sacred Theory of the Earth (1684-89), John Woodward's Essay toward a Natural History of the Earth (1695) and William Whiston's New Theory of the Earth (1696). Even if these works were the first attempts to write the history of the Earth in all its detail, it is not correct to assume that they emerged all of a sudden. On the contrary, they were syntheses of geological ideas and observations that had accumulated during the seventeenth century. On a brief examination one may recognize that various aspects of the Earth were considered by such central figures of the Scientific Revolution as René Descartes, Robert Boyle, Robert Hooke, Christiaan Huygens, Gottfried Wilhelm Leibniz, Edmond Halley and Isaac Newton.[17] It would not be difficult to extend this list, which suggests that the study of the Earth, like other fields of science, was regarded as a topic worthy of discussion in the seventeenth century.

The main purpose of this thesis is to illuminate the development of Earth science in seventeenth-century England, and to show how changes in various intellectual traditions contributed toward the rise of the study of the Earth. I will suggest that there were several different traditions of study of the Earth during the seventeenth century: The cyclic view of the Earth (Chap. 1), the theological view of the Deluge (Chap. 2), the chemical view of the mineral kingdom (Chap. 3), the natural history of the Earth (Chap. 4) and the mechanical view of the Earth (Chap. 6). These separate traditions were brought into contact as a result of the formation of the Royal Society of London. This gave rise to the fossil controversy (Chap. 5) and then the Deluge controversy (Chap. 7). These controversies reached a wider audience and stimulated the study of natural history (Chap. 8), but religious orthodoxy criticized the atheistic implication of the Deluge theory and conditioned the later development of Earth science (Chap. 9). Finally, I will show why Woodward's theory of the Deluge survived and then declined (Chap.10). Thus, this thesis will discuss the relation between the development of geological ideas and "external" factors such as the formation of the Royal Society and cultural milieux. Unlike the works of Davies, Rudwick and Porter, the scope of this thesis ends by the mid-eighteenth century, because the chief centre of geological activity moved from England to the Continent by that time. The rise of geology in the late eighteenth century must be investigated by a thorough consideration of continental geological works,[18] which, I believe, can be done only in another thesis.

The history of science has been studied by two separate traditions: The "internal" approach has been concerned with the substance of science as knowledge and the "external" approach has been concerned with the activity of scientists as a social group within a larger culture.[19] No account that brings together in a fully satisfactory manner the intellectual and sociological factors contributing to the rise of science has yet been achieved. For example, although Westfall has indicated certain sociological aspects of the scientific movement, he keeps his account of these separate from the remainder of his work, believing that "the development of ideas following their own internal logic was the central element in the formation of modern science."[20] Porter has noted the important role of scientific institutions, but he misses the point that the Royal Society provided a forum where different views of the Earth came into productive contact with each other.[21] Although Michael Hunter has suggested that the Royal Society encouraged theoretical diversity, he nevertheless does not admit that its meetings were of scientific importance.[22] All these authors thus treat the "internal" and "external" factors virtually as separate and unrelated.

My challenge here is to synthesize the two approaches for a better understanding of the development of Earth science in the Scientific Revolution, something which has not been fully discussed under the shadow of the "success" stories of other sciences. However, I do not intend to show any relation between the science and the religious ethos of English society as a whole,[23] because such an approach does not help to illuminate the variations and conflicts within the society which eventually gave rise to Earth science in the late seventeenth century.

NOTES

1. Charles Lyell, Principles of Geology, vol. 1 (London, 1830), 4.

2. Ibid., 30.

3. Ibid., 36.

4. Mrs K.M. Lyell, Sir Charles Lyell, Bart., Life, Letters and Journals, ed. by his sister-in-law (London, 1881), 268.

5. Joseph Needham, The Grand Titration (London, 1969), 45.

6. C.C. Gillispie, The Edge of Objectivity (Princeton, 1960), 293.

7. D.B. McIntyre, "James Hutton and the Philosophy of Geology", In C.C. Albritton, ed., The Fabric of Geology (Stanford, 1963), 2.

8. F.D. Adams, The Birth and Development of the Geological Sciences (Dover Publication, 1954), 209-10.

9. A.H. Hagner, "Philosophical Aspect of the Geological Sciences", In C.C. Albritton, ed., The Fabric of Geology, 233-34.

10. Martin J.S. Rudwick, The Meaning of Fossils (London, 1972), Preface.

11. Gordon L. Davies, The Earth in Decay (London, 1969), ix.

12. Roy Porter, The Making of Geology (Cambridge, 1977), 3.

13. Davies, The Earth in Decay, 133; Porter, The Making of Geology, 124.

14. Rudwick, The Meaning of Fossils, 94-95.

15. Richard S. Westfall, The Construction of Modern Science (Cambridge, 1977).

16. Cf. Porter, The Making of Geology, 10-16.

17. René Descartes, Principia Philosophiae (1644); Robert Boyle, An Essay about the Origine and Virtues of Gems (1672); Boyle, Observations about the Growth of Metals in their Ore exposed to the Air (1674); Boyle, General Heads for a Natural History of the Countries (1692); Robert Hooke, Micrographia (1665); The Posthumous Works of Robert Hooke (1705); Christiaan Huygens, The Celestial Worlds discover'd (1698); Gottfried Wilhelm Leibniz, Protogaea (1693); Edmond Halley, "Some Considerations about the Cause of the Universal Deluge", Philosophical Transactions (1694); Isaac Newton, Opticks (1730). As for my observations on these eminent scholars, I must acknowledge my debt to seminars on the history of optics conducted by Prof. R. W. Home in 1979 and of the history of dynamics conducted by him and Visiting Professor R.S. Westfall in 1980, both of which were held in the Department of History and Philosophy of Science, University of Melbourne.

18. Cf. Kenneth L. Taylor, "Nicholas Desmarest and Geology in the Eighteenth Century", In Cecil J. Schneer, ed., Toward a History of Geology (The M.I.T. Press, 1967), 339-56; "Geology in 1776: Some Notes on the Character of an Incipient Science", Two Hundred Years of Geology in America (Hanover: N.H., 1979), 75-79; "Natural Law in Eighteenth-Century Geology: The Case of Louis Bourguet", XIIIth International Congress of the History of Science, Proceedings, VIII (Moscow, 1974); "The beginning of a French geological identity", Histoire et Nature, 19-20 (1981-1982), 65-82. Dr. Roy Porter himself suggested that continental achievements were important to the rise of geology when I visited him at Wellcome Institute for the History of Medicine in London in 1982.

19. Thomas Kuhn, "Science: The History of Science", in the International Encyclopedia of the Social Sciences.

20. Westfall, The Construction of Modern Science, 2

21. Porter, The Making of Geology, 19.

22. Michael Hunter, Science and Society in Restoration England (Cambridge, 1981), 57.

23. Cf. Robert K. Merton, Science, Technology and Society in Seventeenth-Century England (New York, 1970).

1. THE CYCLIC VIEW OF THE EARTH

In his Founders of Geology (1897), Sir Archibald Geikie discussed geological ideas among the ancient Greeks and Romans. While admitting that some sound geological observations had been made by the ancients, he claimed that their fanciful hypothesis had successively been accepted for centuries without any effort to verify it by actual observation of nature.[1] A similar opinion was held by Karl Alfred von Zittel in his History of Geology and Palaeontology (1901). Zittel regarded the ancients' geological speculations and observations as valuable, but concluded that "fanciful hypothesis and disconnected observations cannot be acknowledged as scientific beginnings of research."[2] Referring to Geikie, Frank D. Adams also claimed that "the aim and object of modern geological and palaeontological study was absolutely unknown to the ancients."[3]

Critically considering the works of Geikie, Zittel and Adams, C.E.N. Bromehead attempted to re-evaluate the geological sciences of the ancients and claimed that they were "surprisingly good relative to the contemporary knowledge of the other sciences."[4] He also suggested that the ancients' geological ideas had been rediscovered in the Renaissance and given birth to modern geology.[5] Other recent historians have also shown an awareness of the importance of the ancients' works to the develoment of Earth science. For example, Francis C. Haber has claimed that Aristotle's Meteorologica "was an almost ever-present source for ideas on the nature of change in cosmogony whenever such problems came under consideration in Western thought, and it undoubtedly had an influence on the formulation of uniformitarian views in modern geology."[6] A.C. Crombie has said that the ideas of geologically-oriented works such as Aristotle's Meteorologica, Avicenna's De Mineralibus and Albertus Magnus' De Mineralibus et Rebus Metallicis (c. 1260) were passed on to the seventeenth century.[7] In the sixteenth century, Martin J.S. Rudwick has claimed, "it was not uncommon to accept an Aristotelian view of the ever-changing geography of the globe, with occasional local inundations of purely natural causation."[8] Suzanne Kelly has suggested that Aristotle's idea exerted an influence on geological arguments in the Renaissance.[9] Paisley and Oldroyd, too, have claimed that those who wish to offer a general history of geological ideas should give careful consideration to the ancient doctrines.[10] These recent works have suggested that the ancients' geological ideas were widely held for a very long period and provided an intellectual background to the study of the Earth developed in the seventeenth century.

The Geological Ideas of the Ancients

Although referring to the ancients' ideas, Davies' Earth in Decay, Rudwick's Meaning of Fossils and Porter's Making of Geology have not fully discussed their influence on speculation about the Earth. As will be shown, Aristotle's Meteorologica, Plato's Timaeus and Ovid's Metamorphoses were constant sources of geological knowledge throughout the seventeenth century. Aristotle's Meteologica had various descriptions of geological phenomena. His science, however, while based originally on patient observation, was something more than a collection of scientific observations. It was a philosophical system including metaphysics, ethics and logic. Therefore it was not only a source of scientific information but also a synthesis of human knowledge. According to Aristotelian science, changes occur constantly in nature and these changes are controlled by a final cause. All natural phenomena were regarded as movements directed towards an end. Changes, therefore, in the Earth's surface were analogous to the growth and decay of living creatures.[11]

Comparing the changes in the interior of the Earth with those in animals and plants, Aristotle suggested that the latter grow and decay as a whole whereas the former go on by parts. He recognized that parts of the land had been once under the sea and that parts of the sea floor had been once dry land:

> The same parts of the earth are not always moist or dry, but they change according as rivers come into existence and dry up. And so the relation of land to sea changes too and a place does not always remain land or sea throughout all time, but where there was dry land there comes to be sea, and where there is now sea, there one day comes to be dry land.[12]

Aristotle supposed that these changes followed "some order and cycle". Thus his idea of an interchange of land and sea was harmonized well with his view that nature constantly changes and that "there will be no end to time and the world is eternal."

While Aristotle's geological idea was firmly connected with his wider view of nature, he also had empirical evidence to verify his idea: he regarded the river Nile as a good example of geological changes. He noted that the centre of Egypt, which was located near the coast, was continually becoming drier because of the deposits of the Nile. From such observations he inferred that every river changes its course and that, consequently, the distribution of land and water changes.[13]

Another cyclic phenomenon of the Earth Aristotle discussed was the occurrence of earthquakes and volcanic activities. In his view, the earth is essentially dry, but rain fills it with moisture. Then the heat of the sun warms it and gives rise to wind both externally and internally. The wind inside the earth is the cause of earthquakes. This theory, he claimed, is verified by actual observations in many places:

> It has been known to happen that an earthquake has continued until the wind that caused it burst through the earth into the air and appeared visibly like a hurricane. This happened lately near Heracleia in Pontus and some time past at the island Hiera, one of the group called the Aeolian islands. Here a portion of the earth swelled up and a lump like a mound rose with a noise: finally it burst, and a great wind came out of it and threw up live cinders and ashes which buried

> the neighbouring town of Lipara and reached some of the towns in Italy.[14]

Aristotle noted that earthquakes cause irregularities in the Earth's surface and are often accompanied by volcanic activities which alter the lay of the land. These phenomena repeatedly happen and geological features change in circles, which he thought was supported by empirical evidence.

Plato's Timaeus was another source of the idea that the Earth's surface underwent cyclic change. His description of the "periodic" scourge of the deluge seems to have been based on contemporary stories. In his view, there are "many different calamities to destroy mankind, the greatest of them by fire and water, lesser ones by countless other means." As an example of such destructions, Plato mentioned the myth of Atlantis:

> At a later time there were earthquakes and floods of extraordinary violence, and in a single dreadful day and night all your fighting men were swallowed up by the earth, and the island of Atlantis was similarly swallowed up by the sea and vanished; that is why the sea in that area is to this day impassable to navigation, which is hindered by mud just below the surface, the remains of the sunken island.[15]

Plato thought that such disasters repeatedly arose on the Earth. Even if the story of Atlantis itself were not true, the effects of earthquakes and floods could have been actually observed.

Ovid's Metamorphoses was the other ancient source of geological knowledge which was more than half believed by people in Elizabethan and Stuart England.[16] The main thought in this classical work was that throughout the entire world nothing is constant. In support of this, some kinds of changes to topographical features were enumerated:

> I have seen what once was solid earth now changed into sea, and lands created out of what once was ocean. Seashells lie far away from ocean's waves, and ancient anchors have been found on mountain tops. What was at one time a level plain has become a valley, thanks to the waters flowing down over it, mountains have been washed away by floods, and levelled into plains.[17]

Ovid thus regarded fossil shells as evidence that there had been cyclic interchanges of land and sea. Ovid's conviction that everything comes into being as a transient appearance was supported by observed facts.

Aristotle's Meteorologica, Plato's Timaeus and Ovid's Metamorphoses thus contained "sound" geological arguments, which were also acceptable to the universities of the seventeenth century, judging from the fact that these works were popular textbooks. Mark H. Curtis has examined the educational conditions of Oxford and Cambridge from the late sixteenth to the early seventeenth century, and his extensive work indicates that the study of ancient Greek and Roman works remained dominant in university education during this period.[18] According to P. Allen, the programme of studies in Oxford and Cambridge followed the established medieval pattern, and the classical scientific works prescribed as textbooks were Aristotle's physical, astronomical and biological works, and Plato's Timaeus.[19]

At Cambridge, for example, the mathematics professor had to teach Mela, Pliny, Strabo or Plato in cosmography, and, at least at Clare College, the students read the various works of Aristotle.[20] Before the outbreak of the Civil War the curriculum at Oxford underwent some alterations, which placed classical works in scientific subjects. Sir Henry Savile endowed Chairs of Geometry and Astronomy in Oxford in 1619, and William Sedley endowed a Chair in Natural History in 1612. The Savilian Professors were expected to have drawn "the purer philosophy from the foundations of Aristotle and Plato."[21] The Sedleian Professors were limited by the Laudian Statutes to teach "Aristotle's Physics, or the books concerning the heavens and the world, or concerning meteoric bodies, or the small Natural Phenomena of the same author, or the books which treat of the soul, and also those on generation and corruption."[22] Allen has claimed that such a ruling deterred the development of modern science, but as far as Earth science is concerned the matter stood very differently, as we shall see.

The works of the ancients were expected to be taught by tutors, too. Curtis emphasises that formal lectures and academic exercises were only a part of the instruction available within the colleges of Oxford and Cambridge, and the work of the college tutors was the most important influence on a scholar's education in the seventeenth century.[23] As an example of the work of tutors Curtis refers to Richard Holdsworth, fellow of St. John's College, Cambridge, and later the master of Emmanuel, who drew up detailed instructions to guide his students. Holdsworth's 'Directions for a Student in the Universitie' listed the subjects to be studied and books to be read. His students would read some of the classical works such as Aristotle's Organon, Physics, Ethics, De Anima, De Caelo and Meteorologica.[24] His instructions went beyond the statutory curriculum, and Latin literature including Ovid's Metamorphoses was to be studied.[25] Holdsworth particularly mentioned George Sandy's English translation of Ovid's Metamorphoses.[26] Henry Peacham's handbook for young gentlemen also recommended the work of Ovid.[27] John

Aubrey read various Latin authors during his adolescence and found Sandy's Ovid the most "wonderful helpe to my phansie."[28] Thus the works of Aristotle and Ovid were recommended as textbooks even in informal instruction and were read for cultural purposes.

The Geological Ideas of Seventeenth-Century Academics

The popularity of the notion of cyclic change can be found in several textbooks on geography, natural history and philosophy. In his geographical work, for example, Nathanael Carpenter referred to Aristotle's Meteorologica to support his view of inundation and said that Aristotle seemed to acknowledge changes in the Earth's surface

> in the I Book of his Meteors, the 14 Chapter, where he saith, that by such Accidents sometimes the Continent and firme land is turned into the Sea, and other-where the Sea hath resigned places to the Land.[29]

Carpenter postulated that some islands have been joined to the land and some peninsulas separated from the land and made into islands.

George Hakewill was another author who adopted the idea of the cyclic nature of the Earth. He published An Apologie of the Power and Providence of God in the Government of the World (1627), which contained an argument against "the Common Error Touching Natures Perpetuall and Universal Decay." Hakewill criticized the current opinion that the world and man were decaying, as declared, for example, by Godfrey Goodman in his Fall of Man (1616). Aristotle's Meteorologica provided a cyclic view of the world for Hakewill's argument against Goodman. According to Hakewill, at times islands are swallowed up by the sea and at times new islands rise out of the sea. Referring to Aristotle's Meteorologica, Hakewill also said that "Sometimes parts of the Continent are recovered out of the Sea, as was a place in Egypt called Delta."[30]

Hakewill's principal idea is that things constantly move and change, so that the Earth does not remain in the same state without addition and diminution:

> ...much earth is turned into water, & contrarywise no lesse water into earth. It is not then to be wondered at, if that part of the earth which is now habitable was formerly overflowed with water, and that againe which now is sea, was sometimes habitable, as among fountaines some are dried up and some spring forth a fresh, which may also be verified of rivers and lakes.[31]

Historians such as Goodman held that mountains appeared to be becoming smaller and affirmed that the world itself would likewise perish and come to an end; but Hakewill did not agree to a universal decrease in the whole globe. According to Hakewill, the diminution of mountains is caused partly by rain water and partly by rivers which gradually wash away the tops and sides of mountains. The soil carried away by the water fills up the lower places of the valleys, causing one part to increase in size while the other decreases. In the globe of the Earth as a whole nothing is lost, but only a part is removed from one place to another. Thus in the process of time, mountains are eroded and valleys are raised into mountains.[32] In support of this idea, Hakewill quoted a passage from Ovid's Metamorphoses.[33] In Hakewill's view, things always move and change, and the earth does not remain in the same state without addition or diminution.

While neither Carpenter nor Hakewill referred to the Aristotelian argument about the causes and effects of earthquakes, John Swan, in his Speculum Mundi, first published in 1635, discussed earthquakes extensively, relying on William Fulke's A Goodly Gallery to Behold the Naturall Causes of all kind of Meteores (1563).[34] Fulke expressed the same idea regarding earthquakes as Aristotle, and was quoted by Swan:

> The great caves and dens of the earth must needs be full of air continually, (for there is no vacuum in nature:) but when by the heat of the Sun, the moisture of the earth is resolved, many Exhalations are generated, as well within the earth, as without; and whereas the places were full before, so that they could hold or receive no more except part of that which is in them be let out, it must needs follow that in such Countreys where the Earth hath few pores, or else where they be stopped with moisture, that there, I say, these Exhalations striving to get out, do either rend the Earth, or lift it up; that thereby either a free passage may be had, or else room enough to abide within.[35]

Like Aristotle, Fulke insisted that exhalations under the ground turned into winds which could cause earthquakes. Swan accepted the Aristotelian view of earthquakes from Fulke's work, and pointed out, furthermore, that earthquakes sometimes lowered the level of the ground and sometimes raised it, and if such a rising occurred in the sea, it could produce many islands. Swan considered the sinking of Plato's Atlantis as an effect of an earthquake:

> Thus was the Atlantick Ocean caused to be a sea, whereas before it was an island; according to the testimony of famous Plato, who lived in his flourishing fame about 366 years before Christ was born; and before his time it was that this island sunk.[36]

For Swan the myth of Atlantis was a remarkable piece of evidence to the effect that earthquakes cause changes in the surface of the Earth.

Peter Heylyn was another author who referred to classical literature in support of his geological arguments. In his Cosmography, first published in 1652, he suggested that earthquakes tore away one part of a country from the other or raised parts of the ocean floor above the water to produce islands. Rivers, too, he claimed, carry with them gravel, dirt and weeds which will in time settle to form an island at their entry into the sea. Rough waves can wear away a small isthmus to turn the peninsula into an island, and ocean currents eat away some places and leave others to form islands. As an example of these changes Heylyn quoted a passage from Ovid's Metamorphoses.[37]

Thomas White, too, discussed geological changes under the influence of the ancients. In his Peripateticall Institutions (1656) he claimed that hills and mountains rise out of the earth:

> This is evidenc'd both by ancient and modern Experiments, which tell us of Islands cast up in the Sea: we hear of cinders belcht out of AEtna and Vesuvius; for the most part, falling upon and encreasing the Mountains, but sometimes, too, raising fields into Mountains...[38]

White used the Aristotelian idea of subterranean vapours to explain the cause of earthquakes, islands and mountains.[39] Besides the effects of earthquakes and volcanic activities, he referred to water erosion which would carry away soil into the sea, and, like Aristotle, concluded that "in one place, the Earth is hollow'd away, in another rais'd."[40]

The effects of earthquakes were discussed by William Dugdale, too, who accepted Ovid's idea that some places had arisen from the sea while others had been lost.[41] As another instance of geological change he mentioned a case of a great earthquake:

> In the time of the Consulship of Valentinian and Valens, there was an earthquake, which not only overthrew divers cities, but altred the very bound's of the sea; which so flowed in some parts, that men might sayl in those places, where before they did walk; and forsook other, that they became dry land.[42]

In this way the notion of cyclic change was widely accepted in the seventeenth century. Among others, Aristotle's Meteorologica, Plato's Timaeus and Ovid's Metamorphoses were most authoritative sources of knowledge about the Earth's changes, and were referred to by seventeenth-century authors in support of their geological arguments.

The modern authors such as Carpenter, Hakewill, Heylyn, White, Swan and Dugdale were deeply involved in academic activities. For example, Nathanael Carpenter (1589-1628?) matriculated at St. Edmund Hall, Oxford, in 1605, and was elected a Devonshire fellow of Exeter College in 1607. He received his B.A. (1610), M.A. (1613), B.D. (1620) and D.D. (1626), and became "by a virtuous emulation and industry, a noted philosopher, poet, mathematician, and geographer." Then Archbishop Ussher tempted him into Ireland, where he was appointed schoolmaster of the King's wards in Dublin.[43] George Hakewill (1578-1649) went to St. Alban Hall, Oxford, in 1595 and was elected to a fellowship at Exeter College in the following year. He graduated B.A. (1599), M.A. (1602), B.D. (1610) and D.D. (1611). In 1611 he resigned his fellowship, but many years later, in 1642 he returned to Oxford as the rector of Exeter College and kept the place until his death.[44] Peter Heylyn (1600-1662) was sent to Hart Hall, Oxford, and in 1615 was elected demy of Magdalen College. He took his B.A. (1617) and began to lecture on historical geography. He was elected a fellow of Magdalen in 1618 and published his "Geography" in 1621.[45] Thomas White (1593-1676) was a Roman Catholic, educated at St. Omer, Valladolid and Douay. He graduated B.D. and was employed in teaching classics, philosophy and theology at the English College at Douay.[46] The life of John Swan is not described in the Dictionary of National Biography, but he was a student of Trinity College, Cambridge, and had an M.A. degree.[47] William Dugdale (1605-1686) went to school in Coventry and then broke up his education to marry at the age of seventeen. Later he accompanied Sir Symon Archer, an antiquary, to London where he became known at court and was rewarded with a high heraldic office. When the Civil War broke out, he accompanied the King to Oxford, the Royalist headquarters, remaining there until the surrender in 1646. During his stay in Oxford he often went to the Bodleian and other libraries to collect materials for his antiquarian work, and received from the university the degree of M.A. in 1642. At the time of the Restoration he resumed his heraldic works.[48] Thus, Carpenter, Hakewill, Heylyn, White, Swan and Dugdale all received a university education, an education which still attached much importance to the works of the ancients.

Furthermore, the works of these authors were generally used as university textbooks. According to P. Allen, university students may have read Carpenter's Geography Delineated Forth in Two Bookes (Oxford, 1625).[49] John Swan's Speculum Mundi (Cambridge, 1635) was used as a textbook on natural science.[50] James Master, Trinity College, Cambridge, bought Peter Heylyn's geographical work, Microcosmus, between the years 1646 and 1648.[51] George Hakewill's An Apologie of the Power and Providence of God in the Government of the World (1627), which included geographical arguments, was selected as a thesis for the philosophical disputation at the Cambridge commencement of 1628. Among other educationists, Thomas White, publishing his Peripateticall Institutions in 1656, believed that the true wisdom was to be found in writings which had survived the test of ages.[52] These modern academic works were thus expected to be read by students, and in this way helped to diffuse the ancients' geological ideas.[53]

Empirical Evidence for Cyclic Change

As has been discussed, the ancients' idea that there had been cyclic interchanges of land and sea could be supported by empirical evidence, and Carpenter, Hakewill, Heylyn and Dugdale, in fact, attempted to do it. One constantly cited piece of evidence to prove geological changes was the occurrence of seashells under the ground in the Netherlands. Discussing the geological features of the Netherlands, Richard Verstegan said that the country is even and flat with no hills, and is very low-lying. In various places, moreover, there are many seashells,

> ...in digging about two fadome deep in the earth, though in some places more and in some lesse, innumerable shells of sea fishe are found, and comonly in all places of these plain & even grownds, both in field and town, and heerof to bee throughly informed I have talked with such laboring men as usually have digged welles, and the deep foundations of buyldings, and they all agree, that they do comonly in all places fynd an inumerable quantitie of these shelles, some whole and some broken, and in many places the great bones of fishes whereof I have seen many, and have had some even as they have bin digged out of the earth.[54]

Verstegan considered these seashells and bones of fishes as evidence that the Netherlands had once been covered by the sea. He also found seashells in a higher place which he thought too high to have been under the sea. As for these seashells, he supposed that they had been carried there by the waters of the Universal Deluge. He did not, however, regard seashells in the lowland areas as the deposits of the violent waters of the Deluge, because the volume of shellfish found there was so great that it could not have been produced during the relatively short period of the Deluge. Verstegan also observed that large quantities of seashells lay in a regular manner, such as could not have been produced by turbulent flood-waters. Thus Verstegan, observing that numerous seashells had been deposited in good order, concluded that they must have been gradually heaped up under the sea. On this basis he too suggested that there had been interchanges of land and sea, while making no reference to the ancient writers.

Carpenter considered Verstegan's observations on seashells in the Netherlands as evidence that some parts of the dry land had been under the sea:

> ...some-where the Sea hath bin observed for a great space to leave the Land naked, as Verstegan conjectures of the most part of Belgia, which he sayes, was in ancient time covered with water; which besides many other arguments he labours to prove out of the multitude of fish-shells, and fish-bones, found every-where farre under ground about Holland.[55]

Unlike Verstegan, Carpenter cited these observations referring to the ancients' cyclic view of the Earth. Hakewill too regarded fossil shells found in the Netherlands as evidence of cyclic change and suggested that

> the greatest part of the Netherlands was so recovered, as appeares by their finding innumerable shels of sea-fish almost in every place where they dig, and other parts againe irrecoverably lost by the inundation thereof...[56]

Heylyn was another author who attempted to support the ancients' cyclic view of the Earth, referring to Verstegan's observations:

> the Isles of Zealand have been once part of main sea: and Verstegan proveth it, because that the Husbandmen in tilling and manuring the ground, find sometimes Anchors here and there fixt, but very often the bones of huge and great fishes, which could by no accident come hither.[57]

Heylyn not only discussed Verstegan's observations but also collected hypotheses regarding to other geological changes: The Island of Euboea was divided by an earthquake from the rest of Attica; some great rivers deposit sand at the mouth and form islands; rough waves divided Sicily from Italy, Cyprus from Syria, England from France, and Wight from the rest of England.[58]

Further observations were made by Dugdale to verify the ancients' view that there had been cyclical changes in the Earth's surface. He referred to some ancient ports which had been converted into land far from the sea by the deposition of sand between those ports and the sea. Such instances were St. Omer in Flanders, Old Romney in Kent, and Rye in Sussex.[59] He also produced other evidence of changes in the Earth's surface such as fossil remains of living creatures, and suggested that some great continents with many forests must have been reduced to being the floor of the ocean and have risen again as dry land; thus the enormous quantities of fossil trees and skeletons of seafish.

Ancients or Moderns?

In this way, the ancients' cyclic view of the Earth was referred to by early seventeenth-century authors such as Carpenter, Hakewill, Swan, Heylyn, White and Dugdale, and some of them gave additional evidence for this view. Thus, they did not merely dogmatically repeat the authoritative theory. Furthermore, Carpenter, Hakewill and White declared that they did not follow all the teachings of the ancients. For example, in 1621 Carpenter published his Philosophia Libera, a work chiefly devoted to a plea for liberty in scientific discussion. In the preface of this work he criticized the ancients, mainly Aristotle but more particularly his followers, on the grounds that although Aristotle could have made mistakes, the Aristotelians accepted his philosophy indiscriminately. Carpenter urged the importance of a critical attitude of mind.

Hakewill did not regard the ancients as infallible authority, either, and criticized the Aristotelian method of study:

> ...for the speculative, both himselfe [Aristotle] and his followers seeme to referre it rather to profession and disputation, mater of wit and credit, then use and practice...[60]

Then Hakewill argued against the idea that man and nature had been declining from a perfect state. He thus defended the superiority of the moderns.

White, too, was sometimes critical of Aristotle's system. In his Peripateticall Institutions (1656) he declared that

> I call them Peripateticall, because, throughout they subsist upon Aristotle's Principles; though the conclusions sometimes dissent.[61]

While admitting that his work was based on the works of Aristotle, White did not want to confine himself to the scholastic dogmatism.

Thus, Carpenter, Hakewill and White attacked parts of the Aristotelian method of study, although they accepted the ancients' conclusions with respect to Earth science. R.F. Jones has, in fact, claimed that Carpenter emphasized the need for demonstration, experiment, and observation of nature without special respect for the ancients and that Hakewill attempted to prove modern superiority.[62] C. Hill has also regarded Carpenter as "a favourer of the new learning in Oxford" and "an anti-Aristotelian exponent of the new astronomy", and has pointed out that "Hakewill was in many ways astonishingly modern."[63] We should not, however, overlook the point that both Carpenter and Hakewill consciously followed the chief geological ideas set out in Aristotle's Meteorologica and Ovid's Metamorphoses. Jones has tried to understand the Scientific Revolution in seventeenth-century England in terms of "Ancients" and "Moderns". The geological works considered in this chapter, however, cannot be understood in these terms.

Francis Bacon (1561-1626), in his Novum Organum (1620), drew up an inductive method of science to replace the Aristotelian deductive method, and, in his New Atlantis (1627), presented a plan for a co-operative inquiry into nature which later in the century became a major source of inspiration for the founders of the Royal Society of London. Bacon's attack on the Aristotelian system has been widely regarded as one of the main events of the Scientific Revolution.[64] More recently, however, several scholars have criticized this view, showing that the spirit of undergraduate teaching at Oxford, even in the 1650s, was still based on the Aristotelian textbooks, and, more generally, that the influence of Baconian ideas was less than has been supposed.[65] Such a suggestion is consistent with C.B. Schmitt's view that Aristotelianism did not end with Copernicus, Galileo and Bacon but continued to flourish throughout the sixteenth and seventeenth centuries.[66] As for the study of the Earth, the ancients' ideas were constant and useful sources of knowledge, and, more importantly, new observations were added to the traditional frameworks. Thus the development of Earth science cannot be neglected on the grounds that it was based on the ancients' writings. At least we should not simply claim that investigation of the Earth scarcely advanced in Britain in the first half of the seventeenth century.[67]

NOTES

1. Sir Archibald Geikie, The Founders of Geology (New York: Dover Publications, 1962), 39-40.

2. Karl Alfred von Zittel, History of Geology and Palaeontology (London, 1901), 11.

3. Frank Dawson Adams, The Birth and Development of the Geological Sciences (New York: Dover Publications, 1954), 50.

4. C.E.N. Bromehead, "Geology in Embryo (up to 1600 A.D.)", Proceedings of the Geological Association, London, LVI (1945), 90.

5. Ibid., 91.

6. Francis C. Haber, The Age of the World: Moses to Darwin (The John Hopkins University Press, 1959), 40.

7. A.C. Crombie, Augustine to Galileo, Vol. 1 (London: Mercury Books, 1961), 123-29.

8. Martin J.S. Rudwick, The Meaning of Fossils (London, 1972), 38.

9. Suzanne Kelly, "Theories of the Earth in Renaissance Cosmologies", in Cecil J. Schneer, ed., Toward a History of Geology (The M.I.T. Press, 1969), 214-25. - The idea that there had been cyclic interchanges of land and sea can be found in the following works: Joannis Velcurionis, Commentariorum Libri IIII. In Universam Aristotelis Physicen (London, 1588); Louis le Roy, Of the Interchangeable Course or Variety of Things in the Whole World, Trans. by R.A. (London, 1594); Thomas Lydiat, Praelectio Astronomica de Natura Coeli & Conditionibus Elementorum (London, 1605); Simon Stevin, Les OEuvres Mathematiques de Simon Stevin, Augmentées par Albert Givard (A Leyde: B. & A. Elsevier, 1634).

10. P.B. Paisley & D.R. Oldroyd, "Science in the Silver Age: Aetna, a Classical Theory of Volcanic Activity", Centaurus, 23 (1979), 16. - However, Paisley and Oldroyd have referred only to classical theories of volcanic action. In seventeenth-century England, it

was not volcanic rock but fossiliferous strata that attracted considerable attention.

11. Aristotle, Meteorologica, Bk. I, Chap. 14.

12. Aristotle, Meteorologica, Bk. I, Chap. 14.

13. Aristotle, Meteorologica, Bk. I, Chap. 14.

14. Aristotle, Meteorologica, Bk. II, Chap. 8.

15. Plato, Timaeus and Critias.

16. F. Watson, The Beginning of the Teaching of Modern Subjects in England (London, 1909), 194.

17. Ovid, Metamorphoses, Bk. 15.

18. Mark H. Curtis, Oxford and Cambridge in Transition 1558-1642 (Oxford University Press, 1959), 14.

19. Phyllis Allen, "Scientific Studies in the English Universities of the Seventeenth Century," Journal of the History of Ideas, X (1949), 219, 224.

20. Ibid., 220.

21. Ibid., 225.

22. Ibid., 226.

23. Curtis, Oxford and Cambridge, 107.

24. Ibid., 112.

25. Ibid., 113.

26. Ibid., 133.

27. Henry Peacham, The Complete Gentleman, ed. by V.B. Heltzel (New York, 1962), 100.

28. Michael Hunter, John Aubrey and the Realm of Learning (London: Duckworth, 1975), 40.

29. Nathanael Carpenter, Geography Delineated Forth in Two Bookes (Oxford, 1625), Bk. II, 196.

30. George Hakewill, An Apologie of the Power and Providence of God in the Government of the World (Oxford, 1630), 32.

31. George Hakewill, op.cit., 132.

32. Ibid., 137-38.

33. Ibid., 132-33.

34. According to Christopher Hill, "William Fulke, one of the founders of scientific meteorology in England, who by emphasizing secondary as against supernatural causes did much to reduce superstition, was also an outspoken Puritan." Christopher Hill, Intellectual Origins of the English Revolution (Oxford University Press, 1965), 23. - Although Hill regarded Fulke as a typical puritan scientist who supported modern science, Fulke's idea of earthquakes was identical with that of Aristotle.

35. John Swan, Speculum Mundi (Cambridge, 1670), 190-91.

36. Ibid., 192.

37. Peter Heylyn, Cosmographie in Four Books containing the Chorography and History of the Whole World (London, 1682), 18.

38. Thomas White, Peripateticall Institutions (London, 1656), 128.

39. Ibid., 163, 355-56.

40. Ibid., 129.

41. William Dugdale, The History of Imbanking and Drayning of Divers Fenns and Marshes, Both in Forein Parts, and in this Kingdom (London, 1657), 173.

42. Ibid., 172.

43. Dictionary of National Biography (hereafter D.N.B.).

44. D.N.B.

45. D.N.B.

46. D.N.B.

47. John Swan, Speculum Mundi, The title page.

48. D.N.B.

49. Allen, "Scientific Studies", 224.

50. Ibid., 225; Foster Watson, The Beginning of the Teaching of Modern Subjects in England (London, 1909), xxiii.

51. Allen, "Scientific Studies", 234.

52. Watson, Beginning, 245.

53. As for Dugdale's History of Imbanking and Drayning of divers Fenns and Marshes, five hundred copies of it having been destroyed in the fire of London, the volume became very scarce (cf. D.N.B.).

54. Richard Verstegan, Restitution of Decayed Intelligence in Antiquities concerning the English Nation (Antwerp, 1605), 103.

55. Carpenter, Geography, Bk. II, 196.

56. Hakewill, Apologie, 32.

57. Heylyn, Cosmographie, 18.

58. Ibid.

59. Dugdale, History, 173. Dugdale wrote "Rye in Suffolk" instead of "Rye in Sussex".

60. Hakewill, Apologie, Chap.9.

61. White, Peripateticall Institutions, The Author's Design.

62. R.F. Jones, Ancients and Moderns: A Study of the Rise of the Scientific Movement in Seventeenth-Century England (St. Louis, 1961), 70, 29-36.

63. C. Hill, Intellectual Origins of the English Revolution (Oxford, 1965), 201, 305.

64. For example, R.F. Jones, B. Farrington, C. Hill and M. Purver have emphasized the importance of Bacon's inductive method as opposed to Aristotelianism in the Scientific Revolution. R.J. Jones, Ancients and Moderns; B. Farrington, The Philosophy of Francis Bacon (Liverpool, 1964); C. Hill, Intellectual Origins; M. Purver, The Royal Society: Concept and Creation (The M.I.T. Press, 1967).

65. H. Kearney, Scholars & Gentlemen (London, 1970), 123-26; B. Shapiro, John Wilkins 1614-1672 (University of California Press, 1969), 58-59, 99, 204-205.

66. C.B. Schmitt, "Toward a Reassessment of Renaissance Aristotelianism," History of Science, XI (1973), 163.

67. R. Porter, The Making of Geology (Cambridge University Press, 1977), 16.

2. THE THEOLOGICAL VIEW OF THE DELUGE

As we have seen, the cyclic view of the Earth provided a set of ideas to explain various geological phenomena. However, it was not the only framework for the Earth's history available in the seventeenth century. The study of the Earth was also pursued by those who were engaged in interpreting the first book of the Old Testament. Davies' Earth in Decay, Rudwick's Meaning of Fossils and Porter's Making of Geology note the role of Genesis in the development of Earth science, but they do not fully discuss its influence on the seventeenth-century study of the Earth. As A. Williams has suggested, it is not easy for us to comprehend the importance of Moses' Genesis in the culture of the Renaissance.[1] Most sixteenth and seventeenth-century intellectuals were primarily Christians, and their way of thinking was predominantly theological. If we do not examine the place of Genesis in Renaissance thought, we may fail to gain a proper understanding of that period.

Genesis offered an account of early history, so that it was both sacred and profane. Not only was *Genesis* regarded as a reliable history of the primitive state of human beings, but also it provided a foundation for understanding the whole development of the universe including the Earth. Historians and divines relied on the accounts in *Genesis* when discussing their particular problems. As will be shown, although their interpretations of *Genesis* did not exclude God's role, they tended to explain miracles in terms of natural causes. This trend could have facilitated the scientific study of the Earth's history.

The Extraordinary Effects of the Deluge

Among Christians, the Protestant reformers desired a genuine text of the Holy Scriptures. Their ambition was to revive an older and supposedly purer Christian tradition which they thought had been corrupted by the Roman Catholic Church. As a result, they were much more interested in the words of the Bible itself than Catholics had ever been.

For example, Martin Luther was one of those who wrote a commentary on *Genesis*, in which he treated Noah's Flood as the most powerful agent in geological change. He suggested that Paradise had been utterly destroyed and annihilated by the Flood, so that there was no longer any visible trace of it. The Flood laid everything to waste, just as had been written in Genesis that all the fountains and abysses were torn open. Luther continued

> And so, just as there are mountains after the flood where previously there were fields in a lovely plain, so undoubtedly there are now springs where there were none before, and vice versa. For the entire surface of the earth was changed. I have no doubt that there are remains of the Flood, because were there are now mines, there are commonly found pieces of petrified wood. In the stones themselves there appear various forms of fish and other animals.[2]

Luther thus claimed that the surface of the Earth had been considerably changed by the Flood and marine animals had been lodged in mud and turned into stones. He also suggested that

> after the Flood Noah saw a surface of the whole earth far different from the one he saw before the Flood. Mountains were torn apart, fountains were broken up, and the courses of rivers were changed by the immeasurable force of the rushing waters.[3]

For Luther, then, the Flood was of great importance to understanding the present state of the Earth. Such discussions of the effects of Noah's Flood became topics of controversy in the debate on the causes of the present state of the Earth.

Godfrey Goodman (1583-1656), chaplain to the Queen, in his Fall of Man (1616), attempted to prove that the pattern of life for both man and nature was one of continual decline from a perfect state to the decay of old age and, according to him, at the time of the Deluge the Earth was corrupted. In his view many evidences appear in nature which serve as convincing proofs of the Deluge:

> ...at this day there are found, both in other nations, and (as I am informed) in the Ile of Men certaine trees, which serve both for timber and fuell, in such plenty and quantity, so many fadomes under the earth, as that by al probable conjecture they were there buried and covered in the time of the delug ... 4

In the earth, as well as trees, foundations of buildings were discovered, which Goodman conjectured had been overthrown in the Deluge. And as for rocks and stones jutting out over cliffs without any surrounding earth, they gradually disintegrated, and therefore were not from the first creation; rather the waters had uncovered them and left them there naked and bare as undeniable manifestations of the Deluge. The Earth, he continues, has fallen into decay since the creation of the world; for example,

> When I consider the barrennesse of the earth for many leagues together, I cannot conceave that it should be thus from the beginning, being Gods owne immediat workmanship, but that the salt waters have caused this barrennesse,...[5]

In Goodman's opinion, because the Earth has been subjected to the process of decay, its present state is different from the Earth which God created.

The effects of the Universal Deluge, Goodman thought, could be discovered everywhere on the Earth, and he appears to have observed the strata of the earth and ascribed their condition to the coursing of the waters:

> ...I consider the strange different mould of one and the same earth, as I have often observed, sand upon clay, clay upon gravel, gravel upon chalke, chalke upon sand, &c. Assuredly this diversity never was in the first creation, neither hath it since been effected by any influence or operation of stars, but some general overflowing of waters, hath caused this variety of mould and complection...[6]

The strata of sand, clay, gravel and chalk were attributed to the action of the Deluge. At that time marle-pits and coal-pits were also laid down and buried by the overflowing of waters.[7] The concept of the extraordinary Deluge tended to persuade scholars that they must seek out its remains in the Earth. Goodman's observation on the strata was one such attempt, although it did not arouse great discussion at this stage.

Like Luther, Goodman assumed that the present unevenness of the Earth, its hills and valleys, had been caused for the most part by the Flood. The increase in the level of land would then be in proportion to its decrease in other places, because God observes some kind of proportion in the inequality, seeing that both earth and water should make one perfect globe.[8] For Goodman, decay is a phenomenon which might be observed throughout the world, in both nature and men. This theory is the direct antithesis of the idea of progress which has profoundly influenced modern thought. Goodman, in fact, was such a conservative scholar that he advocated the scholasticism of the medieval ages. He believed in the overriding superiority of ancient learning and held Aristotle in very high esteem. At the same time he observed geological features which seemed to be the result of the Deluge. The inequality and ruggedness of the Earth was evidence enough, in his view, that the Deluge had been so violent as to make the Earth fall into decay.

<u>The Natural Causes of the Deluge</u>

Toulmin and Goodfield have claimed that "the Biblical Flood was regarded as the most powerful single agent responsible for geological change".[9] However, the idea that the present mountains and valleys had been formed at the Deluge was not the only exposition of <u>Genesis</u>. John Calvin, for example, treating the early books of the Bible as an authoritative historical record, attempted to explain the effects of Noah's Flood, but was strongly opposed to the idea that the Earth had been drastically changed at the time of the Flood. In his view, there were some who thought that the courses of rivers had been disturbed and changed, and their springs re-located elsewhere because of the Flood.[10] Such an idea, however, seemed completely unacceptable:

> although I acknowledge that the earth, from the time that it was accursed, became reduced from its native beauty to a state of wretched defilement, and to a garb of mourning, and afterwards was further laid waste in many places by the deluge; still, I assert, it was the same earth which had been created in the beginning.[11]

Relying on the account of the antediluvian world in the Bible, Calvin conjectured that the present state of the Earth was almost the same as the state of the original Earth.

For Calvin a miracle or a supernatural cause should not be excluded from a study of natural phenomena. He claimed that it was an outstanding miracle that at the Creation the waters by their retreat had given a dry land to men. Moses had declared that the waters had covered the whole primitive Earth because that was their natural position. But the waters were gathered together in great sheets by a supernatural cause. According to Calvin, the first cause is sufficient in itself, and intermediate and secondary causes have only what they borrow from this first cause.[12] It was a miracle of God that divided the land from the sea at the Creation, and again a similar miracle caused the Universal Deluge:

> In saying that the fountains were broken up, and the cataracts opened, his language is metaphorical, and means, that neither did the waters flow in their accustomed manner, nor did the rain distil from heaven; but that the distinction, which we see had been established by God, being now removed, and there were no longer any bars to restrain the violent irruption.[13]

Calvin considered that the first appearance of the land and the cause of the Deluge could be explained by divine intervention. After the Flood God by his secret power dried the earth, making use of the wind.[14]

Because he insisted on the need for a supernatural cause, Calvin criticized Aristotle's method of arguing in his Meteorologica, in which he completely ignored any miraculous cause:

> it is impossible to excuse the profane subtlety of Aristotle, who, when he disputes so acutely concerning second causes, in his Books on Meteors, buries God himself in profound silence. Moses, however, here expressly commends to us the extraordinary work of God.[15]

Calvin claimed that Sodom had not been destroyed by a mere earthquake which was not in fact a miracle. It was the will of God that Sodom should be simply swallowed up by an earthquake. Here again Calvin criticized Aristotle for not considering the extraordinary work of God.[16]

The arguments raised by Calvin concerning the Earth's history were fully discussed by Sir Walter Raleigh in his History of the World, in 1614, which became immediately popular. While Raleigh, like many other Protestant historians, relegated the age of miracles firmly to the past, he discussed natural phenomena in relation to God. Nature, he wrote, is

> nothing else but the strength and faculty which God hath infused into every creature, having no other selfability than a clock, after it is wound up by a man's hand, hath.

> Those therefore that attribute unto this faculty any first or sole power, have therein no other understanding than such a one hath, who, looking into the stern of a ship, and finding it guided by the helm and rudder, doth ascribe some absolute virtue to the piece of wood, without all consideration of the hand that guides it, or of the judgement which also directeth and commandeth that hand: forgetting in this and in all else, that by the virtue of the first act all agents work whatsoever they work...[17]

According to Raleigh, God works through angels, the sun, the stars and nature, so all secondary causes are only instruments, or pipes which carry and disperse what they have received from the will of God. He also stated that the Universal Deluge had been caused by the ordained wrought of God himself, but God used secondary or working causes to carry out his will. This statement marks a forward step towards the establishment of the scientific study of the Earth's history. The study of the primitive Earth could be considered as an object of scientific enquiry.

Although declaring his method of study to be different from earlier commentators on Genesis in that he stressed secondary causes, Raleigh relied on Pererius, Zanchius, Calvin and Mercerus in the parts of his History dealing with events such as the Creation and the Universal Deluge which occurred before the Tower of Babel. Raleigh agreed with Calvin that the Universal Deluge had not produced a drastic change in the Earth's surface:

> whereas it is supposed by Aug. Chysamensis, that the flood hath altered, deformed, or rather annihilated this place, in such sort, as no man can find any mark or memory thereof; (of which opinion there were others also, ascribing to the flood the cause of those high mountains, which are found on all the earth over, with many other strange effects:) for mine own opinion, I think neither the one nor the other to be true.[18]

According to Raleigh, the face of Paradise became faded only after the Deluge; if there had been no sign of any such place, then Moses, who wrote of Paradise some 850 years after the Deluge, could not have described it in such detail. The place, moreover, was still the same, and the rivers remained the same rivers. The Flood had not produced mountains; rather mountains had existed from the Creation. This view of the Deluge concurs exactly with that of Calvin.

Besides the effects of the Deluge, Raleigh discussed its causes as well. He maintained that while the many floods which covered various regions at various times may be ascribed to natural causes, the Universal Deluge poured down over the whole face of the Earth by a power above nature, and was wrought by God himself, who at that time increased the volume of the Earth's fountains. Thus the eruption of water was made such that it could not have been effected by natural causes, or by any combination of them, without the aid of supernatural power.[19] Raleigh therefore agreed with Calvin that the Deluge had been brought about by the supernatural power of God.

Raleigh did not rigidly adhere to the idea that the Deluge had been miraculous, but put his own interpretation on its causes. Since he conjectured that God had not created anything new after the initial creation of the world, the question arose as to whether all the earth and air contained waters sufficient to cover the habitable world fifteen cubits above the highest mountains at the time of the Deluge, as described in Genesis. If God had not created new waters to flow over the whole world, there must have been another source. Raleigh's answer was as follows:

> I find no other mystery in the words cataractae coeli, than that the clouds were meant thereby; Moses using the word windows of heaven, (if that be the sense of the words,) to express the violence of the rains, and pouring down of waters. For whosoever hath seen those fallings of water which sometimes happen in the Indies, which are the spouts, (where clouds do not break into drops, but fall with a resistless violence in one body,) may properly use that manner of speech which Moses did, that the windows or floodgates of heaven opened; which is, that waters fell contrary to custom and that order which we call natural. God then loosened the power retentive in the uppermost air, and the waters fell in abundance.[20]

God also, according to Raleigh, called up the waters which had been in the great abyss, and these waters spread out over the surface of the Earth until they had carried out his will. Then God commanded them to return into the abyss, and the rest were rarefied again into air. Raleigh claimed that there was nothing beyond the ordinary course of nature in the overflow of waters at the Deluge. Although the fall of the rain itself was "extraordinary", it could nevertheless be compared to the heavy rain of the West Indies. Without denying God's miracles, Raleigh reduced the area of divine intervention in history.[21]

As Toulmin and Goodfield have suggested, Raleigh's aim was to demonstrate the action of divine Providence through historical events.[22] It is true that for Raleigh Holy Scriptures were an unquestionable authority and contained an essential framework of human history. Historians did not need to look beyond it. Their work, on the contrary, was to fill out this framework by collecting other historical evidence. The real significance of history was to reveal God's Providence concealed in superficial events. In this respect, Raleigh's method was not different from that of other historians. However, we should recognize that Raleigh made considerable effort to understand the extraordinary Flood without placing complete reliance on supernatural causes.

Raleigh wrote about the history of the world not by denying the first cause, but, unlike Calvin, by concentrating his attention on secondary causes. He thus commenced to discuss the development of Jewish history with the following statement: "To say that God was pleased to have it so, were a true but an idle answer (for His secret will is the cause of all things)...wherefore we may boldly look into the second causes."[23] As Christopher Hill has suggested, Raleigh's importance lies in the fact that he employed a secular and critical approach to the study of world history.[24]

The Influence of Raleigh's History

Raleigh's History was so comprehensive that most of those who discussed any aspect of the Deluge did not ignore it. One of those who praised Raleigh was Nathanael Carpenter.[25] In his Geography Delineated Forth in Two Books, Carpenter defined geography as a study involving the description of the entire world and tracing its development back to its origin. The study of geography was thus thought to be connected with an historical approach to the Earth, and Raleigh's description of world history was considered as important in the understanding of the Earth's history.

According to Carpenter, it may be concluded from certain passages in the Scriptures that at the time of the Creation the Earth's surface, being round and uniform, was overwhelmed by waters. And it appears that God afterwards made a separation between the waters and the dry land.[26] Up to this point Carpenter accepted the traditional exposition of the Bible, but he did not admit a supernatural power to explain the phenomenon of the separation. This separation, he claimed, does not seem to have been caused by supernatural restrictions being imposed on the waters to keep them from encroaching on the dry land, because God was not likely to have imposed a perpetual violence upon nature. Carpenter attempted to explain this separation of the waters from the dry land in terms of secondary causes, namely the altering of the Earth's surface, so that some parts of it were worn down and other parts heaped up. Most mountains, valleys and plains he assumed to have been created at the beginning, and few to have been formed by the violence of the Universal Deluge.[27]

Some divines and philosophers, Carpenter said, were of the opinion that the violence of the Deluge had considerably changed the face of the Earth, producing mountains and valleys. Like Calvin and Raleigh, however, he argued against such a view. Firstly, the book of Genesis itself says that the level of the water of the

Flood rose fifteen cubits above the height of highest mountains, which proves that there must have been mountains before the Deluge. Secondly, if the Earth had been altered so greatly as to form mountains, the force of the Deluge would have been sufficient to divert rivers from one place to another, and to destroy great cities. However, the same places after the Universal Deluge retain the names, bounds and descriptions which they had before the Deluge. Lastly, Carpenter asserted that it was certain, arguing from a final cause, that all things were in an ordered state before the Deluge, and that the Earth was adorned with all varieties such as mountains, valleys and plains.[28] Carpenter therefore concluded that the great mountains had been created in the beginning, and not produced by the Flood, although he concluded that some small hills might have been made by the Flood; nevertheless they are "of small note & not worthy of consideration."[29]

For Carpenter, the Universal Deluge was not the only topic to be considered when geographical features were discussed. He suggested that two kinds of inundations had been observed on the Earth, namely universal ones and particular ones.[30] In a universal inundation the whole face of the Earth is covered, whereas particular inundations do not cover the whole Earth, but only particular places or regions. According to Carpenter, no universal inundation may be produced by natural causes, although particular inundations may come about in this way. While Carpenter rather agreed with those who considered the Deluge to be due wholly to supernatural causes,[31] he rejected the idea that the creation of more water had been necessary to drown the whole world. Like Raleigh, Carpenter insisted that there had already existed a sufficient volume of water:

> Now if we compare the hight of the waters in this deluge above the highest mountaines, being 15 cubits, with the depth of the semi-diameter of the Earth to the Center, we shall not find it impossible, answering reason with reason, that all these waters dispersed under the Earth, should so far extend as drown the whole Earth.[32]

Apart from the waters in the ground, Carpenter claimed that, because of the enormous volume of the air, God could have condensed a large part of it to assist with the Deluge.

Carpenter, too, thus made an attempt to discover possible sources of water which would be sufficient to submerge the Earth, although he asserted that the Deluge itself had been supernatural:

> If we consider the meere secondary and instrumentall causes, we might call this effect Naturall, because it was partly performed by their

> helpe and concurrence. But if we consider the mutuall application and conjunction of these second causes together with the first cause, which extraordinarily set them aworke, we must needes acknowledge it to be supernaturall. ...both these causes sometimes concurring together, cause an Inundation: which assertion we may lawfully accept, but with this caution, that Almighty God working by second causes, neverthelesse directs them oftentimes to supernatural and extraordinary ends.[33]

Like Raleigh, Carpenter thus paved the way to explaining the Deluge in terms of natural causes, without denying the idea that the Deluge had been caused by the will of God.

Carpenter might have abstracted geological ideas from Raleigh's History in support of his own arguments about the Earth's history, because Carpenter's opinion on the phenomenon of the Deluge is almost the same as that of Raleigh. Carpenter's Geography in turn seems to have influenced John Swan, whose Speculum Mundi was first published in 1635. Although Swan did not refer to Carpenter's Geography, as will be shown, identical passages may be found in both Carpenter's Geography and Swan's Speculum Mundi.

In Speculum Mundi the six days of the Creation are described in full. Like most other scholars, Swan asserted that water and earth were the two lowest elements, and that the Earth was covered with water until the third day of the Creation. On the third day, says the Bible, the waters gathered and the dry land appeared. Swan raised the question of how the waters had been removed from the earth. To answer this question, he said, some supposed that the waters had run together and covered the part of the Earth opposite to the place where we live, and others had imagined that some powerful mind, or the heat of the Sun, had dried them up.[34] Swan, however, did not agree with these hypotheses, and suggested that there had been holes under the ground before this separation of water and land had taken place, and that the water had poured into them and filled them, producing the dry land. For Swan the appearance of the dry land presented no mystery, because this phenomenon could be explained by natural causes.

The origin of mountains was another important subject in the work of Swan. He noted that there were some who thought that hills and mountains had not existed before Noah's Flood, but had resulted from the violence of the waters of the Flood.[35] Arguing against this view, he attempted to explain how mountains, valleys and plains had been created in the beginning, and had existed before Noah's Flood. According to Swan, if hills had been formed by the Flood, the waters must have been agitated by an extremely violent motion; in fact, however, the movement of the waters could not have been so violent as to produce these higher places. In addition, if the violence were so great as to have formed hills and mountains, then without doubt it would also have diverted rivers, cast down buildings, and uprooted all trees, so that after the Flood nothing would have had the same name, area and appearance which it had before. But the memories of the former ages were not irrevocably buried for posterity; all of the buildings and ancient monuments of the Fathers before the Flood were not obliterated.[36] Swan therefore concluded that the waters of the Flood had not been so violent as to have altered the surface of the Earth.

Like Carpenter, Swan discussed not only the effects of the Flood but also its causes, and maintained that

> this Flood was partly natural, partly supernatural; and to shew how far nature had a hand in this admirable effect, we may distinguish with them, who say, That an effect may be called Natural, two manner of ways: First, In regard of the causes themselves; secondly, In regard of the Direction and Application of the causes. If we consider the meer secondary and instrumental causes, we may call this effect Natural; because it was partly performed by their help and concurrant: But if we consider the mutual application and conjunction of these second causes, together with the first cause, which extraordinarily set them on work, we must needs acknowledge it to be supernatural.[37]

This passage about the first cause and the secondary causes of the Flood is almost the same as Carpenter's.Like Carpenter, Swan did not exclude the first cause from his argument on the Flood, but he suggested that the Flood could be explained by a conjunction of secondary causes alone. Although Swan did not mention Raleigh's History, he might have taken over the ideas of Raleigh from Carpenter's Geography.

The influence of Raleigh's History is also found in the historical works of Alexander Ross (1591-1654), the Scottish master of Southampton Grammar School. In 1650 he published an abridgement of Raleigh's History under the title of The Marrow of History, and in 1652 he published a continuation of Raleigh's History. He then published Some Animadversions and Observations upon Sir Walter Ralegh's History of the World, 1653, in which, referring to the Deluge, he maintained that

> Paradise was utterly defaced with the Flood, which rose fifteen cubits higher then the mountains. It's true that the place was not removed by the Flood, yet the beautie, delights, and form of it was utterly abolished, as a punishment of Adam's sin.[38]

Like Calvin and Raleigh, Ross claimed both that the original Earth had been destroyed by the Flood, and that this had not been so violent as to change the position of Paradise. In his early commentary on Genesis, Ross insists that mountains appeared when God divided the dry land from the waters, and that therefore there existed mountains before the Flood,[39] and mountains made the Earth more fruitful and more commodious for both men and beasts. The Universal Deluge was a direct act of God to destroy a sinful world,[40] but it did not produce new mountains and valleys.

The same view on the cause of mountains was held by John Wilkins (1614-72), bishop of Chester. According to him, some regarded mountains as a deformity of the Earth, as if they were either caused by the Flood, or else left at the Creation like so many heaps of rubble. But Wilkins asserted that mountains provided the "beauty and convenience" of the world. They had been specifically created for many excellent purposes, such as the taming of the violence of great rivers, the breaking of the force of inundation from the sea, and the creating of secure refuges from the violence and oppression of other countries. It was certain, Wilkins claimed, that such benefits had not come about through man's sin, nor had they been produced by the Flood, but created at the beginning through the providence of the Almighty. Although Wilkins did not refer to Raleigh's History, his idea of the cause of mountains was identical with that of Raleigh.[41]

A more obvious influence of Raleigh's History can be found in a work of Edward Stillingfleet (1635-1699), bishop of Worcester, who discussed the causes and effects of the Deluge in his Origines Sacrae, or a Rational Account of the Grounds of Christian Faith, as to the Truth and Divine Authority of the Scriptures, first published in 1662, and which eventually ran to its eighth edition. Like his precursors, Stillingfleet, too, raised the question of the source of the waters which in Noah's time had covered the whole Earth. He agreed with those who claimed it impossible that all the waters contained in the air, supposing that it should condense into rain, could raise the level of the water on the Earth by a foot and a half.[42] Possible alternatives were that either new waters may have been created to submerge the Earth, or that there may have occurred a rarefaction of the water contained in the sea and rivers so as to enable this to cover the mountains at the time of the Deluge. However, Stillingfleet preferred yet another alternative:

> it is evident that the Flood was universal as to mankind, but from thence follows no necessity at all of asserting the universality of it as to the Globe of the earth,...[43]

Stillingfleet denied that the Flood had needed to cover the whole Earth in order to destroy the wickedness of mankind. The Flood needed only to inundate the places where men lived. It then became a much simpler matter to find sources of water which would be sufficient to cover the inhabited parts of the world.

Stillingfleet agreed with Raleigh who suggested that several causes had combined to produce this Deluge. According to Stillingfleet, the air was condensed into clouds which fell down with unabated force and violence, not fragmenting into drops, but in one body "which Sir Walter Raleigh parallels with the spouts of the West Indies."[44] He remarked, moreover, that God who normally held the ocean within its bounds may have released it so that it might carry out his judgement upon the world, and thus the fountains of the great deep were burst up.[45] Stillingfleet surmised that these waters must have caused an inundation so great that it destroyed the inhabited world. Although he does not explicitly discuss the changes in the Earth's surface wrought by the Deluge, he seems to accept Raleigh's argument that there existed mountains in the antediluvian Earth.[46]

Thus Raleigh's History of the World was often referred to when the causes and effects of the Deluge were discussed. Those who accepted Raleigh's idea of the Deluge claimed that there was no notable difference between the state of the antediluvian Earth and that of the present. They thought that the Deluge was not such an extraordinary phenomenon that it could produce mountains and valleys. The idea that the present mountains had been created before the Deluge was more influential at this stage than the idea that they had been formed by the force of waters at the time of the Deluge.

The Diluvial theory had to be in harmony with the doctrines of the ancients. The reconciliation of Greek science with Christian theology had been the main aim in the scholastic learning. As has been shown, the ancients' view of the Earth provided the idea that there had been cyclic interchanges of land and sea. On the contrary, the Christian view of time rejected the circle for the straight line and considered the events from the Creation to the Conflagration to be unique.[47] Although this contradiction does not seem to be compromised, there was not any difficulty in harmonizing cyclic interchanges with Noah's Flood in the seventeenth century.

The harmony of the ancient and Christian view can be found in the works of Raleigh, Carpenter and Swan. For example, Raleigh discussed the floods of Ogyges and Deucalion as well as Noah's Flood. For him it was not difficult to incorporate the ancients' accounts of floods into the Biblical chronology.[48] Carpenter, too, claimed that there were two kinds of inundations; one was universal and the other was particular.[49] A universal inundation happened, he said, both at the Creation and in the age of Noah, and particular inundations happened to bounds of regions as shown in Aristotle's Meteorology and Verstegan's description of Holland.[50] Carpenter treated Noah's Flood as one of the inundations although it was thought to be extraordinary. Swan also discussed the effects of both Noah's Flood and earthquakes referring to Plato's Atlantis as an effect of an earthquake.[51] Thus, the notion of cyclic change was harmonized with the Christian linear view of the world, and Raleigh's History was a typical example of a solution for this problem.

The Rise of History

The popularity of Raleigh's History can be also verified by the fact that it was often recommended. Wheare, the first Camden Reader in History at Oxford, published his lectures as De Ratione et Methodo Legendi Historias in 1623. This London edition was enlarged and published at Oxford in 1625, and still further enlarged in 1637. Five Latin editions were published between 1623 and 1684, and three English translations before the end of the century. The book was used as a textbook at Cambridge, as well as Oxford, down to the beginning of the eighteenth century.[52] In this popular book Wheare claimed that

Raleigh's History was the best except the Bible.[53]

> Sir Walter Rawleigh our Country-man deserves the first place, a Man of great Fame, and for his great both Valour and Prudence worthy of a better Fate. He has built up an Universal History,...,which is written in English, with very great Judgment, in a perspicuous Method, and an Elegant and Masculine Style,...[54]

In his Nature of Truth (1640), Lord Brooke also approved of Raleigh's argument.[55] John Locke was later to recommend Raleigh's History and Wheare's Method to young gentlemen.[56] Carpenter described Raleigh as a "worthy writer",[57] Heylyn regarded Raleigh's History as "excellent",[58] and Hakewill claimed that Raleigh was "machable with the best of the ancients".[59]

The widened interest in Raleigh's History seems to have coincided with the rise of ancient history. Although the subject of history received little attention in the pre-Reformation period, Renaissance scholarship did promote a desire to understand the circumstances of the historical events referred to in the ancient classics, even if it did not directly arouse an educational interest in history.[60] Degory Wheare's book on history, for example, contained "Mr. Dodwell's Invitation to Gentlemen" to acquaint themselves with ancient history. It said that "it may not perhaps be unreasonable, on this occasion, to recommend the study of ancient History to our English Gentlemen."[61] William Holdsworth recommended historical studies to his students, saying that "History is a most useful and necessary study. Cluverius will give you a complete taste of it in general from the beginning of the world till our times. He must be read throughout."[62] Henry Peacham, too, strongly urged young gentlemen to read a book on history, including universal history, Greek and Roman history, and English history.[63] The study of history was thus regarded as a part of the culture considered de rigueur for young gentlemen. History was not studied as an end in itself, but as a means to achieving elegance of literary expression and fullness of detail and description in the examples under discussion. The ancient historians were not studied for their subject matter, but for their beautiful style. The study of history was further encouraged by the foundation of academic positions. In 1622 William Camden endowed a history readership in Oxford, and in 1628 Fulke Greville, Lord Brooke, established a history lectureship in Cambridge.

The history of the primitive Earth was widely discussed when scholars became interested in ancient history, although they differed in opinion over the origin of mountains. Some believed that they had been formed at the time of the Creation while others thought that they had been produced by the violent waters of the Deluge.

Most scholars, however, tended to interpret Genesis in a naturalistic way. They believed that God had executed his will with the aid of secondary causes, so that, without denying the hand of God, they could explain the Deluge in terms of physical causes. In this way, the effects and causes of Noah's Flood became a topic of discussion long before the publication of Thomas Burnet's Theory of the Earth (1684).

NOTES

1. A. Williams, The Common Expositor: An Account of the Commentaries on Genesis, 1527-1633 (Chapel Hill: N.C., 1948), 3.

2. Martin Luther, "Lectures on Genesis, Chapter 1-5", in J. Pelikan ed., The Works of Martin Luther, vol.1 (Saint Louis, 1958), 98.

3. Ibid., 310.

4. Godfrey Goodman, The Fall of Man, or the Corruption of Nature (London, 1616), 284.

5. Ibid., 285.

6. Ibid.

7. Ibid., 285-86.

8. Ibid., 286-87.

9. Stephen Toulmin & June Goodfield, The Discovery of Time (London, 1965), 75.

10. John Calvin, Commentaries on the First Book of Moses called Genesis, ed. by J. King (Grand Rapids, 1948), 119.

11. Ibid.

12. Ibid., 82.

13. Ibid., 270-71.

14. Ibid. 277.

15. Ibid., 512.

16. C. Hill has asserted that Protestants such as Calvin were sceptical of all miracles which were said to have occurred in the primitive church and reduced the area in which direct divine intervention had taken place. (Hill, Intellectual Origins, 25) However, Calvin adhered to the supernatural cause in his discussions on the early history of the Earth. For him the Earth's history could not be regarded as an object for scientific research. Even if Calvinism played

16. continued.

an important role in the development of natural philosophy, it nevertheless rejected a scientific study of the Earth's history. Thus it is still a matter of debate whether Protestantism promoted in general the development of natural science.

17. Walter Raleigh, The History of the World (Edinburgh, 1820), Bk. I, Chap. I, Sect. X.

18. Ibid., Bk. I, Chap. III, Sect. V.

19. Ibid., Bk. I, Chap. VII, Sect. V.

20. Ibid., Bk. I, Chap. VII, Sect. VI.

21. Cf. Hill, Intellectual Origins, 189.

22. Toulmin & Goodfield, Discovery, 107.

23. Raleigh, History, Bk. II, Chap. XIX, Sect. VI.

24. Hill, Intellectual Origins, 187.

25. Nathanael Carpenter, Geography Delineated Forth in Two Books (Oxford, 1625), Bk. II, 208.

26. Ibid., Bk. I, 10.

27. Ibid., Bk. II, 166.

28. Ibid., Bk. II, 167-69.

29. Ibid., Bk. II, 169.

30. Ibid., Bk. II, 191.

31. Ibid., Bk. II, 194.

32. Ibid.

33. Ibid., Bk. II, 195.

34. John Swan, Speculum Mundi (Cambridge, 1670), 153.

35. Ibid., 37.

36. Ibid., 38-9.

37. Ibid., 40.

38. Alexander Ross, Some Animadversions and Observations upon Sir Walter Ralegh's History of the World (London, 1653), To the Reader.

39. Alexander Ross, The First Booke of Questions and Answers upon Genesis (London, 1620), 5-6.

40. Ibid., 12.

41. John Wilkins, The Discovery of a World in the Moone (1640). Reprinted (New York, 1973), 63-4. Wilkins referred to Raleigh when he considered the height of the mountains. Wilkins, Discovery, 71-2.

42. Edward Stillingfleet, Origines Sacrae, or a Rational Account of the Grounds of Christian Faith, as to the Truth and Divine Authority of the Scriptures (London, 1662), 538.

43. Ibid., 539.

44. Ibid., 543.

45. Ibid., 543-44.

46. Ibid., 544.

47. F.C. Haber, The Age of the World (Baltimore, 1959),14.

48. Raleigh, History, Bk. 1, Chap. VII, Sec. II, III.

49. Carpenter, Geography, Bk. II, 191-92.

50. Ibid., 196.

51. Swan, Speculum Mundi, 192.

52. Hill, Intellectual Origins, 177n. The popularity of Raleigh's History of World is discussed in Hill's Intellectual Origins, 203-13.

53. Degory Wheare, The Method and Order of Reading both Civil and Ecclesiastical Histories (London, 1694), 38.

54. Ibid., 42.

55. Hill, Intellectual Origins, 210.

56. John Locke, The Works of John Locke, Vol. 2 (London, 1794), 409.

57. Carpenter, Geography, Bk. II, 208.

58. Heylyn, Cosmography, 7.

59. Hakewill, Apologie, 251.

60. F. Watson, The Beginning of the Teaching of Modern Subjects in England (London, 1909), 45.

61. Wheare, Method and Order, Mr. Dodwell's Invitation to Gentlemen.

62. Curtis, Oxford and Cambridge, 120.

63. Henry Peacham, Complete Gentleman (New York, 1962), 54-67.

3. THE CHEMICAL VIEW OF THE MINERAL KINGDOM

As has been discussed in previous chapters, some seventeenth-century academics thought that the phenomena of the Earth were cyclic and others discussed the causes and effects of Noah's Flood which might have produced the present geological features. Moreover, during this period some of them came to claim that the fossiliferous strata were evidence of cyclic changes in the Earth's surface while others considered them to have been deposited at the time of the Deluge. However, fossils were not the only geological objects studied; minerals and stones in general had attracted considerable attention as shown in encyclopedic works which contained descriptions of the animal, the vegetable, and the mineral kingdom. The importance of a mineralogical study in our story lies in that it provided ideas for building up theories on the formation of the mineral kingdom and the origin of fossils and was thus discussed by another tradition. Although David R. Oldroyd has already discussed seventeenth-century mineralogy,[1] my aim here is different from his in that this chapter will attempt to illuminate how the fossil question came to be treated by this "chemically-oriented" tradition.

A Theory of Subterranean Exhalations

In Aristotle's view, there exist two kinds of subterranean exhalations, one vaporous and the other like smoke. The first is called "moist exhalation"; it rises from the bodies of water on the Earth's surface and condenses into clouds. The second kind which resembles smoke is called "dry exhalation"; it passes into the atmosphere and, under certain conditions, causes thunder, lightning and other atmospheric phenomena. Under the influence of the sun's rays these exhalations also develop at times in the Earth's interior. Moist exhalations produce metals, and dry exhalations "fossils" or stones.[2] This theory of exhalations was modified and transmitted to the seventeenth century.

In his argument about the conflicting views on the origin of the sulphur-mercury theory, Allen G. Debus has said that the theory is most commonly described as an extension of the Aristotelian view of smoky and watery vapours within the earth being transformed into metals and stones,[3] while R. Hooykaas has argued that the sulphur-mercury theory actually originates in the idea of "active" and "passive" elements pursued by the Stoics.[4] In his work on mineralogy in the sixteenth and seventeenth centuries, David R. Oldroyd has suggested that before the middle of the seventeenth century accounts of the formation of minerals were customarily given in "organic" terms.[5] As will be shown, however, English encyclopedic authors in the seventeenth century did not always accept the notion of "active" and "passive" elements.

The sulphur-mercury theory which was derived from the Aristotelian theory of vapours can be found in the encyclopedic works of John Swan, Thomas Browne and Robert Lovell. These works consisted of descriptions of the animal, the vegetable and the mineral kingdom. While Swan was a student of Trinity College, Cambridge, both Browne and Lovell graduated from Oxford and became physicians. They were thus university graduates who were interested in natural history. As their works were general guidebooks to the natural world, they seem to have reflected the wide-spread interest in natural objects.

Swan published his Speculum Mundi in 1635, in which he arranged accounts of the natural phenomena according to the days of the Creation. In this encyclopedic work he discussed the generation of stones, rejecting the idea that there existed a living force in stones:

> stones are bodies perfectly mixt, without life, hard, of a dry and earthy exhalation, mixed with a certain unctuosity.[6]

The matter of stones, Swan said, is watery moisture and thick, unctuous earth. As for their efficient cause, they have come about through the action of heat and cold. Swan followed the "Philosophers", i.e. the Aristotelians, in affirming that heat brought the slow, humid, unctuous matter up through the thin parts of the earth, and cold condensed it. Stones do not have any vegetative life, as do plants which draw their nourishment from their own bodies. The growth of stones, he said, arises from outward increase by the addition of matter adhering to them and, in time, their growth may become less, "in which regard some supposed that they had life, and died."[7]

Alchemists had interpreted Aristotle's idea of the generation of stones and metals in terms of the sulphur-mercury theory: Watery exhalation became mercury, and dry exhalation became sulphur. Swan accepted this sulphur-mercury theory; "The first, or principall metals, are Sulphur and Mercury: These are of themselves, because other metals do not help to make them, but they help to make other metalls."[8] He did not claim that the sulphur-mercury theory was related to the emphasis on active and passive principles. Thus Stoic influence cannot be found in the work of Swan.

The Aristotelian theory of vapours was also adopted by Thomas Browne in his Nature's Cabinet Unlock'd (1657), another encyclopedic work which contained much information on the natural world including the mineral kingdom. In this work Browne discussed the natural cause of the formation of metals and stones. In his view the "Peripateticks" assume that two kinds of vapours hide under the ground: one is dry, and the other moist, and from them stones and metals are formed. The "Chymists", he claimed, do not dissent from this opinion of Aristotle because they assume the "nearer" matter of metals to be sulphur and mercury which grow from the vapours, the "remote" matter of metals.[9] Thus Browne thought that the sulphur-mercury theory did not contradict Aristotle's theory of vapours.

Browne also pointed out that there was a great dispute as to whether metals were animate bodies or not. Rejecting the idea that there existed a living force in the bowels of the Earth which could produce metals, he said that

> It is most certain they perform no vitall action, as other bodies that are endowed with

> a vegetive soul; therefore they are not Animated.[10]

He instead accepted the sulphur-mercury theory to explain the generation of metals:

> ...it is said in the definition, that Metalls are begot...of Sulphure and Quicksilver, mixed and tempered. In which words the efficient causes are included, which are two, Heat and Cold; Heat indeed doth precede, Cold follows the generation of Metalls.[11]

Browne thus understood sulphur and mercury as the efficient causes of metals, that is heat and cold. The sulphur-mercury theory was harmonized with Aristotle's terminology and was interpreted in inorganic terms.

The sulphur-mercury theory was also adopted by Robert Lovell, who studied botany, zoology and mineralogy at Oxford. He published Panzoologicomineralogia, or a Compleat History of Animals and Minerals (1661), in which he defined the meaning of metals as "fossil bodies, hard, that may be melted by the fire, consistent in their own nature, and malleable". He adopted the common view of metals, saying that

> their remote matter is vapour, and the proximater, sulphur and quick-silver...

Like other encyclopedic authors, Lovell interpreted Aristotle's theory of vapours in terms of the sulphur-mercury hypothesis. He, too, did not hold the idea that metals had a vital force which could cause the growth of themselves.

Encyclopedic authors such as Swan, Browne and Lovell did not accept the idea that the mineral kingdom was formed by a vital force while they believed that sulphur and mercury could produce metals in a certain condition. The sulphur-mercury theory was not always associated with the idea that the mineral kingdom was full of life. As these authors principally relied on the Aristotelian theory of minerals, there was no room for acceptance of vitalism.

Thus, a chemical theory which had been derived from Aristotle's idea of the formation of the mineral kingdom was often accepted in the seventeenth century. In this theory, minerals and stones were formed by the action of sulphur and mercury and the mineral kingdom was thought to be lifeless. A similar chemical theory was claimed by Gabriel Plattes, who, however, explained the formation of the mineral kingdom by his own experiment. In 1639, he published A Discovery of Subterraneous Treasure, which reached its third edition by 1679 and was reprinted in A Collection of Scarce... Treatises upon Metals, 1739 and 1740. In this work Plattes considered the natural cause of the generation of rocks, mountains and metals. According to Plattes, some thought that the vast, deformed and craggy rocks and mountains had been created at the beginning. But Plattes did not agree with this opinion because the Creator, he thought, manifested his wisdom in all the created and made nothing deformed or unfit for his creatures. The craggy mountains therefore were formed by accident. Another opinion is that, although mountains came about by accident, they were produced by accretion, like warts, tumours, wenns and excrescences on the surface of a human body. Plattes said that he was of this opinion in his youth, but found what he regarded as a more probable solution by practical experience:

> Let there bee had a great retort of Glasse, and let the same be half filled with Brimstone, Sea-coale, and as many bituminous and sulphurious subterraneall substances as can bee gotten: then fill the necke thereof halfe full with the most free earth from stones that can be found, but thrust it not in too heard, then let it be luted, and set in an open Furnance to distill with a temperate Fire, which may onely kindle the said substances, and if you worke exquisitely, you shall finde the said Earth petrified, and turned into a Stone: you shall also finde cracks and chinkes in it, filled with the most tenacious, clammy and viscous parts of the said vapours, which ascended from the subterraneall combustible substances.[12]

Plattes thus performed a practical experiment on the growth of stones in a laboratory to examine his hypothesis. From this experiment he suggested that rocks and craggy mountains had not existed at the time of the Creation but had been formed by the combustion of bituminous and sulphureous substances kindled in the earth. The veins of metals moreover were claimed to be generated in the fissures of mountains out of the moist and sticky type of subterraneous vapours arising from bituminous and sulphureous substances.[13] In this way Plattes attempted to explain the formation of rocks, mountains and metals in terms of inorganic processes.

The inorganic explanations of the formation of the subterranean substances were thus based on the theory of vapours rising from the earth. These chemical theories had an Aristotelian flavour and opposed the belief that there is a controlling force in mineral substances which is distinct from chemical and physical forces. A.G. Debus has suggested that the historical importance of Plattes' work lies first in his attempt to reproduce geological phenomena in a chemical laboratory.[14] Plattes differed from the encyclopedic authors in that he presented his theory supported by practical experiment. While earlier encyclopedic works were no more than descriptions of animals, vegetables and minerals in alphabetical order, Plattes' Discovery was not a general book on natural history but a mineralogical work. Plattes, a writer on agriculture, devoted much time and money to practical experiments.[15] Although neglected during his lifetime, his work came under a different tradition from the established encyclopedic works.

An Attack against Academic Learning

As will be discussed, similar mineralogical works were published in the seventeenth century, and these works showed the influence of neo-Platonic thought on the discussion of the formation of minerals. In a neo-Platonic view, the world was in a sense alive and filled with the vital force. Therefore, the generation of every substance in the world could be understood in "organic" terms.

In his *Timaeus* Plato described the cosmos as a living creature, endowed by divine providence with soul and reason. Such an idea could offer an "organic" explanation of the formation of the mineral kingdom. It was Marsilio Ficino (1433-99) who was in large part responsible for reintroducing Platonism to Renaissance Europe. He established the Platonic Academy of Florence under the patronage of Cosimo de Medici, and translated the writings of Plato into Latin. Ficino was also important in that he passed on the Hermetic tradition by preparing Latin translations of certain Hermetic tracts. The Hermetic writings provided a view of the cosmos which contrasted strongly with that of Aristotle. It was a world full of magical powers, the secrets of which were given up only to those who were willing to look beyond surface phenomena. On this view, a chemical approach to nature was regarded as the best way to disclose its hidden secrets.[16]

If neo-Platonism had remained the fantasy of a few eccentric alchemists, it would not need to be discussed here. Its approach, however, made an enormous impact upon the intellectual world of Renaissance Europe.[17] By the end of the fifteenth century, the philosophies of Platonism and neo-Platonism were widely available to European scholars. The neo-Platonic trend in the concept of nature provided the main ideas for Paracelsus (1493-1541). He embellished the concepts of neo-Platonism with observations and interpretations of natural phenomena.[18] He saw matter as spirit made manifest to us by some process of materialization, and made use of the concept of seeds in his mineralogical writings. The formation of minerals was thought to be analogous to the growth of plants which developed from seeds. Paracelsus also held that his three principles, salt, sulphur and mercury were composed within the matrix water which was replete with all kinds of seeds, to form the various minerals. The artificer for all these processes was called the Archeus, which would arrange and put in order what ought to be joined together to accomplish the work.

Van Helmont (1579-1644), who was influenced by Paracelsus, had a similar view on the formation of minerals, according to which water acts as a matrix or womb. A seed contains an idea impressed upon it which determines its subsequent development. Minerals develop in their matrices according to the ideas impressed. The ideas originate in the mind of God, and the Archeus acts as God's agent to form minerals. In van Helmont's system all things were produced from water and seed, the latter operating through an inherent spirit to produce its specific form.

In England the works of Paracelsus and van Helmont were highly praised by John Webster, who had studied chemistry under the Hungarian alchemist John Hunyades in London and published Academiarum Examen (1654), in which he criticized the education at the English universities. Arguing about a lack of natural philosophy in the curriculum, he advocated the study of chemistry which he thought offered the proper inductive approach shown in the writings of Robert Fludd and Francis Bacon.[19]

For Webster the arguments of both Fludd and Bacon were based on empirical evidence. In his Metallographia (1671) Webster again opposed a scholastic attitude towards the study of nature:

> What Opinions soever I offer, whether of mine own, or taken from other Authors, are not to impose upon the judgment of any, who am my self no lover of Dogmatizing, and have long wished, and am now most glad to see a way set up for the promoting of Experimental Philosophy, that Mens judgments may no longer be fettered in Scholastic Chains, nor kept always in the Prisons of Academic Opinions.[20]

While Webster admitted that the Scholastic system and method were necessary in the instruction of young students, he condemned them as being unfit for making further discoveries in natural philosophy. He called those who followed the Scholastic learning "Speculative Authors":

> By Speculative Writers I understand such, who by their deep contemplations, notions, and working of their brains, thought they had catched Nature in a Net, and so kept her, that they were able to understand all her operations, both hid and open, and so framed large Volumes of the whole operation of Nature, as though they had been skilled in all things ...[21]

Aristotle himself was one of the butts of Webster's criticism. In his view, Aristotle was generally regarded as "the Prince of Learning" who knew everything about the world, but in fact he was "far short from giving satisfaction to searching spirits, concerning all the particulars of Mineral knowledge."[22] Webster claimed that Aristotle's explanation of the generation of metals was no longer widely accepted. As for the great numbers of followers of Aristotle, they added little or nothing new, remaining content with their master's teaching.[23]

Instead of Aristotle's system, Webster based his work on the theories of Paracelsus and van Helmont who had realized the importance of minerals: whereas the animal and vegetable kingdoms were scrutinized by many observers, Webster claimed, substantial progress was not made in the study of the mineral kingdom hid in the earth except in the works of some chemical philosophers such as Paracelsus and van Helmont. Webster thought that the study of the subterranean world would bring much advantage to the country in general and to the poor miners in particular.[24] Thus the purpose of this work was not to educate university students liberally but to promote a practical knowledge of minerals.

In Webster's view, both observation and experiment were essential to the study of the mineral kingdom. In the Dedication to Prince Rupert, he praised the Royal Society of London as "one of the happy fruits of His

Majesties blessed and miraculous Restoration." Webster believed that the design of the Society was based upon the inductive method which he advocated. He also regarded "experimental observators" such as Georgius Agricola as reliable

> because these Authors speak not altogether by Opinion, Fansie, and Conjecture; but forth of their own experience, and the experience of those that were conversant about the Mines, and getting of Ore, and purifying and refining of them; and therefore more certain to be relyed upon for Leaders and Teachers.[25]

This very method of a mineralogical study was strongly criticized by an orthodox scholar. Defending the Aristotelian philosophy, Thomas Hall condemned Webster for "advising schollars to leave their Libraries, and fall to Laboratories, putting their hands to the coales and Furnance." For Hall this is Webster's way "to bring men to the Devill or the Devill to them."[26]

The Neo-Platonic Theory of Minerals

Webster neither held an academic position nor wrote his works as textbooks for use at university. He was free from academic restrictions. Edward Jorden (1569-1632), too, was in the same position and accepted a neo-

Platonic view of minerals. He was educated at Oxford and Cambridge, and then, like many other English students, went to the Continent, where he obtained his M.D. at Padua. In 1631 Jorden published A Discourse of Natural Bathes and Mineral Waters, which reached its fifth edition by 1673, and, as the title indicates, this book was not a mere encyclopedic work but offered first-hand observations on geological phenomena.

One of the main topics of this book was an explanation of the growth of minerals. In his solution to this problem Jorden suggested the idea of fermentation which was based upon the principle that there was a life force in minerals. According to him, some chemists believed that metals and minerals must have been created at the beginning of the world, as they do not appear to have any seed and their substances are firm rather than flexible.[27] Jorden agreed with the idea that there was not any seed for minerals, but he insisted that they were generated. The manner of the generation of minerals is common to all, but differs from that of animate bodies such as animals and vegetables, in that minerals have no power of reproducing. The species is preserved by a spiritual substance, which does not necessarily exist in every mineral.[28]

Jorden pointed out that the current controversy was not so much over the manner of generation of each type of mineral as over their efficient cause. In Jorden's view there must be one principal efficient cause to give the form to all species. It had been often thought that the principal agent was the influence of the planets and the sun, but Jorden claimed that terrestrial substances did not depend upon the planets for their generation but had the principal causes within themselves.[29] Generation was thought to be effected by a spiritual substance:

> There is a Seminarie Spirit of all minerals in the bowels of the earth, which meeting with convenient matter, and adjuvant causes, is not idle, but doth proceed to produce minerals, according to the nature of it, and the matter which it meets withal; which matter it works upon like a ferment, and by his motion procures an actual heat, as an instrument to further his work; which actual heat is increased by the fermentation of the matter.[30]

This seminary spirit of minerals, Jorden maintained, has its proper wombs, andis like a Prince whose command matter will obey. It is always active, producing and maintaining natural substances until it has completed its work. A natural necessity is inherent in the seminary spirit, and it is the cause of uniformity in every species. Neo-Platonic thought was thus utilized for explaining the growth of minerals.[31]

Unlike earlier encyclopedic works, the work of Jorden contained descriptions of his first-hand observations, but did not refer to the fossil remains of living creatures, which were to receive much attention in the second half of the seventeenth century when the collection of natural curiosities became more highly regarded among Fellows of the Royal Society.

On the Continent Albaro Alonso Barba, Director of the Mines at Potosi in the Spanish West-Indies, published a book on mines in 1640. This book was translated into English in 1669 by Edward Montagu, who, admiral and general at sea, also contributed an article on an eclipse of the sun to the Philosophical Transactions. In Barba's work one may find a neo-Platonic influence on his view of nature:

> It is most certain, that there is some very active Principle or Virtue that operates in the Generation of Stones, as well as upon the rest of Matter of the Universe, that is subject to Generation or Corruption; but the Difficulty lies in knowing what that Principle is, because it operates in no determinate Place, but sometimes Stones are made in the Air, in the clouds, in the Earth, in the Water, and in the Bodies of Animals.[32]

Barba maintained that every individual form of stone had its particular efficacy, as remarkable as that of animals and plants. Living creatures, however, cannot have the uniform nature of stone, because their dispositions are so different and also because they are capable of producing various effects. The hardness of stones also does not allow for the same variety of shapes. Barba suggested therefore that there are no leaves, flowers, fruits, hands and feet in stones. Plants and animals were thought to have greater virtue than stones, but every generative process in the universe was equally explained by an active principle or virtue.

Barba was interested in fossil remains, which were called "formed stones", as well as in ordinary stones. His opinion on the origin of fossils was also based on the idea of an active principle. He did not, however, simply repeat a common opinion, but explained the origin of fossils by considering the locations where they were found.

Barba referred to Avicenna's opinion that fossils were formed from real living creatures:

> ...we meet with Stones that represent Animals, or the Limbs of them, or Plants, or other Things not by superficial Draught or Colouring, but in Bulk and Substance. I believe it may arise from some petrifying Liquor, which that Matter has suck'd into it's Pores, and thereby is become all Stone, and so thinks Avicenna.[33]

Barba does not add any comment to Avicenna's idea of petrification, but he was not a speculative philosopher who was satisfied with a deductive method. He referred to actual observation as a means of solving the problem:

> At the Foot of the Mountains Misnenses, near unto the Lake of Alsatia, Stones are very commonly found that have emboss'd upon their Superficies, the Images of Frogs and Fishes in fine Copper. Anciently they call'd a sort of stone Conchites, which were in all their Lineaments very like unto the Cockles of the Sea; and they thought that those Fish-shells lying a long time in Soil, where much Stones were begotten, the petrifying Liquor entring into the Pores of the Shell, converted it into Stone: And they ground this Opinion upon the Certainty that the Sea in old Time hath overflown the whole Territory of the City of Magara, where only these sort of Stones are found.[34]

In other words, Barba suggested that the actual conditions of fossil shells might confirm Avicenna's opinion of the organic theory. It seemed that fossil shells found in rocks had once lived in the ocean. It could not reasonably be supposed however to have always been so:

> But of latter Times all Colour of Reason is taken away from the foremention'd Conceit, by the wonderful Veins of Stone, some grey, some iron colour'd, and some yellow, which are found in the Highway as one goes from Potosi to Oronesta down the Hill. There they gather Stones that have in them Impressions of divers sorts of Figures, so much to the Life, that nothing but the Author of Nature

> itself could possibly have produc'd such a piece of Workmanship. I have some of these Stones by me in which you may see Cockles of all sorts, great, middle-siz'd, and small ones; some of them lying upwards, and some downwards, with the smallest Lineaments of those Shells drawn in great Perfection; and this Place is in the Heart of the Country, and the most double mountainous Land therein, where it were Madness to imagine that ever the Sea had prevail'd, and left Cockles only in this one Part of it.[35]

This statement shows that Barba himself did fieldwork and collected fossils. He carefully observed the figures of fossils and attached great importance to their location, which persuaded him to believe that only the "Author of Nature" could have produced them. In Barba's opinion the location where these shells were found was too mountainous to have been under the sea. Hence he suggested an inorganic theory of fossils, which was based on a neo-Platonic view of the mineral kingdom.

As for the generation of metals, Barba assumed that there existed particular virtues which could produce metals. First he considered the opinions of Plato, Aristotle and their followers as to the generation of metals. As we have seen, some philosophers explained the generation of stones and metals as coming about from the action of two kinds of exhalations under the surface of the Earth. According to Barba, however, alchemists had a more profound and practical philosophy although the word "alchemist" had become repugnant "by Reason of the Multitude of ignorant Pretenders to that Art."[38] Barba then advocated the alchemical idea that Sulphur and Mercury were the matter from which metals were generated.

Barba also claimed that the heavenly bodies were a universal cause of all things, but he assumed that there was some other efficient cause which, having received virtues from the planets, may have worked upon the proper matter of metals. Aristotle's idea of the elements alone is not sufficient, he thought, to produce any compounded body. They must be governed by some other particular virtue, as is seen in living creatures.[37] Like stones and "formed stones", therefore, metals are produced by particular virtues. Thus by the concept of particular virtues Barba explained the generation of the whole mineral kingdom. As active virtues were regarded as the cause of all other created things, they were also said to produce various kinds of "formed stones". This idea made it possible to explain the origin of fossil shells found in high mountains far from the sea.

Barba, as a director of a mine, was in a position to observe various subterranean phenomena, and under the influence of neo-Platonic thought he attempted to explain the natural world on a universal principle.

A similar view was held by Sir John Pettus (1613-1690), a deputy governor of England's royal mines. In 1670 he published Fondinae Regales; or the History, Laws and Places of the Chief Mines and Mineral Works in England, Wales, and the English Pale in Ireland, in which he, too, discussed the "Seminal Virtues".

> The usual Method of Historians is to begin with the Creation, wherein I might tell you, That when GOD breathed upon the Face of the Waters, that was Petrefying turned into Plains or Levelled Earth, and the Boisterous Waters into Hills and Mountains, according to the proportion of the Billows, and their Spaces into Vallies, which have ever since continued in those wonderful and pleasant Dimensions, the Seminal Virtues of all Sublunary things being locked up, and more durably preserved in them; and from thence they are transmitted through Terrene Pores, either from their own Exuberancies, or the Sun or Stars Extractions into various and visible Forms:...[38]

Thus in Pettus' view seminal virtues pertaining to terrestrial things were enclosed in the earth at the beginning when mountains and plains were formed, and afterwards produced various forms in the ground, such as subterranean trees, serpents and fishes. Pettus thought that "formed stones" had been generated in the same manner as metals. Thus, he suggested that fossils were not the remains of living creatures but products of "Seminal Virtues".

Fossils as the Remains of Living Creatures

Neo-Platonic thought was often connected with the belief that fossils had been formed by hidden virtue. Martin J.S. Rudwick has claimed that "the Neoplatonic thought of the sixteenth century made the modern interpretation of fossils less persuasive than it might otherwise have been, simply because it provided an alternative explanation of the resemblances between some 'fossil objects' and living organisms." [39] Roy Porter has also claimed that the idea that fossils were "lapides sui generis" was integral to the neo-Platonic philosophy of nature.[40] However, those who adopted neo-Platonic thought did not always claim that fossils had an inorganic origin.

For example, John Webster, an eminent defender of the neo-Platonic view of nature, did not connect it with the theory of fossils. Although highly praising "experimental observators" for their precise information concerning the subterranean world, Webster expressed, in his Metallographia (1671), his own a priori idea on the growth of metals. Like Edward Jorden, Webster rejected a general opinion that metals had been created by God at one particular point and did not grow in the earth.

In Webster's view, through the action of the "Archaeus (or Workman) of Nature", the Aristotelian four elements distill heavy water vapour which is the seed of metals and is called mercury. Sulphur is the pure fire concealed in the mercury, which is activated and moved by the motions of the celestial bodies, and transforms the coldness and humidity in the mercury into diverse metallic forms.[41] Webster thought that this explanation concurred with the statement that "Sulphur is the efficient cause, or father, and Mercury the passive or mother of all Metals."[42]

Webster's argument on metals thus depended on the neo-Platonic idea that there existed the seed of metals. Every fact collected by him was interpreted in a way which would accord with this hypothesis. He explained the actual process of the growth of metals as follows:

> That the Water being sharp and salt, and falling down in the subterraneous caverns and passages of the Earth, doth meet with the drie, sulphureous, and warm steams that rise from the lower parts of the Earth, do joyn together, and so becomes unctuous and fat, which setling in close holes, and cavities of Rocks where the air cannot enter, as in a close womb, is in length of time thickned into a soft substance, which they call Gur; and after by the warmth of the place, or womb, and its own internal fire, sulphur, or heat, is concocted into a metallick body, pure or impure, according as the steams were, when they joyned together, and the place in which they are generated.[43]

Like other chemical philosophers, Webster thought that the growth of metals could be explained by a seminal principle. However, he did not use this notion for arguing about the origin of fossils.

Although a diligent observer, Webster's book on metals did not contain an account of the fossil remains of living creatures. However, he defined the term "fossil" as something dug up out of the earth, "not intending subterraneous animal, vegetables, nor any of their parts."[44] It is thus obvious that he noticed the existence of the fossil remains of living creatures, which he thought were different from other mineral substances in the earth. While Barba and Pettus regarded fossils as mere stones and insisted on their inorganic origin, Webster excluded fossils from his arguments about the mineral kingdom. This exclusion suggests that he believed that fossil stones were remains of living creatures. Neo-Platonic philosophy thus did not inevitably persuade the chemical philosopher to believe that fossils had been formed by hidden virtues.

While Webster did not utilize neo-Platonic thought to discuss the origin of fossils, Thomas Sherley (1638-78), physician, applied the same thought to defending the organic theory. He showed his interest in neo-Platonic thought in his <u>Philosophical Essay: Declaring the Probable</u>

Causes, whence Stones are produced in the Greater World (1672), in which he discussed the cause of fossils.

Like van Helmont, Sherley thought that the substance of stones and all other bodies was "water", and their efficient cause was "seed". By "water" was meant the material principle of all bodies, which would readily submit to those motions in which it was put by "Seminal Beings". By "seed" was meant a fine and subtle substance in which God impressed the character of the thing he would have it produce. And all the visible bodies of the world would be produced from the movement of matter stimulated by such seminal principles. Sherley therefore claimed that the origin of bodies could be explained by mechanical principles, or "by the Motion, Shape, Size, Situation, and Connexion of the parts of Matter." He appreciated the way of explication advocated by the mechanical philosophers, but criticized those who omitted "the first principle of Natural Motion; viz. the Seminal principle."[45] For him the mechanical principles were important because they could explain all visible phenomena, whereas the mechanical principles themselves did not explain how the first motion of bodies was brought about.

To make his idea clearer, Sherley referred to Plato's Timaeus. According to Plato, he said, there are two kinds of worlds: one has the form of "a Paradigm, or

Exemplar", which is intelligible and eternal, while the other is "the Image of the Exemplar", which has a beginning and is visible. By the intelligible world Plato understands the divine order which exists in the mind of God. And these original Ideas produce the secondary Idea, namely the seeds of things. The last Idea or seed contains the picture of the thing to be made, and depends upon the primary or original Idea which resides in God. Sherley thought however that this idea of the generation of bodies did not contradict the mechanical philosophy:

> By this declaration of my thoughts, I hope it will plainly appear, that I am no Enemy to that rational way of explicating the phenomena of Nature, used by the Atomical, Cartesian, or Corpuscularian Philosophers...[46]

Following Plato, Sherley supposed that there were two worlds, that is to say, the actual or physical world and the ideal or metaphysical world. He referred to the ideal world to explain the first motion of bodies, but he divested himself of the concept of this ideal world when he argued about the actual world, these two worlds being able to be considered separately. He was therefore sure that his argument on the generation of bodies was in accordance with the mechanical philosophy.[47]

Sherley suggested that his idea of "Seminal spirit" could be applied to every kind of generation:

> As Vegetables, and Animals have their Original from an invisible Seminal spirit, or breath; so also have Minerals, Metals, and Stones.[48]

Sherley believed that nature is uniform in its manner of producing bodies. He did not, however, assume that fossil remains were of inorganic origins, but rather suggested that they were the remains of living creatures which had been changed into stones by "Rocky Seed". Some chemical philosophers such as Barba and Pettus were inclined to adopt the opinion that fossils were formed stones and not once-living creatures. Sherley, however, used the philosophy in a different way and arrived at the opposite conclusion.

According to Sherley, seminal principles produce stony wood. The rocky seed contained in water penetrates the pieces of wood and passes through the pores of the wood or whatever body it is being changed. Thus the bodies of wood are converted into stones.[49] Subterranean trees therefore must have once grown on land. Sherley also discussed the conversion of animals into stone:

> ...the Petrifying Seed, the Human, or other Living Creatures Figure being still intire,

> without any intervening putrefaction, or dissolution of the matter, doth transchange [Totum per Totum] the whole, throughout the whole; that is, as well the Bones, as the Blood, and Skin: So that here is not an incrustation of the stony matter upon the External parts, [only] but a real change, intrinsically, and throughout, of the Bony, Fleshy, and Sinnewy Parts of the Animal into a stony Substance.[50]

Sherley also showed other examples of petrification such as fishes, spiders and toads enclosed in stones.[51]

While it may be seen that both Webster and Sherley regarded fossils as the remains of living creatures, other chemical philosophers did not accept the organic theory of fossils. The historical importance of this however lies in the fact that the chemical philosophers came to be aware of the question as to the origin of fossils. Encyclopedic authors before the mid-seventeenth century were deeply interested in the natural world, but they neither made first-hand observations nor noted fossil remains. Fossils were out of their realm of concern. Some chemical philosophers, on the other hand, established the study of the mineral kingdom as a self-sustaining subject and some of them suggested solutions to questions relating to the origin of fossils.

M.J.S. Rudwick has maintained that a modern interpretation of the origin of fossils was delayed "by the lack of any satisfactory explanation of geographical change."[52] As has been discussed, however, there is no doubt that the ancients' cyclic view of the Earth did discuss the geological change which could produce the fossil remains of living creatures. It would therefore be proper to say that neo-Platonic philosophers were little interested in large-scale geological changes such as the interchanges of land and sea.

The interest and method of chemical philosophers were different from those who discussed the causes of geographical features. Each tradition had its own field of study, and there was not a serious interaction of views between them until the mid-seventeenth century. It was a controversy over the origin of fossils which followed a direct interaction between these two traditions. After the foundation of the Royal Society of London, the members set about collecting fossils and began to debate their origins. Neo-Platonic thought often provided answers to this matter, but such theoretical assumptions could have diverse interpretations. Empirical evidence moreover came to be regarded as essential to the study of nature. Thus neo-Platonic thought could no longer remain a closed system, and was required to conform with observations and experiments.

NOTES

1. David R. Oldroyd, From Paracelsus to Haüy: The Development of Mineralogy in its Relation to Chemistry (University of New South Wales Ph.D. thesis, 1974); Oldroyd, "Some Neo-Platonic and Stoic Influences on Mineralogy in the Sixteenth and Seventeenth Centuries", Ambix, XXI (1974), 128-56.

2. Aristotle, Meteorologica, Bk. III, Chap. 6.

3. Allen G. Debus, The English Paracelsians (London: Oldbourne, 1965), 45, n.35; The Chemical Philosophy, vol. I (New York, 1977), 8, n.8.

4. R. Hooykaas, "Chemical Trichotomy before Paracelsus?", Archives Internationales d'Histoire des Sciences, 28 (1949), 1063-74.

5. Oldroyd, "Some Neo-Platonic and Stoic Influences on Mineralogy", 155.

6. Swan, Speculum Mundi, 254.

7. Ibid., 255.

8. Ibid., 248.

9. Thomas Browne, Nature's Cabinet Unlock'd (London, 1657), 4.

10. Ibid., 5-6.

11. Ibid., 15-16.

12. Gabriel Plattes, A Discovery of Subterraneous Treasure (London, 1639), 6.

13. Ibid., 6-7.

14. Allen G. Debus, "Gabriel Plattes and his Chemical Theory of the Formation of the Earth's Crust", Ambix, ix (1961), 165.

15. D.N.B.

16. Cf. A.G. Debus, "The Medico-Chemical World of the Paracelsians", in M. Teich & R. Young eds, Changing Perspectives in the History of Science (London: Heinemann, 1973), 86-90.

17. Cf. A.G. Debus, The English Paracelsians (London: Oldbourne, 1965).

18. Walter Pagel, Paracelsus. An Introduction to Philosophical Medicine in the Era of the Renaissance (Basel: S. Karger, 1958).

19. John Webster, Academiarum Examen (London, 1654), 105.

20. John Webster, Metallographia (London, 1671), The Preface.

21. Ibid., 26.

22. Ibid., 27.

23. Ibid., 29.

24. Ibid., The Preface.

25. Ibid., 35.

26. Thomas Hall, Histrio-Mastix. A Whip for Webster (as 'its conceived) the Quondam Player (London, 1654), 210.

27. Edward Jorden, A Discourse of Naturall Bathes, and Mineral Waters (London, 1669), 79.

28. Ibid., 81-2.

29. Ibid., 83-4.

30. Ibid., 99-100.

31. David R. Oldroyd has discussed Neo-Platonic and Stoic influences on mineralogy in the sixteenth and seventeenth centuries. [David R. Oldroyd, "Some Neo-Platonic and Stoic Influences on Mineralogy in the Sixteenth and Seventeenth Centuries", Ambix, XXI (1974), 128-156.] I find it difficult, however, to distinguish Stoic from Neo-Platonic influence, perhaps because Neo-Platonism itself absorbed non-materialist and religious doctrines of earlier systems such as the Pythagorean, Peripatetic, and Stoic. [Cf. Paul Edwards ed., The Encyclopedia

of Philosophy, the item on "Neoplatonism".] In this thesis, therefore, I use the notion of Neo-Platonism alone, which has been widely discussed. [Cf. Arthur O. Lovejoy, The Great Chain of Being (Harvard University Press, 1978).]

32. Albaro Alonso Barba, The Art of Metals (1669), trans. by R.H. Edward, in A Collection of Scarce and Valuable Treatises upon Metals (London, 1738), 30-31.

33. Ibid., 45.

34. Ibid., 45-6.

35. Ibid., 46.

36. Ibid., 49.

37. Ibid., 54-5.

38. John Pettus, Fondinae Regales: or the History, Laws and Places of the Chief Mines and Mineral Works in England, Wales, and the English Pale in Ireland (London, 1670), An Introduction to this History.

39. Martin J.S. Rudwick, The Meaning of Fossils (London, 1972), 34.

40. Roy Porter, The Making of Geology (Cambridge University Press, 1977), 49.

41. Webster, Metallographia, 73.

42. Ibid., 83.

43. Ibid., 83-4.

44. Ibid., 84.

45. Thomas Sherley, Philosophical Essay: Declaring the Probable Causes, whence Stones are produced in the Greater World (London, 1672), To the Reader.

46. Ibid., 123.

47. A similar view of nature was held by Robert Boyle, who was referred to in Sherley's argument about petrifaction. In his Excellency and Grounds of the Corpuscular or Mechanical Philosophy (1674), Boyle expressed his views of the mechanical philosophy. He neither agreed to the idea that atoms,

meeting together by chance, are able to produce the world nor supposed that God, after creating matter and motion, does not interfere with them. Instead Boyle distinguished between the original of things and the subsequent course of nature:

> concerning the former, not only...God gave motion to matter, but...in the beginning he so guided the various motions of the parts of it, as to contrive them into the world he designed they should compose, (furnished with the seminal principles and structures, or models of living creatures,)...as to the latter...the universe being once framed by God, and the laws of motion being settled and all upheld by his incessant concourse and general providence, the phaenomena of the world thus constituted are physically produced by the mechanical affections of the parts of matter,... [Robert Boyle, 'The Excellency and Grounds of the Corpuscular or Mechanical Philosophy'(1674), in Marie Boas Hall ed., Robert Boyle on Natural Philosophy (Indiana University Press, 1965), 189.]

Boyle thus sharply distinguished a question about the origin of the world from that of the present natural phenomena. This distinction was identical with the one made by Sherley.

48. Ibid., 28.

49. Ibid., 128-29.

50. Ibid., 130.

51. Ibid., 134-35.

52. Rudwick, The Meaning of Fossils, 39.

4. THE NATURAL HISTORY OF THE EARTH

In the seventeenth century, as has been described, the Earth was discussed by different and independent intellectual traditions which were hostile or indifferent to one another. Each tradition offered a theoretical framework for speculation on geological phenomena. In the course of the century all of them became increasingly aware of the growing amounts of natural knowledge being collected by natural historians.

It is generally admitted that the rediscovery of classical scientific texts by Renaissance humanists gave a significant impetus to scientific studies. Humanism increased the interest in natural history by furnishing new editions of the works of ancients such as Aristotle, Pliny, Theophrastus and Dioscorides, and more exact observation corrected and expanded their accounts and created a new natural history. In Bacon's view,

> it is not to be esteemed a small matter that by the voyages and travels of these later times, so much more of nature has

> been discovered than was known at any former period. It would, indeed be disgraceful to mankind, if, after such tracts of the material world have been laid open which were unknown in former times - so many seas traversed - so many countries explored - so many stars discovered - philosophy, or the intelligible world, should be circumscribed by the same boundaries as before.

Even if a systematic statement of the new learning was first made by Bacon, F.R. Johnson has claimed, "most of the fruitful ideas of science that were popularly associated with the work of Francis Bacon in the seventeeth century were already part of the publicly avowed creed of English scientific workers throughout the latter half of the sixteenth century.[1]

Renaissance Encyclopedic Works

In his Middle-Class Culture in Elizabethan England (1964), Louis B. Wright has extensively discussed encyclopedic natural histories in which pre-Baconian empiricism can be found, although he has not intended to suggest that these works contributed to the advancement of geological knowledge. Encyclopedic works preserved miscellaneous information concerning the natural world from the Middle Ages. For example, Caxton translated from the French and published The Mirror of the World (1481), which is the earliest encyclopedia in the English language. The original French Image du Monde had been well received and so, too, was the English edition. Caxton himself published two editions of the Mirror. Later, about 1527, Lawrence Andrewe reprinted the book with some alterations and additions. It provided a general survey of medieval scientific knowledge, beginning with an account of the Creation and concluding with an exposition of the system of the universe. Another medieval encyclopedia was De Proprietatibus Rerum of Bartholomaeus Anglicus, first printed in 1485, which was the basis of an Elizabethan encyclopedia, Batman uppon Bartholome, his Booke De Proprietatibus Rerum compiled by Stephen Batman in 1582. It contains a resumé of descriptions of beasts, birds, fishes, serpents, herbs, plants, trees, fruit, seeds, metals and minerals.

The ideas of the medieval encyclopedic works passed into the seventeenth century. For example, Pierre de la Primaudaye's French Academie is an encylopedia of all kinds of learning, which was translated and published by T.B. in 1586 and reached its sixth edition in 1618. This work has chapters related to the physical universe which present

> a notable description of the whole world, and of all the principall parts and contents thereof: As namely, of Angels both good and

> euill: of the Celestial spheres, their order and number: of the fixed stars and planets; their light, motion, and influence: Of the fower elements, and all things in them, or of them consisting: and first of firie, airie, and watrie meteors or impressions of comets, thunders, lightnings, raines, snow, haile, rainebowes, windes, dewes, frosts, earthquakes, &c. ingendred aboue, in, and vnder the middle or cloudie region of the aire. And likewise of fowles, fishes, beasts, serpents, trees with their fruits and gum; shrubs, herbes, spices, drugs, minerals, precious stones, and other particulars most worthie of all men to be knownen and considered.[2]

La Primaudaye thus referred to various natural phenomena in the mineral kingdom. Bartas' encyclopedic work, which was translated and published by Joshua Sylvester in 1605 under the title of Bartas: His Deuine Weekes and Workes, was also an important book which was printed at least seven times by 1641. Thomas Lodge translated from French and published A Learned Summary upon the famous Poeme of William of Saluste Lord of Bartas, 1621. In the same year Daniel Widdows published Natural Philosophy, which was translated and abridged from the Rerum Naturalium Doctrina Methodica of G.A. Scribonius. Although the title of this book is Natural Philosophy, it includes "A Description of the World, namely, of Angels, of Man, of the Heavens, of Ayre, of the Earth, of the Water: and of the Creatures in the whole world."[3]

While various encyclopedic works were translated from French, some original compilations appeared in

England. For example, John Maplet published A Greene Forest, or a Naturall History in 1567. Thomas Johnson's Cornucopiae, or Divers Secrets (1595) contained "the rare secrets in Man, Beasts, Foules, Fishes, Trees, Planetes, Stones and such like, most pleasant and profitable, and not before commited to bee printed in English."[4] Thomas Lupton published in 1579 A Thousand Notable Things of Sundry Sorts, which was reprinted at least eight times by 1700. Robert Basset's Curiosities: Or the Cabinet of Nature appeared in 1637. As has been shown, there also appeared John Swan's Speculum Mundi (1635), Thomas Browne's Nature's Cabinet unlock'd (1657), Joshua Childrey's Britannia Baconica (1660)[5] and Robert Lovell's Panzoologicomineralogia (1661).

These encyclopedic works were generally written and translated by non-academics. For example, William Caxton (1422?-1491), printer and translator, was a favorite of Edward IV and Richard III and was patronized by numerous nobles and wealthy mercers, but he did not hold an academic appointment. Stephen Batman, translator and author, went to Cambridge and then became rector of Merstham in Surrey. In 1582 he was one of the domestic chaplains of Henry Cary, Lord Hunsdon. John Maplet, miscellaneous writer, matriculated as a sizar of Queen's College, Cambridge, in 1560, was a fellow of Catharine Hall in 1564. Then he was instituted to the rectory of Great Leighs, Essex, which he exchanged for the vicarage of

Northall, Middlesex in 1576. Joshua Sylvester (1563-1618), translator, was educated in a school at Southampton and was taken from school at thirteen and put into trade. In 1591 he joined the Merchant Adventurers' Company, and in 1606 Prince Henry of Wales became his patron. Thomas Lodge (1558?-1625), poet and playwright, entered Trinity College, Oxford, in 1573 and then went to Lincoln's Inn. But he soon deserted the law for literature. He was a convert to Roman Catholicism and settled in London as a physician. Thus, these authors and translators of encyclopedic works were not academics who held university appointments.

Not only were these encyclopedic works published by non-academics, but also, as Louis B. Wright has suggested, their aim was to satisfy the demand of the non-academic public for enlightenment about the natural world.[6] His suggestion can be supported by the fact that the printer of The Book of Secrets (1617) recommended that the book should be treated as light reading: "Wherefore, use this Book for thy recreation...for assuredly there is nothing herein promised but to further thy delight."[7] Thomas Lupton, too, in his A Thousand Notable Things of Sundry Sorts (c. 1579), attempted to justify such encyclopedic works:

> ...in my judgement, through the stranger and variety of matter it will be more desirously and delightfully read, knowing that we are made of such a mould that delicate Daintiness delights us much, but we loathe to be fed too long with one food; and that long wandering in strange, pleasant and contrary places, will less weary us, than short travel in often trodden ground.[8]

Those who read these encyclopedic works including their accounts of various natural phenomena were intended to be diverted by exotic and varied subject matter. The fact that these works were published in English, not in Latin, provides a further strong argument that they were not intended for a university audience.

Earlier encyclopedic works indicate that the interest in natural history including the mineral kingdom spread wide long before the publication of Bacon's Novum Organum (1620), let alone the foundation of the Royal Society of London (1660). In Renaissance England cultured people began displaying a curiosity about nature, which was to be favourable to the growth of a popular interest in geological objects. It is not proper to say that encyclopedic authors exhibit their ignorance of the Earth's interior.[9] Their passion was simply different from that of later geological practitioners.

The Virtuous Education of the Youth

While the general public pursued encyclopedic knowledge to increase their stock of useful and cultured information, Renaissance courtiers cultivated the arts that made them complete gentlemen.[10] Various "courtesy books" were published in Renaissance England, and in these books the study of natural history was regarded as essential to the making of a cultured man. For example, Sir Thomas Elyot's The Governor (1531) advised gentlemen to study natural history. Elyot's humanism extended beyond a mere revival of interest in classical antiquity to observing the actual state of the world:

> All be it there is none so good lernynge as the demonstration of cosmographie by materiall figures and instrumentes, hauynge a good instructour. And surely this lesson is bothe pleasant and necessary. For what pleasure is it, in one houre, to beholde those realmes, cities, sees, ryuers, and mountaynes, that uneth in an olde mannes life can nat be iournaide and pursued: what incredible delite is taken in beholding the diuersities of people, beastis, foules, fisshes, trees, frutes, and herbes: to knowe the sondry maners and conditions of people, and the varietie of their natures, and that in a warme studie or perler, without perill of the see, or daunger of longe and paynfull iournayes: I can nat tell what more pleasure shulde happen to a gentil witte, than to beholde in his owne house euery thynge that with in all the worlde is contained.[11]

For Elyot the knowledge of cosmography or natural history was necessary in case of war, but also it provided a source of enjoyment for young gentlemen. Thus, an observational study of the world would import delight, ornament and ability.

W.E. Houghton has pointed out that in England the assimilation of Italian culture developed progressively from a predominant concern for practical studies, moral and political, as instanced in Elyot's Governour, to the pursuit of learning purely for curiosity, delight, and reputation in Henry Peacham's Compleat Gentleman published in the early seventeenth century.[12] Like Elyot, however, Peacham urged the importance of cosmography to gentlemen:

> In every country, to give one instance for all, in your observation you are to follow this method: first, to know the latitude, then the longitude of the place; the temperature of the climate; the goodness or barrenness of the ground; the limits of the country, how it is bounded by sea or land or both, by east, west, north, or south; into what provinces it is divided within itself; the commodities it affordeth, as what mines, woods, or forests, what beasts, fowls, fishes, fruits, herbs, plants; what mountains, rivers, fountains, and cities; what notable matter of wonder or antiquity; the manners, shape, and attire of the people; their building, what ports and havens; what rocks, sands, and such-like places of danger are about the place; and, last of all, the religion and government of the inhabitants.[13]

Peacham's Complete Gentleman was written for William Howard, the youngest son of Lord Arundel, and it encapsulated the Renaissance ideal of courtly training. In Peacham's view, too, the knowledge of natural history was necessary to be a complete gentleman.

In Renaissance England, H. Kearney has suggested, there were two systems of education, that of the court and that of the university.[14] One of the features of Renaissance England was the growth of the court and its associated system of patronage. The courtiers were expected to learn cultured manners, which were more likely to be required in the court than in the university. At some time in the sixteenth century, students from the gentry class began to enter Oxford and Cambridge in large numbers. The expansion of the universities and the appearance of the English gentleman were two aspects of the one development of the society. The universities came to provide the educational needs of young gentlemen.

The earlier emphasis on scholastic theology and canon law was replaced by the study of the classics during the Renaissance. The humanists advocated reforms in the teaching of the liberal arts which led to changes in the nature of university education.[15] The students at Oxford now wanted to become "Rationall and Gracefull speakers, and be of an acceptable behaviour in their countries."[16] Instruction in the liberal arts, transformed by humanist methods, became the most important part of university education, now primarily dedicated to the "virtuous education of youth". University students no longer mostly sought learning as a preparation for a career in the Church or as the foundation for higher studies in theology but for general cultural purposes. Many of the young gentlemen who came to the universities had no intention of taking out degrees. They would often come only for one or two years before going down to the Inns of Court, or abroad, or returning to their estates. The universities became places where students pursued learning which would both give pleasure and satisfy curiosity.[17]

This change in education was favourable to the development of natural history. In 1659 an anonymous writer proposed that Oxford should teach "politicks, geography, history, and all other ornaments becoming exact virtuosi."[18] In his New Discovery of the Old Art of Teaching School (1660), Charles Hoole, headmaster of Rotherham Grammar School, referred to John Tradescant the younger, whose father founded a museum of natural history at Lambeth in 1629. Hoole spoke of London as "of all places in England best for the improvement of children in their education, because of the variety of objects which daily present themselves to them, or may easily be seen, once a year, by walking to Mr. John Tradescant's where rarities are kept."[19] Thus the visit to a museum was regarded as a good recreation for young students. In the museum of the Tradescants there were rarities, including "a number of things changed into stone, amongst others a piece of human flesh on a bone, gourds, olives, a piece of wood, an ape's head",[20] which later formed the nucleus of the Ashmolean Museum. Elias Ashmole, "curioso and virtuoso",[21] endowed professorships of chemistry and natural history in Oxford, and the Ashmolean Museum was built in 1683, where the meetings of the Oxford Philosophical Society were held. The knowledge of the natural history of the Earth was by this time regarded as an ornament for students who were to be "virtuosi". As virtuosi were often mere admirers of natural rarities, so Michael Hunter has claimed that their contribution to the advancement of learning often had limitations.[22] As far as Earth science is concerned, however, its early development was sustained by amateur natural historians who sought out and collected every natural rarity in their closets.[23]

Virtuosi as Natural Historians

As Curtis has claimed, the cult of the virtuoso was the most pervasive intellectual movement in Stuart England.[24] A contemporary, Samuel Butler (1612-80), defined the word "virtuoso" in his Characters as follows: A virtuoso "is wonderfully delighted with Rarities, and they continue still so to him, though he has shown them a thousand Times;... Next these he loves strange natural Histories."[25] The rise of the virtuoso was closely related to the popularity of natural history in this period. "Virtuoso" in its original sense meant a lover of learning in general, but the meaning came to be limited to antiquarians, natural historians and collectors of rarities.[26] Remarking upon Houghton's definition of the word "virtuoso", Westfall has suggested that "a more common usage applied it to the true scientist."[27] Westfall's definition of the word excludes "a collector of rarities and natural curiosities" from its meanings. However, this definition is too limited a basis for discussing seventeenth-century scientific activities which originated in the Renaissance spirit of inquiry.

As Westfall himself has pointed out,[28] the virtuosi were an indefinite group compared with that of scientists today, and it is not easy to say what a virtuoso was. The vagueness of the term can be explained by the fact that the new science was not fully institutionalized and few men devoted themselves wholly to the study of nature. Those who were interested in natural history were amateurs and derived their incomes from other occupations. They had a common interest, however, and formed groups, so that they needed a name by which to identify themselves. In this way the word "virtuoso" was used among those whose activities did not fall into any one particular area. However, the foundation of the Royal Society of London (1660) produced a clearer image of virtuosi, to which Westfall's definition of the word can be more aptly applied.

When the Royal Society of London was founded to build up a new system of natural philosophy based on a complete natural history, its members came to be called "virtuosi". John Aubrey mentioned Robert Wood, a Fellow of Lincoln College, Oxford, as one of the "virtuosi" of the Oxford club, which was a predecessor of the Royal Society.[29] In his History of the Royal Society, Thomas Sprat describes how the club was conceived:

> It was therefore, some space after the end of the Civil Wars at Oxford, in Dr. Wilkins his Lodgings, in Wadham College, which was then the place of Resort for Vertuous and Learned Men, that the first meetings were made, which laid the foundation of all this that follow'd.[30]

In his Experimental Philosophy (1664), Henry Power, one of the first elected Fellows under the new charter of 1663, addressed one chapter to "the generous VIRTUOSI, and Lovers of Experimental Philosophy", saying that

> These are the days that must lay a new Foundation of a more magnificent Philosophy, never to be overthrown: that will Empirically and Sensibly canvass the Phaenomena of Nature, deducing the Causes of things from such Originals in Nature, as we observe are producible by Art, and the infallible demonstration of Mechanicks: and certainly, this is the way, and no other, to build a true and permanent Philosophy:...[31]

In his Plus Ultra (1668), Joseph Glanvill, discussing the aim of the Royal Society, said that the plans for natural history "were consider'd also by the later Virtuosi, who several of them combined together, and set themselves on work upon this grand Design."[32] Although there were "very many men of particular Professions", Thomas Sprat said, most of them were men of free mind who had sufficient leisure to devote to natural history.[33]

The Royal Society thus gave many virtuosi a role they had been often denied where academic concerns dominated intellectual life. After the foundation of the Royal Society the strong Baconian influence began to open up the scientific community to a large body of amateurs in addition to the few who had mastered highly technical disciplines.[34] In fact, as Bacon had done, the Royal Society declared that a new system of natural philosophy must be constructed on the basis of natural history. The plan for natural history was realized in the programme and activities of the early Royal Society, which drastically changed the study of the Earth which had not been systematically pursued.

In 1664 the Council of the Royal Society ordered that committees should be set up for the general improvement of science. A week later, the plan for the committees was completed, a total of eight being envisaged with the following responsibilities:

> 1. Mechanical. To consider of and improve all Mechanicall Inventions; 2. Astronomical and Optical; 3. Anatomical; 4. Chymical; 5. Georgical [agricultural]; 6. For Histories of Trades [accounts of crafts]; 7. For Collecting all the Phaenomena of Nature hitherto observed, and all Experiments made and recorded; 8. For Correspondence.[35]

Six committees thus covered particular branches of study, and one committee was given the general task of collecting information about natural phenomena. Such a project allowed amateur scientists to contribute new information to the Royal Society.

Although these committees of the Royal Society did not specifically treat geological phenomena, Sprat, in his History of the Royal Society, showed an interest in fuller information "from Woods, Fields, Mountains, Rivers, Seas, and Lands."[36] Referring to Pliny, Aristotle, Solinus and Ælian, Sprat also expressed dissatisfaction with their natural histories, saying that if the ancients

> could gather together some extraordinary Qualities of Stones, or Minerals, some Rarities of the Age, the food, the colour, the shapes of Beasts, or some vertues of Fountains, or Rivers: they thought, they had perform'd the chiefest part of Natural Historians.[37]

Sprat thus suggested that the Royal Society intended to improve natural history including the study of the Earth.

Some Fellows of the Royal Society in fact gave a discourse on "earthquakes" and "petrifactions" before their weekly meetings.[38] Moreover, the Royal Society received

> Relations of the Effects of Earthquakes, and the moving, and sinking of Earths: of deep Mines, and deep Wells: of the several layers of Earth in a Well at Amsterdam: of the shining Cliffs in Scotland: of the layers of Earth observ'd in divers Cliffs: of Screwstones, Lignum Fossile, Blocks buried in Exeter River, Trees found under ground in Cheshire, Lincolnshire, and elsewhere: of a Coal-Mine wrought half a mile from the shore, under the Sea: of the fatal effects of damps on Miners, and the ways of recovering them.[39]

As this shows, the study of the subterranean world was an active programme within the activities of the Royal Society. Thus, natural history came to be pursued with the co-operation of all interests involved.

The study of natural history was well organized by the central figures of the early Royal Society such as Robert Boyle (1627-91) and Henry Oldenburg (1615?-77). In 1666, for example, Boyle published "General Heads for a Natural History of a Country" in the Philosophical Transactions, which gave an outline for a natural history used as a guide by later natural historians. In the same year Boyle drew up "Articles of Inquiries touching Mines", which was to be sent to the managers of a large number of mines in various parts of Europe, in order to obtain further information concerning the nature and mode of occurrence of mineral resources. Oldenburg, too, realized the importance of natural history and argued in the Philosophical Transactions (1676)

> that a Natural History of Countries is most wanting; which, if well drawn, would afford us a copious view, and a delightful prospect of the great variety of Soyls, Fountains, Rivers, Lakes, etc. in the several places of this globe...[40]

In response to the request for a natural history, John Ray published Observations Topographical, Moral, & Physiological (1673), whose chapters were similar to those which Boyle had recommended. Similar books on natural history continued to appear in the late seventeenth and early eighteenth century: Robert Plot's Natural History of Oxfordshire (1677) and Natural History of Staffordshire (1686); John Aubrey's Memoires of Natural Remarques in the County of Wiltshire (1685); Charles Leigh's Natural History of Lancashire, Cheshire and the Peak (1700); Thomas Robinson's Essay towards a Natural History of Westmoreland and Cumberland (1709); John Morton's Natural History of Northamptonshire (1712).

Virtuosi as Natural Philosophers

Although Boyle and Oldenburg thus promoted a co-operative study of natural history, they themselves did not participate in it to any great extent. Hooke, on the other hand, played an important role in the promotion of geological discussions during the second half of the seventeenth century. Among the various geological phenomena, Hooke paid particular attention to "figured stones", which he thought were unduly neglected. In his discourse of 1668, one may find his interest in fossils:

> The obviousness and easiness of knowing many Things in Nature, has been the Cause of their

> being neglected, even by the more diligent and curious; which nevertheless, if well examined, do very often contain Informations of the greatest value. It has been generally noted by common, as well as inquisitive, Persons, that divers Stones have been found, formed into the Shapes of Fishes, Shells, Fruits, Leaves, Wood, Barks, and other Vegetable and Animal Substances: We commonly know some of them exactly resembling the Shape of Things we commonly find (as the Chymists speak) in the Vegetable or Animal Kingdom; others of them indeed bearing some kind of Similitude, and agreeing in many Circumstances, but yet not exactly figured like any other thing in Nature; and yet of so curious a Shape, that they easily raise both the Attention and Wonder, even of those that are less inquisitive.[41]

Thus, Hooke regarded fossil stones as objects worthy of attention even though they had been generally neglected.

As the members of the Royal Society seriously organized the study of natural history which should have been a good recreation, they became a target of satire. The famous Sir Nicholas Gimcrack in Thomas Shadwell's Virtuoso (1676) says that "We Virtuoso's never find out anything of use, 'tis not our way."[42] The model of Gimcrack is said to have been a Fellow of the Royal Society.[43] Hooke attended a performance of this satirical play in June 1676 and afterwards wrote, "Dammd Doggs. Vindica me Deus, people almost pointed." Shadwell's satire shows that the activities of virtuosi, particularly in the Royal Society, were viewed with a cynical mind. As their works seem useless, Hooke noted, some persons "confidently affirm that they have done just nothing."[44] Calling Robert Hooke and John Ray "virtuosi",[45] Robert Plot noted in 1677 that the study of fossils might be criticized:

> I cannot but reprehend the petulant despisers of this innocent sort of Learning, who in derision have called it, picking of stones;... But let such malicious Scoffers know, that 'tis their pride and ignorance that has engaged them in this Censure:... Besides, who knows but these tings may have a use, that hereafter may be discover'd, though not known at present.[46]

The virtuosi thus continued to be ridiculed because they spent their time collecting such odd things as stones and fossil shells of no apparent usefulness.

In his defence of the aim and activities of the early Royal Society against satirical criticisms, Hooke claimed that its members were not mere collectors, saying that they

> have been imployed in collecting such Observations, and making such Experiments and Trials as being fitly apply'd and judiciously made use of, will very much tend to the advancement of Natural knowledge: And tho' the things so collected may of themselves seem but like a rude heap of unpolish'd and unshap'd Materials, yet for the most part they are so qualified as that they may be fit for the beginning, at least of a solid, firm and lasting structure of Philosophy.[47]

His ultimate aim was not to collect fossils, but to establish a solid system of natural philosophy. Hooke therefore urged the importance of a working hypothesis:

> And though this Honourable Society have hitherto seem'd to avoid and prohibit pre-conceived Theories and Deductions from particular, and seemingly accidental Experiments; yet I humbly conceive, that such, if knowingly and judiciously made, are Matters of the greatest Importance, as giving a Characteristick of the Aim, Use, and Significancy thereof; and without which, many, and possibly the most considerable Particulars, are passed over without Regard and Observation.[48]

This statement reveals Hooke not as a mere collector searching for strange phenomena, but as a natural philosopher who conceived of such a concept as a working hypothesis. David R. Oldroyd has claimed that Hooke "purports to have used hypotheses for pragmatic reasons -- merely to expedite his enquiries -- rather than because of logical difficulties associated with inductive procedures."[49] Hooke, however, claimed here that without an hypothesis important facts would be passed over by an observer. He thus realized the importance of a hypothesis to any scientific observation. For him the study of natural history was not collecting curiosities which other virtuosi had been doing.

NOTES

1. F.R. Johnson, Astronomical Thought in Renaissance England (Baltimore, 1937), 296. Michael Hunter has the same opinion. (Michael Hunter, Science and Society, 15.)

2. Pierre de la Primaudaye, The French Academie (London, 1618), Title-page.

3. Daniel Widdows, Natural Philosophy; or A Description of the World (London, 1621), Title-page.

4. Thomas Johnson, Cornucopiae, or Divers Secrets (London, 1595), Title-page.

5. Childrey (1623-70) said that he "fell in love with L. Bacons Philosophy in ye yeare 1646." (Oldenburg Correspondence, VI, 108.) But the description of the curiosities mentioned in his Britannia Baconica were mostly taken from earlier writers. Nevertheless, his work is different from previous encyclopedic works in that he occasionally referred to his own opinions and observations.

   One subject on which Childrey expressed his own opinion was the origins of fossils:

   > My opinion of all these stones, for many reasons, is that they are not Shel-fish petrified (as some would have them to be, who think that upon the ebb of the deluge these fish were left upon the tops of hills, and turned to stone by degrees, wanting their former moisture to keepe them soft within, like other Shelfish.) (Childrey, Britannia Baconica, 77)

   He considered that fossil stones were not petrified shellfishes because there was an apparent difference between fossil shells and real sea-shells. As for ammonites, he took them for irregular pieces of stone, as it were attempts of nature further to continue gathering certain shapes. Childrey was convinced that these stones were not petrified ones, but his opinion on the fossil question does not seem to have attracted any attention. (Cf. Oldenburg Correspondence.)

6. Louis B. Wright, Middle Class Culture in Elizabethan England (London, 1964), 602.

7. Albertus Magnus, The Book of Secrets of Albertus Magnus, ed. by M.R. Best & F.H. Brightman (Oxford, 1973), xviii.

8. Thomas Lupton, A Thousand Notable Things of Sundry Sorts (London, 1627), The Preface of the Author to the Reader.

9. Porter, The Making of Geology, 12-14.

10. Wright, Middle-Class Culture, 121.

11. Thomas Elyot, The Governour (London, 1937), 43.

12. W.E. Houghton, "The English Virtuoso in the Seventeenth Century", Journal of the History of Ideas, iii (1942), 58.

13. Henry Peacham, Complete Gentleman, ed. by V.B. Heltzel (New York, 1962), 76.

14. H. Kearney, Scholars & Gentlemen: Universities & Society in Pre-Industrial Britain 1500-1700 (London: Faber and Faber, 1970), 22-28.

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5. THE ROYAL SOCIETY AND THE FOSSIL CONTROVERSY

It was Robert K. Merton who criticized the Enlightenment's vision that science was objective and developed independently of cultural and social conditions. In his Science, Technology and Society in Seventeenth Century England (1938), Merton claimed that cultural values conditioned the development of science by promoting or inhibiting its advance. Merton's aim was to examine how science had been elevated to a place of high regard in seventeenth-century England. Although urging the importance of "external" factors to the development of science, Merton suggested that "scientific discoveries and inventions belong to the internal history of science and are largely independent of factors other than the purely scientific."[1] Thus, he claimed that scientific activity itself was autonomous and left its analysis to the historians of science, saying that "it is outside of this study to attempt any systematic presentation of the history of the various sciences during this period."[2] Merton's thesis that Puritanism and economic needs sustained the large-scale pursuit of science was extended by Christopher Hill in his Intellectual Origins of the English Revolution (1965). Hill's work provoked a wide controversy among historians and historians of science.[3] Like Merton, their concern was not the development of any specific science but a general scientific movement such as the formation of the Royal Society.

On the other hand, the "internalists" claimed that science was in its own intellectual right fundamental and not derivative from external factors such as the Reformation and the rise of capitalism. For example, in his From the Closed World to the Infinite Universe (1957), Alexandre Koyré suggested that the Scientific Revolution can be understood as a transformation of intellectual attitudes. In his view the developments involved "stand out clearly in the works of a few great thinkers who, in deep understanding of its primary importance, have given their full attention to the fundamental problem of the structure of the world."[4] For Koyré sociological factors were not essential to an understanding of the intellectual activity of great thinkers. This conviction was shared with other "internalists" such as Richard S. Westfall. While paying almost no attention to the social and economic setting in which the science of dynamics emerged, Westfall has claimed that "it is impossible to conclude from seventeenth-century literature on mechanics that practical considerations, technological problems set by the economic system, guided and determined the conceptual development of the science."[5]

Thus, the traditional "external" and "internal" approaches both generally claimed that scientific activity itself is independent of sociological factors. Such a view was challenged by Thomas S. Kuhn. In his Structure of Scientific Revolutions (1962), Kuhn suggested that scientists in a specific field form a closed community. This view has been even more clearly expressed in his "Postscript - 1969", in which he said that scientific practitioners

> have undergone similar educations and professional initiations; in the process they have absorbed the same technical literature and draw many of the same lessons from it. Usually the boundaries of that standard literature mark the limits of a scientific subject matter, and each community ordinally has a subject matter of its own.[6]

Kuhn claimed that a scientific community is "normally" insulated from the cultural milieu in which it exists, but the activity of its members is conditioned by other members and by its institutional norms. Scientific communities are also viewed as an interacting group when new channels of communication are created between previously disparate specialities, a process which may produce a new theory. In Kuhn's view, "the apparent autonomy of the internal approach is misleading in essentials."[7]

Sociologists of science such as Michael Mulkay, too, attempt to establish a view of the relation between sociological factors and the production of scientific knowledge. Mulkay urges the importance of interaction between scientists to the development of science:

> The extent to which one interpretation rather than another becomes accepted by participants is the outcome of processes of social interaction or negotiation: that is, as members exchange views and attempt to convince, persuade and influence each other, these views may be modified, abandoned or reinforced.[8]

Mulkay thus claims that the development of science is influenced by sociological factors inside a scientific community. Besides these micro-sociological factors, he even insists that there are the connections between scientific knowledge and society at large. However, such a macro-sociological analysis is not relevant to this thesis which is based on the assumption that there are variations and conflicts in the society.

Kuhn's suggestion to synthesize the "external" and "internal" approach has been followed in recent arguments over the development of science in seventeenth-century England, but these attempts have been unsatisfactory partly because the role of the Royal Society has not been fully recognized. For example, Roy Porter has claimed that the Society's role "was not to hatch theory, but rather to boost the empirical investigation of Britain." Michael Hunter has suggested that the Society's "real achievement was less in the practice of science than in its organisation."[9] These views miss the important point that the formation of the Royal Society caused a productive interaction between different intellectual traditions which had been formerly separated.

As mentioned in previous chapters, the cyclic view of the Earth was generally held by university academics while the theological view of the Deluge was usually expressed by theologians and historians. On the other hand, some practically minded "mineralogists" held the neo-Platonic view that the mineral kingdom had been formed by hidden and fundamental forces of nature. At the same time, the general educated public was not so much interested in these professional views as in natural wonders. As a result, the study of the Earth was pursued by different and separate intellectual traditions before the foundation of the Royal Society.

It was the Royal Society that provided a forum where these separate traditions could come into contact.

Because of this interaction, Fellows of the Royal Society became engaged in a controversy over the origin of fossils. The organic origin of fossils was associated with the idea of cyclic change or the Deluge, while the neo-Platonic view of minerals claimed to explain the formation of fossils in a quite different way. As will be shown, these different views were introduced to the Fellows by Oldenburg, and the fossil controversy itself was stimulated by Hooke's lectures to the Society. Moreover, the publication of the Philosophical Transactions facilitated the spread of the controversy. This chapter thus suggests that the development of geological ideas was conditioned and sustained by "external" factors such as institutional conditions and interaction between scientists,[10] but does not investigate scientists' debt to the wider society because such a macro-sociological investigation does not illuminate the controversy among Fellows of the Royal Society.

Oldenburg Correspondence

Henry Oldenburg, who had been tutor to the Boyle family and who held the Secretaryship of the Royal Society from 1662 until his death in 1677, played an important role in the introduction of different views of nature among the Fellows of the Royal Society. He corresponded with various scientists at home and abroad and at meetings brought up matters reported in letters. Michael Hunter has noted that Oldenburg "tried to stimulate scientists to work on specific problems by reporting the progress of others," [11] but he has not discussed how Oldenburg actually did it.

Some of Oldenburg's correspondents showed an interest in the origin of fossils. One of the difficulties in the fossil question was the location of fossil shells. For example, Manfred Settala (1600-80), son of the famous Milanese physician, who was an engineer, wrote in a letter to Oldenburg in 1667 that he had no decisive answer to this question:

> In a Voyage I made a few years since to Genoa, when I was to passe some mountains, I met with some Pesants, who digging on the sides of a Hill, had found and gathered very many Cockle-shells of divers kinds; which I wondring at, stopped my intended journey; and went to the very place, where I was satisfied of the truth of the relation, finding great store of different shells, as the Turbinets, Echini, and some Pearl-shells, whereof one had a fair Pearl in it]. These shells, placed in the Settalian Museum, were the subject of a lecture by my learned physician Terzago. Conspicuous among them was a certain flat shell whose connecting ligament still had a fleshy appearance. Frcm what fertile womb were these beings generated? Satisfy my desire to know this, and you will be to me as great as Apollo.[12]

As this letter suggests, it was not easy to solve the problem of why seashells were found in mountains. René François de Sluse, a Belgian mathematician, too, wrote a letter to Oldenburg, in which he puzzled over the location of fossil shells:

> Lately some stones were brought me; I enclose the shape of one of them sketched from either side, since the person who could make the sketch was at hand; only perhaps it was not so big. They are dug, I am told, five miles from here in a hill near Huum. It is strange that such little creatures should be found, hardened by a petrifying juice, so far from the sea; unless indeed they are the results of nature's playfulness.[13]

The idea that nature might be playful was also suggested by James Long (1617-92), FRS, in a letter to Oldenburg in 1663:

> I diggd for some of the screw stones and found that the sandy stone in wch many of thes are some greate and some small some perfect others but a halfe globe was full and as it were confected of sundry shells of sea fish although it bee on a hill in an in land country. there are cocles and musles and long wrought periwincles amongst thes screws so that it seemes nature is gamesome in that place. there are also under thos sandy rocks and a harder rock wch lyes under it. about 30 or 40 foote deepe peeces of a matter betwixt a wood and a stone very heavy. it seemes to have a bark a sapp and a hart like oake but assuredly it is no more oake or wood then the seeming shells are shells indeed.[14]

Thus, some of Oldenburg's correspondents suggested that nature was playful so as to form fossil stones. This idea could be explained by the neo-Platonic theory that mineral substances were formed by hidden virtue.

Those who rejected the chemical theory tended to explain the location of fossil shells by geological changes. In 1669 De Martel, a French scientist, wrote to Oldenburg, explaining the location of seashells by an interchange of land and sea:

> Upon the way of Beziers to Narbonne, in a place pretty large, raised by estimation above the level of the Sea, (which is two Leagues distant from it) about 15 or 16 fathoms, I saw Rocks, which inclosed a good number of big Oysters petrify'd: And upon the same way above the place, which is call'd Nice, at the highest place of the descent, very cragged, where the Rock is cut to make a passage, is seen a Bed two foot large, of many Cockle-shells petrify'd, heap'd up, as ordinarily they are on the Sea-shoar; which notes sufficiently, that the Sea formely cover'd this place, according to what Aristotle somewhere saith.[15]

De Martel thus adopted Aristotle's theory that "where now is dry land once was ocean", and explained the location of seashells by that theory. The cyclic change of the Earth could be a good reason why seashells were enclosed in the land, although it was not clear how such ground was raised from the bottom of the sea.

Besides communicating with various scientists at home and abroad, the Royal Society reviewed some geological works in the Philosophical Transactions, which, too, created contacts between different views of nature: Neo-Platonic thought was presented in Athanasius Kircher's Mundus Subterraneous (1664-65) and John Webster's Metallographia (1671) while the organic theory of fossils was expressed in Nicolaus Steno's Prodromus (1671). Steno's work, first published in Latin in 1669, was translated into English by Oldenburg. In this work Steno followed the ancients' idea that fossils had an organic origin.[16] After his election to the Royal Society in 1671 the English physician and naturalist Martin Lister (1638?-1712) commented on Steno's work in a letter sent to Oldenburg for publication in the Philosophical Transactions.

In this letter Lister explained why his opinion of fossils differed from that of Steno: "if my sentiments on this particular are somewhat different from his, it proceeds not from a spirit of contradiction, but from a different view of Nature."[17] This letter was read at a meeting of the Royal Society on 2nd November 1671, "which gave occasion to some of the members to discourse on the subject of petrified shells, some applauding Mr. Lister's notions of it; but Mr Hooke endeavouring to maintain his own opinion, that all those shells are the exuviae of animals."[18] As we have seen, those who believed the organic theory of fossils explained their location by the cyclic interchange of land and sea which had been suggested by the ancients. On the other hand, those who claimed that fossils were minerals based their arguments on the neo-Platonic view of nature. These two views originated in different traditions and could not be easily compromised.

On this occasion Lister admitted that seashells found near the shores of the Mediterranean were real ones:

> But, for our English-inland Quarries, which also abound with infinite number and great varieties of shells, I am apt to think, there is no such matter, as Petrifying of Shells in the business...but that these Cockle-like stones ever were, as they are at present, Lapides sui generis, and never any part of an Animal.[19]

Lister observed that fossil shells in English quarries did not differ in texture from the surrounding material, but "Iron-stone Cockles are all iron stone; Lime or marble all Lime-stone and Marble; Sparre or Chrystalline-shells all Sparre." Quarries of different stone yield quite different species of shells, different not only one from another but from anything in nature. Having thoroughly studied molluscs, moreover, he was convinced that seashells which resembled these fossil shells had never existed.

Lister continued to write letters to Oldenburg, insisting on the inorganic theory of fossils. In November 1673, he sent Oldenburg an account of some of the parts of certain stones figured like plants.[20] Oldenburg, in replying to this letter, wrote that the paper had been read at a meeting of the Society and that several Fellows, especially Hooke, had affirmed that such stones had once been plants.[21] In December 1673, Lister again wrote to Oldenburg that these stones had certain common external features which resembled plants, "though in most other particulars they wholly differ from any vegetable yt I know of in Nature."[22]

Lister thus maintained the inorganic theory because he found that the shapes of some fossils were obviously different from those of real living creatures. He never considered the possibility of the evolution or extinction of certain species that was suggested by Hooke. There were adequate grounds for Lister's opinion which was based on a chemical point of view, if it were assumed that species did not evolve or become extinct.

John Beaumont, another Fellow of the Royal Society, likewise sent letters to Oldenburg and supported the idea that fossils were "Lapides sui generis". His letters were published in the Philosophical Transactions (1676), and in them he confirmed a chemical explanation of certain stones figured like plants:

> As to that opinion which generally solves those various Phaenomena of the several figur'd Stones, which we find in Mines and else where, by saying that they are parts of Plants and Animals, or whole ones, petrified; it seems not to be grounded on practical knowledge: Thus when we find several sorts of Shellfish in Mines, as there are some in the clay where those Stone-Plants grow, we must not flie to petrifaction, as though they had been brought there by the Sea, or otherwise, and so petrified; but we must take that to be (as it is truly) the natural place of their birth; some of them being raw-clay, others of the same texture with the Rock where they grow, and others of as absolute a shelly substance as any in the Sea; these being only different gradations of Nature, which can as well produce shells in Mines as in the Sea.[23]

Like Lister, Beaumont pointed out that some fossils were of the same substance as the surrounding rocks. From this observation he concluded that fossil stones had been formed by a "seminal root" similar to the "seminal principle" or "plastic virtue" claimed by chemical philosophers and the Cambridge Platonists. Referring to the saying of Heraclitus "where there is a strong internal light to expand the Idea's, and a drought to terminate them the vertue of a soul is still present which imprints them in the matter", Beaumont claimed that

> Nature is most busie in the kind where her intentions are highly raised by the presence of her chief principles, Salts, Sulphurs, and Mercury...[24]

Beaumont thus believed that the chemical explanation could be the answer to the fossil question.

The correspondence of Oldenburg indicates that he tolerated theoretical diversity and tried to stimulate Fellows to argue over specific problems by reporting and publishing letters of his correspondents. As Oldenburg himself did not present geological views, his role in the development of Earth science has not been well recognized. When Earth science was not regarded as an independent subject, Oldenburg did much more than popularize the science; he also helped to bring the cyclic and chemical views into a direct confrontation.

Even after the death of Oldenburg in 1677, the Royal Society maintained the tolerant policy which had aroused the fossil controversy. In 1679 Beaumont showed his "starr stones" to Hooke and other Fellows at Jonathan's coffee-house in London.[25] Beaumont did not give up his inorganic theory of fossils.[26] In 1683 another letter was published in the Philosophical Transactions, in which he again discussed the origin of "Rock-plants" and explained why he was inclined to believe this to be inorganic. According to Beaumont, trunks of stone plants could not be regarded as parts of living species because they were different in shape from any known species of living creatures. To solve this difficulty, Hooke and Ray supposed that all these species were lost. Beaumont pointed out, however, that these "Rock-plants" were not peculiar to any one place, but were found generally in England and foreign countries. Certain particular species of plants growing only in some determinate place may happen to have been lost but it was hard to imagine, he said, how many species diffused through many parts of the Earth should happen to have been lost completely.[27]

Beaumont's argument was not based on the theological assumption that all the works of God at the Creation should be preserved, although the chemical view of minerals was essential for his inorganic theory of fossils. The Society's theoretical diversity stimulated the Fellows to defend a theory by observed facts.

Hooke's Theory of Fossils

While Oldenburg communicated with various scientists at home and abroad, Robert Hooke, the first Curator of Experiments from 1662 to his death in 1703, took a leading part in the meetings of the Royal Society and defended his organic theory of fossils. At a meeting of the Society in 1664, John Beal (1603-83), a country correspondent of Oldenburg, presented "a box of stones to illustrate the process of the plastic spirit in shaping perfect cockles, muscles, scallops, headless serpents, fishes, thunder-stones, etc."[28] Beal attempted to explain the origin of fossils by the chemical notion of "plastic spirit" hidden in the earth. At meetings of the early Royal Society, however, such a chemical explanation does not seem to have been dominant because of the lectures of Hooke.

At a meeting of the Royal Society in 1663 Hooke read some observations upon a piece of petrified wood.[29] This paper was later printed in Hooke's Micrographia (1665), in which he also presented his opinion of the organic origin of fossils and rejected the chemical idea of "Plastic virtue":

> From all which, and several other particulars which I observ'd, I cannot but think, that all these, and most other kinds of stony bodies which are found thus strangely figured, do owe their formation and figuration, not to any kind of Plastic virtue inherent in the earth, but to the Shells of certain Shel-fishes, which, either by some Deluge, Inundation, Earthquake, or some such other means, came to be thrown to that place, and there to be fill'd with some kind of Mudd or Clay, or petrifying Water, or some other substance, which in tract of time has been settled together and hardned in those shelly moulds into those shaped substances we now find them...[30]

Hooke's Micrographia was a report of observations made with a microscope and in it he described the difference he had noted between minerals, vegetables and animals. This difference provided a reason why he thought fossils could not be formed by "plastic virtue":

> ...the clods and parcels of Earth are all irregular, whereas in minerals she (Nature) does begin to geometrize and practise as it were, the first principles of mechanicks, shaping them of plain, regular forms and figures, as triangles, squares, etc and tetrahaedrons, cubes, etc. But none of their forms are comparable to the more compounded ones of vegetables; for here she goes a step further, forming them of more complicated shapes, and adding also multitudes of curious Mechanick contrivances in their structure. (In Animals) we shall find, not only most curiously compounded shapes but most stupendious mechanisms and contrivances.[31]

Thus, Hooke's microscopic observations led him to conclude that fossil remains were completely different from minerals and stones in their origin. In 1666, at another meeting of the Royal Society, Hooke "brought in a petrified fish called Echinus Spaticus, by which he convinced his notion of figured stones to be confirmed."[32]

In Hooke's microscopic observations there was no room for the idea of plastic virtue. M.J.S. Rudwick has suggested that Hooke's most persuasive reason for believing in the organic theory of fossils was derived from the philosophical principle: Nature "does nothing in vain". Hooke's opinion, however, was based on his observations on the similarity in microscopic structure between fossils and living creatures. Moreover, the teleological view never became a serious issue of the fossil controversy; instead the central issues were the shape, matter and location of fossils. There is not any evidence to support Rudwick's claim that Hooke's teleological view formed "a powerful argument in favour of the organic origin of fossils".[33] Judging from Hooke's actual activities, his fundamental philosophical principle was mechanistic rather than teleological.

Hooke's Lectures on Earthquakes

In the course of the fossil controversy, the location of fossils came to be one of the main topics of discussion. Those involved realized that the observation of the shapes and materials of fossils themselves was not enough to understand their origin. Studies on minerals in general before the mid-seventeenth century had excluded the environment of specific objects, and had centred on the objects themselves. As the origin of fossils came to be argued, however, their surroundings had to be considered in support of each opinion. The method of the study of fossils was thus changed.

This change can be found in Hooke's lectures at meetings of the Royal Society. Hooke had concentrated his attention on the microscopic structure of fossils in the early stages of his study of them, but later he observed the cliffs and strata which contained various shells. In 1667 Hooke reported that

> he had observed cliffs of stone for near four miles together; that natural position was horizontal, though in some places he had found them to lie much sloping, and in others perpendicular; which, he thought, might fall into those odd positions by some great earthquakes; and he was of opinion, that the great hills and mountains have been raised by earthquakes.[34]

This report indicates that Hooke had attempted to confirm his idea of geological changes by his own observations. His theory of the Earth was not a mere ad hoc device to support the organic theory of fossils.[35] Hooke then referred to a cliff in the Isle of Wight where he found several kinds of shells, and thought that they might possibly have been raised by earthquakes.[36] Fossil shells found near the coast must have facilitated his conclusion that they had once lived at the bottom of the sea.

At the Royal Society Hooke frequently gave lectures on earthquakes in which he discussed the origin of fossils. In a discourse written in 1668 he argued against two opinions leading to an inorganic theory of fossils. The first was that fossils were produced from some extraordinary celestial influence. Hooke regarded this view as an astrological and magical fancy. The second was that fossils owed their formation to "some vegetative or plastic Vertue" inherent in the Earth. Hooke thought that this opinion was not without grounds, there having been found in countries far from the sea great quantities of bodies resembling seashells both in substance and shape. Because of their vast distance from the sea, he said, some believed these objects to be real stones formed into these shapes by some "plastick Vertue" inherent in those parts of the Earth. Many natural historians and philosophers had puzzled over how to account for these phenomena. But Hooke maintained that careful observation "both of the Bodies themselves, and of Circumstances obvious enough about them" would lead to the solution.[37]

Although insisting on the similarity between fossil stones and real seashells, Hooke realized that their occurrence in such locations was a great objection to the organic theory of fossils. By what means were those shells, woods and other such substances transported to, and buried in the places where they were found? Hooke had a clear answer to this objection and presented it as a proposition:

> That a great part of the Surface of the Earth hath been since the Creation transformed and made of another Nature; namely, many Parts which have been Sea are now Land, and divers other Parts are now Sea which were once a

> firm Land; Mountains have been turned into Plains, and Plains into Mountains, and the like.[38]

Hooke thus adopted the idea of an interchange of land and sea which had been held by many earlier seventeenth-century academics.

Like others who relied on the cyclic view of the Earth's history, Hooke made light of the effects of the Universal Deluge on the state of the Earth's surface, and regarded the Deluge simply as one of the alterations in the Earth -- although it could, he acknowledged, be regarded as an extraordinary event. Hooke conjectured that the great change had been caused by the movement of the waters to another part of the Earth's surface as a result of an alteration of the Earth's centre of gravity, or by the eruption of subterraneous fires or earthquakes, by which great quantities of earth might have been raised above the former level.[39] Such a change seemed to be the chief agent which had transported these petrified bodies, shells, woods and animals and deposited them in some parts of the Earth. Hooke doubted, however, that the general Deluge had transported and left these petrified shells:

> Now 'tis not probable that other Mens Hands, or the general Deluge which lasted but a little while, should bring them there; nor can I imagine any more likely and sufficient way than an Earthquake.[40]

Hooke thus claimed that the duration of the general Deluge had not been long enough to carry all the seashells to the land. The beds of fossil shells moreover were too thick to be explained by only one deluge. Instead he surmised that several inundations had occurred since the Creation. The Universal Deluge was thus not, for him, the only cause of the present geological features.

The strange shapes of fossil shells presented another difficulty in the acceptance of the organic origin of fossils. It was observed that the shapes of some fossil remains were unlike these of any living creatures. To solve this problem, Hooke suggested the possibility of the extinction of some species of living creatures:

> ...there have been many other Species of Creatures in former Ages, of which we can find none at present; and...'tis not unlikely also but that there may be divers new kinds now, which have not been from the beginning.[41]

This statement was novel in the seventeenth century because it was the common belief that God did not extinguish the living creatures He had created. Hooke's opinion was dangerous in the sense that it contradicted this established and theologically reassuring idea. Hooke claimed, nevertheless, that various species of living creatures might have been wholly destroyed and annihilated. In his opinion, there are some kinds of animals and plants peculiar to certain places, and if such a place were to be inundated, it is probable that they may have been destroyed by a flood.[42] Thus, Hooke's reasoning was completely free of the theological doctrine that all creatures should be preserved. Apart from extinction, he even suggested the evolution of living creatures, claiming

> That there may have been divers new varieties generated of the same Species, and that by the change of the Soil on which it was produced; for since we find that the alteration of the Climate, Soil and Nourishment doth often produce a very great alteration in those Bodies that suffer it; 'tis not to be doubted but that alterations also of this Nature may cause a very great change in the shape, and other accidents of an animated Body.[43]

Hooke, being convinced that fossils were the remains of living creatures despite their strange shapes, thus suggested that in some species their shapes had become changed, which he thought could be explained by a change of environment. This idea of evolution, however, was not taken up by other natural historians, and so was of little historical importance.

Hooke continued to give geological lectures, which stimulated other Fellows to discuss the origin of fossils. Hooke wrote in his diary in 1677 that he had "a great dispute about petrifactions" at Jonathan's with Robert Plot, who claimed an organic origin by the work of a "plastic virtue". At a meeting of the Royal Society in

1683, Hooke again argued with Lister, who said that there were no shellfish known that corresponded to some fossils.[44] Michael Hunter has suggested that the meetings of the Royal Society "were really of little scientific improtance."[45] So far as Earth science was concerned, however, this is incorrect, because the Society's meetings provided a forum where different views were debated in ways which helped to clarify various geological questions.

Hooke's argument was at this stage concentrated on the nature of fossils and did not seriously incorporate any historically-oriented insight into the nature of the Earth. After the publication of Thomas Burnet's Theory of the Earth Hooke changed his method of studying the Earth and began to consider the historical aspect of the Earth. This new idea, too, came to be discussed at the meetings of the Royal Society.

The Spread of the Fossil Controversy

The Philosophical Transactions of the Royal Society included reviews of books written by Fellows, and some of these books, including John Ray's Observations Topographical, Moral and Physiological (1673), Matthew Hale's Primitive Origination of Mankind (1677) and Robert Plot's

Natural History of Oxfordshire (1677), discussed the fossil question. Through publications such as these, the fossil controversy reached a wider audience.

The difficulty concerning the origin of fossils was clearly expressed by Ray, one of the leading natural historians of the period. In a private letter to Martin Lister in 1671, Ray wrote that he was of a different opinion from Lister regarding the origin of "petrified shells".[46] Two years later, Ray gave an account of the opinions of eminent authors concerning the origin of fossil stones. Like Hooke and Steno, he thought that fossil stones were originally the shells or bones of creatures living in the sea.[47] Ray admitted, nevertheless, two considerable objections to this view.

First, if the organic theory were accepted, it would follow that the Earth's surface had once been covered by the sea for a long time. But Ray thought that the distribution of fossil stones could not be explained by the Universal Deluge, and also expressed doubts over whether mountains on which such shells were found had been under the sea and afterwards raised up by earthquakes, because although mountains raised by earthquakes were recorded in histories, they were very few and of no considerable height compared with high mountains such as the Alps. Ray supposed that the surface of the Earth had suffered little change since the earliest recorded history, the same mountains, islands, promontories, lakes and rivers still remaining, and very few of them being added to, lost or removed:

> Whence it will follow, that if the Mountains were not from the beginning, either the World is a great deal older than is imagined or believed, there being an incredible space of time required to work such changes as raising all the Mountains,...or that in the primitive times and soon after the Creation the earth suffered far more concussions and mutations in its superficial part than afterward.[48]

Ray thus noted that those who supported the organic theory of fossils had to solve the difficult problem of fossils in the Earth's surface.

The other objection against the organic theory of fossils was that they were different in shape from real living creatures:

> There are found in the earth many such like figured stones which we know not whither to refer, as resembling neither any part of an Animal, nor of a Plant... And if there are now no such things in being, they that defend the contrary Opinion must have recourse to that gratuitous supposition that such Species are lost out of the World.[49]

The idea of the extinction of living creatures was difficult to accept, because the loss of any one species was generally thought to render the universe imperfect.

Divine Providence was supposed to preserve all the works of the Creation. Ray did not make a definite reply to this second objection. Although Ray was inclined to believe the organic theory of fossils, his indecisiveness shows how difficult it was to solve the problem at this stage.

Matthew Hale, accepting the idea of interchange of land and sea, defended the organic theory of fossils but invoked the idea that "Seminal Ferments" lodged in the ground could have given rise to them. He had made actual observations on fossil stones and it was on this basis that he considered them to be the remains of living creatures:

> For my own part, I have seen such apparent Evidences in and near the place where I live of things of this nature, that I am satisfied that many of them are but the Relicks of Fish-shells left by the sea, and there in length of time actually Petrified; and the Instance of the great Fish-sceleton found at Cammington seems an undeniable Evidence thereof. And I remember in my youth, in the Lisne of a Rock at Kingscote in Glocestershire, I found at least a Bushel of Petrified Cockles ...[50]

Hale rejected the opinion that fossil stones were no other than "Lusus naturae" or the effects of the "plastic power" of the earth, and surmised instead that certain "Seminal Ferments" could have been easily brought to land by the waters of floods and had been lodged in the ground. They grew up there and then turned into fossil stones.

Hale was convinced that the position of the sea and dry land had not always been the same, but "there might then be Sea where there is now dry Land, and dry land where there is now Sea."[51] As an example of such interchanges Hale referred to Plato's Atlantis:

> ...it is not impossible, but in that long tract of 4000 Years at least, which hath hapned since the Universal Deluge, there hath been great alterations in the situation of the Seas and Earth: possibly there might be anciently Necks of Land that maintained passage and communication by Land between the two Continents. Many Instances of this kind are remembred by Pliny, not only of the great Atlantick Island mentioned by the Egyptian Priest in Plato's Timaeus...[52]

Hale thus thought that Plato's Atlantis was but one of the islands which had sunk into the sea and that such alterations had produced the geographical features of the present. Hale also quoted Dugdale's accounts of the Earth's changes and a passage of Ovid's Metamorphoses to support his idea.[53] Although Hale adopted the cyclic view of the Earth and regarded fossils as evidence that changes had happened in the Earth's surface, the fact that he expressed a modified opinion of the organic theory of fossils, too, indicates that the question as to the location of fossils was not easily solved at this stage.

The spread of the fossil controversy can be verified by the title of a chapter in Plot's Natural History of Oxfordshire, namely "The great Question now so much controverted in the world". In this work Plot inclined to Lister's view that fossils were "Lapides sui generis", rather than remains of living creatures. Acceptance of the organic origin of fossils seemed, in his opinion, to cause more problems than the inorganic theory. Those who insisted that fossil stones were once living creatures had to assume that they were brought there by the Deluge, or by some other inundation. This raised the question of the nature of the Deluge. If it had ensued from rain, there was more likelihood that it would have carried shells down into the sea, rather than have brought them up to the tops of mountains. If the fountains of the great abyss had been broken up and the overflowing of the sea had been a gradual process, then shellfish would not have left their beds in the sea and been carried to the tops of mountains. If the Deluge had been violent, it would have scattered all sorts of shells over the whole face of the Earth. These shells, however, were "not scattered neither indifferently one amongst another, but for the most part those of a kind together; and of the same kind too, those of different lineations together."[54] In other words, Plot observed the structure of strata and noticed that each stratum contained a different type of fossil: "Thus at Cornwell and Hornton we find only Conchites or Cockle-stones, and those striated (if at all) from side to side transversly."[55] He thought that this regularity of strata could not be explained by the Deluge, and he concluded, therefore, that fossil stones were not remains of living creatures.

Plot claimed, with Lister, that in most countries there were all kinds of seashells included in rocks or earth far from the sea, and petrified.[56] He did not deny that some fossil shells were remains of real seashells. But as for other fossils such as Astroites, Belemnites, Brontiae, Cornua Anmonis and so on, he believed that they were formed by "some latent plastic power of the Earth" because they did not represent either animals or plants. To Hooke's claim that Nature did nothing in vain, Plot replied that it was in the wisdom and goodness of Supreme Nature that the world was endowed with these varieties of fossil stones.[57] In other words, to justify the idea that fossils were formed by the plastic power of the earth, he invoked the wisdom of Nature, which he interpreted for his own ends.

The works of Ray, Hale and Plot thus included arguments about the origin of fossils. Through these publications a wider audience was able to acquire up-to-date knowledge of the fossil question. As these works indicate, there was no dominant theory of fossils at this stage and the fossil controversy itself further stimulated natural historians to observe geological phenomena.

The Oxford Philosophical Society

Geological phenomena were studied by scholars from Oxford such as Nathanael Carpenter, John Aubrey, Robert Lovell and Robert Hooke. However, it was the Ashmolean Museum there that particularly facilitated the study of the Earth by keeping and encouraging the search for natural rarities.

The first foundation of the Ashmolean Museum was laid in 1679 and it was finished in 1683 to keep the collections of Elias Ashmole which consisted of the rarities collected by the Tradescants. In March 1683 the University of Oxford appointed Plot first keeper of the newly established Ashmolean Museum and its Ashmolean professor of chemistry. Plot was also one of the leading members in the Oxford Philosophical Society established in 1682. He thus acquired an institutional foundation from which to diffuse his opinion as to the origin of fossils, and soon found followers such as Edward Lhwyd.[58]

Moreover, John Wallis, another leading member of the Oxford Philosophical Society, also adopted the inorganic theory of fossils. A.J. Turner has given the texts of previously unpublished letters of Wallis to Edmond Halley which were part of a regular correspondence between the Royal Society and the Oxford Philosophical Society.[59] In one of these letters, Wallis said that it seemed too extravagant to admit that "the whole face of the Earth should have been...many times all covered with water and dryed again."[60] He continued:

> ...(unless it were before ye Creation of Adam) we cannot find a time wherein the Earth should (so often) have been tossed & turned upside down,...[61]

Wallis in fact rejected the idea that the interchanges of land and sea were the cause of fossils. But his argument had difficulty in explaining the origin of fossils which resembled real living creatures. To answer the question, Wallis said

> ...(to omit what Steno & others have at large discoursed on that subject) we were minded, by one of our number, of what had been lately presented to us, from a D^{r} of Physick of good credit, which was (to all appearances) a Fish-shel, taken by himself out of y^{e} Kidney of a Woman. Which yet we thought more likely to have been formed there, than that this Kidney had once been Sea.[62]

Thus like Plot, Wallis suggested that fossil shells had been formed in the ground and had not been carried from the sea. At this stage the inorganic theory of fossils seems to have been popular among the members of the Oxford Philosophical Society.[63]

Nevertheless, it does not necessarily follow that Hooke's cyclic view of the Earth based on the organic theory was altogether implausible in the seventeenth century.[64] Neither party surrendered its ideas on the origin of fossils and both continued to assert that the empirical evidence favoured their theory. Actual observation of natural phenomena proved not sufficient for either side to refute the opposition. Lister and Plot were deeply concerned with a "chemical" analysis of fossils, and they believed that the earth had "plastic power" or "virtue" to generate fossil stones. Such an idea originated from the neo-Platonic view of nature. Hooke, on the other hand, was sure that the remains of living creatures could turn into stones, which were completely different in structure from other stones and minerals. And as a "mechanical philosopher", he would not have found the basis of the chemical theory acceptable.

Both the chemical and the cyclic view of the Earth provided research programmes for the study of fossils, and neither research programme collapsed under the weight of newly discovered facts. Thus the fossil controversy did not settle down and was still a burning issue when Thomas Burnet published his Theory of the Earth in 1684.

The new perspective on the Earth's history presented in this work eventually offered advantages to the organic theory of fossils.

NOTES

1. Robert K. Merton, Science, Technology and Society in Seventeenth Century England (New York, 1970), 75.

2. Ibid., 50.

3. Cf. Charles Webster ed., The Intellectual Revolution of the Seventeenth Century (London, 1974).

4. Alexander Koyré, From the Closed World to the Infinite Universe (New York, 1957), 3.

5. Richard S. Westfall, Forces in Newton's Physics (London, 1971), X.

6. T.S. Kuhn, The Structure of the Scientific Revolutions (The University of Chicago Press, 1970), 177.

7. Thomas S. Kuhn, "Science: The History of Science", The International Encyclopedia of the Social Sciences.

8. Michael Mulkay, Science and the Sociology of Knowledge (London, 1979), 93-94.

9. Porter, The Making of Geology, 19; Hunter, Science and Society, 57-58.

10. Sociologists often understand the word "institution" as "cultural values", not as "formal organizations". (Cf. Grary A. Abraham, "Misunderstanding the Merton Thesis", Isis, 74 (1983), 374.) Such a usage could minimize the role of scientific organizations in scientific activity itself. (Ibid., 381.) Here I simply use the word as "scientific organizations", but I do not intend to ignore the importance of "cultural values" in the development of science. (See Chapters 4, 8 and conclusion.)

11. Hunter, Science and Society, 50.

12. Henry Oldenburg, The Correspondence of Henry Oldenburg, II, 456.

13. Oldenburg, Correspondence, V, 90.

14. Oldenburg, Correspondence, II, 121-22.

15. Oldenburg, Correspondence, VI, 335.

16. Referring to Descartes, Steno concerned himself with the historical aspect of the Earth. (Nicolaus Steno, Prodromus, "The Strata of the Earth".) While Descartes had built up a grand theory of the Earth, Steno applied it to an interpretation of the history of the Tuscan landscapes. The implications of his geological history, however, were not fully realized by the members of the Royal Society at this stage. Lister regarded him simply as an advocate of the organic theory of fossils. (Martin Lister, "A Letter of Mr. Martin Lister...concerning Petrify'd Shells," Phil. Trans., VI (1671), 2282.)

17. Lister, "Petrify'd Shells", 2282.

18. Gunther, Early Science in Oxford, VI, 382.

19. Martin Lister, "A Letter of Mr. Martin Lister... concerning Petrify'd Shells," Phil. Trans., VI (1671), 2282.

20. Oldenburg, Correspondence, X, 324-32.

21. Ibid., 363-64.

22. Ibid., 368.

23. John Beaumont, "Two Letters by John Beaumont...concerning Rock Plants and their Growth", Phil. Trans., XI (1676), 737.

24. Ibid., 740.

25. Henry W. Robinson & Walter Adams eds, The Diary of Robert Hooke, M.A., M.D., F.R.S., 1672-1680 (London, 1935), 422.

26. Later Beaumont changed his opinion about fossils and came to agree with Hooke. Beaumont regarded Hooke as "a worthy Member of the Royal Society" (John Beaumont, "A Further Account of Some Rock Plants growing in the Lead Mines of the Mendip Hills", Phil. Trans., XIII (1683), 278), and Hooke himself might have profoundly influenced him in the giving up of his previous opinion, because Beaumont dedicated to Hooke his Considerations on a Booke, entituled The Theory of the Earth, publisht by Dr Burnet (London, 1693), in which he accepted Hooke's views.

27. Beaumont, "A Further Account of Some Rock Plants", 276-79.

28. Gunther, Early Science in Oxford, III, 221.

29. Gunther, Early Science in Oxford, VI, 130, 131, 135-37.

30. Robert Hooke, Micrographia (London, 1665), 111.

31. Ibid., 154.

32. Gunther, Early Science in Oxford, VI, 269.

33. M.J.S. Rudwick, The Meaning of Fossils (London, 1972), 54, 55.

34. Gunther, Early Science in Oxford, VI, 307.

35. However, Roy Porter has claimed that "Hooke's speculations on earthquakes were at this stage a bold, essentially ad hoc device introduced to justify his interpretation of fossils." (Porter, The Making of Geology, 83.)

36. Gunther, Early Science in Oxford, VI, 341-42.

37. Hooke, Posthumous Works, 289.

38. Ibid., 290.

39. Ibid., 291.

40. Ibid., 320.

41. Ibid., 291.

42. Ibid., 372.

43. Ibid., 327.

44. Robinson & Adams, Hooke's Diary, 314; Thomas Birch, The History of the Royal Society, IV, 237.

45. Hunter, Science and Society, 57.

46. E.R. Lankester, The Correspondence of John Ray (Ray Society: London, 1848), 95.

47. John Ray, Observations Topographical, Moral and Physiological (London, 1673), 120.

48. Ibid., 126-27.

49. Ibid., 130.

50. Matthew Hale, The Primitive Origination of Mankind (London, 1677), 192.

51. Ibid., 193.

52. Ibid., 189.

53. Ibid., 191.

54. Robert Plot, The Natural History of Oxfordshire (Oxford, 1677), 112.

55. Ibid., 112-13.

56. Ibid., 119.

57. Ibid., 121.

58. Gunther, Early Science in Oxford, I, 222.

59. A.J. Turner, "Hooke's Theory of the Earth's Axial Displacement: Some Contemporary Opinion", The British Journal for the History of Science, 7 (1974), 166-170.

60. Ibid., 168.

61. Ibid., 169.

62. Ibid.

63. One L.P. wrote two essays (1695) "from Oxford", in which he defended the inorganic theory of fossils. John Woodward believed it the work of Tancred Robinson, a fellow doctor and member of the Royal Society. Robinson admitted publicly to assisting the author. According to Seth Ward, it was generally thought that Martin Lister was the author. (Cf. Levine, Dr. Woodward's Shield, 37.)

64. However, Turner regarded Wallis' letters as evidence that Hooke's cyclic theory of the Earth had been implausible in the context of seventeenth-century knowledge. (Turner, "Hooke's Theory",167.) Moreover, Turner did not consider that Wallis had changed his opinion and had claimed the possibility of great geological interchanges. (John Wallis, "A Letter...relating to the Isthmus, or Neck of Land, which is supposed to have joyned England and France in Former Times", Phil.Trans., No.275 (1701), 967-79.

6. THE MECHANICAL VIEW OF THE EARTH

In the first half of the seventeenth century there appeared a spontaneous movement towards a mechanical conception of nature in reaction to the neo-Platonic as well as the Aristotelian philosophy. In the field of mineralogy, mineral substances, too, came to be discussed in either "mechanical" or "organic" terms.[1] In seventeenth-century England, however, the neo-Platonic philosophy did not provide an explanation for the early history of the Earth.[2] Instead, as has been shown in a former chapter, the study of the Earth's history was closely related to an exposition of *Genesis*. Therefore, the mechanical explanation of the Earth's history did not have to attack the neo-Platonic point of view, but had to account for the miracles in the Bible.

Descartes' Cosmogony and Moses' Genesis

One possible solution to the problem of miracles was to ignore the Bible itself when discussing the Earth's history. This attitude was taken by René Descartes (1596-1650), who exerted the greatest influence on the development of the mechanical view of nature. In his Philosophia Principiae (1644), Descartes presented his own cosmogony, completely ignoring Moses' Genesis. He explained the formation of the Earth in terms of particles of matter and their motion. According to Descartes, the outer surface of the primitive Earth was a hard crust underneath which there was a layer composed of a watery substance. The heat of the summer sun dried out the crust until it was checkered with several fissures, and the heat also expanded the liquid under the crust until part of it escaped through the pores of the crust. In the winter, however, the fissures were contracted until they blocked the return of the watery particles. As a result, there came to be a space left between the crust and the layer of the liquid. Being weakened by the fissures and with no support under it, the crust eventually collapsed. However, the base of the waters was not extensive enough to receive all the pieces of the crust in the same position as they were before, so that some had to fall on one side and lean against each other. Some pieces which were not covered with water became plains and mountains, and the water which was forced out of its place became the seas of the world.[3]

Descartes thus explained the formation of the primitive Earth without referring to any miracle. The particles of matter and their motion were the only factors which had to be considered. There was no final cause nor any active principle in the Cartesian view of the world. It was an aimless and lifeless world. The importance of Descartes for our story lies in that he explained the formation of the Earth in physical terms.

A similar method was adopted by other French intellectuals. The two volumes of the Collection of the Discourses of the French Virtuosi were translated from Renaudot's Conférences du Bureau d'Adresse by G. Havers and published in London in 1664-65. In the second volume of the Collection, one may find that some French virtuosi discussed the origin of mountains without referring to miracles.

In this book one virtuoso asserted that, God having created the world in a perfect state, there should have been plains and mountains on the Earth from the beginning. The second virtuoso claimed, on the contrary, that the Earth must have had a perfect round shape at the beginning, otherwise the waters could not have covered it as they did:

> 'Tis certain then that God gave the Earth that spherical form, it being to serve for the bulk and centre to all the other Elements, by means of which roundness the Water covered it equally, but when it was time to render the Earth habitable to Animals, and for that

> end to discover a part of it, it was to be rendered more hollow in some places and more elevated in others, since there is no Mountains without a Valley,...[4]

Although higher places were created for land animals, the change was not drastic at this stage. The great change happened at the time of the Universal Deluge:

> when the many Gulfs below and Windows on high, as the Scripture speaks, overflowed the whole Earth for forty days and forty nights together; the Earth being a Sea was in a manner new shaped by the torrents of the waters, and the violence of the same waves, which made Abysses in some places and Mountains in others,...[5]

According to this opinion, then, the mountains were produced by the violent waters of the Deluge, although there had been some unevennesses in the antediluvian Earth.

The third virtuoso claims that some mountains were produced at the Creation and others afterwards, partly by rains and torrents and partly by winds and earthquakes, which have sometimes levelled hills and reduced them to valleys. Therefore, he says, we cannot assign one general cause to all. According to this view, the Creation and the Universal Deluge are of no particular importance to the matter of the origin of the mountains.

These French virtuosi thus did not rely on the miracle in their arguments on the origin of mountains. Not referring to Cartesian cosmogony, they attempted to explain the Earth's history in a naturalistic way.[6] Their arguments reveal a shift in emphasis from an attempt to discover the mysterious work of Providence to an enquiry into the natural phenomena themselves. The design of the conferences was to "rescue the liberal sciences from the bondage of Scholastical Obscurities."[7] The discussion about the Earth's history now departed from a mere exposition of Genesis.

The influence of Cartesian cosmogony can be found in several works on the history of the Earth. Nicolaus Steno, for example, wrote his Prodromus (1671) referring to Descartes' theory of the Earth. Steno suggested as follows:

> If all the particles in a stony stratum are seen to be of the same character, and fine, it can in no wise be denied that this stratum was produced at the time of the creation from a fluid which at that time covered all things; and Descartes also accounts for the origin of the earth's strata in this way.[8]

Like Descartes, Steno claimed that the strata had been formed at the time of the Creation. Afterwards they were able to change their position in two ways. The first is the violent thrusting up of the strata caused by a sudden burning of subterranean gases or a violent explosion of air. The second is

> the spontaneous slipping or downfall of the upper strata after they have begun to form cracks, in consequence of the withdrawal of the underlying substance, or foundation. Hence by reason of the diversity of the cavities and cracks the broken strata assume different positions; while some remain parallel to the horizon, others become perpendicular to it, many form oblique angles with it, and not a few are twisted into curves because their substance is tenacious. This change can take place either in all strata overlying a cavity, or in certain lower strata only, the upper strata being left unbroken.[9]

Steno used the idea of a collapse of the crust in order to show how the present state of strata came about. Thus Descartes' idea was used to explain a regional geological feature. In Steno's argument, too, a role for miracles was completely removed.

The influence of Descartes' cosmogony is also found in books which were reviewed in the Philosophical Transactions in 1670. These books were Louis de Beaufort's Cosmopoeia Divina (1656), Joannes Amerpoel's Cartesius Mosaizans (1669), Samuel Gott's The Divine History of the Genesis of the World (1670), Des Fourneillis' A Discourse in Vindication of Des Cartes's Systeme and Francis Bayle's The Systeme General of the same Cartesian Philosophy (1670). These Cartesian-inspired works were reviewed because "it would not be unacceptable to the Ingenious, to give them here a taste of these Treatises, thereby to excite them to a further disquisition and elusidation of this matter."[10] Although the early Royal Society does not seem to have argued about Descartes' cosmogony, these reviews show that some members were interested in it.

In these works a mechanical explanation of the Earth's history was harmonized with the Biblical exposition. In his Cosmopoeia Divina, for example, Beaufort used the Cartesian notion of vortices to explain the creation of the world. Descartes' cosmogony was reconciled with Moses' Genesis. A similar attempt was made by Amerpoel who, in his Cartesius Mosaizans, took pains to draw a parallel between the first chapter of Genesis and the principles of Descartes. The Cartesian doctrine of the distinction of the earth from the waters and air was thought to be consistent with that of Genesis. Des Fourneillis showed that most of Descartes' tenets conformed to Moses' pronouncements in Genesis. Samuel Gott, who regarded Moses as the only true philosopher, maintained that Cartesian philosophy "described the World in Paper otherwise than God hath made it to be in Nature."[11] All these authors thus attempted to interpret Descartes' cosmogony in such a way that it would fit the Biblical account of the Creation.

Matthew Hale, too, accepted the need for a physical explanation of the development of the Earth. Criticizing

Cartesian natural philosophy, however, he regarded the Universal Deluge as a major geological phenomenon. This argument was made in his Primitive Origination of Mankind, 1677, which in the same year was reviewed in the Philosophical Transactions.

In this book Hale argued against Isaac Vossius' claim that the Flood was a purely local phenomenon. According to Vossius, even if the Flood were not universal, it would have been sufficient to destroy all who were living within the radius of Syria and Mesopotamia in the time of Noah. All species of animals and birds might have preserved themselves simply by flight away from the place where the Flood prevailed, and without any difficulty repopulated the same place after the subsiding of the waters. Hale, however, was not satisfied with this opinion which denied the universality of the Flood.

Although Hale believed that the Flood was universal, he nevertheless refused to explain it by supernatural causes:

> ...although I take this Flood to be somewhat more than Natural, and a thing instituted by the Will of God, yet do I not esteem it a thing purely Supernatural or Miraculous, neither do I suppose those Waters created de novo, nor sent out of the Orbs of Heaven to drown the Earth...[12]

For Hale it was not difficult to account for the Flood's having occurred without Divine intervention:

> I do not think the Face of the Earth and Waters were altogether the same before the Universal Deluge, and after; but possibly the Face of the Earth was more even than now it is, the Seas more dilate and extended, and not so deep as now; the Waters possibly more than now, and in those respects more capable of diffusion over the dry land.[13]

If the antediluvian Earth had been smoother, the Flood could more easily have covered the whole land. There were, moreover, Hale said, subterranean waters which could have helped cover the Earth's surface. If it could be assumed that the surface of the Earth had subsided and brought pressure to bear on the reservoir of water in the ground, this might provide enough water to drown the Earth without resorting to the creation of new sources. In addition, there was the air, which might by condensation have yielded sufficient water to cover the whole world.[14]

Hale thus supposed that the Earth before the Flood was flatter than it is now, without high mountains and deep valleys. This assumption facilitated his explanation that the universality of the Flood was due to natural causes. This idea of the smoother surface of the antediluvian Earth was later adopted by Thomas Burnet.

Was Burnet a Millenarian?

Thomas Burnet was of Scottish extraction, and was born at Croft in Yorkshire in or about the year 1635. He was educated in the Freeschool of North-Alverton under one Thomas Smelt. In 1651 he was admitted to Clare Hall in Cambridge, where his tutor was John Tillotson. Ralph Cudworth transferred from the Mastership of Clare Hall to that of Christ's College in 1654, and Burnet followed him thither to become a fellow of that college in 1657, and receive his Master of Arts in 1658. After the Restoration Burnet became senior proctor of the university, then he travelled abroad as governor of young earls and had a chance to cross the Alps, which he thought had been formed at the time of the Universal Deluge.

Burnet established a great reputation for himself by publishing Telluris Theoria Sacra in Latin in 1681. This work was well received by the learned, and King Charles II encouraged Burnet to publish it in English as well. The translation, The Sacred Theory of the Earth, was published in 1684 with a dedication to the King. In 1685 Burnet was elected Master of the Charterhouse and a short time later received his Doctor of Laws. After the Glorious Revolution he succeeded Tillotson as clerk of the closet to King William III. In 1689

Burnet published the second part of his Theory in Latin, and in 1690 completed an English edition with an elegant dedication to Queen Mary.

In 1692 Burnet published his Archaeologiae Philosophicae sive Doctrina Antiqua de Rerum Originibus with a dedication to King William. Burnet attempted in this work to reconcile the account of the Creation in Genesis with his theory, but a great clamour was raised against him for allegorizing the Scriptural account. Burnet subsequently wrote a letter to a "bookseller" and asked to have the most offensive parts omitted in future editions. This, however, came too late and Burnet was obliged to retire from his post of clerk of the closet to his Majesty. He remained in the Charterhouse until his death in 1715.

Jacob and Lockwood have suggested that "Thomas Burnet's Sacred Theory of the Earth figures as one of the first attempts to devise a cosmogony and a natural history of the earth",[15] but, as has been shown, there existed similar attempts long before the publications of Burnet in the 1680s. However, it was Burnet's theory that was the most influential unification of Cartesian cosmogony and Moses' Genesis. Referring to his Theory, Burnet said that

> The first part of the Theory, which treats the Origin of Things, or of the Originary World, escapes the View and Attention of many, to whom those Things appear trifling and empty.[16]

In spite of various offences in it, Burnet's Theory was widely read and provoked a controversy which involved a wide range of intellectuals.[17] Burnet's Theory was successful in the sense that it attracted popular attention when the study of the Earth's history was not highly esteemed. Then, the question may be raised why he wrote at length about this "trivial" subject.

Jacob and Lockwood have claimed that "millenarianism played a fundamental role" in Burnet's writing his work because Burnet "was a churchman at a time when events in the political order dominated his thinking."[18] It is a historical fact that when Burnet wrote the Sacred Theory, English Protestants felt threatened by the possibility of Catholic domination. Moreover, when King James II asked in 1686 that Andrew Popham, a Roman Catholic, be admitted as a pensioner at the Charterhouse, Burnet refused the King's request. From these facts Jacob and Lockwood concluded that Burnet's Theory was millenarian propaganda against Roman Catholicism.

In the second volume of the Theory, however, Burnet maintained that "Scripture itself will be a more visible

Guide to us in these following parts of the Theory, than it was in the former." (Chap. I, Bk. III) As Burnet suggested, the second volume of the _Theory_ differs in nature from his first volume. In the first volume he treated what had happened in the past and discussed it in the same way as historians had done. But in the second, like the millenarians, he conjectured on what would happen in the future. Therefore, the suggestion that Burnet's _Theory_ was a millenarian book may not be applied to the first volume of the _Theory_.

Moreover, in reference to the second volume of the _Theory_ which treated the future of the world and the Conflagration, Burnet said that "very few Christians will dispute these Articles."[19] As a matter of fact, Burnet's contemporaries did not dispute his opinion on the future world. The first volume of the _Theory_, on the contrary, aroused a hot controversy in which Burnet made every effort to advocate his ideas concerning the Earth. It would be very difficult to understand this controversy if Burnet's main interest and his critics' concern were the coming of the millenium.

More importantly, Burnet first wrote his _Theory_ in Latin, and then published its English edition. The fact that he first published the Latin edition indicates that the book was written not as political propaganda but as an academic work.[20] Millenarianism may not have been fundamental to the first volume of Burnet's Theory.

Was Burnet a Theorist?

Burnet has been considered "an eccentric of little significance, a man who wasted most of his time writing and defending an absurd scheme of the formation and history of the earth",[21] but he also has been regarded as an important figure in the history of Earth science. For example, J. Roger has suggested that Burnet's work "paved the way to an entirely historical interpretation of Nature."[22] Other commentaries furthermore stress the importance of Burnet's theory in the formation of historically-oriented study.[23] According to Rudwick, Burnet's theory exerted "the most important influence on the course of the debate about fossils in the late seventeenth century."[24] These authors have paid attention to Burnet's argument about the past state of the Earth, and have regarded him as a theorist of the Earth. Such comments, however, miss the fact that Burnet himself considered his Theory to be a natural history.

Indeed, Burnet's work can be seen as a natural history of an unknown world. The first two books of The Theory of the Earth concern the Paradise and the Deluge. In the dedication to the King Burnet maintained that

> Your Majestie's Sagacity, and happy Genius for Natural History, for Observations and Remarks upon the Earth, the Heavens, and the Sea, is a better preparation for Inquiries of this kind, than all the dead Learning of the Schools.

Burnet suggested that it required a knowledge of natural history to understand his work, although he did not deny the validity of academic learning.

To give a physical explanation for the Earth's history, in fact, Burnet referred to general observations on natural phenomena such as the great channel of the ocean, subterranean cavities and waters, mountains and rocks. According to him, the inside of the Earth was hollow and broken in many places, and was not one firm and united mass. Burnet pointed out that there were many such examples recorded in natural histories of all countries, or in geographical descriptions of them.[25] In his view subterranean rivers, volcanoes and earthquakes were obvious demonstrations of the hollowness of the Earth. If the body of the Earth were compact, he argued, there would be no such phenomena in nature as earthquakes or volcanoes. From these facts he concluded that the irregularity of the surface of the Earth was not the direct and original work of God.[26]

Burnet claimed that mountains were also a result of geological change and thus were nothing but great ruins. However, he complained that

> the generality of people have not sence and curiosity enough to raise a question concerning these things, or concerning the original of them.[27]

The origin of mountains was not a topic of discussion in England, even though natural historians went out into the field and collected various stones and seashells to keep them in their own repositories. Burnet confessed, however, that he was impressed by huge mountains:

> There is nothing doth more awaken our thoughts or excite our minds to enquire into the causes of such things, than the actual view of them; as I have had experience my self when it was my fortune to cross the Alps and Appennine Mountains, for the sight of those wild, vast and indigested heaps of Stones and Earth, did so deeply strike my fancy, that I was not easie till I could give my self some tolerable account how that confusion came in Nature.[28]

Like other natural historians, Burnet made personal observations on the real natural world although his observations were general. He also pointed out that geographers were not painstaking enough in the recording of the great number or the situation of mountains in their charts, while they marked the boundaries of countries, the sites of cities and towns, and the course of rivers, which, to Burnet's mind, were useful for civil affairs, but not for natural history.[29]

Burnet regarded mountains as essential to a better understanding the geological change of the past. He placed importance on the distinction of St.Peter between the present and the antediluvian Earth. Some writers, he acknowledged, were of the opinion that the heavens and the Earth had been in the same condition since the beginning of the world and that there had been no change in nature. Burnet thought, however, that the Universal Deluge had drastically changed the surface of the Earth and formed mountains for the first time. The antediluvian Earth was smooth and without seas and mountains, whereas the present Earth is rugged and has seas and mountains. For Burnet the study of the antediluvian Earth was an extended field of natural history:

> ...as travellers, when they see strange Countries, make it part of their pleasure and improvement, to compare them with their own, to observe the differences, and wherein they excel, or come short of one another: So it will not be unpleasant, nor unuseful, it may be, having made a discovery, not a new Country, but of a new World, and travell'd it over in our thoughts and fancy, now to sit down and compare it with our own...[30]

The search for the antediluvian world was thought to be similar to a geographical survey of unknown countries, in that the aim of these studies was a discovery of a previously unknown world. Burnet thus attempted to establish the natural history of the antediluvian Earth as a new area of scientific research.

The Natural History of the Antediluvian Earth

Burnet attempted to base his theory on the present state of the Earth, and claimed that the present form and structure of the Earth answered exactly to his theory concerning the form and dissolution of the antediluvian Earth.[31] Descartes had presented a similar hypothesis to explain the irregular shape of the present Earth. Therefore, G.L. Davies has said that Burnet probably owed more to Descartes than he chose to admit.[32] M.H. Nicolson has maintained that Burnet followed Descartes almost step by step in his account of the emergence of the Earth.[33] M.J.S. Rudwick has suggested that Burnet followed Descartes when he attributed physical events to natural causes inherent in the construction of the Earth.[34] In many respects Burnet's theory was, in fact, similar to that of Descartes, but, unlike Descartes, Burnet was anxious about Genesis. He even asserted that Descartes had never so much as thought of the Deluge, nor considered the first Earth as a real habitable world.[35] Burnet's approach to the history of the Earth differed from that of Descartes in that Burnet regarded the speculation on the first Earth as the natural history of the antediluvian Earth.

Burnet complained of an imperfect knowledge of the Paradise and the Deluge, the names of which were well known. His theory of the Deluge was based on Moses' account in Genesis. He found it extremely difficult, however, to account for the waters which caused this Universal Deluge, because an enormous quantity of water seemed to be necessary. To extricate themselves from this difficulty, some had claimed that God created new waters to produce the Deluge, and had then done away with them when the Deluge was over. Burnet did not agree with this solution because "this is to cut the knot when we cannot loose it."[36] He was strongly opposed to having recourse to miracles in this way when a difficult problem arose.

Although it was thus difficult to explain the Deluge in terms of natural causes, Burnet insisted on the universality of the Deluge and pointed out that there were traditions concerning floods in all parts of the world. He conceived the idea that the form of the Earth at that time may have been different from what it is at present, and more even. If this were so, it might easily have been inundated by a much smaller volume of water:

> This opinion concerning the plainness of the first Earth, I also found in Antiquity, mention'd and refer'd to be several Interpreters in their Commentaries upon Genesis,... And a late eminent person, the honour of his profession for Integrity and Learning, in his discourse concerning the Origination

> of mankind, hath made a like judgement of the State of the Earth before the Deluge, that the face of it was more smooth and regular than it is now.[37]

Burnet here intimated that he owed his idea of a smoother Earth to Sir Matthew Hale's Primitive Origination of Mankind. Like Hale, Burnet adhered strictly to natural causes to explain the universality of the Deluge.

Burnet had naturally to justify his supposition that the primitive Earth was smoother than the one we now observe. The Earth, he asserted, had its beginning, and had not existed from timeless infinity. Like many other seventeenth-century scholars, he rejected Aristotle's idea of the eternity of the world. Thomas Aquinas' integration of Moses' Genesis and Aristotle's doctrine was denied by Burnet. Instead Burnet relied on the authority of Moses who had said that the Earth was without form in the beginning. Burnet supposed that the form of the antediluvian Earth, or of the Earth which first arose from the Chaos, was different from that of the present Earth. A fluid substance always forms itself into a smooth and spherical surface equidistant everywhere from the centre of the gravity. And the first concrete state that emerged out of the Chaos must have been of the same form as the last liquid state. Burnet therefore proposed that the face of the Earth before the Deluge was smooth, regular and uniform, without mountains and seas.

By the Chaos Burnet was referring to the orderless matter of the Earth and heavens, and this he considered to be a fluid mass containing the materials and ingredients of all bodies. The first change must have been that the heaviest and largest parts sank down towards the middle of the Chaos which was its centre of gravity. These larger parts which thus sank down and became more and more compressed constituted the interior parts of the Earth. The rest of the mass, which remained swimming above, was divided by the same principle of gravity into two orders of bodies, one liquid like water and the other volatile like air. But the liquid mass which covered the Earth was not mere water, but a mixture of all liquids that belonged to the Earth. There were two main kinds of liquids, an oily liquid and a thin liquid. The lighter and more oily part of this mass surmounted the other, and floated upon it.

The changes in the Chaos up to this point would have been over in a short time. But an abundance of little particles would have remained floating in the region of the air, after the large particles had sunk down. These lesser and lighter particles would sink more slowly and over a longer period, eventually meeting the oily liquid on the surface of the watery mass, which would prevent their passing through. Thus the lighter particles would accumulate there and, mixing with the oily substance, would change into a certain light earth spreading upon the face of the waters. This thin crust of earth would gradually increase, and begin to grow more stiff and firm. Its external form would be smooth, regular and uniform, without mountains and seas.

Then Burnet discussed how the Earth came to be covered with the waters of the Deluge. According to him, when the heat of the sun penetrated through the shell of the Earth and reached the waters under it, it began to rarify them and draw them up into vapours. This rarefaction made them require more space than they had needed before. Being enclosed in the abyss, they pressed violently against the covering, forcing it to give way to their eruption. Any vapours enclosed within the Earth, said Burnet, strive to burst forth and in their effort to break free often shake the ground. As the heat of the sun increased the force of these vapours, so it commensurately weakened the crust of the Earth, and at last when the appointed time came, the whole crust of the Earth broke and was shattered into pieces, and the fragments fell down into the abyss.

Burnet speculated on whether such a supposition would provide a solution to the phenomena of Noah's Flood which, he thought, had really occurred. Comparing his explanation with Sacred history as set out in the Bible, he attempted to confirm his ideas. It was not of first importance to him, however, to discuss the

Biblical account in his book, and so he allowed the reader to omit the discussion concerning the Scriptures: "they who have not this doubt, and have a mind to see the issue of the Theory, may skip this long Chapter, and proceed to the Following."[38] Moreover, he regarded his explication of the Deluge as "a true piece of Natural History."[39] It is clear that his aim in his book was not to give a commentary on Genesis, but to present his own thoughts concerning the Earth's history.

Burnet then insisted that his theory did not detract from the power of God, even though it explained the Deluge by natural and secondary causes.[40] Burnet declared that he had no intention of excluding divine providence, either ordinary or extraordinary, from the causes of the Deluge. Besides the ordinary providence of God revealed in the ordinary course of nature, Burnet referred to an extraordinary providence that attends the greater revolutions of nature. Burnet pointed out a difficulty in the discussing of this extraordinary providence:

> ...'tis hard to separate and distinguish an ordinary and extraordinary Providence in all cases, and to mark just how far one goes, and where the other begins. And writing a Theory of the Deluge here, as we do, we were to exhibit a series of causes whereby it might be made intelligible, or to shew the proximate natural causes of it; wherein we follow the example both of Moses and S. Peter; and with the same veneration of the Divine Power and Wisdom in the government

> of Nature, by a constant ordinary Providence, and an occasional extraordinary.[41]

Burnet's approach to Providence liberated nature completely from the supernatural, and he specifically warned against having recourse to the supernatural when natural causes would suffice. Although God remained the first cause, He employed secondary causes which could be investigated and understood by human beings. The natural phenomena of the past Earth were thought to be objects of scientific studies.

Profane and Sacred History

Burnet's interest in the natural history of the antediluvian Earth seems to have been connected with his study of history. He regarded the natural world as the foundation of civil history:

> As the Animate World depends upon the Inanimate, so the Civil World depends upon them both, and takes its measures from them: Nature is the foundation still, and the affairs of Mankind are a superstructure that will be always proportion'd to it.[42]

Burnet showed in fact his deep interest in history when discussing a general objection to his theory, namely that if there had been such a primitive Earth so remarkably different from the present one, it could not have been so utterly forgotten. Against this objection Burnet said that this primitive world was not wholly lost from the memory of man, because some account of it had been preserved by Moses and the ancients. But Burnet admitted that little attention was given to the antediluvian world:

> The Greeks and Romans divided the Ages of the World into three periods or intervals, whereof they call'd the first the Obscure Period, the second the Fabulous, and the third Historical. The dark and obscure Period was from the beginning of the World to the Deluge; what pass'd then, either in Nature or amongst Men, They have no Records, no account, by their own confession; all that space of time was cover'd with darkness and oblivion; so that we ought rather to wonder at those remains they have, and those broken notions of the Golden Age, and the conditions of it,..., and all its differences from the present.[43]

Burnet considered that the learning of Greeks and Romans originated from that of the East such as Egyptians, Phoenicians, Chaldeans, Assyrians and Persians. However, the famous library at Alexandria, which had a collection of all the Eastern learning as well as Greek books, was burnt during the sacking of the city by Caesar, a fact which made it more difficult for us to acquire a better knowledge of "the Antiquities, and Natural History of the first World."[44]

Although most human writings have perished, it might have been expected that the memory of the primitive Earth should have been preserved in the Holy Scriptures. Burnet proclaimed, however, that "we could not expect in the Scriptures any Natural Theory of that Earth, nor any account of it."[45] He did not place uncritical trust in the Bible for a realistic account of the antediluvian Earth, because the Scriptures are capable of being interpreted in various ways:

> ...that which is most natural, proper and congruous, suitable to the words, suitable to the Argument, and suitable to the Context, wherein is nothing superfluous or impertinent, that we prefer and accept of as the most reasonable interpretation.[46]

If the Bible could be interpreted in various ways, its testimony becoming unreliable, the best way to acquire a knowledge of the actual facts about the past would be to search in the natural world itself. Burnet therefore did not accept a literal interpretation of the Holy Scriptures. He interpreted Moses' description of the abyss and St. Peter's account of the antediluvian Earth in accordance with geological observations.

The Author of Nature

Burnet's theory begins with the first Creation of this world and extends to the last Conflagration in one continuous account of the changes which took place in nature. What is nature? Upon what superior causes does it depend in all its motions? These are the questions which Burnet raised, and in reply he stated that nature, in reference to the physical world, was defined as "the powers of matter with the laws established for their action."[47] Like Descartes, Burnet set out these laws as follows:

> There will also be no great controversie what these Laws are, As that one part of Matter cannot penetrate another, nor be in several places at once; That the greater Body overcomes the less, and the swifter the slower; That all Motion is in a right line, till something obstruct it or divert it;...[48]

The question, however, was what produced the laws of motion and of matter itself, and how matter came initially to be actuated. Here, too, he drew upon Descartes:

> ...it is accidental to Matter, that there should be Motion in it, it hath no inward principle from whence that can flow, and its Nature is compleat without it; Wherefore if we find Motion and Action in Matter, which is of it self a dead inactive mass, this should lead us immediately to the Author of Nature...[49]

Burnet thus conjectured that motion in matter was caused by the Author of Nature. This is some external power distinct from matter, and the cause of all motion in the world and of the diversity in nature. The matter of the universe is diversified in countless ways, into "Heavens and Earth, Air and Water, Stars, Meteors, Light, Darkness, Stones, Wood, Animals, and all Terrestrial Bodies." Burnet considered that if the concept of the Auther of Nature were excluded and there existed nothing but matter in the world, this diversity could not come about. And if matter moved of itself, that would certainly hinder all sorts of natural concretions. Burnet claimed therefore that matter could not take on such a variety of compositions without the direction of a superior external cause, which might be termed the Author of Nature.

It may be said that the foundation of the world did not come about as a result of deliberation, but of necessity, that is, that matter being once set in motion by the action of the laws, it might of itself evolve by degrees from one state into another, until it arrived at its present form. Burnet, however, vigorously opposed this view:

> though all the Laws of Motion be admitted, they cannot bring Matter into the form of a World, unless some measures be taken at first by an intelligent Being; I say some

> measures be taken to determine the Primary Motions upon which the rest depend, and to put them in a way that leads to the Formation of a World.[50]

Burnet thus claimed that the Author of Nature was in no way excluded even if matter strictly obeyed the laws of motion. If matter were to be agitated in a confused way, this would not be a sufficient cause to produce a world. Burnet criticized Epicureans who asserted that atoms might chance upon a fortuitous combination of motions and thus form a world. Burnet did not accept such a concept of pure mechanical necessity at the very beginning of motion.

Burnet did, however, adopt the mechanical view of the course of nature after the Creation. Therefore, he found himself confronted with the question of whether miracles, that is, extraordinary and supernatural phenomena, had occurred after the Creation. Holy Scriptures contain the most considerable records of miracles, and Burnet considered that if the Bible were regarded as a true history, such events must have occurred.[51] He did not, however, regard the Bible as a literal account of what had happened. Miracles in the Bible were, in fact, separated from Burnet's view of the Earth's history. As for other claims regarding the supernatural which are not recorded in the Scriptures, Burnet asserted that we should "examine them more strictly before we receive them." In other words, he was disposed to doubt all miracles in the natural world.

Having accepted the mechanical philosophy, Burnet rejected resorting to miracles to explain particular effects and criticized the general attitude towards miracles:

> The power Extraordinary of God is to be accounted very Sacred, not to be touch'd or expos'd for our pleasure or conveniency; but I am afraid we often make use of it only to conceal our own ignorance, or to save us the trouble of inquiring into Natural Causes.[52]

In order to make the knowledge of natural providence intellectually plausible, Burnet considered that we should not abandon the search for natural causes in keeping with the true philosophy, which would be of a geometrical and mechanical nature.

> God made all things in Number, Weight and Measure, which are Geometrical and Mechanical Principles; He is not said to have made things by Forms and Qualities, or any combination of qualities, but by these three principles, which may be conceiv'd to express the subject of three Mathematical Sciences, Number, of Arithmetick; Weight, of Statisticks; and Measure and Proportion, of Geometry;...[53]

All things in the world were said to be made according to mechanical principles. Therefore, to understand the manner of their construction, we must search for them by the same principles and resolve them back into these. Like Descartes, Burnet ruled out mysterious principles from his mechanical world.

Because of the directive of the Author of Nature who set matter in motion at the very beginning, the world proceeds to its determined destination. Burnet was, therefore, not satisfied with Aristotle's cyclic view of the world, which excluded the concept of a destination. According to Aristotle, the universe above the moon was changeless and it would always remain in the same state. As for the sublunary world, there would be no great revolution in nature, no generation of a form of the Earth, but only some few localised corruptions and generations. Aristotle's system of the universe, however, had been doubted since the Copernican Revolution:

> ...if we consider the Earth, as one of those many Planets that move about the Sun, and the Sun as one of those innumerable fixt Stars that adorn the Universe, and are the Centers of its greatest Motions; and all this subject to state and change, to corruptions and renovations; This opens a large Field for our Thoughts, and gives a large subject for the exercise and expansion of the Divine Wisdom and Power, and for the glory of his Providence.[54]

If the universe were subject to change, we should not be content to consider only the present state of nature, but should look back into the first state of things and trace the progress of nature from one state to another.

Burnet asserted that Aristotle was in error when he observed the world as it is now, and supposed it to have been in the same state throughout the ages.

Burnet's efforts do not seem to have stemmed from his religious passion. He distinguished natural history of the past Earth from an exposition of the Bible in order to preserve the authority of the latter:

> 'Tis a dangerous thing to ingage the authority of Scripture in disputes about the Natural World, in opposition to Reason; lest Time, which brings all things to light, should discover that to be evidently false which we had made Scripture to assert.[55]

Burnet considered that no truth concerning the natural world would conflict with religion, but he carefully discriminated between the interpreting of Scripture and scientific disputes. It was dangerous to discuss natural phenomena from the standpoint of any kind of authority. Burnet realized that the authority of the Scriptures could eventually be weakened by its misuse.

Moreover, Burnet later accounted for his writing The Sacred Theory of the Earth as follows:

> When I first applied my Thoughts to write, concerning the Earth, my Design was only to handle the Theory of it Philosophically, purely by the Assistance of Reason and the Light of Nature, without medling at all with either Sacred or Profane Writings...[56]

The authority of the Sacred Scriptures and the ancients' writings were regarded as nothing to do with his original idea. They were used only to support his argument:

> ...while I went on Philosophising, new Light still broke in, both from the Holy Scriptures, and the Monuments of the Ancients, which appeared like Witness, who, after the Cause is begun, come in of their own Accord, without being summoned.[57]

As M.H. Nicolson suggested, "If at first we arbitrarily separate Burnet's theology from his science and consider each separately, we do so without violence to Burnet himself."[58]

Some contemporary writers followed Burnet's idea of miracles. For example, Archbald Lovell, Brother and Pensioner of the Charterhouse, adopted this idea in his Summary of Material Heads which may be Enlarged and Improved into a Compleat Answer to Dr. Burnet's Theory of the Earth, 1696. Arguing about the causes of the Universal Deluge, Lovell attempted to show "how without a Miracle, Water enough may be had in the World, to bring a Flood upon the Earth, and drown it in the manner Moses has related it."[59] He claimed that he could explain how the waters of the Deluge covered the tops of the highest mountains by natural causes. Francis Walsh, too, made a similar attempt in his Antediluvian World; or, A New Theory of the Earth, 1743. Following

Burnet, Walsh explained "how the Universal Deluge could, and did happen, by natural causes, without any Recourse to Miracles."[60]

Burnet, in fact, realized that the rise of natural philosophy would reduce the role played by the Scriptures in the study of nature. He was not the first who urged the importance of natural causes -- he owed much to the achievements of Descartes and other natural historians -- yet it was Burnet who contributed most to establishing the natural history of the past as a science, by writing a book on the Earth in an attractive and readable style.

A Cosmological Romance

Even after Burnet's death, his book retained its popularity, and throughout the first half of the eighteenth century publishers continued to find it a good investment. Its popularity may be measured from the fact that it reached a tenth edition in 1759. As Thomas Birch said in 1752, Burnet's Telluris Theoria Sacra "had raised him a great reputation in the learned world."[61] In 1759 an anonymous biographer of Burnet said that

> ... The Reader perhaps may be ready to wonder, that a Book fundamentally wrong should run through so many Editions, and be so much read...

This biographer of Burnet explained the reason why The Theory of the Earth had been widely read:

> The Reason is plain, no Man reads Homer's Iliad for History, any more than he reads Milton's Paradise Lost for Divinity; though it is possible that there may be true History in the one, as it is certain, that there is true Divinity in the other. Such Works are read purely to entertain and amuse the Fancy; and it is not the Story, but the Imagery, that is principally sought after. Why may not Burnet's and Whiston's Theories be read with the same View? They are not, it may be said, strictly true in the philosophic Part, and so in that Light are not to be depended on: yet they present to the Imagination new and amazing Scenes; and therefore will always furnish out the highest Entertainment to a Reader, who is capable of being pleased as well as instructed.[62]

Burnet's cosmological romance, tracing the physical history of the world from the Creation to the Conflagration, was enjoyed even by such men of letters as William Wordsworth and S.T. Coleridge.

The Spectator, in which virtuosi were often mentioned, cited a passage from Thomas Burnet's Theory of the Earth, which shows his personal motive for studying:

> For what is this Life but a Circulation of little mean Actions? We lie down, and rise again; Dress and undress; feed wax hungry; Work or Play, and are weary; and then we lie down again, and the Circle returns. We spend the Day in Trifles, and when the Night comes we throw our selves into the Bed of Folly, amongst Dreams and broken Thoughts and wild Imaginations. Our Reason lies asleep

> by us, and we are for the time as arrant Brutes as those that sleep in the Stalls or in the Field. Are not the Capacities of Man higher than these? And ought not his Ambition and Expectations to be greater? Let us be Adventurers for another World: 'Tis at least a fair and noble Chance; and there is nothing in this worth our Thoughts or our Passions. If we should be disappointed we are still no worse than the rest of our Fellow-Mortals; and if we succeed in our Expectations, we are Eternally Happy.[63]

Speculations on the unknown world had nothing to do with the everyday life of the time, but they would fill people with intellectual satisfaction. The study of the Earth's history, then, became comfort to the leisured class. The widespread interest in natural history would be a key to understanding the reason why Burnet wrote about the natural history of the past Earth.

NOTES

1. David R. Oldroyd, "Mechanical Mineralogy", Ambix, 21 (1974), 157-178.

2. On the Continent, there were some attempts to explain the Earth's history in "organic" terms. Cf. Allen G. Debus, The Chemical Philosophy, I (New York, 1977).

3. René Descartes, Principles of Philosophy, Trans. by V.R. Miller and R.P. Miller (D. Reidel, 1983), Part IV, 181-203.

4. G. Havers tr., Another Collection of Philosophical Conferences of the French Virtuosi (London, 1665), 311.

5. Ibid., 311-12.

6. The influence of Descartes on the conference was discussed by Harcourt Brown in his Scientific Organizations in Seventeenth Century France (New York, 1967), 25.

7. Ibid., 29.

8. Nicolaus Steno, The Prodromus to a Dissertation concerning Solids naturally contained within Solids (New York, 1968), 228.

9. Ibid., 231.

10. The Philosophical Transactions of the Royal Society, No. 59 (1670), 1051-52.

11. [Samuel Gott], The Divine History of the Genesis of the World (London, 1670), 5.

12. Hale, Primitive Origination, 187.

13. Ibid.

14. Ibid., 187-88.

15. Jacob and Lockwood, "Political Millenarianism and Burnet's Sacred Theory," Science Studies, II (1972), 265.

16. Thomas Burnet, Doctrina Antiqua de Rerum Originibus, Trans. by Mr. Mead & Mr. Foxton (London, 1736), 2.

17. M.H. Nicolson, Mountain Gloom and Mountain Glory (Ithaca: New York, 1959), 187.

18. Jacob & Lockwood, "Political Millenarianism", 279.

19. Thomas Burnet, Doctrina Antiqua de Rerum Originibus, 2. M.J.S. Rudwick has suggested that the second volume of Burnet's work provoked lively controversy whereas the first volume had created little stir in spite of its speculative implications. (Rudwick, The Meaning of Fossils, 81.) However, not only is Rudwick's suggestion incompatible with Burnet's observation, but also it is not supported by substantial evidence.

20. Bernard Capp has suggested that millenarianism was spreading among pre-revolutionary Puritans and that the 1650s witnessed a retreat from a doctrine which had become a political ideology. [Bernard Capp, "'Godly Rule' and English Millenarianism", in Charles Webster ed., The Intellectual Revolution of the Seventeenth Century (London, 1974), 386-98.] Earlier millenarianism cannot be identical with that of the late seventeenth century.

21. J. Redwood, Reason, Ridicule and Religion: The Age of Enlightenment in England, 1660-1750 (London, 1976), 119.

22. J. Roger, "La Thēorie de la Terre au XVII^{e} Siēcle," Revue d'Histoire des Sciences, XXVI (1973), 23.

23. For example, K.B. Collier, Cosmogonies of our Fathers (New York, 1934); J. Greene, The Death of Adam (Iowa State University Press, 1959); F.C. Haber, The Age of the World (Baltimore, 1959); G.L. Davies, The Earth in Decay: a History of British Geomorphology, 1578-1878 (London, 1969); Roy Porter, The Making of Geology (Cambridge University Press, 1977).

24. M.J.S. Rudwick, The Meaning of Fossils (London, 1972), 77.

25. Thomas Burnet, The Sacred Theory of the Earth (London, 1684), 116.

26. Ibid., 128.

27. Ibid., 140.

28. Ibid., 140.

29. Ibid., 141.

30. Ibid., 239-40.

31. Ibid., 109.

32. G.L. Davies, The Earth in Decay (London, 1969), 72.

33. Nicolson, Mountain Gloom, 202.

34. Rudwick, The Meaning of Fossils, 78.

35. Thomas Burnet, Telluris Theoria Sacra (London, 1681), 184 and Burnet, Theory, 114.

36. Burnet, Theory, 18.

37. Ibid., 28.

38. Ibid., 79.

39. Ibid., 96.

40. Ibid., 105.

41. Ibid., 108.

42. Ibid., 246.

43. Ibid., 276-77.

44. Ibid., 277.

45. Ibid., 285.

46. Ibid.

47. Ibid., 290.

48. Ibid.

49. Ibid., 290-91.

50. Ibid., 293.

51. Ibid., 303.

52. Ibid., 314.

53. Ibid., 315.

54. Ibid., 317.

55. Burnet, Theory, Preface to the Reader.

56. Burnet, Doctrina Antiqua, 1.

57. Ibid., 2.

58. Nicolson, Mountain Gloom, 196.

59. Archbald Lovell, Summary of Material Heads which may be Enlarged and Improved into a Compleat Answer to Dr. Burnet's Theory of the Earth (London, 1696),2.

60. Francis Walsh, The Antediluvian World; or, a New Theory of the Earth (Dublin, 1743).

61. Thomas Birch, The Life of the Most Reverend Dr. John Tillotson (London, 1752), 278.

62. Anon., "An Account of the Life and Writings of the Rev. Thomas Burnet", in the 7th edition of Thomas Burnet's Sacred Theory of the Earth (London, 1759), xxxii-iii.

63. The Spectator, No. 143, 1711; Burnet, Theory, The Conclution to the Book III.

7. EARTHQUAKES OR THE UNIVERSAL DELUGE

As has been mentioned in a previous chapter, Robert Hooke made a close examination of fossil stones which he considered had once lived under the sea, and he suggested that successive earthquakes could explain the origin of fossils found in the ground. By the time of his lectures of 1687 at the Royal Society, however, he began to justify his idea of the Earth's history from the Creation to the present time by reviving the writings of the ancients. Margaret 'Espinasse has suggested that Hooke began to develop his view on the Earth's history in the 1680s and 1690s.[1] Roy Porter has explained this change by claiming that "his explanatory ambitions had changed".[2] Then, why did he change his aims at this stage?

David Kubrin has asserted that "Robert Hooke's cosmic speculation in many ways paralleled those of Burnet."[3] Although Hooke had begun to theorize about the Earth's history many years before he came upon Burnet's theory, in his later work he seems to have been considerably influenced by Burnet's works. Hooke's lectures on Burnet's theory of the Earth have not been given much attention, but, as will be shown, they make it clear that, by the end of the 1680s, Hooke had become absorbed in Burnet's idea of the natural history of the past Earth.[4]

Martin J.S. Rudwick has suggested that indirectly Burnet's theory "was the most important influence on the course of the debate about fossils in the late seventeenth century,"[5] but he has not shown how the work written by a scholar of a different tradition gave influence on a scientific community. It is not my aim here to value Burnet's ideas in the ultimate scheme of things but to examine how they spread at a particular time and affected certain historical situations. In this chapter I will suggest that owing to Hooke's lectures the Deluge theory took root among Fellows of the Royal Society although Burnet's theory itself was rejected.

Hooke's Lectures on Burnet's Theory of the Earth

We have seen that it was in 1681 that Thomas Burnet published his Telluris Theoria Sacra. On 2 February 1681, the work was reported to the Royal Society, being said to be a book "concerning an hypothesis to solve all the phenomena of Noah's Flood consonant to the Scriptures, the writing of the antients, and the Cartesian philosophy."[6] On 27 April 1681, Dr. Gale read an account of Burnet's book "which was discoursed of and well approved of as to some particulars of the theory, though the proof and management thereof could not be judged of without a perusal of the discourse itself."[7] A short review of the work subsequently appeared in the Philosophical Collections in 1681. Although Burnet's work was thus introduced to Fellows of the Royal Society, it did not provoke discussion among them at this stage. They were much interested in the origin of fossils, but not, as yet, in a grand theory of the Earth's history. On 12 December 1683, Hooke debated the fossil question with Lister who insisted on an inorganic origin of fossils.[8] In order to advocate the organic origin of fossils, Hooke repeatedly argued that very great changes had taken place in the Earth's surface.[9]

It was not until some time in the mid-1680s, however, that Hooke began to consider the historical aspect of the Earth systematically. On 26 January 1687, he read a lecture to a meeting of the Society in which he presented a new hypothesis on how fossil shells came to be buried deep in the Earth and in places which were above sea level.[10] He surmised that the diurnal rotation of the Earth had formed the surface of the Earth into a compressed spheroid "by its vis centrifuga taking off part of gravity." Then if the axis were movable, the greatest diameter would be likewise altered, and as a result parts of the earth would appear out of the sea and conversely other regions would be flooded. This idea could explain the inundations which he presumed had occurred several times.

The most striking change in Hooke's thinking at this time concerning the Earth is that he now began to regard the remains of shells as evidence in support of the ancients' idea that great changes in the Earth had occurred. That is, Hooke shifted his interest from the origin of fossils to the history of the Earth. He also noted that the study of the natural history of the past had not kept pace with civil history:

> Now, because when we look into Natural Histories of past Times, we find very few, if any, Footsteps of what alterations or transactions of this Nature changes of shape or constitution of the earth have been performed, we must be fain to make use of other helps than what Natural Historians will furnish us with, to make out an account of the History thereof. Nor are there any Monuments or Medals with Literal, Graphical, or Hieroglyphical Inscriptions that will help us out in this our Inquiry, by which the Writers of Civil Histories have of late Years been much assisted from the great curiosity of modern Travellers and Collectors of such Curiosities.[11]

Burnet had already treated features such as rugged mountains, hills and coasts as physical evidence of the past state of the Earth, but Hooke did not specifically investigate these general geographical features. Instead, he regarded the remains of shells as the main witness of the past:

> I shew'd that the ruggedness and inequalities of Hills and Dales, Mountains and Lakes, and also the alterations of these superficial Parts of the Earth, as to the seeming Irregularities thereof at present, seem'd to me to be most probably ascribable to another Cause, which was Earthquakes and Subterraneous Eruptions of Fire. That there had been many such alterations I indeavour'd to prove from the almost universal Disposition of those curious Medals of former Ages now found in the petrify'd Monuments of the parts of several both Terrestial and Aquatick Animals and Vegetables, but especially by those Productions of the watery Element found in places now far remov'd from the Sea, and far above its Level.[12]

Not having any doubts concerning the organic origin of fossils, Hooke attempted to prove the great changes in the Earth from the fossil remains: He thus came to be interested in the natural history of the primitive Earth.

Hooke's shift of interest may be explained by the strong influence of Thomas Burnet, whom Hooke called "the ingenious Author of the Sacred Theory of the Earth." Like Burnet, Hooke considered the natural history of the Earth as the foundation of human affairs,

> This great Body being the Mother of all Terrestial Productions, which make up the greatest part of Natural History; and the Foundation, as it were, upon which, not only all that History, but all the other Parts and Superstructures almost do rest.[13]

Although Burnet did not refer to fossil remains, his notion of the antediluvian Earth was useful to Hooke, who was to discuss it in earnest. As historians and antiquarians collected coins and medals as historical evidence, so Hooke speculated on the past state of the Earth from fossil remains. As Kubrin suggested, Hooke had begun to formulate his views on the Earth's history before he came to know the work of Burnet,[14] yet it was after its publication that Hooke set about confirming his former hypothesis on the basis of the wisdom of the ancients.[15]

Like Burnet, however, Hooke noticed that histories did not preserve any account of the great alterations of the superficial parts of the Earth. In addition, they seemed to be "Romantick, Fabulous, and Fictious" and could not be regarded as trustworthy:

> History has not furnish'd us with Relations of any such considerable changes as I suppos'd to have happen'd in former Ages of the World; I do confess our Natural History as to these and many other matters of the first Ages is very thin and barren...[16]

Yet Hooke conceded that histories might be found to contain accounts of the natural history of former ages if they were examined with more attention. He referred to Hanno's Periplus, Plato's Timaeus, Ovid's Metamorphoses, and Aristotle's Meteorologica to prove that great alterations had occurred in the Earth's surface. These works were regarded as books on natural history in ancient times, therefore, it was not altogether unsuitable for the scheme of the Royal Society to consult the works of the ancients.

On 2 November 1687, Hooke read a discourse on Hanno's Periplus at the Society's meeting, and declared that there were several things in it to favour his theory of great changes. Hanno in his work described "the burning Coast of stinking Volcano's, from whence there run out into the Sea Rivers of Fire",[17] and Hooke interpreted this as a description of past catastrophes. Less than a month later, on 1 December, he gave another lecture, citing passages out of Plato's Timaeus in support of this hypothesis of floods and conflagrations.[18] According to Hooke, Plato conjectured that "there had been in many preceding Ages of the World, very great changes of the superficial Parts of the Earth by Floods, Deluges, Earthquakes, etc. For as much as he could suppose a Continent or Island as big as the third part of the known world, to be by one Earthquake sunk into the Sea and overwhelmed by it."[19] Both Plato's Atlantis and Hanno's descriptions of volcanoes were considered to be true accounts of prodigious alterations. Hooke submitted his conjectures "to the Judgment of such as are more knowing and better read in Historical Matters."[20] Just as Burnet had consulted the works of the ancients in an attempt to find a description of the antediluvian Earth, Hooke now followed suit in order to find evidence that there had been catastrophes in the past.

On 14 December 1687 and 4 January 1688, Hooke gave discourses on Ovid's Metamorphoses, and suggested that his theory of the changes of the Earth was also supported by this work.[21] In one of these lectures, Hooke now discussed the history of the Earth from the beginning to the present. According to Ovid, Hooke maintained, the original matter of the world was "a quantity of matter without any particular form". A centre which attracts matter did not exist, so that there was no actual gravity at the beginning of the world. After God had created the centre of attraction, however, the heavier matter descended towards the centre and the lighter rose from it. The Earth was separated from the heavens, and the waters from the Earth. In this way God produced order in the chaotic mass, and, after dividing it up, arranged it in its constituent parts:

> So that it seems there was a notion that the middle part of the Ball of the Earth was filled with Water as well as the outside overed with it: To which also agrees Des Cartes Theory and that of the ingenious Dr. Burnet in this Theoria Sacra.[22]

Although Hooke referred thus to the theories of Burnet and Descartes, which in his opinion concurred with the first verses of Ovid, he did not here comment further on them. Hooke's lecture shows, however, that he was prepared to present a hypothesis on the origin of the Earth, being aware of the works of Burnet and Descartes.

Ovid called the first age of the world the Golden Age, when the surface of the Earth was still smooth, soft and moist. Then, he said, the Earth became dry, having lost much of its original moisture; and he referred to this state as the Silver Age. Subsequent to this, in the Brazen Age, the surface of the Earth was petrified, and then conflagrations, floods and earthquakes occurred. The sea overwhelmed parts of the land and other parts emerged from under the sea. Hooke followed this general theory concerning the Earth's history, and also made the assumption that the age of the world was much greater than that which is recorded in the Bible:

> What space of Time he [i.e. Ovid] allows to each of these Ages it does not so readily appear, but it is certain that the Chaldeans, AEgyptians, Brachmans, and some Heathen Historians have assigned spaces large enough and even beyond belief almost; and Mr. Graves tells us, that the Chinese do make the World 88640000 Years old.[23]

Hooke's opinion concerning the age of the world was different from that of Burnet. The latter did not direct his attention to fossil remains and the alternation of strata, but Hooke, having a good knowledge of strata which contained fossils, believed that a long period of time since the Creation must be assumed if it is claimed that strata have accumulated under the sea. Burnet's approach to the Earth's history was speculative in the sense that he did not refer to fossil remains. Hooke modified Burnet's framework to fit his reasoning which he had arrived at from actual observations.

In later lectures, on 15 and 29 February 1688, Hooke departed somewhat from Burnet. In these lectures he presented his ideas about Noah's Flood, and used Aristotle's Meteorologica in support of his argument. Hooke here again expressed his belief that the superficial parts of the Earth had been greatly altered by earthquakes which had brought about an interchange in the location of land and sea. On this occasion, Hooke "proceeded to prove out of Aristotle from severall passages that the same was his opinion, particularly in Cap. 14.lib.1 de Meteoris he expressly teaches that there hath been those great changes in the Earth."[24] In fact, Hooke cited Aristotle's work as follows:

> The same parts of the Earth (says he) are not always dry or moist, but they receive a change from the increase or defect of Rivers; therefore parts bounding Sea and Land change often, nor is the same part always Sea or always Land, but is changed in time, and that which was Sea is Land, and that which was Land is Sea.[25]

Hooke applied Aristotle's idea also to a discussion concerning the effects of Noah's Flood. Although he assumed that Noah's Flood had produced some very great changes, he was skeptical about whether the distribution of fossils could be explained by the Universal Deluge alone:

> I conceived that those universal Phenomena of the remainders of the Sea which are found in all parts almost of the present superficial Parts of the Earth, could not be caused by the general Flood of Noah, if the manner of performance and executing thereof were such as is for the generality supposed and explained by Commentators by reason that they make the time of the continuance of the present superficial Parts of the Earth under the Waters to be no longer than the time of the duration of the Flood, as it is recorded in Holy Writ....for that space will not be found of duration long enough to produce de novo such multitudes of those Creatures, and to such Magnitudes and Ages of growth as many of them seem to have had, and it will be difficult to be imagined, that such Creatures as do not swim in the Water, should, by the Effects of that Deluge, be taken from their Residences in the bottom of the Sea and carried to the top of the Mountains, or to places so far remote from those Residences.[26]

Using his knowledge of fossil remains, however, Hooke considered the questions as to the phenomenon of Noah's Flood that had been raised by Burnet. Hooke now proceeded to apply Aristotle's geological idea to a discussion concerning the effects of the Deluge, suggesting that the fossil remains of shells which were found in almost all parts of the Earth's surface could be partly explained by an interchange of land and sea at the Deluge:

> unless we supposed that there were thereby a change wrought of the superficial Parts

> of the Globe, and that those Parts which before the Flood were dry Land became Sea, and the Parts which were before covered by the Sea after the said Deluge, became the dry Land, it seems to me, that these appearances cannot be solved by Noah's Flood.[27]

Thus Aristotle's idea of the interchange of land and sea was used to explain the location of the remains of living creatures.

Hooke believed that Noah's Flood had been universal, but did not accept that it could be understood only in terms of a supernatural cause. Like Burnet, he assumed that the universality of the Deluge could be physically explained. Hooke strongly opposed, however, the details of Burnet's account and said that there was not "any need of supposing the Earth to be broken to pieces since the Flood, and the Antediluvian World without any visible Sea."[28]

Nevertheless, Hooke continued to evince interest in Burnet's work, as is shown by his diary entry for 22nd November 1688: "Burnets 2d part of Telluris Theoria Sacr: read 8 chap."[29] It remained a topic of interest for Hooke until 11th December.[30] Then, on 12th and 19th December 1688, at meetings of the Royal Society, Hooke read "an account of the third part of Dr. Burnetts Telluris Theoria Sacra", and "an extract of the fourth Book" of Burnet's Theory of the Earth.[31]

On 9 January 1689, Hooke returned to the question of the past history of the Earth and read a discourse concerning the first part of Burnet's Theory of the Earth. On this occasion he discussed the problem of interpreting the Scriptures. Like Burnet, Hooke thought that the design of the Scriptures was "not so much to teach Natural Philosophy, as to shew the wisdom and power of god in making the world as it is." He, too, asserted that the Scriptures could not be interpreted literally, although he did not deny that they might nevertheless contain "a more Philosophicall sense and Theory of things." Burnet's way of interpreting the Scriptures was accepted, but Hooke expressed the wish that Burnet "would please to clear some particulars which seemed to Mr. Hook to be Materiall objections against this Hypothesis."[32]

Hooke was thus absorbed in Burnet's theory of the Earth, and gave a series of lectures on it at meetings of the Royal Society between the end of 1687 and the beginning of 1689. As Hooke believed that there had been several great changes in the Earth's surface, Burnet's idea of the Universal Deluge was not acceptable to him. Hooke, however, agreed with Burnet that a great change had happened at the time of the Deluge, on the condition that there had been sea on the antediluvian Earth. For Hooke, the Universal Deluge was one of the interchanges of land and sea which he thought had occurred several times.

Critically examining Burnet's theory, Hooke made his own position clear. The importance of this lies in that Hooke introduced a historically-oriented work to the Fellows of the Royal Society who had been discussing the origin of fossils. Roy Porter has suggested that it was John Woodward who bridged a gap between theory-making and fieldworking,[33] but this way had been substantially paved by Hooke.

Woodward's Theory of the Deluge

Referring to Hooke's Discourse of Earthquakes, Gordon L. Davies has said that "unfortunately his writing on the subject is vague and diffuse",[34] but this does not necessarily follow that his lectures and activities at the Royal Society were not influential. On the contrary, Hooke dominated over other Fellows of the Royal Society by giving a series of discourses.

Hooke's approach to the Earth was partly accepted by John Woodward, who was in complete accord with Hooke's method for the study of fossils, and, like Hooke, made use of them in an attempt to understand the past state of the Earth. Woodward made Hooke's acquaintance in 1693 at the latest. In 1692 Dr. Stillingfleet, the professor of physic in Gresham College left that position upon his marriage and Woodward was chosen to succeed him. Woodward became resident at Gresham College, with the help of his fellow professor Robert Hooke. On May 13 and 27, 1693, Hooke attended Woodward's lectures at the College, and the topic of one of the lectures was fossil shells.[35] Without doubt Hooke and Woodward shared an interest in petrified shells and other geological problems. On November 15, 1693, Woodward was proposed by Hooke for the Royal Society and was soon elected and admitted.[36] Since Woodward and Hooke both lived in Gresham College, where the Royal Society was located, they must have often seen each other.[37] Perhaps that could be why no correspondence between them survives.

Before meeting Hooke, Woodward had already embarked on the study of fossils. He was born in Derbyshire in 1665, and educated at a country school, where he gained a ready acquaintance with Latin and Greek. Some time after he met with Dr. Peter Barwick, a physician who took him under his tuition into his own family. In this environment Woodward studied philosophy, anatomy and medicine until he was invited by Sir Ralph Dutton to his country seat at Sherborne in Gloucestershire. There Woodward began to do fieldwork and to collect objects relating to the past state of the Earth. He himself gave the following account:

> The country about Sherborne and the neighbouring parts of Gloucestershire, to which I made frequent excursions, abounding with stone, and there being quarries of this laid open almost every where, I began to visit these, in order to inform my self of the nature, the situation, and the condition of the stone. In making these observations I soon found, there was incorporated with the sand of most of the stone thereabouts great plenty and variety of sea shells, with other marine productions.[38]

Like Hooke, Woodward believed that fossil shells were once-living creatures. The question regarding the origin of fossils was still being hotly debated in the 1690s; Woodward, however, had no doubts about his organic theory of fossils. In a letter to Martin Lister in 1690, Edward Lhwyd wrote that Woodward

> has lately made a collection form'd stones in Summersetshire & Glowcestershire; & told me he does not much question but he has found out ye causes of those productions; & added that they seem soe plain yt he wonders no body thought of it sooner.[39]

From his own observations Woodward seems to have concluded that they must have resulted from some general cause, namely, the Universal Deluge. By the end of 1693 he had begun to draft a book on fossil shells and plants, as shown in his letter to Lhwyd:

> I have now (I thank God) setled my affairs, & so far conquerd my late accessary businesse

> yt I hope very suddenly to fall upon a review of my papers in order to ye publication of somewhat concerning these shells, plants, & c. in stone & c.[40]

At Gresham College Woodward prepared to publish his Essay Toward a Natural History of the Earth which appeared in 1695. In this work he compiled his history of the antediluvian Earth and its dissolution at the Universal Deluge, an alternative to Burnet's theory which seems to have stimulated Woodward to speculate on the Earth's history.

Woodward considered Burnet's theory too speculative because Burnet did not ever refer to fossil remains. Like Hooke, Woodward was convinced that actual observation was the only sure foundation for a lasting and substantial philosophy.[41] Hooke had already urged the necessity of fossil collecting to gain a knowledge of the past state of the Earth, and Woodward adopted the same viewpoint: As the ancient monuments and hieroglyphics were keys to early human history, so did fossils provide evidence concerning the natural history of the antediluvian Earth.[42] This new method for the study of fossils, which Hooke had established, was expounded in Woodward's popular work.

Woodward made first-hand observations in England in order to inform himself on the condition of the earth and all bodies contained in it. He also claimed that he sent off a list of questions on this subject to all parts of the world:

> The Result of this was, that in time I was abundantly assured, that the Circumstances of these Things in remote Countries were much the same with those of ours here: that the Stone, and other terrestrial Matter, in France, Flanders, Holland, Spain, Italy, Germany, Denmark, Norway, and Sweden, was distinguished into Strata, or Layers, as it is in England: that those Strata were divided by parallel Fissures: that there were enclosed in the Stone, and all the other denser kinds of terrestrial Matter, great number of Shells, and other Productions of the Sea, in the same manner as in that of this Island.[43]

By the same means, Woodward also got information about geological features in North Africa, Egypt, Guinea, Arabia, Syria, Persia, Malabar, China, Jamaica, Barbados, Virginia, New England, Brazil, Peru, and so on. Then, he claimed, it is upon these observations that he grounds all his general conclusions concerning the Earth. Geological observation was thus combined with a theory of the Earth. However, Woodward did not discuss the origin of the Earth, but confined himself to considering how things were now disposed. Unlike Burnet, he ignored questions relating to the Creation and the Conflagration, and considered only the effects of the Universal Deluge.

Woodward observed that the surface of the Earth was divided into strata which contained the shells of oysters, scallops, mussels, cockles, periwinkles, and other marine productions. Hooke had already referred to the stratified rocks and inferred from their vast thickness that they had been under the sea for an extremely long period of time. Like Hooke, Woodward claimed that the strata had accumulated in the sea and that the sea-shells were real ones. As we have seen, some naturalists such as Martin Lister and Robert Plot suspected that these shells were not real, but were imitations, being in fact mere stones formed by a sleight of hand in nature. Although Woodward did not concur with such an idea, he acknowledged that his opponents had good reasons for their opinion.

Like Hooke and Ray, the other advocates of the organic theory of fossils, Woodward fully realized the difficulties inherent in this theory. Firstly, the location where these bodies were found was sufficient in itself to support the view that they were minerals. Some fossils were found at the very bottom of mines, while others were found on the tops of the highest mountains. Secondly, certain bodies that had the shape and appearance of cockles, mussels and other shells consisted of sandstone, flint or some other kind of mineral matter. Thus the materials of which they were made was quite unlike that of those shells which were found under the sea. Thirdly, there were some fossils which did not match any species of shellfish found on the seashore. Woodward conceded that these were powerful arguments; yet he claimed that it was not so difficult to prove that the sea had given birth to these bodies and that they had not been formed like ordinary minerals. He boasted that

> some of the most eminent of those very Gentlemen who formerly were doubtful in this Matter, and rather inclinable to believe that these were natural Minerals, and who had wrote in defence of that Opinion, do notwithstanding upon strict and repeated Inspection of these Bodies in my Collection, and upon farther Enquiry, and procuration of plain and unalter'd shells from several parts of this Island, fully assent to me herein, and are now convinced that these are the spoils and remains of Sea-Animals.[44]

Although some shells were found on land that did not resemble any species of shells appearing on the shores, Woodward affirmed that even the most strange and enormous of them had all the essential characters of seashells.

To account for them, while Woodward had similar views in certain matters to Hooke, he did not admit the extinction of species, which Hooke had suggested. Woodward referred to the stories of pearl-divers that there were many kinds of shellfish perpetually concealed in the deep. The shells which are found on the shores were only those cast up and stranded by tides or storms. Thus they are exuviae of those kinds that live near the shores, and not of those that inhabit the deeper and more remote parts of the ocean. The ones which did not resemble any found upon the shores he assumed to be those which would be found in the deep. Because Woodward firmly believed that "there is not any one intire species of Shell-fish, formerly in being, now perished and lost."[45] Hooke's theory of the extinction of species was too odd to be accepted in the seventeenth century.

Like Burnet and Hooke, Woodward also urged the necessity of studying the works of the ancient authors to prove the cause of the present geological features:

> It would certainly have been much better, had they taken the pains to have look'd a little into Matter of Fact: had they consulted History and Geography, in order duely to acquaint themselves with the past and the present state of the terraqueous Globe; and not to have pass'd Sentence till they had first compared the most ancient Descriptions of Countries with the Countries themselves as now they stand.[46]

Woodward referred to the ancient authors who discussed seashells found on land, such as Eratosthenes, Herodotus, Xanthus, Lydus, Strabo, Pausanias, Pomponius Mela, Theophrastus, Strato and Plutarch,[47] and he showed that these authors, too, had suggested the organic theory of fossils; he believed, however, that the strata and shells had all been deposited by the Universal Deluge. According to him, at the time of the Deluge all the stones and minerals were broken into pieces and the separated particles, together with seashells and other animal and vegetable bodies, were suspended in the water. In time, however, all these bodies again subsided,doing so in the order of their specific gravity. That is, heavier bodies sank down first and settled in the lower part, and lighter bodies subsided later and formed the strata upon the former.[48]

Woodward also claimed that the strata had originally all been parallel, plain, even and regular, and that the Earth's surface had been likewise smooth.[49] After some time, however, the strata were broken on all sides of the Earth, being elevated in some places and depressed in others. Caves, perpendicular fissures, mountains and islands were the result of these breaks in the strata. Woodward thus claimed that the whole terraqueous globe had been brought to its present condition soon after the Deluge, which he thought was the greatest catastrophe since the Creation.

Although both Hooke and Woodward critically examined Burnet's theory and utilized the Deluge theory to explain the location of fossils, Woodward's theory of the Deluge was completely different from Hooke's. Hooke had held a cyclic view of the Earth's history and had attempted to account for the location of fossils by interchanges of land and sea. However, Woodward rejected this idea, and claimed that all shells found on land were the remains of the one Universal Deluge. Woodward stressed the importance of the Deluge as the agent that had formed the original strata of the Earth. As a result of the

Deluge, Woodward claimed, the habitable Earth broke all to pieces, and fell into decay. As Burnet had done, Woodward explained the present state of the Earth by its dissolution. Although Hooke had suggested that mountains had been successively raised by earthquakes, Woodward opposed this opinion because he thought that earthquakes only lowered the ground into the abyss.[50]

In spite of the flood of criticisms, Gordon L. Davies has suggested, Woodward "made little attempt to defend his conception of Earth-history."[51] This suggestion can be applied to the period before the death of Hooke in 1703. At meetings of the Royal Society Woodward seems to avoid a topic of discussion which could have led him to a direct confrontation with Hooke. On 31 October and 14 November 1694, Woodward talked about unpetrified shells found near Woolwich. On 28 February 1699, Woodward "read a Lecture concerning the creation of the world & out of the 1 chap. of Genesis." On 26 November 1701, when the origin of trees found under ground became a topic of discussion, Hooke claimed that "Earthquakes or subteraneous mutations might have been the Occasion of these Trees being found so." Woodward, however, only said that "he had seen Trees under Ground with their Tops undermost and their Roots upwards", and did not present his idea of the Universal Deluge to explain the location of these trees.[52] Woodward's theory only facilitated the wider acceptance of the organic theory of fossils, but was not yet dominant under the shadow of Hooke.

An Interchange of Land and Sea

Although Hooke was a most active Fellow of the Royal Society, David R. Oldroyd has suggested that "Hooke's daring cyclic earth theory may have seemed absurd to his contemporaries." Following Oldroyd's suggestion, A.J. Turner has claimed that it is entirely understandable that Hooke had no followers in his geological theories, "for, however, plausible in themselves, they were quite implausible in the context of seventeenth-century knowledge."[53] Such comments miss the fact that the cyclic view of the Earth was popular throughout the seventeenth century, which can be further verified by the opinion of a contemporary author that great changes repeatedly happened to the sea and the land.[54] Moreover, the idea of an interchange of land and sea was accepted by some members of the Royal Society.

For example, John Aubrey, in his "Memoires of Naturall Remarques in the County of Wilts" (1685), criticizing Thomas Burnet's "ingeniose Hypothesis of the Theorie of the Earth", gave an approving summary of Hooke's theory that the present state of the Earth's surface was formed by earthquakes, but not by the Deluge alone. Like Hooke, Aubrey considered that petrified shellfish provided clear evidence that the primitive world had been covered with water, as had been suggested by Ovid:

> As the World was torne by Earthquakes; as also the Vaulture by time foundred, and fell in, so the water subsided, and the dry land appeared, according to Ovid...[54]

In Aubrey's view, the primitive Earth under the water was generally smooth and even, and had then been torn by earthquakes and become rough and uneven. Aubrey also conjectured that the world was much older than was commonly suggested, because of "the Stratum supra Stratum's found every where in digging."[56] As Hooke had done, Aubrey was disposed to place more credence in the greater age of the world in order to account for the thickness of the strata. He accepted without reservation Hooke's ideas on the Earth's history, regarding them as a reliable guide to the natural history of the past Earth.

John Beaumont was another colleague of Robert Hooke's for many years. Under the Society's plan regarding natural history, Hooke advised Beaumont to write the natural history of the district where Beaumont lived. Beaumont embarked on this project in his "account of Ookey-hole, and several other Subterraneous Grottoes and Caverns in Mendipp-hills in Somersetshire" (Philosophical Collections, No.2, 1681), and then presented an account of his work to the Society. Beaumont described Hooke as "a worthy Member of the Royal Society, and well known among the ingenious of Europe."[57] It was under the influence of Hooke that Beaumont published his argument against Burnet's theory in 1693.

According to Hooke's diary, Beaumont read the first book of his refutation of the theory of Burnet at Jonathan's London coffeehouse on 9th December 1692.[58] On 24th February 1693 Hooke wrote that "Mr Jo. Beaumont presented me his Book (Considerations on Dr. Burnets Theory etc): when he was gone I found he had Dedicated it to me."[59] A week later, on 1st March 1693, Hooke read an account of the first part of the work at the meeting of the Royal Society; he was later to read a full account of the two parts.[60] Hooke thus showed considerable interest in Beaumont's book which, following Hooke's ideas, argued against the theory of Burnet.

Beaumont's work was entitled Considerations on a Book, entitled The Theory of the Earth. In it he suggested that the ancient philosphers had already discovered from a contemplation of the Earth that there had been a general deluge which had covered the whole surface of the Earth. Like Hooke, Beaumont referred specifically to Ovid's Metamorphoses, but he also argued in more general terms that

> all ancient Histories, as well as modern, tell us of such marine Bodies found on Mountains; some urging them as Arguments for such Changes:

> as there are learned Men now living, who think they can demonstrate from such Bodies, found on Mountains at all distances from the Sea, that there is no part of the Land now appearing, but has sometime been cover'd by the Sea.[61]

Earlier, in both 1676 and 1683, Beaumont had claimed that fossil stones were not the remains of living creatures. He later changed his opinion, and by the time his book was published in 1693 he had come to regard fossils as evidence that the ground containing them had been once under the sea.[62] Beaumont's argument against the theory of Burnet was based partly on this idea which Hooke had already expressed.

Like Hooke, Beaumont strongly opposed Burnet's assertion that the antediluvian Earth had been without mountains and seas, and suggested instead that the world had had mountains and seas from the beginning. Beaumont, however, was a firm believer in a supernatural agency.[63] Although he had abandoned his earlier alchemical interpretation of fossils, he was still interested in such things as "Occult astrology"[64] and believed that seminal principles were the motivating force in the formation of the world:

> The main Error, as I conceive, on which the Author has grounded his whole Theory for the Composition of his Earth, as it rose from a Chaos, is, that he has here consider'd the Chaos, which it must necessarily have been from the infinite variety of seminal Principles of a contrary Nature therein contained (as

> all Antiquity has represented it) and from this fundamental Error has concluded, that in the Separations and Settlements of the Chaos, all things pass'd according to the common Laws of Gravity, observ'd in the subsiding of unfermented Bodies.[65]

According to Beaumont, when the Chaos initially parted to frame the primitive Earth, the different components did not entirely separate. On the contrary, the elements must have been mixed together in order to produce a habitable world, animals, plants and minerals. The primitive Earth, fermented by the seeds of all the things it contained, may have had force enough to produce mountains.

Beaumont's argument on the origin of mountains was different from Hooke's in that Hooke did not consider "seminal principles". Like Hooke, however, Beaumont agreed with Aristotle that the surface of the Earth had been many times changed:

> I am of opinion there is no Mountains on the Earth now, that is an original Mountain, or that existed when the World first rose, and conclude with Aristotle, that the Sea and Land have chang'd places, and continue so to do; and I think it not possible for any Man fairly to solve the Phenomenon of marine Bodies, found in Mountains, by any other Principle; especially by a Deluge caus'd as the Author has propos'd.[66]

Beaumont thus accepted the organic theory of fossils and explained their location by postulating an interchange of land and sea. As Hooke had done, Beaumont asserted that the Deluge proposed by Burnet could not account for the general phenomena of fossils. He also surmised that the surface of the Earth was more changeable than Burnet allowed.

A view which is similar to Hooke's was also adopted by Abraham de la Pryme, who was elected F.R.S. in 1702 and who wrote that he would consider Hooke in a letter to Dr. Hans Sloane.[67] In his paper in the Philosophical Transactions (1700), he presented the idea that there had happened an interchange of land and sea at the Deluge.

Pryme, in this paper on fossil shells observed in the quarries near Broughton in Lincolnshire, stated that many of the fossils he observed were "most miserably crack'd, bruis'd, and broken, and some totally squeezed flat by the great weight of Earth that yet lies and that was cast upon them in the Noachian Deluge." He went on to describe how the Earth had suffered great violence during the Universal Deluge. Like Hooke, he did not concur with Burnet's theory that the antediluvian Earth had been smooth and even:

> My notion of the Antidiluvian World is, that it had an external Sea as well as Land, and Mountains, Hills, Rivers, and Fruitful Fields and Plains, that it was about the bigness that our Earth is at present of; and that when God had a mind, for the wickedness of the inhabitants that dwelt thereon, to destroy the same by Water, he broke the Fountains and Subterraneous Caverns and Pillars thereof,

> with most dreadful Earthquakes, and caused the same to be for the most part, if not wholly absorb'd and swallow'd up, and covered by the Seas that we now have, and that this Earth of ours rise then out of the bottom of the Antidiluvian Sea in its room; just as many Islands are swallow'd up, and others thrust up in their stead.[68]

Even though Pryme does not refer to Hooke, it may be seen that Pryme's opinion is similar to that of Hooke. As the old Earth fell in, so the new was lifted up to maintain the balance. As did Hooke, Pryme believed that one such interchange of land and sea had occurred at the time of Noah's Flood. If this theory were admitted, one would not need to allow for such a great quantity of water to cause the Universal Deluge, and it would not be a cause for wonder that beds of fossil shells were found in mountains, and in the bowels of the Earth. These must have originated in the antediluvian sea, and then been raised up with the mountains at the time of the Deluge.

In support of his argument, Pryme claimed that the island of Atlantis had been drowned in the waters of Noah's Flood:

> Thus in most probability was the old World drowned and destroyed, and thus had we that whereon we now dwell in its place, and that which Plato tells some 6 or 700 years before Christs time, That in old times there was a huge Island much bigger than Asia and Africa put together, abounding with all the delights of Nature, swallow'd up in the Atlantick Ocean by dreadful Storms, and a huge Earthquake

> and Flood, I question not at all, but that this was the Antidiluvian World that they meant, a very great part of which was absorb'd and drowned there, which account thereof they might have both by Books and Tradition from their Fore-fathers, seeing that one of them that was in the very Ark, was first that peopled Egypt.[69]

Pryme thus supposed that a great interchange of land and sea had happened at the time of the Universal Deluge and that it was at this time that the land of Atlantis disappeared into the sea. He did not, however, discuss the other changes which Hooke had postulated. For Pryme, Noah's Flood was the only major past change that had occurred in the Earth's surface, although he did not deny a series of minor interchanges of land and sea.

Even at the end of the seventeenth century Hooke was both active and influential. In 1699 Tancred Robinson wrote to Edward Lhwyd, referring to Hooke's lectures:

> Dr. Hooke reads Lectures every week about figured stones and fossil shells at Gresham, which disturbs some gentlemen, who do not fail to snarl at him. Both Parties pretend to demonstration; one for the universal Deluge, the other for Earthquakes, which throw them up from the subterraneous sea.[70]

Most Fellows of the Royal Society by that time accepted the organic origin of fossils, but there remained the question of by what agency these shells had been carried. Referring to beds of oyster-shells, James Brewer asked

> how they should come to the place where I dug for them, and where for so many succeeding Generations they have been found...[71]

In reference to "some strange bones", an anonymous author, too, asked

> admitting that (supposing it, I mean, a Sea-bred Creature) how then (will some say) should it possibly come there?[72]

The question as to the location of fossils could be explained either by Hooke's notion of earthquakes or Woodward's Deluge. However, Hooke's idea of interchanges of land and sea seems to have been more dominant among Fellows of the Royal Society even at the beginning of the eighteenth century.

The general acceptance of cyclic theory can be found in some papers in the Philosophical Transactions. In 1701 John Lustkin, in his letter concerning some large bones found in a gravel-pit near Colchester, wrote about geological change:

> 'tis easily explained why these Bones should at this day be found at such depths, if we consider the Alteration or rising of the Valleys, by the continual washing down of the loose Earth or Soyle by the Rains and Snows from the adjacent Hills...[73]

In the same year John Wallis, Professor of Geometry at Oxford, wrote a letter concerning geological changes to Hans Sloane, Secretary to the Royal Society, which was published in the Philosophical Transactions. Referring to William Sommer of Canterbury, "a learned Antiquary", Wallis wrote that

> He is of opinion (with Mr. Camden, and other Antiquaries, whom he cites,) That it is highly probable (if not absolutely certain,) That France and England (or Gaul and Britanny) were anciently joyned by an Ithmus, or Neck of Land; where now is the Narrow Passage between Dover and Calais: Which, many Ages since, (beyond the reach of any History now extant) was by the Seas violently beating upon it on both sides) worn away, or broken through.[74]

Besides the erosion of land, Sommer added an account of fossil teeth and bones found under the ground, which he judged were the remains of some hippopotamus or other marine animal and had been covered with earth. Sommer thus discussed both the erosion and deposition of earth as an example of geological change. In support of Sommer's argument, Wallis referred to Plato's Atlantis, which was believed to have been swallowed up by the sea.[75] In Wallis' opinion,

> many such alterations (no doubt) have been of the Face of the Earth, all the World over, of which we have no particular Histories.[76]

In this way, Wallis thought that there had been interchanges of land and sea.

A letter from Samuel Dale to Edward Lhwyd was published in the Philosophical Transactions in 1704, in which Dale discussed regional geological changes. Referring to fossil shells in Harwich Cliff, he asked

> Why the same Strata of Sand, and fragments of Shells, with the same Fossils imbedded, are to be found Walton Ness on the other side of the AEstuarium... How it comes to pass that none of those Buccina Heterostropha, (whereof such plenty of their Exuviae are in all the Cliffs hereabouts) are not now to be found in this Chanel, nor the adjacent Seas?[77]

In answer to these questions, Dale suggested that the mouths of great rivers undergo changes by the lodgement of sands and that Harwick Cliff was constantly washed away. These changes, he claimed, can be the reason why fossil shells were found in the cliff. In Dale's view, it is "a constant observation, that where the Sea gaineth on one side it loseth on other."[78]

The cyclic theory of the Earth, however, became less popular after the death of Hooke in 1703,[79] and Woodward's hypothesis created a research programme for the study of the Earth.[80] Meanwhile Hooke's idea that fossils were evidence of the past Earth survived in the works of Woodward.

Hooke's Contributions

As Gordon L. Davies has suggested, modern historians of science "have rescued Hooke from the obscurity into which he had fallen and have reminded us that he made important contributions to an astonishingly wide range of Scientific subjects."[81] To the modern philosopher of science, Oldroyd has said, "Hooke's notions have all the hallmarks of a genuine scientific theory."[82] Looking back from the present point of view, Hooke in his thinking was far in advance of any other "geologist" of the seventeenth century. Indeed, Davies has concluded that Hooke was too advanced for his time that his geological "ideas made no impact on his contemporaries".[83] His importance for the development of Earth science, however, does not lie so much in his having advanced ideas which were ignored by his contemporaries, but in his involvement in current geological arguments.

As has been shown, Hooke was originally interested in the origin of fossils, but sometime at the end of the 1680s he began to discuss the historical aspect of the Earth. Following this change, some members of the Royal Society came to argue about the effects of the Deluge which Burnet had discussed. In this way, the study of fossils became associated with a historically-oriented view of the Earth. As Hooke did not write about his own theory of the Earth in a systematic way, his achievements have been rather neglected. First appearances can, however, be misleading. Hooke's series of lectures at the Royal Society clearly show that he played a leading role in the geological debate of the period. Without considering his activities and influence, it would be difficult for us to understand the course of Earth science in late seventeenth-century England.

NOTES

1. Margaret 'Espinasse, Robert Hooke (London: William Heinemann, 1956), 80.

2. Porter, The Making of Geology, 83.

3. David Charles Kubrin, Providence and the Mechanical Philosophy (Cornell University Ph.D. thesis, 1968), 151.

4. Journal Book of the Royal Society, 14 Dec. 1687, 4 Jan. 1688, 29 Feb. 1688, 12 and 19 Dec. 1688, 9 Jan. 1689, 14 and 21 Dec. 1692, 1 March 1693.

5. Rudwick, The Meaning of Fossils, 77.

6. Thomas Birch, The History of the Royal Society of London, IV (London, 1757), 69.

7. Ibid., 83.

8. Ibid., 237-38.

9. Ibid., 513.

10. Birch, History, IV, 521.

11. Hooke, Posthumous Works, 334.

12. Ibid., 372.

13. Ibid., 371.

14. Kubrin, Providence, 151.

15. Less than a decade before, on 24 November 1679, Hooke wrote to Newton that "If had been such changes in the world as have been supposed why have we not records of them and why have not such been observed for these Last 2000 years." (Robert Hooke, MSS Trinity College, Cambridge, O.11a. 1[22], 1679) He does not seem, however, to have discussed this question any further at this stage.

16. Hooke, Posthumous Works, 372.

17. Ibid., 375.

18. Gunther, Early Science, VII, 710.

19. Hooke, *Posthumous Works*, 374.

20. Ibid., 376.

21. Gunther, *Early Science*, VII, 711 and Journal Book of the Royal Society of London.

22. Hooke, *Posthumous Works*, 378.

23. Ibid., 395.

24. Journal Book.

25. Hooke, *Posthumous Works*, 410.

26. Ibid., 412.

27. Ibid.

28. Ibid., 416.

29. Gunther, *Early Science*, X, 75.

30. Ibid., 75, 80, 81.

31. Journal book.

32. Ibid.

33. Porter, *The Making of Geology*, 26.

34. Davies, *The Earth in Decay*, 89.

35. Robert Hooke, "Hooke's Diary", in *Early Science in Oxford*, ed. by R.W.T. Gunther, vol. X (Oxford, 1935), 242, 239, 244.

36. Journal Book of the Royal Society of London, November 15, 1693.

37. Woodward's interest in Hooke's works can be found in the following account: "Dr. Woodward said that having bought several of the late Dr. Hookes Bookes he had found several loose Manuscripts of his own hand in them which he was pleased to offer the Sight of to the Council of the Royal Society if they my be found usefull to Explane any of his Writings." May 5, 1703. The Council Minutes of the Royal Society.

38. John Ward, *Lives of the Professors of Gresham College* (London, 1740), 284.

39. Edward Lhwyd, "Life and Letters of Edward Lhwyd", in *Early Science in Oxford*, ed. by R.W.T. Gunther, vol. XIV (Oxford, 1945), 106.

40. Lhwyd, "Life and Letters", 210

41. John Woodward, An Essay toward a Natural History of the Earth (London, 1695), 1.

42. Ibid., 155-58.

43. Ibid., 6.

44. Ibid., 24.

45. Ibid., 28.

46. Ibid., 62.

47. Ibid., 65.

48. Ibid., 29.

49. Ibid., 79.

50. Ibid., 110-11.

51. Davies, The Earth in Decay, 83.

52. Journal Book.

53. David R. Oldroyd, "Robert Hooke's Methodology of Science as exemplified in his 'Discourse of Earthquakes'", The British Journal for the History of Science, vol. 6, No.22 (1972), 130; A.J. Turner, "Hooke's Theory of the Earth's Axial Displacement: Some Contemporary Opinion", The British Journal for the History of Science, vol.7, No.26 (1974), 167.

54. Thomas Pope Blount, A Natural History: containing Many not Common Observations: Extracted out of the best Modern Writers (London, 1693), 404-6.

55. John Aubrey, Memoires of Naturall Remarques in the County of Wilts (Royal Society MSS, 1685), 102.

56. Ibid., 112.

57. John Beaumont, "A further account of some rock plants growing in the lead mines of the Mendip Hills," Phil. Trans.,xiii (1683), 278.

58. Gunther, Early Science, X, 195.

59. Ibid., 217.

60. Ibid., 220; Journal Book of the Royal Society, 1st March 1693.

61. John Beaumont, Considerations on a Booke, entituled The Theory of the Earth, publisht by Dr Burnet (London, 1693), 4.

62. On April 28, 1691, Edward Lhwyd wrote that John Beaumont had shown him a manuscript of his book opposing Thomas Burnet's Sacred Theory of the Earth, and remarked that Beaumont "doubts not but all shell-stones, teethstones & c. have proceeded from animal mold; & he shewd us some flints with roots of plants in ym (as he seemd fully persuaded) petrified." (Lhwyd, "Life and Letters", 139.)

63. Beaumont claimed that certain seminal principles played an important role in the formation of this world. He looked upon the phenomena of the Creation, the Deluge and the Conflagration "as works grounded on an extraordinary Providence", therefore he wrote "I have always found my self absorpt in Miracle". (Beaumont, Considerations, 169) He ascribed general change in the Earth's surface to miracles, but no one supported this idea.

64. Gunther, Early Science, X, 206.

65. Beaumont, Considerations, 26-7.

66. Ibid., 30.

67. Abraham de la Pryme, The Diary of Abraham de la Pryme (Edinburgh, 1870), 236.

68. Abraham de la Pryme, "A Letter...concerning Broughton in Lincolnshire with Observations on the Shell-fish observed in the Quarries about that Place," Phil. Trans., xxii (1700), 679, 683-84.

69. Ibid., 684-85.

70. Tancred Robinson, A Letter from Robinson to Lhwyd, 4th February 1699 (Bodleian MS Ashmole 1817 a.f. 343).

71. James Brewer, "Part of two Letters...concerning Beds of Oyster-shells found near Reading in Barkshire", Phil. Trans., No.261 (1700), 484.

72. "Chartham News: Or a Brief Relation of some Strange Bones there lately digged up, in some Grounds of Mr John Sommer's in Canterbury," Phil. Trans., No.272 (1701), 885.

73. John Lustkin, "Part of a Letter concerning some large Bones, lately found in a Gravel-pit near Colchester," Phil. Trans., No.274 (1701), 926.

74. John Wallis, "A Letter...relating to the Isthmus, or Neck of Land, which is supposed to have joyned England and France in Former Times," Phil. Trans., No.275 (1701), 968.

75. Ibid., 973-74.

76. Ibid., 979.

77. Samuel Dale, "A Letter...concerning Harwick Cliff, and the Fossil Shells there," Phil. Trans., No.291 (1704), 1573-74.

78. Ibid., 1575-76.

79. By the death of Woodward in 1728, the idea of the interchange of land and sea seems to have revived. For example, Ephraim Chambers, in his Cyclopaedia (1728), regarded Pryme's geological idea as the best solution for the fossil question. (The item on "the Deluge".) In 1745 Henry Baker, in his paper in the Philosophical Transactions, suggested that fossils were evidence of "the surprising alterations that must have happened as to the Disposition of Sea and Land." (Henry Baker, "A Letter...concerning an extraordinary large fossil Tooth of an Elephant," Phil. Trans., No.475 (1745), 334.

80. Between the publication of Hooke's Posthumous Works (1705) and the death of Woodward (1728), the main topic of geological papers published in the Philosophical Transactions was the state of strata: William Derham, "Observations concerning the Subterraneous Trees in Dagenham, and other Marshes bordering upon the River of Thames, in the Country of Essex," Phil. Trans., no.335 (1712), 482; Fettiplace Bellers, "A Description of the several Strata... To which is added, a Table of the Specifick Gravity of Each Stratum: By Mr. Fr. Hauksbee...", Phil. Trans., no.336 (1712), 541-44; John Strachey, "A Curious Description of the Strata observ'd in the Coal-Mines of Mendip in Somersetshire," Phil. Trans., no.360 (1719), 968; Benjamin Holloway, "An Account of the Pits for Fullers-Earth in Bedfordshire," Phil. Trans., no.379 (1723), 421; John Strackey, "An Account of the Strata in Coal-Mines," Phil. Trans., No.391 (1725), 397-98; James Kelly, "An Account of the Strata met with in digging for Marle, and of Horns found under Gound in Ireland," Phil. Trans., no. 394 (1726), 123. The Rev. Mr. Lewis, "An Account of the several Strata of Earths and Fossils found in sinking the mineral Wells at Holt," Phil. Trans., no.403 (1728), 490.

81. Gordon L. Davies, "Robert Hooke and his Conception of Earth History", Proceedings of the Geological Association, LXXL (1964), 493.

82. Oldroyd, "Robert Hooke's Methodology of Science", 130.

83. Davies, The Earth in Decay, 91.

8. NATURAL HISTORY AND THE DELUGE THEORY

Burnet's Theory of the Earth, Beaumont's Considerations, Woodward's Essay toward a Natural History of the Earth and Whiston's New Theory of the Earth gave a strong stimulus to those who were interested in the natural phenomena of the Earth. These works on the Earth's history reached a wider audience, and even country virtuosi who did not attend the meetings of the Royal Society could acquire a knowledge of systematic theories of the Earth's history.[1] Moreoever, all these works were reviewed in the Philosophical Transactions, which, too, enabled country virtuosi to share common frameworks for Earth science with London counterparts.

However, most natural historians were not interested in the Universal Deluge itself. Edward Lhwyd, for example, a devoted natural historian, wrote to John Ray:

> For my part I have been always, being led thereunto by your example, so much the less admirer of Hypotheses; as I have been a lover of Natural History.[2]

Although natural historians such as Lhwyd did not evince much interest in theories of the Earth, those who discussed the origin of fossils became interested in the effects of the Universal Deluge which had been argued about in the works of Burnet, Beaumont, Woodward and Whiston. Referring to the Deluge theory, Roy Porter has claimed that "the need to establish a historical theory of the globe in the 1690s produced a framework in which the organic interpretation of fossils was truly functional." [3] Even if Porter's claim seems to be correct, he does not explain how Deluge theory influenced natural historians who believed the inorganic theory of fossils.

The Ray-Lhwyd Correspondence

The influence of the Deluge theory is particularly evident in the writings of Edward Lhwyd, and adherent of the inorganic theory of fossils. In 1682 Lhwyd entered Jesus College, Oxford, and soon became assistant to Robert Plot, professor of chemistry and first keeper of the Ashmolean Museum, opened in 1683. Lhwyd also assisted Martin Lister with lists of Oxfordshire species of molluscs and fossils, and some of his specimens were used in Lister's *Historiae sive synopsis methodice Conchyliorum* (1685-92). In 1686 Lhwyd presented to the Oxford Philosophical Society a new catalogue of the shells in the Ashmolean Museum.

Like Plot and Lister, Lhwyd claimed that figured stones were "lapides sui generis" or "sports of nature":

> ... I think it all most an absurdity to believe they ever were shells, not doubting but they are lapides sui generis yt owe their forms to certain salts whose property 'tis to shoot into such figures as these shellstones represent...[4]

At this stage therefore Lhwyd believed that fossil shells had been formed by a chemical change. By 1690 Plot resigned all his Oxford posts because of his marriage and left for his country estate, Sutton Baron. Then Lhwyd succeeded Plot as keeper of the Ashmolean Museum, and began a regular correspondence with John Ray. Lhwyd was persuaded to change his view on fossils by Ray, who was already an eminent scholar when Lhwyd began his study of natural history.

On May 7, 1690, Ray wrote to Lhwyd that he had a great variety of Glossopetrae, excavated in Malta, which he considered were originally none other than sharks' teeth.[5] On November 7, Ray wrote again:

> I have long fluctuated in my opinion concerning the Originall of these stones, whether they be shells of fishes petrified, or primary productions of nature in imitation of shels: the Arguments for & agst both are so strong & pressing that they constrein me to settle in a middle opinion, that some are of one kind, some of another. Some of the Bodies you sent me, are to my apprehension real shels, having

> not only the figure, but also the consistence... & all the other accidents of shels.[6]

Ray seems to have been unable to reach a decision, but he was evidently sure that at least some of the shells Lhwyd had sent him were once-living creatures.

Shortly afterwards, on November 25, 1690, referring to Pectinites (scallops) and Echinites (sea-urchins), Lhwyd replied to Ray that

> Whether they were ever the tegumenta of animals or are only primary productions of nature in imitation of them, I am constrained to leave in medio, and to confess I find in myself no sufficient ability or confidence to maintain either opinion, though I incline much to the latter.[7]

On January 14, 1691, writing to Lhwyd, Ray declared his mind on the organic origin of fossils:

> I have again and something more carefully revised ye formed stones you were pleased to send me, but shall at present make no remarks upon them. ... But as to ye conchites or petrified shels as they are called, if you can believe that those you mentioned were only mock-shels, then you elude the strongest argument to prove them to be sea-shells or Bones petrified.[8]

Ray thus attempted to persuade Lhwyd to accept the organic origin of at least some fossils. On April 6, 1691, Ray wrote again to Lhwyd, approving of his plan to publish a catalogue of fossils. Ray, however, advised Lhwyd to consider their origin very carefully:

> You must promise a generall discourse about ye Originall of those stones. I am not able to suggest to you a better method for ye disposing of them, then will safely occurre to your own thoughts upon consideration, you having so comprehensive a knowledg of them. The best way therefore is first to draw up a method your self, without suffering your facy to be biassed or inclined by another mans thoughts; & then I may send you mine.[9]

Ray's attempt to persuade Lhwyd to accept the organic theory of fossils became more effective once the theories of the Deluge came to be seriously discussed. On April 28, 1691, Lhwyd told Martin Lister that John Beaumont had shown him a manuscript of his book opposing Thomas Burnet's Sacred Theory of the Earth, although Lhwyd did not make any comment on the history of the Earth. A month later, on May 27, 1691, Ray wrote to Lhwyd that "I never saw Dr. B[urnet] Theory of ye Earth, but by wt I have heard of it I think it needs no great confutation."[10] Burnet's work was first published in 1681, but we learn from this letter that Ray had still not seen it some ten years later. Being primarily interested in natural history, Ray presumably did not take a serious view of such a theory. Ray also said that "All ye knowledge I have of Mr. Woodward is from your letters."[11] Ray lived in Black Notley, Essex and was relatively isolated from the theorists in London. On February 30, 1692, referring to Burnet's hypothesis, Lhwyd wrote to Ray that "though I admire his learning and ingenuity, yet I must confess I cannot (as yet) reconcile his opinions either to Scripture or reason."[12] Although he criticized Burnet's theory, Lhwyd evidently became interested in the history of the Earth at this time, which is evident also from a letter of April 3, 1692, to John Aubrey in which Lhwyd asked Aubrey to describe his hypothesis of the Earth:

> Does yr hypoth. of y Globe differ much from Burnet's? What is Mr Hooks opinion of ye origin of Form'd Stones? Did they come by ye flood, b ye motion of ye earth, or some other means?[13]

Lhwyd was forced to take into account the theories of the Deluge when he argued about the origin of fossils. Diluvial theory had become the focus of a controversy in the 1690s, and natural historians who discussed the origin of fossils were obliged to consider the effects of the Deluge simply because fossils could be the results of the action of the violent waters.

On October 7, 1692, Lhwyd wrote to Ray that he suspected that certain belemnites called "Unicornu fossile" were the bones of some marine animal. As for "Cornua Hammonis" (ammonites), he surmised that they were all of the nautilus kind.[14] Thus Lhwyd now admitted that some fossils were the remains of sea-animals. Ray was satisfied with this opinion and wrote to Lhwyd on November 7, 1692, that "I see you are now, & not without good reason, come over to their opinion, who hold the Cornua Ammonis to be ye Nautilus kind."[15] Lhwyd again wrote to Ray on December 20, 1692:

> As to the fossil Oysters, and my other observations of late in this kind, they do, I must confess, confirm me in my apostacy; for I have been inclined to a misbelief of their being mineral forms.[16]

Lhwyd thus now admitted that fossil oysters, too, were not minerals but remains of living creatures. He had embarked on his study of fossils as an assistant to Plot, who was a leading advocate of the inorganic theory, but now he renounced the theory of his teacher.

The controversy over the Deluge once provoked, Ray, too, began to consider various hypotheses concerning the Deluge and its effects. On march 22, 1693, Ray wrote to Lhwyd that he looked upon Burnet's theory as "no more or better then a meer chimaera or Romance."[17] On October 26, 1693, he again wrote to Lhwyd that John Beaumont's Considerations upon Dr. Burnet's Theory of the Earth had overthrown Burnet's hypothesis in a few words, by the supposition that the ocean contains no more water than could cover the whole Earth.[18] Ray, however, showed a more serious interest in John Woodward's account of the Deluge. In a letter of September 7, 1694, he advised Lhwyd to read the papers of Woodward, who was then writing his Essay toward a Natural History of the Earth, published in 1695. On January 1, 1695, Lhwyd in turn wrote to Martin Lister that Woodward

> would always have me believe that he could give such acct of the Deluge, as would serve not onely to explain how marine bodies are lodged in the bowels of the earth & c. ...so that surely we must expect some hypothesis different from the History of Moses, and the Theory of Dr Burnet.[19]

It was under the influence of the Deluge controversy that Lhwyd came to consider the effects of the Deluge, namely, how marine animals came to be embedded in the ground. After abandoning the inorganic theory of fossils, he was obliged to solve the problem of their location. On March 28, 1695, Lhwyd wrote to Lister and criticized Woodward's work as well as that of Burnet, on the grounds that it did not agree with "reason and common sense".[20] Lhwyd in fact preferred natural history to such "romantic theories". Although now believing that fossils were deposited under water, Lhwyd did not explain how they came to be found on dry land.

On April 8, 1695, Ray wrote to Lhwyd that John Beaumont had given a hint which might solve the question of the location of fossils. Beaumont concluded with Aristotle that the sea and land changed places and continued to do so, and thought it possible by means of this principle to account for marine bodies found on mountains. Ray, however, hesitated to accept the conclusion, and wrote to Lhwyd that he was still puzzled as to how those remains of animals came to be lodged in the places where they were found.[21] Hence he did not give a definite answer to this question:

> I know it is a hard task to give a good Account of the originall of Fossil shels & formed stones, & a satisfactory Answer to all Objections against either opinion: & therefore a man hazards his reputation that is positive & confident on either side.[22]

He remained convinced, however, that fossil shells were real seashells, and that they had been deposited in the ground by inundations of the sea. The difficult question was what possible inundation of the sea could carry them up to the upper parts of high mountains. On June 8, 1696, Ray wrote to Lhwyd, and at last expressed his opinion on this problem:

> ...it seems to me that at first the Earth was covered with water: that ye land was raised up by subterraneous fires at the Divine command, & that gradually first where Animals & men were created, & then further & further, the waters being driven back. Afterward when the greatest part of the Earth was thus raised, the skirts were altered by the sediments of rivers & flouds, whence & from ye inundations of the sea came the severall beds or layers of Earth.[23]

He referred to a bed of shells found at Amsterdam as evidence that the ground there had been under the sea and that all the earth above it was the sediment from subsequent floods. He did not regard the Universal Deluge as the agent which had carried seashells up high mountains, because in his opinion it was more probable that the waters of the Deluge had carried shells down to the sea. The layers must therefore be explained as having been formed by several inundations, and the Deluge then was not of especial importance.

Although Ray attempted in this way to solve the question of the location of fossils, Lhwyd was cautious about submitting his own idea to public scrutiny. Regarding Whiston's New Theory of the Earth, Lhwyd considered that Whiston's theory, that all the phenomena of formed stones could be explained by a comet that had appeared at the time of the Deluge, would appear even more ridiculous than those of Burnet and Woodward. It was his hope therefore that "ere long we shall have this wrangling philosophy laugh'd out of countenance, and ye plain Natural History better esteem'd of."[24] Instead of suggesting a grand theory, he continued to advance his new concept of the organic theory of fossils. In 1698, for example, Lhwyd wrote to William Nicolson, the Archdeacon of Carlisle, that "we not only see daily new sorts of shell-fish, & bones of marine animals, together with trees and leaves of plants, but we also meet with many fossil bodies which for many ages were rankt with minerals, that upon a more nice survey, sufficiently prove their origin to have been animal, or even vegetable."[25]

Lhwyd was not satisfied with the various attempts to solve the matter of the location of fossils, and said that "what one days observations suggested, was by those of ye next called in question, if not totally contradicted & overthrown.[26] In 1698, however, he suggested an alternative hypothesis:

> I have in short imagin'd they might be partly owing to fish-spawn, received into the chincks and other meatus's of ye earth in the water of the Deluge, and so be deriv'd (as the water could make way) amongst the shelvs or layers of stone, earth, & c: and have further thought it worth our enquiry whether the exhalations which are raised out of the sea and falling down in rains, fogs, & c. do water the earth to ye depth here requir'd, may not from the seminium or spawn of marine animals, be so far impregnated with, as to the naked eye invisible, animalcula (& also separat or distinct parts of them) as to produce these marine bodies,...[27]

Thus although he now accepted the organic theory of fossils, Lhwyd did not believe, even yet, that fossil shells found in the ground had once lived in the sea. Fossils, he suggested, owed their origin to the spawn of sea-animals which had been lodged in the ground by the waters of the Deluge. Lhwyd's compromise between two theories of fossils was supported by an anonymous author,[28] but did not receive much attention.

Ray and Lhwyd were thus at first engaged in the fossil question, but after the publication of the rival theories of Beaumont, Woodward and Whiston, they could not avoid discussing the Universal Deluge as an agent which might have carried marine animals on to the dry land. For both of them the Deluge theories of Burnet, Woodward and Whiston were too ridiculous to be given serious consideration. Under the influence of these theories of the Earth, however, Ray artfully persuaded Lhwyd to change his inorganic theory of fossils. The process of this persuasion would explain why Lhwyd and Ray "showed startling vacillations".[29]

The Decline of the Chemical View of Fossils

The influence of the Diluvial theory on natural historians may also be seen in the writings of Thomas Robinson, rector of Ousby, who discussed the nature of the Earth in his Anatomy of the Earth published in 1694, one year before the publication of Woodward's Essay toward a Natural History of the Earth. Robinson argued that there was a close analogy between the body of the Earth and that of an animal. In his view, just as does an animal, the Earth has a plastic power infused into it by the spirit of nature, and it produces grass, trees and plants in the same way as the skin of an animal grows hair. Because the Earth is alive, the ebbing and flowing of the sea is its own natural motion. Lacking sufficient strength however and being beaten back by the seashores, the water is forced to retreat. "Yet, if it should please God once more to unite the Upper and Lower - waters (as in the Days of Noah) they would again be able to perfect their natural and circular Motion, and so cause another Universal Deluge."[30] Although he thus discussed the cause of the Universal Deluge, Robinson did not in this work discuss its effects.

Referring to the works of Burnet, Woodward and Whiston, Robinson extended his view of the animated world in another work published two years later, New Observations on the Natural History of this World of Matter and this World of Life (1696). To Robinson's mind, the hypotheses of Burnet and Woodward were inconsistent with reason, common sense, experience and Scripture. Instead of building up a grand theory of the Earth's history, Robinson concentrated his attention on objects of natural history. Although he referred to Scilla and Steno who believed that fossils were the remains of living creatures, like Martin Lister, Robinson emphasized that genuine shells were found in animal bodies:

> If true Shells can be form'd within Stones of the Bladder, and in many other Parts of the Bodies of Creatures; then by the same Argument a Million may be form'd in the Bowels of the greater World, every ways resembling those of the Sea.

Robinson did not ascribe the origin of fossils either to the Deluge or to earthquakes. In this work he followed those philosophers who were generally of the belief that the origin of fossils should be explained by chemical action. He also criticized William Whiston's New Theory of the Earth because it depended "too much upon mechanical & necessary Laws (as several other late Theorys and Hypotheses do)." Robinson thought that Noah's Flood had not come about without any relationship to the Fall of man. For him the supernatural cause could not be omitted from an argument concerning the cause of the Flood.

Robinson further extended his argument concerning the generation of fossils in his Essay towards a Natural History of Westmoreland and Cumberland (1709), where he suggested the idea of an active and passive principle which might generate stones:

> It is most certain, that there is a very active Principle, or Virtue, that operates in the Generation of Stones, as well as upon the rest of the Matter of the Universe, that is subject to Generation and Corruption; but the difficulty lies in knowing what that Principle is, because it operates in no determinate place; but sometimes Stones are made in the Air, in the Clouds, in the Water, and in the Bodies of Animals; and it's taken for granted that in all Generations there are concern'd two essential Principles, (viz.) an active and passive Principle.[31]

Besides these two Principles, Robinson surmised that there was a plastic spirit in nature which would assume the forms of animate or inanimate bodies, on meeting with the chemical principles of Salt, Sulphur and Quicksilver. Matter was thought to be modified through the action of this plastic spirit into the bodies of fishes, insects and other creatures.[32]

Although Robinson thus claimed that many fossil stones were formed by chemical action, he did not explain the origin of all types of fossil remains in this way. He admitted that some fossils were once living creatures:

> It seems most probable, that those Firr-Trees, bury'd under Ground in Lincolnshire, were brought thither by the Devastations made by Noah's Flood: But it cannot be imagin'd, that those shell-Fish should be lodged and petrified to Stone, upon the Tops of high Mountains, and inclosed in the middle of hard Rocks by that general Flood: but it seems more likely, that when God by the Division of the Waters, made the dry Land to appear, these shell-Fish, which were not Loco-motive, were left behind, and by the general Petrefaction, with the rest of the now solid Strata, were petrified into Stone.[33]

He had originally advocated the inorganic theory of fossils, but he became interested in the effects of the Universal Deluge after the rise of Diluvial theories. As a result, Robinson accepted the idea that certain fossil stones had their origin in living creatures, although they were not thought to have been deposited at the Deluge.

Charles Leigh, physician and naturalist, took a similar position regarding the origin of fossils. In his Natural History of Lancashire, Cheshire, and the Peak, in Derbyshire (1700), Leigh claimed that the morasses in these districts had come about as a result of Noah's Flood, and this hypothesis was supported by the great quantities of exotic trees, marine shells and other phenomena which might be observed there.[34] He stated in addition that there were vast beds of every type of marine shell on the summits of high mountains, which he believed could not have been deposited there by any other agency than the Deluge.[35] He saw moreover in marle near Lancaster the skeleton of an elk, a creature foreign to England, and he concluded that this must also have been deposited by the Universal Deluge.[36]

Although Leigh thus listed various phenomena which had come about through the Deluge, he believed that certain fossil plants found in solid rock and the forms of several other creatures could not be accounted for by the Deluge. It was his belief that they were sports of nature which had been produced by different mixtures of bituminous, saline and earthy particles:

> My Sentiment of the whole is this, (that as it is observable in Chymistry that the Salts of some Plants will divaricate themselves into the figure of the Plants) that these representations of Plants in Rocks are nothing but different Concretions of saline, bituminous and terrene Particles.[37]

Like Thomas Robinson, Leigh claimed that the origin of some fossils could be explained by alchemical principles. He was himself a chemical philosopher for whom "the Phaenomena of Nature cannot be mechanically accounted for."[38]

Like Robinson, Leigh was thus involved in the controversy on the origin of fossils, and applied himself seriously to the question of the effects of Noah's Flood after the advent of the Diluvial theories. Unlike the grand theorists, he did not assume that the Deluge had caused great damage to the Earth's surface, but he was convinced that the Universal Deluge had occurred and had destroyed all living creatures except those in Noah's ark. Therefore, he believed that the traces of the Deluge might be found everywhere on the surface of the Earth. In this way at least some fossils came to be regarded as once-living creatures.[39]

Moreover, the chemical philosophy was falling into decay because of the rise of the mechanical philosophy, and this, too, worked against the inorganic theory of fossils. By the beginning of the eighteenth century, the organic theory had come to be widely accepted among virtuosi. In 1702 Lhwyd wrote to Richard Richardson that "all the virtuosoes of the south are fully persuaded that the marine fossils are coal plants are the effects of the deluge."[40] Those who believed the inorganic theory did not have their followers. Plot died in 1696 after having left Oxford. Lister was appointed one of Queen

Anne's physicians in 1702 and almost ceased scientific activity until his death in 1712. Leigh died in 1701(?) and Thomas Robinson died in 1719, and they were typical natural historians who lived in isolated countryside. William Nicolson, who held the inorganic theory, was also a country virtuoso.[41]

The decline of the chemical philosophy can be traced in some articles in the Philosophical Transactions. In his paper on "balls of hair taken from the uterus and ovaria of several women" published in 1707, James Yonge, F.R.S., claimed that

> Such Philosophers who call those extraordinary Appearances Lusus Naturae, seem like those of old, who wearied in their Natural Searches by some puzling Difficulty, take Refuge in Words, ascribing the Cause of Things which they can't discover or discern, to Occult Qualities, and so on.[42]

Yonge rejected the opinion that Lusus Naturae meant the sport or recreation of nature. In 1728 Frank Nicholls, Professor of Anatomy at Oxford, contributed a paper on mines and metals to the Philosophical Transactions. In this paper he said,

> When I speak of a Plastick Power, I would be understood as meaning only a Modus of Attraction, by which the attracted Particles are rang'd in this or that determin'd Form.[43]

Nicholls thus understood the word "Plastick Power" in physical terms. In 1749 William Borlace observed that the organic theory of fossils was firmly accepted:

> ...the Learned are now very well satisfy'd that such extraneous Fossils as are mentioned above, are not the Lusus Naturae; but the Exuviae of Animals brought where we find them by the Waters of the Deluge.[44]

As the inorganic theory of fossils lost its theoretical foundation that nature had hidden forces which could form the imitations of living creatures, the decline of the theory was hastened.

The Order of Strata

Among the theories of the Deluge, the work of Woodward provided the greatest stimulus to natural history. There was strong opposition to his hypothesis that the order of the strata was according to their specific gravity, and few natural historians acepted his theory of a total dissolution of the Earth's strata at the time of the Universal Deluge. But Woodward's Essay was widely read by both London and country virtuosi and stimulated them to observe the strata in detail.

Country virtuosi such as Thomas Robinson and Charles Leigh, who were not in direct contact with London virtuosi, based their arguments against Woodward's hypothesis on regional observations. In reference to Woodward's theory on the order of the strata Robinson claimed it to be notoriously false:

> the Strata, Layers, or Beds of Sediments...do not lie according to their different Weights, or according to the Statick Laws of descent of Solids in Fluids, for the Strata of Marble, and other Stone, of Lead, and other Metals, lye often near the top or Superficies, having many lighter Strata under them.[45]

Robinson remarked moreover that the changes which the Deluge had made upon the Earth could only have been sustained in the exterior part, and he was not in agreement with Woodward's hypothesis that all the stone and marble of the antediluvian Earth had been totally dissolved at the time of the Deluge. A similar view was held by Leigh, who observed the strata in mines:

> In these Mines it is plain no specific Gravitation is observ'd, for Coals, Strata of Marle, Coal, Slats, in all the Mines I have seen always ly promiscuously; for sometimes you come to a Stratum of Marle, afterwards to a Stratum of Free-stone, Iron-stone, or the Pyrites; then to a Coal or Kennel-Mines, then to a Stratum of several kinds again, and then to Coals or kennel again, and sometimes to Coals above them all.[46]

Woodward's hypothesis therefore was rejected because it contradicted what Leigh actually observed. Robinson and Leigh thus rejected Woodward's theory of the Deluge but did not explain how the strata had been deposited.

These country virtuosi were only interested in the actual state of nature.

Those who lived in contact with London virtuosi, on the other hand, must have acquired a knowledge of up-to-date geological ideas discussed by Hooke and other Fellows of the Royal Society. Like Hooke they in fact postulated that several inundations had occurred which had brought about the present state of strata. For example, an author who identified himself only as L.P. published Two Essays, sent in a letter from Oxford, to a Nobleman in London (1695), in which the hypothesis of Woodward was critically examined.[47] It was his view that if we observe the strata of the globe, the metals are often at the top, and vegetable, testaceous and other animal-like bodies in the lower strata. The same shells and marine-like bodies moreover are found not only deep in beds of earth and stone, but also on the surface of the earth. It is difficult to conceive how leaves and light shells should subside in water with the much heavier parts of marbles and minerals, and be embedded with them in the same strata according to the principles of specific gravity. Arguing against Woodward, L.P. surmised that such phenomena revealed that the whole mineral kingdom had not been dissolved at the time of the Deluge.[48] Then he concluded:

> I cannot but continue in my old opinion, that the world was thus formed from the beginning, no total dissolution, nor any universal inundation; some particular great changes have happened, as new mountains by turning up of the earth; some new islands, especially at the mouths of great rivers, by their sediments of earth brought down from the land; some new lakes, by earthquakes, and some other mutations from particular floods or volcanoes...
> 49

L.P. thus insisted that there had been a multitude of small-scale regional changes which had formed the present state of the strata. Woodward's theory of the Deluge stimulated L.P. to consider the strata, but his theory itself was rejected because the order of the strata was not such as would have come about according to the law of specific gravity.

A similar view on the formation of the strata was maintained by John Arbuthnot (1667-1735), physician and wit, who lived in London and became a Fellow of the Royal Society in 1704. In his Examination of Dr. Woodward's Account of the Deluge (1697), Arbuthnot admitted that the strata near the surface of the Earth resembled a sediment which had been deposited in accordance with the law of gravity, but he made the observation that in general they were not arranged thus because sometimes the heavier layer lay uppermost. He held that the strata were the sediment from a fluid, but that they had not been all deposited at the same time: "their diversity and Order seems rather to persuade that they were compiled by little and little, and at different times." In Arbuthnot's view, therefore, Woodward's hypothesis was inconsistent with what had been observed in the field. If only, he wrote, "People were more diligent in observing, and more cautious in System-making."[50] Like Hooke, Arbuthnot explained the formation of strata by the notion of successive sedimentation.

The idea that the strata had been successively deposited was defended by a translation of an Italian geological work. Robert St. Clair suggested, in his Abyssinian Philosophy confuted : or, Telluris Theoria Neither Sacred, nor agreeable to Reason (1697), the cosmogony of Descartes did not greatly differ from the "Abyssinian", or Burnet's theory.[50] St. Clair's book was, for the most part, a translation of the Italian naturalist Petrus Ramazzini's Of the Wonderful Springs of Modena, in which Burnet's theory was critically discussed. In Ramazzini's view, it was certain that the surface of the Earth had been greatly changed at the time of the universal Deluge, but that the state of the world before the Deluge was not very different from what it is now. Ramazzini rejected Burnet's notion of an antediluvian Earth which had neither seas nor mountains, and he suggested that there was a constant change on the surface of the Earth. Referring to Ovid and Aristotle, Ramazzini assumed also that some plains in the Earth had once been a part of the sea:

> Yet this growing up of the Ground, which is observ'd by the great Depth of these Wells, ... was but slowly made, and by slices, as it were, through length of time, as the several Lays of Earth do witness, which are observed in all Wells constantly in an equal Order and Distances when they are digged; so that this growing up of the Ground...ought to be thought rather the Product of so many Ages, than the tumultuary and confus'd Work of the common Deluge.[52]

Ramazzini believed that the strata had been formed by several inundations including the Universal Deluge. He thus did not ignore the Deluge, but regarded it as one of several floods. The effect of the Universal Deluge was greatly minimized by Ramazzini, a tendency which was to prove essential for a better understanding of the process of the formation of the strata.

The works of L.P., Arbuthnot and Ramazzini which adopted the idea of cyclic change show that the question concerning the origin of strata became a new focus of geological attention. The change of emphasis reached to John Roy, who lived in Essex. On February 13, 1704, Ray wrote to Lhwyd that

> I am also to seek about ye original of beds or strata of severall kinds observed in broken mountains. I cannot imagine whence they should proceed but from the sedimts of land-flouds or inundations of the sea.[53]

Being convinced that the strata had not been deposited at the same time, Ray was sure that they had been formed by a series of floods.

Such were the criticisms which were levelled at the Deluge theories by natural historians in the 1690s. The publications of the Deluge theories were instrumental in stimulating a wider audience to more careful observations of geological phenomena such as the strata. By 1696 the Universal Deluge became "the Subject of most of the Philosophical Conversations of the Virtuosi about the Town."[54] Country virtuosi like Robinson and Leigh did not take the initiative in moulding and guiding a prevailing opinion as to the Earth's history. Their geographically isolated position hindered them from having an acquaintance with the latest geological arguments. As a result, they tended to become old-fashioned in their views, and Hooke called such a natural historian "a simple asse".[55] The geological phenomena, however, now attracted widespread attention throughout the country.

Virtuosi Ridiculed

The interaction of natural history and the Deluge theory led to a new stage in the development of Earth science. Unlike the fossil question which required specific knowledge to handle, the Deluge controversy attracted a wider audience as most men of those days were fairly familiar with the legend of Noah's Flood. Even if "public interest was not in minutiae" and was not to be engaged in "classifying fossils or charting the strata",[56] the large audience was a most important factor in the development of the science which had not been highly esteemed.

The controversy over the Deluge was followed by an extension of the meaning of the word "virtuoso". In the 1690s, when the Diluvial theories began to be discussed, the word "virtuosi" came to refer not only to collectors of rarities but also to theorists of the Earth. When arguing about the Creation and the Deluge, Thomas Burnet and Erasmus Warren called each other "virtuosi".[57] Thomas Robinson in attempting to point out where he could not concur with the theories of Burnet and Woodward, referred to them as "these great Virtuoso's". Robinson also referred to some "who value themselves upon Glittering Title of Virtuosi, and have undertaken to entertain the World with new Schemes and Theories of this Earth."[58]

Unlike fossil collecting, the theories of the Earth provided men with a framework for the Earth's history. Although criticizing Woodward's work, Lhwyd thought that it would have a good effect, because "these enquiries after Form'd Stones, & c. will not hence forward be thought so trivial, as not to deserve the attention of the best philosophers."[59] Neither were these theories, however, exempted from severe criticisms. Thomas Robinson was afraid of "some ill-natur'd and peevish Critick."

Charles Leigh sought protection from the members of Oxford University to evade "the Censorious Criticks".[60] In John Gray's vulgar comedy Three Hours after Marriage, John Woodward was portrayed in the guise of Dr Fossile. Virtuosi in every field were ridiculed by Mary Astell in her Essay in Defence of the Female Sex (1696). According to Astell, the virtuoso

> is one that has sold an Estate in Land to purchase one in Scallop, Conch, Muscle, Cockle Shells, Periwinkles, Sea Shrubs, Weeds, Mosses, Sponges, Coralls, Corallines, Sea Fans, Pebbles, Marchasites and Flint stones;... His study is like Noah's Ark, the general Rendezvous of all creatures in the Universe, and the greatest part of his Moveables are the remainders of his Deluge.
> ...
> He visites Mines, Colepits, and Quarries frequently, but not for that sordid end that other Men usually do, viz. gain; but for the sake of the fossile Shells and Teeth that are sometimes found there.[61]

The virtuoso searched for rarities in nature, but he also set up for a philosopher in his attempt to discuss the whole history of the Earth, inferring details from his collections. Thus he

> struts and swells, and despises all those little insignificant Fellows, that can make no better use of those noble incontestable Evidences of the Universal Deluge, Scallop and Oyster Shells, than to stew Oysters, or melt Brimstone for Matches. ... He shakes the World to Atoms with ease, which melts before him as readily as if it were nothing but a Ball of Salt. He pumps even the Center, and drains it of imaginary stores by imaginary

> Loopholes, as if punching the Globe full of holes cou'd make his Hypothesis hold Water. He is a Man of Expedition, and does that in a few days, which cost Moses some Months to compleat.[62]

W.E. Houghton surmised that Astell's virtuoso collected curiosities at random.[63] Astell, however, implicitly referred in the above passage to the hypotheses of Burnet and Woodward. Her virtuosi thus diligently collected strange stones and fossils and tried to use them to build up a philosophy. The word "virtuosi" acquired a new meaning as the realm of their activities was expanded. According to The Tatler (No.236, 1710), "several of our modern virtuosi" pursue natural philosophy, although "their speculations do not so much tend to open and enlarge the mind, as to contract and fix it upon trifles." A new type of virtuoso was mentioned here, one no longer content with mere collecting.

The various types of the virtuosi were fully examined by Anthony Ashley Cooper, third Lord of Shaftesbury (1671-1713) in his Characteristics. First, Shaftesbury defined the original meaning of the word, which included "the real fine Gentlemen, the Lovers of Art and Ingenuity" who

> have seen the World, and inform'd themselves of the Manners and Customs of the several Nations of EUROPE, search'd into their Antiquitys, and Records; consider'd their Police, Laws and Constitutions; observ'd the Situation,

> Strength, and Ornaments of their Citys, their principal Architecture, Sculpture, Painting, Musick, and their Taste in Poetry, Learning, Language, and Conversation.[64]

Before the mid-seventeenth century, the word "virtuoso" mainly referred to such well-cultured gentlemen. This type of virtuoso was never a target of criticism.

After the foundation of the Royal Society, its members had begun to collect natural curiosities and to keep them in cabinets. This type of virtuoso had become "the Subject of sufficient Raillery, and is made the Jest of common Conversations."[65] Furthermore, some virtuosi sought eagerly for rarities merely "for Rareness sake", and this truly deserved ridicule. Shaftesbury wrote, moreover, that the ridicule was directed against philosophers as well as virtuosi:

> Many things exteriour, and without our-selves, of no relation to our real Interests or to those of Society and Mankind, are diligently investigated:... Hypothesis and fatastick Systems erected; a Universe anatomiz'd;... Creation it-self can, upon occasion, be exhibited;...[66]

Shaftesbury included the theorists of the Earth among these philosophers and suggested that the defects of such philosophers and those of virtuosi were of the same nature. Most theorists seemed to be ridiculous because they attached great significance to trifles.

Virtuosi Defended

In spite of the bitter satire that was directed at virtuosi, they found some support for their undertakings. Arguing against Mary Astell, William Wotton emphasized:

> since so many Learned and Industrious Men have thought it worth their while to make Enquiries after the nicest Varieties, and most minute Productions of their Mother Earth, they have found such incredible Numbers of formed Stones, and Shells..., that they have thereby been enabled to raise several Hypotheses, hereafter, when Men are better acquainted with the Productions of the Subterraneous World, be a means of solving some of the greatest Difficulties in the Mosaical History.[67]

Wotton thus suggested that fossil collecting had enabled natural historians to reconstruct the history of the Earth. He thought that "excellent Naturalists" such as Edward Lhwyd and John Woodward deserved strong commendation for their seemingly useless labours. He advocated both fossil collecting and "world making". Moreover, even those who ridiculed virtuosi did not always reject the study of nature, as is illustrated by the satire:

> Nature is full of wonders; every atom is a standing miracle, and endowed with such qualities, as could not be impressed on it by a power and wisdom less than infinite. For this reason, I would not discourage any searches that are made into the most minute and trivial parts of the creation. (Tatler, No.216, 1710)

The activities of the virtuosi seemed ridiculous to those who thought that the study of nature was not an end but a means of becoming a "virtuoso". The study of natural phenomena "should be the diversions, relaxations, and amusements; not the care, business, and concern of life." (Tatler, No.216, 1710) Even though Shaftesbury criticized the virtuosi, he did not deny the value of speculation itself on the natural world, because virtuosity and philosophy were "in their nature, essential to the Character of a Fine Gentleman and Man of Sense."[68]

For the leisured class the study of nature not only made one a virtuoso but also was a source of pleasure. Edward Lhwyd in reply to the objection that fossil collecting was generally looked upon as trivial and unworthy wrote:

> Gentlemen & others who have sufficient estates, may if they please make these their main studies, since 'tis noe point either of Religion, Moralitie, or human reason to propose ye getting of money to be ye end of all our endeavours."[69]

Not only utility but also a search for pleasure seems to have excused men for studying the subterranean world. For example, one gentleman who had a lead mine in the mountains:

> took pleasure, not only in viewing the Management of that Work, but having a Mineral Spirit,

> and being Curious in making Natural Observations, took occasion frequently to survey our Mountains.[70]

In this way, the study of the Earth was pursued by curious gentlemen and ladies such as "the Reverend and universally Learned Dr. Ralph Bathurst, Vice-Chancellor of Oxford", "the virtuous young Lady Madam Ann Bowes of Elford" who had rarities in her "closet", "the learned Lady, the Lady Guise" who was in correspondence with the naturalist Charles Leigh, Mr. Hornsby, the Minister, who sent Thomas Robinson a bag full of pebbles, and "Edward Baynard, Esquire, Doctor of Physick, who ... Marry'd the Virtuous Lady Madam Ann Crackenthrop."[71] They ransacked every part of the earth to obtain natural curiosities because of "the desire of knowledge, and the discovery of things yet unknown."[72] Captain Hicks made his living by furnishing ladies' "closets" with various shells.[73] For gentlemen and ladies the knowledge of natural history was an ornament.

The popularity of natural history can be also verified by a number of collections of rarities. Richard Mead (1673-1754), a successful physician, had a spacious house in Great Ormond Street, which "became a repository of all that was curious in nature or in art, to which his extensive correspondence with the Learned in all parts of Europe not a little contributed." Robert Hubert, "Gent. and sworn servant to his Majesty", had a collection of "divers stones of strange shapes and regular forms." William Courten or Charleton (1642-1702) was a "most curious preserver of both natural and artificial rarities, which were bequeathed on his death to Sir Hans Sloane whose collections became the trunk of the British Museum."[74] The study of natural history was thus provided its institutional foundations.

NOTES

1. Cf. Hunter, Science and Society,80-81.
2. Edward Lhwyd, "Life and Letters of Edward Lhwyd", in Early Science in Oxford, ed. by R.W.T. Gunther, vol. XIV (Oxford, 1945), 393.
3. Porter, The Making of Geology, 53.
4. Lhwyd, "Life and Letters", 79-80.
5. John Ray, Further Correspondence of John Ray, ed. by R.W.T. Gunther (London, 1928), 207.
6. Ibid., 210.
7. Lhwyd, "Life and Letters", 110; John Ray, The Correspondence of John Ray, ed. by E. Lankester (London, 1848), 227.
8. Ray, Further Correspondence, 213.
9. Ibid., 216-17.
10. Ibid., 218.
11. Ibid., 223.
12. Lhwyd, "Life and Letters", 159.
13. Ibid., 162-63.
14. Ibid., 167-68.
15. Ray, Further Correspondence, 231.
16. Lhwyd, "Life and Letters", 171.
17. Ray, Further Correspondence, 237.
18. Ibid., 242.
19. Lhwyd, "Life and Letters", 257.
20. Ibid., 268.
21. Ray, Further Correspondence, 257, 259.
22. Ibid., 265.

23. Ray, Further Correspondence, 267.

24. Lhwyd, "Life and Letters", 283.

25. Ibid., 364-65.

26. Ibid., 381.

27. Ibid., 389-90.

28. [Charles King], An Account of the Origin and Formation of Fossil-Shells (London, 1705), 82-3.

29. Porter, The Making of Geology, 49.

30. Thomas Robinson, The Anatomy of the Earth (London, 1694), 21.

31. Thomas Robinson, An Essay towards a Natural History of Westmorland and Cumberland (London, 1709), 26.

32. Ibid., 31.

33. Ibid., 33.

34. Charles Leigh, The Natural History of Lancashire, Cheshire and the Peak in Derbyshire (London, 1700), 59.

35. Ibid., 62.

36. Ibid., 62-3.

37. Ibid., 99.

38. Ibid., 60.

39. The Deluge theory did not always favour the organic theory. Although admitting that there were several floods, one writer thought that they had nothing to do with fossils. Supporting Lister, he claimed that all the marine-like bodies dug out of the bowels of the Earth might be original creatures of the earth rather than total strangers brought in by universal inundations. He thought that there was no contradiction or absurdity in ascribing the origin of these objects resembling marine shells to the plastic power of the earth. (L.P., Two Essays, 31) He believed in an inorganic origin of fossils, because he thought it was difficult to explain the location of fossils even by several inundations.

40. Richard Richardson, Extracts from the Literary and Scientific Correspondence of Richard Richardson (Yarmouth, 1835), 63.

41. William Nicolson, Letters on Various Subjects... to and from William Nicolson, ed. by J. Nicolson, vol.1 (London, 1809), 33.

42. James Yonge, "An Account of Balls of Hair taken from the Uterus and Ovaria of Several Women", Phil. Trans., no.309 (1707), 2291.

43. Frank Nicholls, "Some Observations towards composing a Natural History of Mines and Metals", Phil. Trans., No.401 (1728), 404.

44. William Borlace, "An Enquiry into the original State and Properties of Spar, and Sparry Productions, particularly, the Spars, or Crystals found in the Cornish Mines, called Cornish Diamonds", Phil. Trans., No.493 (1749), 252.

45. Robinson, New Observations, Advertisement with Additional Remarks.

46. Leigh, Natural History, 66.

47. Whoever wrote these essays, it was Tancred Robinson, physician in ordinary to George I, who organized the attack on Woodward. (Cf. The Dictionary of National Biography)

48. L.P., Two Essays sent from Oxford, 1695, in A Collection of Scarce and Valuable Tracts, ed. by John Somers, vol. 12 (London, 1814), 22.

49. Ibid., 23.

50. John Arbuthnot, An Examination of Dr. Woodward's Account of the Delug, &c. (London, 1697), 24, 62.

51. Robert St. Clair, Abyssinian Philosophy confuted: or, Telluris Theoria Neither Sacred, nor agreeable to Reason (London, 1697), To the Reader.

52. Ibid., 116.

53. Ray, Further Correspondence, 284.

54. William Wotton, A Letter...concerning an Abstract of A. Scilla's Book, in John Arbuthnot, An Examination of Dr. Woodward's Account of the Deluge (London, 1697), 66.

55. Robert Hooke, The Diary of Robert Hooke 1672-1680, ed. by H.W. Robinson & W. Adams (London, 1935), 292.

56. Porter, The Making of Geology, 88.

57. Erasmus Warren, Geologia, or a Discourse concerning the Earth before the Deluge (London, 1690), 43; Thomas Burnet, A Short Consideration of Mr Erasmus Warren's Defence of this Exceptions against the Theory of the Earth (London, 1691), 476.

58. Robinson, New Observations, To the Reverend; Robinson, Essay, Preface.

59. Lhwyd, "Life and Letters", 268-69.

60. Robinson, New Observations, To the Reverend; Leigh, Natural History, The Epistle Dedicatory.

61. Mary Astell, An Essay in Defence of the Female Sex (London, 1696), 96-8.

62. Ibid., 99-100.

63. Houghton, "English Virtuoso", 54.

64. Anthony Ashley Cooper, third Lord of Shaftesbury, Characteristicks, vol. III (London, 1737), 156.

65. Ibid., 157.

66. Ibid., 160.

67. William Wotton, Reflections upon Ancient and Modern Learning (London, 1697), 273.

68. Shaftesbury, Characteristicks, III, 161.

69. Edward Lhwyd, "Life and Letters", 78.

70. Robinson, Essay, 42.

71. Robert Plot, The Natural History of Oxfordshire (Oxford, 1677), 131; Robert Plot, The Natural History of Staffordshire (Oxford, 1686), 179; Leigh, Natural History, 120; Robinson, Essay, 32, 42.

72. Astell, Essay, 102.

73. Hunter, Science and Society, 66.

74. David Murray, Museums: Their History and their Use, vol. I (Glasgow, 1904), 123, 129, 140.

9. DIVINE PROVIDENCE AND THE MECHANICAL PHILOSOPHY

While Woodward's hypothesis regarding to the order of the strata was criticized on the scientific ground that it was contrary to observed facts, Burnet's theory was regarded as a serious offence against Divine Providence and was examined from a theological as well as a scientific point of view. Calvin had denied a number of superstitions relating to Christian doctrine, and the rise of the mechanical philosophy tended to separate the role of God from natural necessity. The miracles recorded in the Bible, however, were still regarded as the foundation of the Christian religion. To be skeptical of them was considered tantamount to doubting Christianity itself. As the Earth's history could not be written without referring to the Biblical accounts, Burnet's emphasis on natural causes raised the question of whether the Deluge might be made an object of scientific study.

The Removal of the Supernatural Cause

The Earth's history could be considered a subject of scientific enquiry if the miracles in the Bible were removed from historical arguments. Attempting to explain the Universal Deluge in natural terms, Edmond Halley (1656-1742) omitted the supernatural from his discussion on it, denying the existence of miraculous phenomena. He delivered an essay on the Deluge before the Royal Society in 1694, which was printed at a later date in the Philosophical Transactions (1724). Being primarily concerned in his paper with fossil remains,[1] Halley regarded Burnet's hypothesis as irrelevant. Halley's essay on the Universal Deluge was, in fact, a reply to Robert Hooke's solution to the problem, namely that the Deluge had been caused by a compression of the Earth into a prolate spheroid which had forced the water of the abyss out under the crust. Halley claimed that only the two poles would be covered with water in such a compression of the globe, and moreover, "such a supposition cannot well be accounted for from physical causes, but requires a preternatural digitus Dei, both to compress, and afterwards to restore the figure of the globe." Halley did not accept an explanation of natural phenomena which was dependent on such a supernatural cause, because, he said, God generally makes use of "natural means to bring about His will."[2] In contrast to Woodward, who did not seriously consider the question of the cause of the extraordinary Deluge, Halley regarded it as being in the realm of natural phenomena.

Halley proposed the collision of the Earth with a comet as an expedient to explain such strange phenomena as the vast quantities of earth overlaying beds of shells which had been once the sea bed. Such a collision, he said, would have caused waters to run violently towards that part of the globe which was the point of impact. The force of the waters would have been sufficient to rake the entire bed of the ocean and to carry it up on to the land, which may account for the long continuous ridges of mountains.

Halley's theory of a natural cause for the Deluge was followed by William Whiston, who was engaged as Newton's assistant lecturer in mathematics at Cambridge. Whiston's most important work is A New Theory of the Earth (1696), which was dedicated to Newton and went through six editions. Under the influence of Halley's theory Whiston made the hypothesis that the Earth had been formed from the atmosphere of a comet and that Noah's Flood had been caused by the approach of a comet. That is, like Halley, he tried to show how the events described in Scripture could have been brought about by natural causes.

Whiston protested that Woodward's hypothesis was "so strange, and so miraculous in all its Parts; 'tis so wholly different from the natural series of the Mosaick History of the Deluge."[3] Whiston nevertheless highly esteemed Woodward's hypothesis and often referred to him. Like Woodward, Whiston thought that the great number of shells, bones of animals and plants, whether complete or in part, had been buried at the time of the Deluge. The parts of the present upper strata had been broken into fragments and had floated in the waters of the Deluge, and then descended by degrees and settled on the bottom almost in accordance with the law of specific gravity. In regard to these effects of the Deluge Whiston fully agreed with Woodward that fossiliferous strata had been deposited in the water. Whiston, however, did not accept Woodward's view that the Deluge had been miraculous.

Both Halley and Whiston thus attempted to give an explanation of the process of the Universal Deluge without relying on supernatural causes. It was dangerous, however, to exclude the supernatural from theories relating to the Deluge. Halley, in fact, initially refrained from publishing the paper on the Deluge "lest by some unguarded Expression he might incur the Censure of the Sacred Order." When his paper was published in 1724,[4] the Deluge controversy was over and it did not attract much attention. On the other hand, in 1701 Whiston became

Newton's deputy at Cambridge and then succeeded Newton as Lucasian Professor, but in 1710 the University expelled him for his heterodoxy. He was even excluded from the Royal Society by the opposition of Newton. Moreover, the Scottish Presbyterians banned Whiston's New Theory of the Earth.[5] Neither the geological ideas of Halley nor those of Whiston did exert a substantial influence on their contemporaries.

The Burnet Controversy

An early and typical expression of orthodox objections to Burnet was raised by Herbert Croft, Bishop of Hereford, who realized the danger of explaining the Earth's history by mechanical principles.[6] Croft felt that Burnet gave him "sufficient ground to affirm, that either his Brain is crackt with over-love of his own Invention, or his Heart is rotten with some evil design." It was Croft's view that Burnet "will stick to his own method of having Natural Causes for all things, and will not allow God the liberty to use any extraordinary means."[7] In other words, Burnet was wrong in permitting no miraculous intervention in the Deluge and explaining it by natural causes.

A similar but more substantial attack by Erasmus Warren, rector of Worlington in Suffolk, was published in 1690 under the title of Geologia: or a Discourse concerning the Earth before the Deluge. Warren wrote that Burnet had struck at the root of religion and that was why the manuscript of his work had had difficulty in passing the censorship:

> The Book has laid by in Manuscript a great while. Why it did so, is well known to some good Men; and I need not trouble all with the Reasons of it.[8]

As Warren indicated, Burnet's work had been examined by the censors for a longer time than Burnet had expected. Warren recognized at least that Burnet's approach to the Earth's history was a direct challenge to Christian doctrine.

Warren criticized the Cartesian system, upon which the theory of Burnet was based:

> It only shows, that the French Philosopher (of so great fame) is too short to fathom the deeps of Nature, and by no means quicksighted enough to see to the bottom of her profound Mysteries.[9]

Warren condemned Descartes for his excluding miracles, which, he said, threatened the authority of the Bible. As Descartes had done, Burnet based his arguments on natural causes. In his view therefore the world would have been submerged regardless of whether or not mankind had sinned. It was precisely this matter which Warren was disputing. Warren asserted that God must have altered the course of nature to bring about the Universal Deluge because a change in the way of thinking in itself could not have affected a change in the course of events in the physical world.[10]

Warren opposed Burnet's idea that the disruption of the Earth's crust into the abyss had caused the Universal Deluge. He considered that the waters of the Deluge had not produced the dramatic change which Burnet had suggested, and explained it in a different way. In regard to the overflowing of the waters, Warren argued that there was a great error in the common hypothesis concerning the waters' depth. Whereas they had been estimated to be fifteen cubits higher than the highest mountains, it was his view that they were only fifteen cubits higher than the average level of the Earth.[11] Warren's explanation of the Deluge was thus not dependent on the large quantity of water demanded by that of Burnet. Warren nevertheless considered the Universal Deluge extraordinary:

> The Flood was a Miracle in good measure. Or had so much miracle running through it, and interwoven with it; that all passages in it, are not to be accounted for by Reason and Philosophy. And truly where Nature was

> over-ruled by Providence; it is but fit that Philosophy should give place to Omnipotence: and Faith sway our Minds to assent to those things, which Reason is unable to apprehend and explicate.[12]

In reply to Warren, Burnet published An Answer to the Exceptions made by Mr. Erasmus Warren against The Theory of the Earth (1690). Although Warren had criticized him for excluding an extraordinary Providence which had inflicted the punishment of the Deluge upon mankind, Burnet asserted that his theory did contain a full account of both an ordinary and an extraordinary Providence in reference to the Deluge. God was assumed to be the arbiter of the natural as well as of the moral world. However, Burnet's method of interpreting the Bible did suggest the possibility that miracles might be excluded from an exposition of Genesis:

> Upon the whole, you see, it is no Fault to recede from the literal Sense of Scripture; but the Fault is, when we leave it without a just Cause:... ... We all leave the literal Sense in certain Cases, and therefore that alone is no sufficient Charge against any Man. But he that makes a good Separation, if I may so call it, without good Reasons, he is truly obnoxious to Censure.[13]

Burnet claimed that man should not leave the literal sense of the Scripture where it could be interpreted without absurdity. From this statement, however, he perceived other instances where allegorical interpretation might be permissible.

Criticizing Burnet's theory as a threat to religion, Warren returned the attack with A Defence of the Discourse concerning the Earth before the Flood, being a full Reply to a late Answer to Exceptions made against the Theory of the Earth (1691). The principal aim of this work "is farther to defend the truth of God, and to rescure some Texts of the Holy Bible from such imputations of falsehood, as the Doctrine of the Theory involves them in."[14] According to Warren, if the least single passage of God's word were shown to be false, it would show the rest to be false also. He never accepted the idea that the Bible was written allegorically.

Although Burnet considered the moral world, it is obvious that he initially attempted to establish the Earth's history as an independent scientific subject. In his Short Consideration of Mr. Erasmus Warren's Defence of his Exceptions against the Theory of the Earth (1691), Burnet defended himself as follows:

> The Truth is, this Gentleman hath a mind to appear a Virtuoso, for the new Philosophy, and the Copernican System; and yet would be a Zealot for Orthodoxy, and the Church-way of explaining Things: Which two Designs do not well agree, as to natural World: and betwixt two Stools he falls to the Ground, and proves neither good Churchman, nor good Philosopher.[15]

Burnet realized that there was a contradiction between orthodox doctrines relating to the moral world and the new scientific arguments concerning the natural world. Until this problem was resolved, the study of the Earth's history could not fully develop. Burnet's efforts were concentrated on enlarging the realm governed by natural causes. Arguing against Warren, Burnet protested at his abrupt censure that Burnet did only rely upon natural causes and did not argue from final causes. For Burnet, natural causes were sufficient in themselves to reveal what had occurred in the past:

> ...if this be the Use he makes of final Causes, to tell God Almighty what is best to be done, in this or that World, I had rather content myself with physical Causes, to know what God hath done...[16]

The removal of miracles from natural necessity which had taken place in the study of present-day natural phenomena, thus spread to speculation on the past state of the Earth. Even if, as Roy Porter claims, the Burnet-Warren controversy had been fruitless,[17] the controversy was an unavoidable step forward a scientific study of the Earth's history.

Erasmus Warren was not the only author who attacked the Cartesian philosophy and its mechanical view of nature. In a similar way John Keill criticized the theory of Burnet in his Examination of Dr. Burnet's Theory of the Earth. Together with some Remarks on Mr. Whiston's New Theory (1698), and claimed that Cartesianism was incompatible with the Scripture. Keill attended the University of Edinburgh, studying under David Gregory, whose teaching was based on the newly published Newtonian philosophy. Keill received a M.A. before going on to Oxford with Gregory. In 1712 he became Savilian professor of astronomy, and remained there until his death in 1721. Keill was one of the most important of the followers of Newton who transmitted his philosophical principles to the scientific and intellectual community. He asserted that natural philosophy should acknowledge the important role played by Divine Providence, and attacked Cartesian natural philosophy, on which reconstructions of the world were based:

> ...M. Des Cartes the great Master and deliver of the Philosophy from the tyranny of Aristotle, is to be blamed for all, for he has encouraged so very much this presumptuous pride in the philosophers, that they think they understand all the works of Nature, & are able to give a good account of them, whereas neither he, nor any of his followers, have given us a right explication of any one thing. So ridiculous are the things he has delivered in his principles of Philosophy, that it is a wonder how they should be believed by any, but it is still a greater wonder how they came to be so much applauded and received among the Learned,...[18]

Keill also criticized the "sacred writers" who not only claimed that the world had been created by the laws of mechanism without the extraordinary concurrence of divine intervention, but also that all the great catastrophes such as the Universal Deluge were the necessary consequences of natural causes. To Keill's mind, "flood-makers" gave the atheists an argument to support their cause, which "can only be truely answer'd by proving an universal Deluge from Mechanical causes altogether impossible."[19] He thought it incorrect to explain the Creation and the Deluge by natural causes alone. The Bible gives an account of several miracles wrought by the hand of God, and it was Keill's belief that the miraculous character of this universal destruction of the Earth should not be denied:

> Miracles are the great & wonderful works of God, by which he sheweth his Dominion and Power, and that his kingdom reacheth over all, even Nature herself, and that he does not confine himself to the ordinary methods of acting, but can alter them according to his pleasure.[20]

Keill, a competent mathematician, was convinced that the functions of natural laws at present in operation within our own experience could be determined by observation and mathematical analysis. In his opinion, however, the miraculous phenomena described in the Bible were not to be understood by human deduction. The Aristotelian notion of final causes became the butt of bitter criticism in the seventeenth century, and thus God tended to be excluded from speculations on nature, although He might still play an important role as an efficient cause. The mechanical philosophers made a pretence of showing the manner in which the universe had been formed by the principles of matter and motion and did not concern themselves with the end for which God made anything. Keill claimed, however, that final causes were certainly worthy of the consideration of all men because through them Divine Providence was revealed. Keill's criticism of Burnet and Whiston was part of a general attack on Cartesianism and was eventually favourable to the Newtonian system.

In 1699 Keill again wrote against Burnet under the title, An Examination of the Reflections on The Theory of the Earth, Together with A Defence of the Remarks on Mr. Whiston's New Theory, in which he once more advocated the supremacy of Divine Providence. On this occasion he referred to Christiaan Huygens' theory of the Creation:

> Monsieur Huygens I think, was at least as great a Philosopher as the Theorist [i.e. Burnet], and it may be easily suppos'd, that he understood Mechanism somewhat better; yet he says, that he would be contented, and should think, that he had done a great matter if he could come to the knowledge of things as they are now, never troubling himself about their beginning, or how they were made, knowing that to be out of the reach of human knowledge, or even conjecture.[21]

To Keill's mind, the whole process of the creation of the world was the work of the direct hand of God, who had accomplished the task without the need of second causes. Such an opinion was certainly in accordance with

Huygens' statement that it was impossible to know the nature of things at the beginning.[22] Burnet was mistaken in his having this world come about through mechanical principles and in his assigning natural causes to the extraordinary events described in the Bible. It was Keill's view that questions relating to the Earth's history were beyond scientific research and should be considered exclusively in terms of Divine Providence.

Gordon L. Davies has suggested that "paradoxically, Keill, the scientist, was eager to invoke supernatural forces in explanation of events in Earth-history, while Burnet, the cleric, was equally eager to demonstrate the entire sufficiency of natural processes."[23] This comparison misses the point that there was no clear distinction between scientists and theologians in the seventeenth century. The issue raised by the controversy was whether the study of the Earth's history could be a scientific subject independent of Divine Providence.

The Existing Order of Nature

The rejection of the mechanical philosophy was associated with the defence of traditional doctrine. Isaac Newton had realized this discrepancy between the mechanical conception of nature and the traditional Christian doctrine of providence. When Thomas Burnet sent him a copy of Telluris Theoria Sacra prior to its publication, Newton took objection to some passages in it, while remarking that "Of our present seas, rocks, mountains etc., I think you have given the most plausible account."[24] As Burnet had done, Newton admitted an allegorical interpretation of the Mosaic account of the Creation, saying that Moses had described reality "in a language artificially adapted to the sense of the vulgar." Newton, however, suggested an alternative theory to that of Burnet, that mountains had been formed at the Creation:

> As I am writing, another illustration of the generation of hills proposed above comes into my mind. Milk is as uniform a liquor as the chaos was. If beer be poured into it, and the mixture let stand till it be dry, the surface of the curdled substance will appear as rugged & mountanous as the Earth in any place.

Newton thus explained the generation of mountains in a different way from Burnet who surmised that there had been no mountains at the time of the Creation. Newton was, however, in general agreement with Burnet and reassured him that "All this I write not to oppose you, for I think the main part of your Hypothesis as probable as what I have here written, if not in some respects more probable."

Although Newton was thus prepared to ascribe the natural phenomena of the past to natural causes, he did not exclude God's hand from the entire natural world. He confessed that he did not know of any convincing natural cause for the Earth's diurnal motion:

> Where natural causes are at hand God uses them as instruments in his works, but I do not think them alone sufficient for ye creation & therefore may be allowed to suppose that amongst other things God gave the earth it's motion by such degrees & at such times as was most suitable to ye creatures.

In 1692 Newton confirmed this theory relating to Divine Providence in a famous letter to Richard Bentley, writing that "the Motions which the Planets now have could not spring from any natural Cause alone, but were impressed by an intelligent Agent."[25] It was plain to Newton that there was no natural cause which could determine the movement of all the planets in the same manner and on the same plane. This must, he concluded, have been effected by divine wisdom. The very beginning of the Creation was thus removed from the realm of scientific research.

Newton declared his acceptance of basic criticism against the mechanical theory of the Creation in his Opticks published in 1706. In its famous 31st Query he wrote:

> Now by the help of these Principles, all material Things seem to have been composed of the hard and solid Particles above-mention'd, variously associated in the first Creation by the Counsel of an intelligent Agent. For it became him

> who created them to set them in order. And if he did so, it's unphilosophical to seek for any other Origin of the World, or to pretend that it might arise out of a Chaos by the mere Laws of Nature; though being once form'd, it may continue by those Laws for many Ages.

Richard S. Westfall has claimed that Newton "could not really tolerate the thought that God might upset the laws of nature which He had created."[26] But the above quotation indicates that Newton believed that the world would continue by the laws of nature for "many Ages", but not forever. Westfall's claim contradicts the following note in the Portsmouth Paper, too. Newton said that

> For miracles are so called, not because they are the works of God but because they happen seldom and for that reason create wonder. If they should happen constantly according to certain laws impressed upon the nature of things, they would be no longer wonders or miracles but would be considered in philosophy as part of the phenomena of nature notwithstanding that the cause of their causes might be unknown to us.[27]

It is a mistake to claim that Newton's world left no place for a direct providence of God. What he said was that miracles were only rare events. This is the way how Newton excluded miracles from the "ordinary" course of nature.

Newton's view of God's Providence can be also found in his Principia, where, in the concluding "General Scholium", he claimed that "All that diversity of natural things which we find suited to different times and places could arise from nothing but the ideas and will of a Being necessrily existing" and "He endures forever, and is everywhere present". But as miracles seldom happen, the course of nature is normally natural: "God suffers nothing from the motion of bodies; bodies find no resistance from the omnipresence of God." Thus Newton thought that one would not have to consider miracles in a discussion about the existing order of nature. Newton, in the "Query" and "General Scholium", limited his field of scientific research to the present natural phenomena, working in accordance with the laws of nature.

In his argument about the Universal Deluge, Woodward adopted the same method of study as Newton did. John Ray, referring to Woodward's theory, wrote to Lhwyd that "the new theory seems to me pretty odd and extravagant and it is borrowed of Mr. Newton in great part."[28] In fact, Woodward thought it important to consider the specific gravity of bodies when discussing the order of the strata which he said had deposited at the Deluge. He claimed that the power of gravity surpassed all powers of nature and did not proceed from any unstable agents, but emanated from a firm foundation,

> being intirely owing to the direct Concourse of the Power of the Author of Nature, immediately in his hand, and the main Engine whereby this stupendous Fabrick of the Universe is managed and supported...[29]

Thus, like Newton, Woodward ascribed the cause of gravity to God, the Author of Nature, and rejected the Cartesian idea that subtle matter could produce gravity in bodies. For Woodward the mechanism of gravity could not be explained by mechanical principles alone.

In Woodward's view the whole frame of nature depends on the Author of Nature and on this premise he argued against the Epicurean idea that the world was formed by chance. According to Epicurus, the world was not formed by any higher principle than an accidental congress of atoms: as every part of the world is in constant change, so the sea overflowed the land in some places and the ground was raised to a higher level than the sea floor. Woodward opposed ,however, the idea of constant change in the natural world, and claimed that God, who had in the beginning created this world out of nothing, would continue to preserve it until the reason for its preservation ceased.[30] He believed that God had created the world in such a way that nothing was done without his continual government.[31] The Aristotelian idea of the succession of all natural things was rejected because it completely ignored Divine Providence. The Earth, the sea and all natural things were thought to continue in the same state without the slightest decay unless God's mighty power were not exercised in the natural world.

Woodward in fact found it difficult to explain the universality of the Deluge in terms of natural causes. Hooke had solved the question of the universality of the Deluge by introducing the idea that an interchange of land and sea had occurred at the time of Noah's Flood. Woodward, however, in rejecting such an idea of interchange, was forced to consider possible sources of water which would be sufficient to cover the whole surface of the Earth. He pointed out that Burnet had envisaged a smooth antediluvian Earth much like that of Descartes, which made it easy for him to account for the universality of the Deluge. Woodward, nevertheless, did not agree that the surface of the Earth had been smooth before Noah's Flood. A Universal Deluge, therefore, was more difficult for him to explain by natural causes, and finally he abandoned his search for the sources of water:

> For my part, my Subject does not necessarily oblige me to look after this Water: or to point forth the place whereinto 'tis now retreated. For when, from the Sea-shells, and other Remains of the Deluge, I shall have given undeniable Evidence that it did actually cover all Parts of the Earth, it must needs follow that there was then Water enough to do it, wherever it may be now hid, or whether it be still in being or not.[32]

Woodward thus argued that it was unnecessary to discuss the causes of the Deluge, because his aim in his book was merely to show evidence that the Earth had been submerged at the time of the Deluge. However, he promised that he would discuss the causes of the Deluge in a larger work which in fact was never published.[33] Just as Newton did not explain the cause of the gravitational attraction which operates over long distances without physical contact, so Woodward ceased his investigation into the causes of the Universal Deluge.

Woodward also criticized Burnet's explaining the Universal Deluge in terms of natural causes. In his view, the Earth was destroyed by Divine Providence at the time of the Deluge:

> That the Deluge did not happen from an accidental Concourse of Natural Causes as the Author above-cited is of Opinion. That very many Things were then certainly done, which never possibly could have been done without the Assistance of a Supernatural Power. That the said Power acted in this Matter with Design, and with the highest Wisdom. And that, as the System of Nature was then, and is still, supported and established, a Deluge neither could then, nor can now, happen naturally.[34]

Woodward thus claimed that natural phenomena were in the control of the Author of Nature and that the Universal Deluge had been caused through divine intervention. In other words, certain natural phenomena could not be explained without referring to a supernatural cause.

Woodward emphasized the importance of Divine Providence which could bring about extraordinary events, but at the same time he confined his research to a study of the existing order of nature. He put the supernatural cause to one side because he attempted to investigate nature scientifically. Woodward carefully avoided discussing a matter which could not be subjected to observations. All scientific statements, he said, had to be based on genuine facts. From this point of view Woodward criticized Burnet's theory of the antediluvian Earth. For Woodward, Burnet's theory had no real foundation in nature or history.[35] Burnet had suggested that the surface of the Earth before the Deluge was smooth, but Woodward believed that it was covered with mountains, valleys, plains, seas, lakes and rivers. He asserted that the remains of shellfishes were evidence in support of his theory:

> As the Sea-shells afford us a sure Argument of a Sea, so do the River-ones of Rivers in the Antediluvian Earth. And if there were Rivers, there must needs also have been Mountains; for they will not flow unless upon a Declivity,...[36]

Unlike Burnet, Woodward did not describe the state of the antediluvian Earth in detail and only suggested that there had been mountains and sea before the Deluge. It was sufficient for him to point out that fossil remains had deposited at the Universal Deluge.

Woodward's view of nature can be also found in his letter to Gottfried Wilhelm von Leibniz. Woodward criticized him for postulating a grand theory of the Earth. Leibniz was interested in questions concerning the Creation and the Deluge, and formulated his ideas in his Protogaea (1691), in the context of a general history of Brunswick from the time of the Creation. A summary of this work was presented in the Acta Eruditorum of Leipzig (1693), but the larger work did not appear until 1749. Like Descartes, Leibniz believed that the Earth was once a smooth molten globe, and admitted some kind of collapse of the crust into subterranean depths of water as the cause of the Deluge. Woodward, however, strongly opposing Leibniz' views, wrote to him as follows:

> I had determined neither to advance nor to assert anything which was not either manifest from observation of the thing itself or declared by the authority of Holy Scripture.[37]

Leibniz defended his views and the method of Descartes and claimed that it was possible to give a more liberal interpretation of the Bible. Such an opinion, however, was precisely what Woodward had opposed. To Woodward's mind, the Creation and the Deluge were of a miraculous nature and could not be adequately explained by mechanical principles. On another occasion, Woodward insisted that his work on medicine was founded entirely "upon Nature, Observations, and Fact, and not spun as usual out of

Fancy, or drawn out of the Writings of others."[39] Both Newton and Woodward claimed that it was wrong to exclude Divine Providence from the course of nature, and concentrated their attention upon the existing order of nature. It was not coincident that the success of Newton and Woodward occurred precisely at the same time.

NOTES

1. In 1687 Halley wrote to John Wallis that "Mr. Hook read a further discourse of his, being by way of Introduction to a Theory of his concerning petrified shells & c. found on the tops of hills & deep ground." (Halley, 1937, 77) Halley was thus familiar with the debate as to the origin of fossils. On 13 October 1694, Halley reported at the Society's meeting that there was near Reading a very large bed of oyster shells which lay bare to the open air and covered a good part of the surface of a large valley. (Journal Book) He was fully convinced that these remains of marine bodies had been once under the sea.

2. Edmond Halley, "Some Considerations about the Cause of the Universal Deluge," Phil. Trans., No.383 (1724), 121.

3. William Whiston, A New Theory of the Earth (London, 1737), 276.

4. Halley, "Some Considerations", 118-25.

5. Abraham de la Pryme, The Diary of Abraham de la Pryme (Edinburgh, 1870), 159.

6. The question of the Biblical miracles had earlier been discussed by Jean Baptiste Bossuet, bishop of Meaux, and Baruch de Spinoza. Arguing against Spinoza's view of the Bible, Bossuet attempted to write the history of the world by treating the Bible as the source of all historical truth. However, Spinoza, in his Tractatus Theologico-Politicus (1670), critized the first five books of the Old Testament and excluded the possibility of miracles on the ground of his mechanical philosophy. (Cf. H. Kearney, Science and Change 1500-1700, 224-26.)

7. Herbert Croft, Some Animadversions upon a Book intituled the Theory of the Earth (London, 1685), Preface, 39.

8. Erasmus Warren, Geologia: or a Discourse concerning the Earth before the Deluge (London, 1690), To the Reader.

9. Ibid., 89.

10. Ibid., 124.

11. Erasmus Warren, Geologia, 300.

12. Ibid., 355.

13. Thomas Burnet, An Answer to the Exceptions made by Mr. Erasmus Warren against the Theory of the Earth(1690), In Thomas Burnet, The Sacred Theory of the Earth (London, 1759), 444.

14. Erasmus Warren, A Defence of the Discourse concerning the Earth before the Flood, being a full Reply to a late Answer to Exceptions made against the Theory of the Earth (London, 1691), 2.

15. Thomas Burnet, A Short Consideration of Mr. Erasmus Warren's Defence of his Exceptions against the Theory of the Earth (1691), in Thomas Burnet, The Sacred Theory of the Earth (London, 1759), 476.

16. Ibid., 500.

17. Porter, Making of Geology, 85.

18. John Keill, An Examination of Dr. Burnet's Theory of the Earth. Together with some Remarks on Mr. Whiston's New Theory (London, 1698), 11-12.

19. Ibid., 12.

20. Ibid., 32.

21. John Keill, An Examination of the Reflections on the Theory of the Earth, Together with a Defence of the Remarks on Mr. Whiston's New Theory (London, 1699), 34.5.

22. Christiaan Huygens, The Celestial Worlds discover'd (London, 1698), 160.

23. Davies, The Earth in Decay, 73.

24. Isaac Newton, The Correspondence of Isaac Newton, ed. by H.W. Turnbull, Vol. II (Cambridge, 1960), 329.

25. Isaac Newton, Four Letters from Sir Isaac Newton to Doctor Bentley (London, 1756), 5.

26. Richard S. Westfall, Science and Religion in Seventeenth-Century England (The University of Michigan Press, 1973), 204.

27. L.T. Moore, Isaac Newton, a Biography (New York, 1934), 623.

28. John Ray, Further Correspondence of John Ray, ed. by R.W.T. Gunther (London, 1928), 227, 301.

29. Woodward, Essay, 57.

30. Ibid., 60-61.

31. In the famous controversy (1715-17) with Leibniz, Samuel Clarke defended Newton's point of view on the Providence of God. In this controversy, the two men debated the religious implications of the mechanical philosophy. Clarke, following Newton, argued that the universe needed continual divine government. Leibniz regarded such a conception as a derogation from God's perfection, and insisted that God must be perfect and foresaw everything. Woodward's opinion as to this question was just the same as Clarke's. [Cf. Alexandre Koyré, From the Closed World to the Infinite Universe (The Johns Hopkins University Press, 1957), 236-72.]

32. Woodward, Essay, 162-63.

33. Ibid., 163.

34. Ibid., 165-66.

35. Ibid., 245.

36. Ibid., 254-55.

37. Joseph M. Levine, Dr. Woodward's Shield (University of California Press, 1977), 112.

38. Woodward to Scheuchzer, Feb. 13, 1719. Cited in Joseph M. Levine, Dr. Woodward's Shield (University of California Press, 1977), 11.

10. THE RISE AND FALL OF WOODWARD'S THEORY

V.A. Eyles has suggested that "no one would compare Woodward's scientific attainments with those of his contemporary, Newton, yet, as a naturalist whose work attracted much attention not only in Britain but also in much of Europe, both during and after his lifetime, he deserves recognition by historians of Science." Although Roy Porter has claimed that "Newton had his principate, but of Earth science there was no king,"[1] Woodward's geological ideas in fact became more popular and dominant after the death of Hooke who had exerted a strong influence on the shaping of scientific arguments throughout the second half of the seventeenth century.

The Defence of Woodward's Theory

Before the death of Hooke, Woodward did not defend his hypothesis on the Universal Deluge even though it was criticized by various virtuosi. Hooke died in 1703; in the same year Newton was elected president of the

Royal Society, and this seems to have created a more favourable environment for Woodward to advocate his hypothesis. Both Newton and Woodward believed in divine intervention in the form of miracles and insisted on studying the existing facts of nature, receiving the following eulogy from Richard Bentley, who attacked Thomas Burnet in his Boyle lectures:

> Who nature's Treasures would explore,
> Her Misteries and Arcana know
> Must high as lofty Newton soarr,
> Must stoop as delving Woodward low.[2]

In the course of the discussion on the origin of fossils, both Hooke and Woodward supported the organic theory, but Hooke seems to have been unsatisfied with Woodward's hypothesis concerning the Universal Deluge because Woodward employed the idea of a total dissolution for his theory of the strata. While Hooke gave lectures on Burnet's <u>Theory of the Earth</u> and Whiston's <u>New Theory of the Earth</u> at the Society's meetings, he did not ever discuss Woodward's <u>Essay toward a Natural History of the Earth</u>. Woodward's hypothesis became appreciated while Newton was President of the Royal Society.

Not only did Woodward use the concept of Newtonian gravity as the foundation of his theory of the Universal Deluge and share with Newton the view of Divine Providence, he also had close personal links with Newton himself.

In 1709 Woodward reported that "his observations on the strata of the Earth were conformable to his Theory", when Newton was present at a meeting of the Society.[3] On another occasion, Woodward praised Newton's achievements:

> Now lately Sir Isaac Newton hath advanced several very extensive and considerable Hypotheses. Indeed the Delivering these to the World is the main Design of what he has publish'd: and One of these, that of Attraction, Dr. Freind hath undertaken peculiarly to illustrate and confirm... 'Tis true, the most exact Caution ought to be used that those Hypotheses have good Warrant, and firm Support, from the Observations and Experiments:...[4]

In a letter to Newton which was published in 1728, Woodward indicated that Newton had encouraged him to conduct research into the nature of fossils:

> I send you, with this Letter, a Tract relating to the Method of Fossils; which, if not your own, is wholly owing to you; it being begun, carried on, and finished at your Request.[5]

After the death of Robert Hooke in 1703, Newton, as the new president of the Royal Society, seems to have requested Woodward to develop his study of the Earth. Indeed Newton laid down a scheme for a reorganization of the Royal Society which included a provision for the study of "Mineralogy and Chemistry, and the knowledge of the nature of Earths, Stones, Corals, Spars, Metals,...; and the causes of subterraneous Caves, Rocks, Shells, Waters, Petrifactions, Exhalations, Damps, Heats, Fires, and Earthquakes, and the rising or falling of Mountains and Islands."[6]

The Royal Society under the leadership of Newton attempted to continue the study of the Earth, and Woodward's method of research into fossils and strata did not contain anything which contradicted Newton's system.

It was under such circumstances that Woodward defended his hypothesis in his Naturalis Historia Telluris, published in 1714, which was subsequently translated into English by his disciple Benjamin Holloway and published under the title of The Natural History of the Earth, Illustrated, Inlarged, and Defended (1726). This work was written on the occasion of some objections made against Woodward's hypothesis by Elias Camerarius, Professor of Physic at Tübingen. Before the publication of his Essay, Woodward boasted, naturalists were generally of the opinion that fossil shells were not the remains of living creatures, but mere stones formed in the ground. However, there were now very few who disputed that they were the real remains of creatures. As an example of the influence of his work, he cited Johann Jacob Scheuchzer, who in his De Generatione Conchitarum (1697) had attempted to prove that these bodies ought to be considered native stones, but who after reading Woodward's work had publicly acknowledged his mistake and come over to Woodward's opinion.[7] In fact, after the appearance of the theories of the Earth, the main focus of controversy did become the order of the strata, not the origin of fossils, and, as Woodward alleged, most naturalists came to accept the idea that fossils were the remains of either the Universal Deluge or particular local floods. However, there were strong objections to Woodward's idea of a total dissolution brought about by the Deluge.

Like several other naturalists, Camerarius had claimed that the strata could not have been formed and laid one over another according to their specific gravity, because the strata were in fact so unequally intermixed. To this objection Woodward replied that the unequal order of strata did not affect his doctrine of the orderly subsidence of the dissolved matter of the earth, because "this is most certain, the Subsidence could not be every where uniform, and the same."[8] M.J.S. Rudwick has suggested that "Woodward's explanation of stratification in terms of specific gravities was easy enough to disprove empirically",[9] but it was also easy enough to defend by an ad hoc theory. Woodward could still claim that, although the whole affair was performed exactly according to the laws of gravity, a great part of the mass might have sunk confusedly and been laid down without any regular order, and as a result the constitution of the strata could be varied and without order. Besides, Woodward insisted, the strata themselves have apparently not remained in the same state, but have undergone considerable changes since the time they were first formed and compacted.[10] Thus the evidence against Woodward's hypothesis did not automatically prove it to be wrong and was regarded by him as minor exceptions. Moreover, Woodward's followers such as Benjamin Holloway insisted that there was "the regular Disposition the Earth into like Strata, or Layers of Matter, commonly through vast Tracts."[11] Holloway thus noted that the surface of the Earth generally consists of regular strata.

Woodward did not lack other disciples. John Harris, for example, who was elected a fellow of the Royal Society in 1696, defended Woodward's hypothesis in his Remarks on the some late Papers relating to the Universal Deluge, and to the Natural History of the Earth (1697). Furthermore, Harris adopted Woodward's ideas in his Lexicon Technicum: or, an Universal English Dictionary of Arts and Sciences (1704). Of this, Edward Lhwyd wrote to Richard Richardson that "If you turn over Harris's Dictionary, you will still meet with fresh Eulogiums of the Essay as tho' it were an Abyss of Inventions and eternal Truths always own'd by mankind."[12] In the Lexicon Harris criticized Burnet's effort to find waters which could cover the whole Earth on the grounds that "the great Creator of the World could soon either educe Subterranean, bring down Supercelestial, or create Waters on purpose for such an Occasion; for nothing can be too hard for Omnipotence to effect." In Harris' view Burnet's account of the Universal Deluge depended on secondary causes too much, but the matter lay in another point:

> ...,when we look into the Internal Parts of the Earth..., we find there that the Body

> of the Terrestrial Globe is composed of Strata, Rows or Layers lying one over another, and which appear to every one that observes them to be the Sediments of a Flood; besides, in the Bodies of these Strata,... ..., we find a prodigious variety of the Exuviae or Remains of Fishes, such as their Shells, Teeth, &c, as well Marine ones as those which live in Lakes and Rivers. And from a due Observation of these, and repeated Considerations upon them it was that the Learned and Ingenious Dr. Woodward, Professor of Physick in Gresham College, founded what he delivers upon this Subject.[13]

Harris thought that Woodward's hypothesis was "not so much a Theory, as necessary Deductions and unavoidable Consequences drawn from matter of fact." Like Woodward, however, Harris wanted to leave the Biblical mystery untouched and claimed that the Universal Deluge could not be explained by mechanical principles alone.

Later editions of Bernhard Varenius' Complete System of General Geography was another work in which Woodward's idea was totally accepted. The original of this work was improved by Isaac Newton and reprinted in 1672, and then James Jurin added an appendix containing the latest discoveries for a further edition published in 1712. This was in turn the source from which later eighteenth-century editions derived. In Jurin's appendix, the system of Descartes was rejected and instead the Newtonian philosophy was introduced to account for the natural phenomena "as being much more eligible than the Cartesian."[14] This edition has several notes on Woodward's ideas including a clear summary which says that Woodward

> reasonably supposes all these Commixtures of the Particles of Bodies in the Strata of the Earth, to proceed from those strange Alterations that were every where made in the Terrestrial Globe at the Deluge, when the whole Globe was dissolved, and the Particles of Stone, Marble, and all other solid Fossils dissevered, taken up into the Water, and there sustained together with Sea Shells, and other animal and vegetable Bodies: that at length all these subsided from the Water, according to the Nature of their Gravity.[15]

Woodward's idea of the Universal Deluge was thus totally accepted here as a reasonable supposition.

John Morton, rector of Great Oxendon, who was elected a Fellow of the Royal Society in 1703, also followed Woodward's ideas. In 1705 a letter of Morton's on fossils was published in the Philosophical Transactions. In it, he gave an account of the progress he had made in the natural history of Northamptonshire. Following Woodward, he supposed that marine animals had been lodged deep in the Earth at the time of the Universal Deluge.[16] He developed this idea further in his Natural History of Northamptonshire (1712). According to him, Woodward was "certainly a Gentleman of great Penetration, and very clear Insight into Nature."[17] Referring to Woodward, Morton discussed the origin of fossil shells, and claimed that fossil shells agreed in every particular with the shells of living shellfishes and had most exactly the same substance, texture, magnitude and shape as living ones:

> To be brief, 'Tis as certain that those Shells are real: That they were once the Covers of Shell-fish, and had their Origin at Sea, as that our Senses are capable of making a true Report of any thing whatever... And to these the foregoing Observations, and Dr. Woodward's Account of them in his Natural History of the Earth,...I apeal; It being not to be doubted that these will be perfectly satisfactory.[18]

Like Woodward, Morton did not doubt that fossil shells were real seashells. As for the present state of these marine bodies, he pointed out that they were found even at the very bottom of deep pits, and, he claimed, the shells of the heavier kinds such as cockles lay for the most part in the lower strata and the shells of the lighter sorts such as echini and oysters lay in the upper strata. Following Woodward, Morton suggested that the heavier shells had been lodged in stone and the lighter in stony earth according to their specific gravity. Although the organic theory of fossils was accepted without any doubt, yet there remained the question as to how they had become lodged in the earth. Morton thought that Woodward's hypothesis explained this completely:

> From the like Observations which I have made in these Parts, I cannot but draw the same Inferences, and particularly this, That the steril Admixture, which we now find in the outmost Stratum, is not as old as the Creation of the World, neither has it been made since by any particular Agents, but was effected at the general Subsidence at the Deluge. Nothing

> less could produce such a general Affection as this is, and withal account for all the Circumstances of it.[19]

Morton thus interpreted the strata of the Earth as having originated in water and as having settled down out of the waters of the Deluge according to the laws of gravity. The remains of seashells and land animals destroyed by the Deluge had been deposited concurrently, also according to their specific gravity.

Woodward even had research assistants like John Hutchinson, who made observations in the field to confirm Woodward's hypothesis. One of the results of his research was the Observations made in the Year 1706. Later Hutchinson came to be on bad terms with Woodward and wrote his own physico-theological work, Moses's Principia (1724-27). However, this work demonstrated that the Earth had been destroyed by Noah's Flood by the action of God's agents, and thus verified Woodward's hypothesis.

The Examination of Woodward's Theory

Though Woodward's hypothesis was influential, it was not accepted uncritically. William Derham, for example, who was elected a fellow of the Royal Society in 1702, published a paper on "subterraneous trees" in the Philosophical Transactions in 1712, in which he mentioned his observations on the specific gravity of the strata and said that "I can assure this Curious and most Learned Society...that in three Places where I have try'd it, the Strata are in a surprising manner, gradually specifically heavier and heavier, the lower and lower they lye."[20] In other words, Derham critically examined Woodward's hypothesis on the order of strata and found it to accord with the facts he observed. However, he reached no firm conclusion as to when the strata had been deposited. He only suggested that they must have been laid down either at the Creation of the world or at the Universal Deluge:

> At that time (whatever it was) when the Terraqueous Globe was in a Chaotick State, and the earthy Particles subsided, then those several Beds were, in all Probability, reposited in the Earth, in that commodious Order in which they now are found; and that, as is asserted, according to the Laws of Gravity.[21]

Derham's support for Woodward was associated with his argument against Thomas Burnet. Derham criticized Burnet for suggesting that mountains and hills were ruins of the Universal Deluge and thus did not have any marks of God's counsel. Derham saw danger in Burnet's mechanical explanation of the cause of mountains, and insisted that even the present surface of the Earth was not a work of mere chance but had been formed according to the will of the Author of Nature.[22]

Geological facts observed in the field were always likely to undermine the foundation of Woodward's hypothesis. For example, when Fettiplace Bellers published a decription of the several strata of earth, stone and coal found in a coal-pit at Dudley in Staffordshire in the Philosophical Transactions in 1712, Francis Hauksbee added a table of the specific gravity of each stratum, "by which it is evident, that the Gravities of the several strata are in no manner of Order; but purely casual, as if mixt by chance."[23] The detailed observation of strata became a central consideration of natural historians, and Hauksbee realized that Woodward's hypothesis could not be always accepted. This alone, however, was not enough to refute his hypothesis completely. Thus John Strachey continued to adhere to Woodward's idea of the Universal Deluge and attempted to explain away the observed order of the strata. He supposed that the mass of the terraqueous globe consisted of various kinds of minerals, and that all were originally in a soft and fluid state, tending towards the centre of the Earth. It must necessarily follow, he said, by the continual revolution of the crude mass from West to East, like rolling up the leaves of a paper-book, that each stratum, though reaching the centre, must also appear to the surface of the Earth. In this case the lighter strata could be deposited in the upper region as well as in the deep.[24] In this way, Strachey's ad hoc theory saved Woodward's fundamental notion that the strata had been deposited according to their snecific gravity.

The Decline of Woodward's Theory

Woodward's hypothesis was influential even after his death in 1728. He left a will under which a Geological Professorship was founded in Cambridge with the intent to oppose the theory of Elias Camerarius who had argued against Woodward's Essay. It is evident that Woodward's primary object in this foundation was the permanent commemoration of himself and his achievements. The first Woodwardian Professor was Conyers Middleton, D.D., of Trinity College, appointed in 1731. He was a good scholar and a distinguished man of letters, but had no knowledge of science, so his published work contains only compliments to Woodward.[25] He retired in 1734, being succeeded by Charles Mason, D.D., of Trinity College. Mason printed a single Latin lecture in 1734, and like Middleton, he devoted it to praise of Woodward.[26] In this way, Woodward's hypothesis was blindly followed by the early Professors of Geology.

The other reason why the Diluvial theory was widely accepted was that it fitted well with Christian orthodoxy. John P. Breyne's letter on "Observations, and a Description of some Mammoth's Bones dug up in Siberia", published in the Philosophical Transactions in 1737, included his idea that the teeth and bones of elephants had been carried to Siberia by the Deluge and left behind after the waters returned into their reservoirs, and were buried in the earth even near to the tops of high mountains.[27] In the course of his argument, Breyne suggested that "the Holy Scripture may serve to prove natural history", and "the truth of the Scripture may be proved again by natural history." So far as the effects of the Universal Deluge were concerned, God's role in the Deluge could be preserved.

Although Diluvial theory was popular even after the death of Woodward, his hypothesis gradually came to be doubted on the grounds that it was contradicted by the actual state of the strata. Benjamin Martin was one author who argued against Woodward's hypothesis. He was remarkable as one of the great popularizers of science in the eighteenth century. His Philosphical Grammar, first published in 1735, ran to no fewer than eight editions. In this work Martin praised Isaac Newton's Principia, and rejected the Cartesian philosophy, including its application to geology:

> Burnet's Theory of the World and Deluge, must be valued at no greater Estimation than an ingenious Romance: And thus must Mr. Whiston's, and all other World-mongers Systems and Theories, dissolve into a philosophical Nothing, which want actual and repeated Experiments to support them.[28]

Martin also raised the question as to the order of strata, and answered flatly that "they do not lie in Order of their specific Gravities."[29] To the question how the strata had been deposited, he answered that "some say at the Creation, others at the Flood; others supposed in the chaotick state of the Earth the heavier Bodies subsided, and lay in this Order by the Law of Gravitation; but Experience rather contradicts than confirms this Hypothesis."[30] Martin thus broke the previously accepted harmony between Woodward's hypothesis and the Newtonian system, accepting the Newtonian system yet arguing against Woodward's hypothesis.

When Woodward was encouraged by Newton to study natural history, the question as to the age of the world was not raised. The formation of strata was generally ascribed to the Universal Deluge and the age of the world was confined within the chronology of the Bible. However, in time this, too, came to be questioned. For example, a letter from Moreton Gilks published in the Philosophical Transactions in 1740 shows that he doubted whether the received opinion of the world's age was true, on the basis of his conjectures concerning the formation of the strata in limestone he had observed.[31] Moreover, Woodward's hypothesis came to be openly criticized to the point where it could be stated in the Philosophical Transactions that

> Dr. Woodward's Hypothesis, or Manner of bringing these Shells, and all other Fossils, into the Places where we now find them, by a total Dissolution of Matter, is indeed very pretty; but so many Difficulties arise (however plain it might appear to him) I believe few now-a-days are of his Opinion.[32]

Woodward's hypothesis on the order of strata had at first stimulated natural historians to observe the strata carefully. As they did so, they eventually realized the difficulties raised for Woodward's theory by actual observations. In reference to the formation of pebbles, William Arderon wrote to Henry Baker in 1747:

> I shall trouble you with no Hypothesis, nor form any random Guesses, to account for such their Situation, and the Condition wherein they are found...[33]

The passage quoted above suggests that the age of grand theories of the Earth was now over in the mind of an English natural historian.

NOTES

1. V.A. Eyles, "John Woodward, F.R.S. (1665-1728): Physician and Geologist", Nature, 206 (1965), 868; Roy Porter, The Making of Geology, 78.

2. Richard Bentley, The Grove or a Collection of Original Poems (London, 1721), 244-46.

3. Journal Book of the Royal Society of London, November 30, 1703.

4. John Woodward, The State of Physick: and of Diseases (London, 1718), 54-55. There is a note written by Newton in 1726:

   "Dr. Woodward desires to see the second edition of my optiques viz that in Octavo. And also the chronological tables printed in ffrance. Also the third edition of the Principles."

   New College MSS, II, fol.60 in Frank E. Manuel, Isaac Newton Historian (Cambridge, 1963), 259n.

5. John Woodward, Fossils of All Kinds digested into a Method (London, 1728), Letter to Sir Isaac Newton. In Newton's library the works on the Earth's history included Johann Joachim Becher, Physica Subterranea (Leipzig, 1681); Thomas Burnet, Archaeologiae Philosophicae (London, 1692); Burnet, Telluris Theoria Sacra (London, 1681-89); William Derham, Astro-Theology (London, 1715); John Harris, Remarks relating to the Universal Deluge (London, 1697); John Woodward, Naturalis Historia Telluris (London, 1714); Woodward, The Natural History of the Earth (London, 1726); John Ray, Three Physico-Theological Discourses (London, 1693). Cf. Frank E. Manuel, Isaac Newton Historian (Cambridge, 1963), 287n.

6. Sir D. Brewster, Memoir of the Life, Writings and Discoveries of Sir Isaac Newton, Vol.1 (Edinburgh, 1855), 103.

   After the publication of Hooke's Posthumous Works (1705), several papers on an interchange of land and sea were published in the Philosophical Transactions. For example, W. Sherard, "An Account of a New Island raised near Santerini, in the Archipelago," Phil. Trans., XXVI (1708), 67-68; Bourguignon, "A Relation of a New Island thrown up near the Island of Santerini", Phil. Trans., XXVI (1708), 200-208; Father Goree, "A Relation of a New Island which was raised up from the Bottom of the Sea...in the Archipelago", Phil. Trans., XXVII (1711), 354-75; John Chamberlane, "An Account of the sunk Island in Humber, lately recovered from the Sea", Phil. Trans., XXX (1719), 1014-16; Thomas Foster, "Part of a Letter concerning a New Island lately raised out of the Sea near Tercera", Phil. Trans., XXXII (1722), 100-101; William Borlase, "An Account of the Great Alteratins which the Islands of Sylley have undergone since the Time of the Ancients", Phil. Trans., XLVIII (1753), 55-69; Alexander Dalrymple, "On the Formation of Islands", Phil. Trans., LVII (1767), 394-97. These papers, however, were not presented in support of Hooke's theory of earthquakes.

7. John Woodward, The Natural History of the Earth, illustrated, inlarged and defended (London, 1726), 5-6.

8. Ibid., 40.

9. M.J.S. Rudwick, The Meaning of Fossils (London, 1972), 90.

10. Woodward, Natural History, 44.

11. Benjamin Holloway, "An Account of the Pits for Fullers-Earth in Bedfordshire", Phil. Trans., No.379 (1723), 421.

12. British Museum MS. Sloane 4064, f.24.

13. John Harris, Lexicon Technicum: or a Universal English Dictionary of Arts and Sciences (London, 1704), the item on "Deluge".

14. Bernhard Varenius, A Complete System of General Geography (London, 1765), vii.

15. Ibid., 97.

16. John Morton, "A Letter...containing a Relation of River and Other Shells", Phil. Trans., No.305 (1705), 2210.

17. John Morton, The Natural History of Northamptonshire (London, 1712), 34.

18. Ibid., 250.

19. Ibid. 34.

20. William Derham, "Observations concerning Subterraneous Trees in Dagenham", Phil. Trans., NO.335 (1712), 482-83.

21. William Derham, Physico-Theology (London, 1727), 66.

22. Ibid., 70.

23. Fettiplace Bellers, "A Description of Several Strata ...To which is added, a Table of the Specifick Gravity of Each Stratum: By Mr. Hauksbee...", Phil. Trans., No.336 (1712), 544.

24. John Strachey, "An Account of the Strata in Coal-Mines", Phil.Trans., No.391 (1725), 398.

25. R.T. Gunther, Early Science in Cambridge (Oxford, 1937), 433.

26. Ibid.

27. John P. Breyne, "Observations, and a Description of some Mammoth's Bones dug up in Siberia", Phil. Trans., No.446 (1737), 129.

28. Benjamin Martin, The Philosophical Grammar (London, 1738), 18.

29. Ibid., 239.

30. Ibid.

31. Moreton Gilks, "Some Account of the Petrefactions near Matlock Baths in Derbyshire", Phil. Trans., No.456 (1740), 355.

32. William Arderon, "Observations on the Precipices or Cliffs on the North-East Sea-Coast of the County of Norfolk",Phil.Trans., No.481 (1746), 280.

33. William Arderon, "Part of a Letter...concerning the Formation of Pebbles", Phil. Trans., No.483 (1747), 467.

CONCLUSION

This thesis has discussed developments in Earth science in the age of the Scientific Revolution which eventually created favourable conditions for the rise of geology in the eighteenth century. Discussing the Scientific Revolution, R.F. Jones has explained the rise of the scientific movement in seventeenth-century England in terms of "ancients" and "moderns".[1] This dichotomy has been adopted by Christopher Hill, who has also insisted that there was a link between science and Puritanism.[2] Such views have been criticized by Hugh Kearney and Allen G. Debus on the ground that they ignore the Neo-Platonic tradition which, too, was a formative influence leading to modern science.[3] Kearney and Debus have described the Scientific Revolution as a three-way conflict between the ancient, the neo-Platonic and the mechanical philosophy. This view is supported by Frances A. Yates' works on the Hermetic tradition.[4] Hill, too, later noted the importance of the Hermetic tradition to the development of modern science.[5] Then, can we claim that the development of Earth science was closely connected with these three intellectual traditions?

Earth Science and the Scientific Revolution

The cyclic view of the Earth and the Biblical theory of the Deluge were respectively expressed by two different traditions. These two traditions were harmonized when the effects of the Deluge were not considered extraordinary. This synthesis can be seen as a consequence of long efforts of the Scholastic-Aristotelian or ancient tradition. As has been shown, a new trend of scientific method appeared within these academic traditions: The empirical method of study was esteemed and the phenomenon of the Universal Deluge was explained by natural causes. These traditions provided a foundation for scientific argument about the Earth's history.

The study of the Earth was changed when the Cartesian cosmogony was introduced to natural historians in England. The theories of the Earth which were based on the mechanical philosophy emphasized the role of the Universal Deluge in the formation of present geological features. Looking back upon the theories of the Earth published in the late seventeenth century, John Whitehurst wrote a century later as follows:

> The several theories of the earth produced near a century ago, contain indeed many important truths. Yet it must be owned that the state of physical science at those particular aeras, necessarily rendered all such learned

> attempts, too hypothetical for the present age, which only admits of deductions from facts and the laws of nature: for having no permanent basis to found their inquiries upon, every one thought himself at liberty to model the earth according to the dictates of his own imagination.[6]

As Whitehurst suggested, the mechanical theory of the Earth was not the final winner of the Scientific Revolution. First, the grand theories were criticized by natural historians who claimed that the actual state of the fossiliferous strata could not be explained by the Universal Deluge alone. Secondly, those who believed the Deluge to be supernatural opposed the idea that it had been caused by natural causes alone, and did not regard the Deluge as an object of scientific enquiry. Because of this controversy, observation of the existing strata became one of the most important geological activities, and this method of study was compatible with the prestigious system of Newton. According to Whitehurst, it was Newton who established the "true" scientific study of nature, and sought after "those which really existed in nature".

A neo-Platonic influence can be found in mineralogical works of the seventeenth century. The neo-Platonic philosophers criticized Scholastic learning for not searching after the hidden secrets of nature. Thus they urged the importance of experiment and observation, and one of their main interests was the mineral kingdom. The neo-Platonic tradition regarded the study of minerals and stones as an independent and practical subject. The neo-Platonic view of minerals was not complementary to the cyclic view of the Earth when the members of the Royal Society began to debate the origin of fossils. The fossil controversy was brought about by a direct interaction of these two traditions. The spread of the organic theory of fossils was facilitated by the rise of the Deluge theory and the mechanical philosophy. The inorganic theory lost its foundation when the neo-Platonic philosophy began to decline in the late seventeenth century.

Thus the study of the Earth was closely connected with ancient, neo-Platonic and mechanical traditions, and the changes of outlook that occurred were an integral part of the Scientific Revolution. In addition, the seventeenth-century development of Earth science illuminates another aspect of the Scientific Revolution. As has been shown, its development was largely sustained by a large number of amateur natural historians, who were much interested in natural rarities themselves. The tradition of natural history provided useful knowledge for building up "geological" theories. The study of the Earth's history was facilitated by the foundation of museums such as the Ashmolean Museum at Oxford, Woodward's collection at Cambridge, and Sloane's collection in London. In his Structure of Scientific Revolutions, Thomas Kuhn has suggested that sciences progress through revolutions,[7] but the study of natural history could progress by the accumulation of natural knowledge and was not directly affected by the interaction of the other traditions. In order to understand the Scientific Revolution correctly, we need to take the observational sciences more into account than we usually do.

More importantly, the thesis has discussed how these separate intellectual traditions came into contact and formed a framework for Earth science within a scientific community. The Royal Society did more than simply organize scientific activities for the advancement of natural history; it also brought different view of the Earth together, and this in turn led to the fossil and the Deluge controversies. The formation of the Royal Society was essential to this productive interaction between different views. As I have shown, the "internal" development of the science was conditioned by "external" factors such as scientific organizations and interaction between scientists.[8]

Earth Science and the Virtuosi

Although having limited the meaning of "external factors" in my argument about the "internal" development of Earth science, I have not minimized the importance of "cultural values" to the pursuit of this immature science.[9] In order to explain why Earth science attracted a wide range of practitioners, we must know who devoted themselves diligently to the study of the Earth when it did not promise a future career. One may note that the rise and fall of the virtuosi coincided with the process of the Scientific Revolution. According to _the New and Complete Dictionary of Arts and Sciences_ (1754), "Virtuoso" was

> an italian term, lately introduced into english, signifying a man of curiosity and learning, or one who loves and promotes the arts and sciences: but among us the term seems to be appropriated to those who apply themselves to some curious, and quaint, rather than immediately useful, art or study, as antiquaries, collectors of rarities of any kind, microscopical observers, and so on.[10]

As this definition suggests, the virtuosi were mainly amateur scientists, a group who became dominant in seventeenth-century English intellectual life. The geological activities of the virtuosi declined in the eighteenth century, when "geologists" began to take over the study of the Earth.[11] The achievements of the virtuosi were partly transmitted to the geology of late eighteenth-century England, but their activities were not identical with those of specialists in geology.

In his Science, Technology and Society in Seventeenth-Century England, Robert K. Merton did not fully discuss the activities of amateur scientists. Instead, he sought evidence mainly in mining and transportation that the priorities of scientific research were closely shaped by the technical and economic requirements of English society. In his view, a certain proportion of theoretical "pure" science was directly connected with practical problems.[12] Merton has claimed that "such influence may be exercised directly through social organizations specifically set up for that purpose."[13] It might be correct to say that the requirements of industrial technology can exert a powerful influence on the direction of scientific research. It is not necessarily the rule, however, that scientific practitioners always belong to well-established scientific institutions. Most seventeenth-century scientific practitioners were amateurs who studied nature only as a diversion.

Merton himself realized the social estimation which drove gentlemen to study the natural world.[14] He referred to John Wallis who observed that "the practice of chemistry is a piece of knowledge not misbecoming a gentleman." John Wilkins likewise recommended to gentlemen the study of "mechanical Geometry." Charles II himself showed an interest in chemistry and navigation. Prince Rupert, too, commended the study of natural philosophy. Merton thus noted that science became fashionable and highly approved in the seventeenth century. It became common for a "gentleman of culture" to acquire natural knowledge. Merton correctly claimed that

> Science had definitely been elevated to a place of high regard in the social system of values; and it was this positive estimation of the value of science...which led ever more individuals to scientific pursuits.[15]

Without developing the point that science was a species of knowledge becoming to gentlemen, Merton claimed that scientific pursuits most obviously linked to utilitarianism gained most in prestige and popularity.[16] This claim, however, cannot explain the rise of the virtuosi who eagerly discussed "trivial" topics such as the origin of fossils and the Universal Deluge.

A.C. Crombie has said that "the conception of the virtuoso,...seems to me to be of the essence of the European morality, meaning both habits and ethics, out of which the European scientific movement was generated and engineered."[17] The importance of the virtuosi to the development of modern science may be clarified if we take a glance at the intellectual life of another civilization where the Scientific Revolution did not happen even when it was confronted with Western science.

In the case of Japan, one finds that Japanese Confucians who were officially recognized by the Tokugawa shogunate did not show any interest in the study of nature, their object of study being human life. For example, Jinsai Ito (1627-1705) despised the search for physical truth, regarding it as a hobby. Sorai Ogyu (1666-1728) thought that the heavens were unknowable and that they were the object of respect, not of investigation. Minzan Nakae (1655-1726) insisted that cosmology and cosmogony were too difficult for men to study. Ichido Tojyo (1778-1858) and Taiho Tsukada (1745-1832) said that even a sage did not discuss the universe itself. According to Seishisai Aizawa (1782-1863),

> "The creation of the universe is unknowable. Even if we were to know about it, the knowledge would be useless to politics, education and practical ethics. Therefore we have no need for it."

For these Japanese Confucians, speculation about the universe was only useless and odd.[18]

A reaction against these Japanese Confucians was represented by a school of "Dutch" scholars in eighteenth-century Japan. They were much interested in the study of medicine and natural philosophy introduced by the Dutch in Hirado, Nagasaki, where foreigners were permitted to reside during the period of the Exclusion Policy in Japan (1641-1854). Scholars of Dutch learning, however, were isolated from other scholars and citizens. For example, Gennai Hiraga (1726-79) complained that he was called a humbug only because he examined natural matter to learn about the laws of nature. Kokan Shiba (1738-1818) wrote that he was impressed by the mystery of divine creatures, but others were not interested in such a thing. Choei Takano (1804-50) insisted on the importance of natural philosophy, criticizing the Japanese people for not searching for the causes of natural phenomena. Toshiaki Honda (1744-1821) wrote that those who studied natural philosophy were called heretics and were hated by the people.[19] "Dutch" scholars were thus aware of the superiority of the natural science of the West, but they could not establish a firm foundation for it in Japan.

The case of Japanese intellectuals of the feudal age suggests that the early development of modern science was extensively conditioned by a prevailing academic tradition or by contemporary common sense. Its early development required support from a number of the leisured class who enjoyed scientific things for their own sake. Every culture has had its own cosmology and ideas about the Earth, but there has never been any other civilization which has stimulated so many intellectuals to study the natural world for seemingly useless purposes.[20] Only in the western part of Europe did a large number of amateurs come to "spend their time in a kind of knowledge, which promises no advantage."[21] Advocating the activities of the virtuosi, William Wotton wrote:

> There would have been a stop put to a Progress of Learning long ago, if immediate Usefulness had been the sole Motive of Men's Enquiries.[22]

Besides the foundatin of the Royal Society which created a new intellectual milieu, the activities of the virtuosi constitute one important reason, I believe, for the rise of Earth science at this time in the West rather than elsewhere.

NOTES

1. Richard F. Jones, Ancients and Moderns: A Study of the Rise of the Scientific Movement in Seventeenth-Century England (St.Louis, 1961).

2. Christopher Hill, Intellectual Origins of the English Revolution (Oxford, 1965).

3. Allen G. Debus, Science and Education in the Seventeenth Century (Macdonald and American Elsevier Inc.: New York, 1970); Hugh Kearney, Science and Change 1500-1700 (McGraw-Hill: New York, 1971).

4. Frances A. Yates, Giordano Bruno and the Hermetic Tradition (Chicago, 1964); The Art of Memory (Chicago, 1966); The Rosicrucian Enlightenment (London, 1972).

5. Hill, The World Turned Upside Down (London, 1972), 231-46.

6. John Whitehurst, An Inquiry into the Original State and Formation of the World (London, 1786), 2.

7. Thomas Kuhn, The Structure of Scientific Revolutions (The University of Chicago Press, 1970).

8. As for other "external" factors, economic influence on the Royal Society has been shown by Robert K. Merton. (Merton, Science, Technology and Society in Seventeenth-Century England, 137-83.) As Merton himself has noted, however, this does not necessarily follow that such influence directly changed the "internal" development of science. (Ibid., 48)

9. In this thesis, however, I have not intended to show the value-orientation of English society as a whole. Instead I have seen that there were variations and conflicts in the society. The Puritanism-science thesis, which is based on the assumption that there were the one dominant religious ethic and the only one science, is simply irrelevant to this thesis. In his defence of the Merton thesis, Gary A. Abraham has adhered to this assumption. (Gary A. Abraham, "Misunderstanding the Merton Thesis", Isis, 74 (1983), 368-87.) However, such a macro-sociological approach would only create a stereotype of the society but would not explain why conflicts occurred within the society. [Cf. Social Analysis, no. 5/6 (1980).]

10. Society of Gentlemen ed., The New and Complete Dictionary of Arts and Sciences (London, 1754-55), The item on "Virtuoso".

11. W.T. Houghton, "English Virtuoso", 219; D.R. Dean, "The word <geology>", Annals of Science, 36 (1979), 35-43. This change can also be found in the fact that the word "virtuoso" has lost its original meanings as the age of virtuosi is over. According to the Oxford English Dictionary, the word "virtuoso" means

 1. One who has a general interest in arts and sciences, or who pursues special investigations in one or more of these; a learned person; a scientist, savant, or scholar.

 2. One who has a special interest in, or taste for, the fine arts; a student or collector of antiquities, natural curiosities or rarities, etc.; a connoisseur; freq., one who carries on such pursuits in a dilettante or trifling manner.

 Today the word is not used in these senses.

12. Robert K. Merton, Science, Technology and Society in Seventeenth-Century England (New York, 1970), 154.

13. Ibid., 156.

14. Ibid., 27.

15. Ibid., 28.

16. Ibid., 30.

17. A.C. Crombie, "Science and Arts in the Renaissance: The Search for Truth and Certainty, Old and New", History of Science, XVIII (1980), 233.

18. Shigeru Nakayama, Nihon no Tenmongaku (Japanese Astronomy), (Tokyo, 1972), 154-60.

19. Gennai Hiraga, Furai Rokubu-shu (Six Books by a Vagabond), in Nihon no Meicho (Great Books of Japan) 22 (Chuokoron-sha, 1971), 399; Kokan Shiba, Dokusho Bogen (Wild Talk with a Solitary Smile), in Nihon no Meicho 22 (Chuokoron-sha, 1971), 481; Choei Takano, Ensei Suihitsu-ron (An Occidental Chemical Theory of Water), in Nihon no Meicho 25 (Chuokoron-sha, 1972), 294; Toshiaki Honda, Seiiki Monogatari (A Tale of Western Regions), in Nihon no Meicho 25 (Chuokoron-sha, 1972), 436.

20. C. Blacker and M. Loewe have covered various ancient cosmologies. C. Blacker & M. Loewe, Ancient Cosmologies (London, 1975). Joseph Needham has discussed the geological works of Shen Kua (1031-95) and Chu Hsi (1130-1200), both of whom were eminent Chinese scholars. Their achievements were not followed by other intellectuals. Joseph Needham, Science and Civilisation in China, vol. III (London, 1959). Shigeru Nakayama has considered the reactions of Japanese Buddhists, Confucians and Shintoists to the modern western cosmology. S. Nakayama, A History of Japanese Astronomy: Chinese Background and Western Impact (Harvard Univ. Press, 1969).

21. Benjamin Stillingfleet, Miscellaneous Tracts relating Natural History, Husbandary, and Physick (London, 1762), 162.

22. William Wotton, Reflections, 274.

POSTSCRIPT : SOME ASPECTS OF EIGHTEENTH-CENTURY GEOLOGY

C. Schneer has suggested that a historical science of the Earth, as presented by Robert Hooke, was reconstructed during the late eighteenth century: Hutton, Smith, Guettard, Demarest and Cuvier "were perhaps unaware of their debt to the men of the seventeenth century, but they built nevertheless in an atmosphere that had developed from the fossil controversy and the later controversy over the flood."[1] While Schneer did not give evidence to support this suggestion, G.L. Davies has noted the similarity between Robert Hooke's Discourse of Earthquakes and James Hutton's Theory of the Earth (1785).[2] Following Davies' suggestion, Ellen T. Drake has claimed that the similarity is not by happenstance and that Hutton was thoroughly aware of Hooke's writings in geology.[3]

In his critical comment on Drake's claim, Giorgio Ranalli has suggested that the similarities between passages describing the non-permanence of land and sea are not very convincing because Hooke's sentence quoted by Drake is also similar to passages in classics such as Ovid's Metamorphoses.[4] Thus Ranalli reduced the realm of Hooke's influence on Hutton which Drake had expanded. Ranalli, however, has failed to consider standard ideas of Earth science of the second half of the eighteenth century. In this postscript I suggest that Hutton owed his theory of the Earth to the geological achievements of his contemporaries, although his contribution to the scientific community of the age does not lie so much in his speculation on the Earth's history as in his theory of igneous rocks which provoked the Huttonian - Wernerian controversy.

Buffon's Natural History

One of the eminent eighteenth-century natural historians was Georges Louis Comte de Buffon, who published the first volume of his famours Natural History in 1749. F.D. Adams has suggested that Buffon's Natural History marked the close of the long period of imaginative effort to narrate the Earth's history.[5] C.C. Gillispie had a similar view and said that Buffon "was often as imaginative as the generally orthodox Burnet."[6] M.J.S. Rudwick has suggested that Buffon's system "lay near the end of an old tradition, not at the start of a new."[7] It is moreover said that "Buffon's own theories about the age of the Earth made little immediate contribution to geology proper, and the cosmological approach to the subject soon went out of fashion."[8] It is true that Buffon had a speculative way of arguing in which he deduced the Earth's history from a general theory of the planetary system.

Buffon, however, provided a set of geological ideas by which the formation of the strata could be explained. R. Rappaport has claimed that there was a new geological climate of opinion in France after the publication of Buffon's Natural History.[9] He agrees with J. Roger that "Buffon's synthesis brought to a close one era in the history of geology and opened another during which geologists paid more attention to the solution of specific problems than to the broader issues involved in a theory of the earth."[10] In fact, Buffon was of the opinion that the deposition of sedimentary strata had required a very long time and that the Earth's crust had been formed in stages. This idea had been held, as we have seen, by Hooke and some others in the late seventeenth century. What distinguished Buffon's work was his view on the Universal Deluge. As J.C. Greene has suggested, Buffon excluded the Biblical account from the domain of natural history and confined himself to a probable hypothesis based on actual observations.[11]

Among the theories of the Earth published in the late seventeenth century, Woodward's hypothesis survived the early eighteenth century but even it came to be doubted on the grounds that it did not accord with the actual state of the strata. Buffon's system can be seen as an attempt to reduce the widening gap between the idea of the total dissolution brought about by the Deluge and the accumulated geological observations. Buffon based his argument upon the observation that the strata were always parallel to each other, and of the same thickness through their whole extent, and that they continued from one hill to another hill:

> In neighbouring hills, beds or strata of the same materials are uniformly found at the same levels, though the hills be separated by deep and large valleys.[12]

Moreover, he said that shells, skeletons of fishes and marine plants are often found in the bowels of the Earth and on the tops of mountains. From these facts Buffon concluded that

> the dry land which we now inhabit, and even the summits of the highest mountains, were formerly covered with the waters of the sea; for shells, and other marine bodies, are still found upon the very tops of mountains. It likewise appears, that the waters of the sea have remained for a long track of years upon the surface of the earth; because, in many places, such immense banks of shells have been discovered that it is impossible so great a multitude of animals could exist at the same time.[13]

The accumulation of strata must, he argued, have been gradual and successive, because sea-bodies are sometimes found more than one thousand feet below the Earth's surface. Such thick strata could not be accumulated in a short period. It is certain that the waters of the sea remained for a succession of ages upon what is now dry land, and that the strata are not the effects of any sudden revolution, because

> nothing is more frequent than strata composed of heavy materials placed above light ones, which never could have happened, if, according to some authors, the whole had been blended and dissolved by the deluge, and afterwards precipitated.[14]

Buffon thus argued against Woodward's idea that the strata all originated in the Deluge and claimed that their present state could not be explained by a total dissolution of the Earth's surface. Only successive sedimentations from water could possibly produce the regular position of the various strata of which the superficial part of the Earth is composed.

Buffon excluded extraordinary causes from his argument on the Earth's history, insisting that "this parallel and horizontal position of strata must necessarily be the opertion of a uniform and constant cause."[15] To understand the cause in question Buffon stated,

> the dry and habitable part of the earth has for a long time remained under the waters of the sea, and must have undergone the same changes which are at present going on at the

> bottom of the ocean. To discover what has formerly happened to the dry land, let us examine what passes in the bottom of the sea.[16]

The question remained, however, how mountains had been elevated from the bottom of the sea. According to Buffon, mountains were not produced by earthquakes, or other accidental causes, but are effects equally resulting from the operation of general laws of nature. Buffon suggested that the sea gained ground on certain coasts and lost it on others, and that such a change would not be suddenly accomplished but would require a very long period. He insisted that "it happened naturally; for if a judgment of the future is to be formed from the past, we have only to attend carefully to what daily passes before our eyes."[17] Thus the laws of nature operating at present were supposed to be applied to understand past phenomena. No extraordinary cause was allowed to explain the state of the strata or the formation of mountains.

Although Buffon acknowledged that Burnet was the first author who discovered the subject of the Earth's history and treated it in a systematic manner,[18] he thought that Burnet's work was merely "an elegant romance". Burnet fell into error because he regarded the Deluge as an effect within the compass of natural causes even though the Scripture represented it as an immediate operation of God. It is beyond the power of any natural cause, said Buffon, to produce a sufficient quantity of water to overflow the whole Earth's surface. Buffon believed that the Universal Deluge must have been caused by a supernatural cause, because it was too miraculous to be explained in terms of natural causes. However, Buffon suggested that

> the sole design of the deluge was the destruction of men and other animals, and that it changed not in any manner the surface of the earth; for, after the retreat of the waters, the mountains and even the trees, kept their former stations, and the land was suited for the culture of veins and other fruits of the earth.[19]

The importance of this statement for geology lies in the assertion that the Universal Deluge was not thought to change the Earth's surface. According to M.J.S. Rudwick, Buffon insisted, without denying the reality of the Deluge, that "it had been moral in its purpose and as miraculous in its effects as in its cause: for scientific purposes, therefore, it could be ignored."[20] But it was on the grounds that the Deluge had not caused any change in the Earth's surface that Buffon excluded it from his natural history.

Buffon's Natural History was widely read and provided natural historians with a common source of information concerning the Earth. His ideas were disseminated in Britain in publications such as A New and Complete Dictionary of Arts and Sciences (1754), Rudolf Erich Raspe's Specimen Historiae Naturalis Globi Terraquei (1763), William Worthington's Scripture-Theory of the Earth (1773), Oliver Goldsmith's History of the Earth, and Animated Nature (1774) and the Rev. James Douglas's Dissertation on the Antiquity of the Earth (1785). As will be discussed, whether or not Buffon's contemporaries took the idea of the gradual deposition of sedimentary strata from his Natural History, the idea itself gained wide popularity after 1749.[21]

The Continuity of the Strata

Roy Porter has claimed that "few seventeenth-century thinkers had believed strata in themselves could reveal much of Earth history" and that "Englightenment views of an active Earth, gradually changing its form over time, themselves suggested that strata and rock masses had a significant history."[22] As has been discussed, however, it was not uncommon to believe in the late seventeenth century that the strata had been formed at different times. It was Woodward's hypothesis on the order of the strata that rejected the idea of their successive deposition, while natural historians of the second half of the eighteenth century realized that the continuous strata were the key to the Earth's history. Sometime in the mid-eighteenth century there was a shift in interest from the vertical order of the strata to their lateral continuity.

The continuity of strata was often observed by country natural historians of the second half of the eighteenth century. For example, Charles Smith, an Irish natural historian, did fieldwork in the county of Kerry in Ireland and published The Antient and Present State of the County of Kerry (1756). In this work Smith discussed the following:

> ...it appears, that the several substances beneath the surface of the earth, are ranged with more order and regularity than has been hitherto taken notice of, and that they are not scattered at random but are joined together in different ranges, so that they may be traced from one country to another.[23]

Smith attempted to describe the natural history of Kerry and did not intend to build up a grand theory from his observations on the strata. The aim of his inquiry was to "give great light to the industrious searcher into minerals, and fossils, who, by knowing the true direction of any of these beds, may discover the same kind of matter as limestone, coal, slate, and several other metals at great distances from the place of their first appearance."

The Bristol clergyman Alexander Catcott was another natural historian from about the same period, who observed the strata in the Mendip Hills. In his Treatise on the

Deluge, Catcott took a Woodwardian view of the Deluge and maintained that all the antediluvian strata had been destroyed by the waters of the Deluge. This theory was based on his observation that the strata could be traced from mountain to mountain:

> ...if a person was to view the naked ends or broken edges of the strata in a mountain on one side of a valley and compare them with their correspondent ends in the mountain on the other side of the valley, he would manifestly perceive that the space between each was once filled up, and the strata continued from mountain to mountain.[24]

Catcott tried to integrate actual observations into his geological theory, but his theory itself does not seem to have been important to the development of Earth science. Catcott's theory, based on the idea of the total dissolution at the Deluge, was simply out of date and could not explain the complexity of the strata which had been discovered.

Observation of the strata was not always made without a well-articulated framework for the Earth's history. John Michell, the then Woodwardian Professor of Geology at Cambridge, for example, built up his theory from careful observations on the strata. In his opinion, the surface of the Earth was not composed of heaps of matter casually thrown together, but of regular and uniform strata:

> These strata, though they frequently do not exceed a few feet, or perhaps a few inches,

> in thickness, yet often extend in length and breadth for many miles and this without varing their thickness considerably.[25]

According to Michell, such strata of the Earth are frequently very much bent, being raised in some places, and depressed in others, although they are generally horizontal. What is very remarkable is that the strata in mountainous countries are generally formed out of the lower strata of earth. From these observations Michell concluded that large tracts of mountainous terrain had been raised, which had caused the discontinuity of the strata.

John Whitehurst, too, discussed his observations of the state of the strata, particularly in Derbyshire, in his Inquiry into the Original State and Formation of the Earth:

> The arrangement of the strata in general is such, that they invariably follow each other, as it were, in alphabetical order, or as a series of numbers;...the order of the strata in each particular part, how much soever they may differ, as to quality, yet they follow each other in a regular succession, both as to thickness and quality: insomuch that by knowing the incumbent stratum, together with the arrangement thereof in any particular part of the earth, we come to a perfect knowledge of all the interior beds, so far as they have been previously discovered in the adjacent country...[26]

As Porter points out, Whitehurst's Inquiry preserved a distinction between a general theory and a separate appendix of local facts and his theory did not offer any explanation of the state of the strata.[27] This separation, however, does not necessarily mean that Whitehurst did not have any idea to explain the formation of the strata. The view that the strata had been deposited under the sea was widely held thoughout the eighteenth century. Whitehurst might have avoided discussing what most natural historians had accepted.

A more detailed observation on the strata was made by John Walker, Professor of Natural History and Keeper of the Museum at the University of Edinburgh from 1779 to 1803. He divided the mountains into primitive and secondary. The strata of which these mountains consisted were likewise termed primitive and secondary strata. He supposed that they had been formed at two very different times. A third kind of strata he called accidental, these being the effects of the present or recent operations of nature.[28] This distinction of the strata was, of course, incompatible with Woodward's hypothesis about the Deluge, because Woodward thought that all the strata had been deposited at the time of the Deluge.

According to Walker, the primitive strata, of which all the highest mountains consist, are always vertical, that is disposed at an angle with the horizon of 60 to 90 degrees. As for the secondary strata, they are all horizontal, or inclined at the smaller angles of 20 to 40 degrees, and generally occupy the sides of mountains.

They extend themselves about the middle and the foot of mountains, but they chiefly occupy the surrounding valleys and plains. The difference in dip between the two kinds of strata persuaded Walker to believe that the secondary strata had been deposited on the primitive strata at a different stage. In addition, he thought that the primitive strata had been deposited when there were no living creatures:

> As the petrified plants and Animals which are found do all subsist in the secondary strata, it has therefore been concluded that the primitive strata were in point of existence previous to all organiz'd bodies. But that on the contrary the earth had been inhabited both by plants and Animals before the formation of the Secondary Strata is evident, as in these strata we find their remains.[29]

Besides the primitive and secondary strata, he observed, the tertiary strata generally occupy the deep valleys, the plains and the sea shores. They are also found at the mouths of rivers, especially at those of great rivers.

Although Porter has pointed out that Walker "would not wish to be thought to deliver anything like a Theory, but merely a natural history of the earth",[30] his lectures show that he had a clear perspective of the history of the Earth. It would not be correct to assume that "no well-defined theory of the strata was formulated" at this stage.[31] At least, natural historians such as Walker noted that the strata had been originally continuous and afterwards had been deformed.

The Interchange of Land and Sea

During the second half of the eighteenth century the formation of the strata was generally explained by the idea that there had been interchanges of land and sea in the surface of the Earth. Edward Owen was one who, regarding the Deluge as an agent of geological changes, discussed the successive changes of the Earth's surface in his Observations on the Earths, Rocks, Stones and Minerals, for some Miles about Bristol (1754) Like other natural historians, he observed various kinds of fossil shells found in hard stone:

> It is a very singular observation, and many have referred their coming to these places, and being sunk in the bodies of stone, to the changes that were wrought upon the earth at the time of Noah's flood. Perhaps a great many of them may be as old as that time: but we know that changes happen in the earth so frequently, that a great many may have come by their present situation otherwise.[32]

Owen thus did not deny that Noah's Flood had carried seashells to the dry land. It is remarkable, however, that he suggested that other changes, too, could have been the cause of fossil shells.

As for minor geological changes, Owen maintained that "the sea has in many places deserted the shores, and rivers have changed their course in the same manner."[33] If this happend, the clay which was at the bottom of the water may have hardened into stone, and the shells which lay upon it may have turned to stone with it. Thus in Owen's account the possibility of several geological interchanges was discussed.

A similar view was expressed by William Borlase in his Natural History of Cornwall (1758). He adopted the old idea of an interchange of land and sea to explain the cause of the Universal Deluge. According to him, the bottom of the sea must have been lifted up and the wrinkles of the Earth's surface smoothed to raise the sea to a sufficient height to cause the Universal Deluge. When Divine Justice was satisfied, the bottom of the sea returned to its former level and left some parts above the seas.[34] Hence Borlase did not ignore the effects of the Universal Deluge on the Earth's surface, but he added that "a few subsidences may have happened since the deluge, from the same exhausting dissolvent powers of water, inundations, or by the force of earthquakes."[35] Borlase ascribed the irregularity of the strata to those interchanges. In other words, the Universal Deluge was but one of several floods which had changed the Earth's surface.

The idea of an interchange of land and sea at the time of Noah's Flood became one of the most popular solutions as to the Earth's history in the eighteenth century. For example, Edward King of Lincoln's Inn, F.R.S., in an article in the Philosophical Transactions (1767), applied the idea that some parts of the Earth had been raised from the bottom of the sea to an account of the Universal Deluge. God created the Earth with sea and land, and it continued in that state for many ages, during which the bottom of the sea became covered with shells and other marine bodies. At the appointed time, the subterranean fires burst out at once with great violence, and this

> raised up the bottom of the ocean, so as to pour out the waters over the face of what was before dry land, which by that means became sea, and has perhaps continued so ever since, as that which was before the flood the bottom of the sea, probably from that time has continued to be Continent and dry land.[36]

A similar idea was adopted by William Pryce in his Mineralogia Cornubiensis (1778), in which he pointed out that William Borlase's theory of the Earth's history had been well received by natural historians.[37] In his opinion, it was agreed by most naturalists that some parts of the present dry land had been part of the ocean floor before the Deluge. Pryce moreover insisted that many alterations had happened to various parts of the

Earth before, at and after the Deluge, and that these had caused many irregularities in the disposition of the strata.[38]

Pryce's statement that the theory he held was very popular among natural historians is confirmed by Ephraim Chambers' Cyclopaedia. In the item on "Deluge", Chambers referred to Thomas Burnet's Theory of the Earth, and discussed the influence of Descartes' system of the formation of the Earth on Steno, Burnet, Woodward and Scheuchzer. Chambers said that Burnet's hypothesis was elegantly written, but it not only contradicted the physical principles of nature but was also utterly inconsistent with the Bible. He insisted that "there seems none better calculated to solve the phenomena of these petrified exuviae, than that of M. de la Pryme."[39] In Pryme's opinion, as has been shown in a previous chapter, the antediluvian world had sea and land with mountains and rivers. The Universal Deluge was effected by breaking the subterranean caverns by means of earthquakes, which caused land to be swallowed up and covered by the sea. Then, the present dry land arose out of the bottom of the antediluvian sea. Chambers entirely agreed with Pryme's theory:

> From this system, which is very agreeable to Scripture, the great difficulties that clog all the other systems, seem easily solved. It is no longer a wonder, that shells, and shell-fish, and the bones of fishes, and four-footed creatures, with fruits, & c. should

> be found in beds and quarries, in mountains and valleys, and the very bowels of the earth: for here they bred in the antediluvian sea; thither they were elevated with the hills and mountains, in the time of the deluge...[40]

Chambers also referred to Edward King's account of the Universal Deluge which resembled that of Pryme. The idea of an interchange of land and sea at the Deluge was thus accepted in a popular encyclopedia of the eighteenth century.

John Whitehurst was another natural historian who held the idea of an interchange of land and sea. He developed his geological ideas as early as 1763, when Benjamin Franklin wrote to him that "Your new Theory of the Earth is very sensible, and in most particulars quite satisfactory."[41] Whitehurst later published his Inquiry into the Original State and Formation of the Earth in 1778, in which he discussed some geological changes which had produced the dry land. Like other natural historians of the eighteenth century, Whitehurst did not neglect the effects of the Universal Deluge. He supposed that there had been the strata of subterranean fire in the centre of the Earth. If the fire were increased, the bottom of the sea would consequently ascend by the expansive force of the fire and the water of the sea would flow over the lower parts of the land. Since the subterranean fire operated universally, the Deluge would have prevailed universally over the Earth. Thus the primitive state of the Earth seems to have been totally changed by the first convulsion at the time of the Deluge. The bottom of the antediluvian sea was elevated and converted into the postdiluvian mountains and continents. Whitehurst insisted that

> this conjecture is remarkably confirmed by the vast number of fossil shells, and other marine exuviae, found imbeded near the tops of mountains, and the interior parts of continents, remote from the sea, in all parts of the world hitherto explored...[42]

From his observations on fossil shells, Whitehurst attempted to construct the Earth's history, even if he saw the Deluge as an important agent in forming the present Earth.

Whitehurst also referred to volcanic activities as something which had contributed to form the geological features. Because of volcanic activities mountains have been broken to pieces and their fragments thrown down into the adjacent valleys. Great fissures have burst open and lava has flowed from these and covered the adjacent country. Thus from subterranean convulsions in the past Earth, both the interior and exterior parts of the Earth have suffered considerable change. In addition, fragments of stones, sand, ash and so on have been spread over the Earth's surface by such subterranean convulsions, and these too have made up parts of the strata.

In Whitehurst's view, the remains of volcanic activities could prove the old doctrine that there had been many changes in the Earth's surface. From his observations on the strata of lava among sedimentary rocks he concluded that volcanic activities must have happened again and again. This he took as decisive proof that not all the upper part of the Earth had been formed at the same time. Porter has claimed that Whitehurst's theory "reveals the shortcomings of the age",[43] and Davies has suggested that it "carries us back to the days of Burnet, Woodward and Whiston".[44] However, Whitehurst's observations on the remains of volcanic activities show that he absorbed a new trend of Earth science. His work is by no means a mere revival of the seventeenth-century theories. The strata of lava divided the Earth's history into "sundry periods of time".

The Actual Laws of Nature

The decline of the idea that there had been a total dissolution of the Earth was associated with the idea that the strata had been formed by constant and uniform causes. For example, William Borlase was such a natural historian who urged the importance of the present laws of nature to understand past geological changes. In his Observations on the Ancient and Present State of the

Islands of Scilly (1756), Borlase said that the continual advances which the sea made upon the land at present were plain to everybody, and like Buffon suggested that

> ... What we see happening every day may assure us of what has happened in former times, and from the banks of Sand and the low lands giving way to the Sea, and the breaches becoming still more open and irremediable, it appears that there has been a gradual declension and diminution of the Solids, and as gradually a progressive ascendancy of the Fluids for many ages.[45]

Borlase thus held that the present phenomena of the Earth could be a key to the understanding of the changes in the past. He developed this idea in his Natural History of Cornwall (1758). According to him, the chief naturalists agreed that some mountains and land areas had once been parts of the bottom of the sea, so that the bed of the sea had been undoubtedly moved upward in some places.[46] However, he continued, it is not easy to decide how and when these parts became raised to their present position. No earthquake could be the cause of this, because the convulsions of an earthquake would not leave the pebbles and sands so horizontally placed. The cause of the elevation must have been equal in force to an earthquake, but gentle and regular, acting under the laws of nature, in order to accomplish such great changes in the Earth's surface.

Like Buffon, Rudolf Erich Raspe, a German natural historian living in England, argued against the grand theories of Burnet, Woodward and Whiston and insisted that nature acts more simply and more predictably with her own proper forces:

> Indeed the whole question concerning the evidence presented by us can be resolved more surely and with greater probability through forces which we know are active in nature and by phenomena which can occur daily and take place even now.[47]

Raspe thus attempted to exclude extraordinary forces from natural history and insisted that ordinary forces were sufficient to account for geological phenomena. He remarked that the almost forgotten lectures of Hooke concerning the Earth's changes were sound.[48] As we have seen, Hooke had suggested that the Earth's surface had been not only moved and shaken by subterranean force, but also elevated to become mountains and islands. Hooke had further claimed that other parts of the Earth's surface had been lowered by subsiding or collapse of subterranean caverns. Raspe agreed with Hooke tht there had been such interchanges of land and sea, but he did not agree that the Universal Deluge had drastically changed the state of the Earth's surface. He thought it wrong to maintain that "these alterations of land masses into sea and of ocean floor into continents, mountains, and islands have occured for the most part as the result of the universal flood."[49] Such an idea, Raspe said, is against "the laws of history".

Edward King, too, held the idea of gradual sedimentation, even though he did not give up the idea of the Universal Deluge. Referring to fossil shells, he argued that

> it may always be remembered, that the fossil shells found in all parts of the earth, are sufficient proof of the truth of its having been at some time or other entirely covered with water, however fallible any attempt to account for the deluge may be.[50]

King criticized Woodward's hypothesis that the Deluge had brought about a dissolution, for he thought the order of the strata could not be explained by the Deluge alone. Although King did not neglect the effects of the Deluge, he insisted that geological changes are constantly occurring:

> We find to this day great changes are continually making, within the memory of man, both on the face of the earth, in the shores, and in the bottom of the sea, even in those small parts of it that we are acquainted with; and such changes must also have happened before the flood...[51]

King thus suggested that present geological changes are the same in nature as those of the antediluvian Earth.

John Walker, too, insisted that the present principles dominating the natural world could be applied for the understanding of past natural phenomena:

> The Strata of the globe bear all the appearance of a subsidence of a fluid; from a fluid we know that solid bodies naturally subside, stratum super stratum; thus we may see every day in the bed of the ocean and rivers, strata of sand, clay, gravel etc. disposed exactly in the same manner and on the same principles with the Strata over the whole globe.[52]

According to Walker, John Ray and Robert Hooke were the first who had ascribed the origin of mountains to earthquakes. They had been followed by many others, but a great number of other philosophers attributed mountains to volcanoes. Walker, however, criticized all such ideas because

> their regular form, their regular chains, their general direction, their continued ridges, the salient and receding angles, their strata and the matter of which they consist, evidently shew that they never have arisen from such partial or contiguous Causes as Earthquakes or Volcanoes, but that they owe their origin to a Cause more universal and much more uniform. It is upon the whole much more probable that they have been formed in water than either by earthquakes or volcanoes.[53]

Walker insisted that the mountains had been formed by uniform forces, but he did not claim that geological changes were always gradual and adopted the idea that the Earth had been remarkably changed at the time of the

Deluge:

> It is my firm persuasion, and not upon slight grounds, that at some distant period the Earth has undergone changes which could not be the effects of those laws of Nature by which the aeconomy of the terraqueous Globe is at present Regulated. And further that those changes so vast and universal could only be accomplished by the extraordinary interposition of that omnipotent POWER by which the Globe was at first created.[54]

Thus for Walker the Deluge was a great event in the Earth's history. But he did not discuss the effects of the Deluge themselves. His main concern was the gradual formation of the strata which constitute the present Earth. The idea that the strata had been deposited by degrees was based on the view that the laws of nature were always constant. Even if the Deluge was believed to have happened, it was by now considered to have been of no special importance to the formation of the strata.

The Ancients' View Revived

If uniform forces had been working in the past, it would have required a long time to form the present geological features. Buffon recognized in his Epocks of Nature (1778) that the Earth required a long timescale. Gustavus Brander, when discussing fossils, suggested that some were of the opinion that the length of time is indefinite:

> Various are the Opinions concerning the Time, when and how these Bodies became deposited: some there are who conceive it might have been effected in an indefinite length of time by a gradual changing and shifting of the Sea; others again, that this Globe may have undergone many, even total Revolutions, of which we neither have nor can have any idea, but from these traces.[55]

The Universal Deluge was a mystery to Brander because he could not definitely state what impression it had left on the Earth. Brander seems to have doubted that the Deluge was the main agent of geological change, while he referred to the opinion that the length of time is indefinite.

The decline of the Deluge theory was often accompanied with a rise of the ancient doctrine that the Earth's surface is constantly changing. For example, Raspe, who insisted that ordinary forces are always active in nature, pointed out that such an idea was not new but had been held by the ancients. He cited Strabo, in particular, who in his Geographia had suggested that the Earth's surface had certain irregularities which had developed through many alterations caused by water, earthquakes, eruptions and so on. These forces, he said, do not change the overall shape of the Earth, but raise and lower the floor of the ocean, which is why fossil shells may be found far from the sea. Raspe thought that Strabo's idea of the Earth's history was very reasonable:

> Although this theory of Strabo...may be sounder than all the others and may contain the first threads of a more accurate hypothesis, it is a wonder how heedlessly it was afterwards considered and immediately obscured by new errors. So much so that several recent scholars have disputed this view, either challenging or defending it, and finally after may centuries there has again been a return to this tenet of Strabo.[56]

According to Raspe, the ancients' ideas about geological changes had been forgotten because of the rise of the Dilüvial theories at the end of the seventeenth century. Burnet, Woodward and Whiston had insisted that the Universal Deluge had caused the total collapse of the Earth's surface. But Raspe argued against such a grand theory and defended the idea that the course of nature could be explained by ordinary forces.

Raspe critically examined the works of John Ray, Antonio Lazzaro Moro, Buffon and Samuel Christian Hollmann and valued aspects of their geological arguments similar to those of the ancients.[57] In Raspe's opinion, Ray's view that mountains had been gradually elevated from the floor of the sea was in some measure a return to the ancient doctrine. Raspe claimed, however, that Ray had been obstructed by great difficulties because he had preferred to explain marine shells enclosed in the ground by the Universal Deluge. A similar view to Ray's idea was adopted by the Rev. Father Antonio Lazzaro Moro, who refuted the opinions by Burnet, Woodward and Whiston on the ground that nature was constantly changing. Moro urged the importance of volcanic activities and supposed that the strata had their origin from the material that poured from volcanoes, such as sand, stones, ashes, lava, minerals and metals. This material had formed the various strata according to the order in which it was erupted, had covered the animals living in the sea, and then had finally been elevated above sea level by some subterranean force. Then Raspe referred to Buffon, who had suggested that the earth which is now inhabited and even the peaks of the highest mountains had once and for a long period of time been concealed beneath the ocean and afterwards gradually raised. Finally, Raspe discussed a similar idea suggested by Samuel Christian Hollmann, a professor at the University of Göttingen. According to Raspe, Hollmann criticized the teachings of those who attributed the disorder of the Earth to Noah's Flood. The Earth's surface, he argued, displays everywhere evidence that it has been covered with water. Hollmann agreed with Moro that the floor of the sea had been gradually elevated above its surface, Raspe thus pointed out that all these authors shared the ancient view that the strata had been formed under the sea and then raised above the sea.

John Whitehurst was another natural historian who insisted that the ancients' geological idea which had been defeated by the seventeenth-century theorists of the Earth should be revived. He said that he had learned from Pliny and many other ancient natural historians that the surface of the Earth had suffered considerable changes: Many mountains have been raised, and others depressed or totally swallowed up into the bowels of the Earth.

Criticizing the Diluvial theories, Whitehurst suggested that the formation of the present geological features would have required a long span of time:

> For I have frequently observed in the fissures of the lime-stone strata, fragments of the same shells adhering to each side of the cleft, in the very state in which they were originally broken: insomuch that if the several parts were brought together, they would apparently tally with each other. Whence it is evident that a considerable space of time had elapsed between the chaotic state of the earth and the deluge; which according to the Mosaic account was upwards of 1600 years: but these observations are rather a digression from the subject, and only serve to shew the agreement between revelation and reason:...[58]

Whitehurst did not wish to disturb the Biblical chronology because the age of the world was not a main problem to him. He only observed the strata and the fissures of them, and inferred that there had been "a considerable space of time" between the Creation and the Deluge.

A further retreat to the ancients' view of the Earth may also be found in the writings of George Hoggart Toulmin and James Hutton, both of whom totally neglected the Deluge in their arguments on the Earth's history. Toulmin between 1780 and 1789 published four books containing his theory of the Earth's history, which was, in fact, similar to Hutton's theory of the Earth published in the same period. In his Antiquity and Duration of the World (1780), Toulmin did not regard the high mountains as of original and permanent existence, but supposed that they had been formed by gradual processes and were subject to the most regular changes. He saw every production of nature as unstable and subject to perpetual variations,[59] and insisted that "as the vegetables rise and fall, and men exist and die, the earths are formed, and vary in their natures."[60] In short, every existing thing equally participates in a gradual formation and dissolution. The same philosophy had been advocated by Aristotle, and Toulmin thought that "Such reasonings alone will ever be found essential to sound philosophy and the true knowledge of antiquity."[61]

Like most other natural historians of the eighteenth century, Toulmin suggested that fossil remains found in the earth were sufficient evidence to show that they had been deposited successively in every part of the globe. Over a great span of time, the seas had successively occupied and then deserted every part of the earth.

The causes of these changes had been earthquakes, volcanoes, the discharge of substances from the mouths of rivers, and the agitation of the waters of the sea. Toulmin thought that "granting that there have been periods of time sufficiently extensive, it cannot be denied but that such causes are amply sufficient to produce the effects."[62] Toulmin's fundamental idea was that everything was formed by slow degrees, that is to say, "nature lives in motion".[63] This idea was combined with his discussion of the eternity of the world:

> The world, the universe itself, are composed of moveable particles, qualified for eternal agitation. If then numerous modifications of matter thus exist; if events similar to those already described, daily do take place; what in the nature of things should hinder such events from having always happened?
>
> Nature is invariably the same, her laws eternal and immutable. Substances that seem inanimate are yet perpetually in action, admit of changes regular and uniform: and as the vegetables rise and fall, and men exist and die, thus they have ever done, and ever will do.[64]

Completely ignoring the Biblical accounts, Toulmin thus returned to the Aristotelian idea that the world is eternal.[65] Toulmin's book seems to have been widely read, if we are to judge from the number of editions. However, it received almost no notice from contemporary geologists, compared with the works of Hutton.[66]

Hutton's Theory of the Earth

In 1785 James Hutton, "a private gentleman" of Edinburgh, presented the result of thirty years' research at a meeting of the Royal Society of Edinburgh, and this paper was eventually published in 1788. Less than a decade later, he published his Theory of the Earth (1795). Hutton's geological ideas were in various ways similar to those of his contemporaries. His theory can be seen as a retreat to the ancients' doctrine which had been revived.

In Aristotle's view, the world was eternal and events followed a cyclical course. For the Christians, on the contrary, the world had a beginning and an end. Therefore, Scholastic Aristotelianism contradicted itself from the beginning. To avoid this contradiction, Thomas Aquinas maintained that the Creation of the world in time is philosophically undemonstrable, and also that the eternity of the world is equally undemonstrable.[67] However, along with the Protestant movement, many commentaries on Genesis affirmed that time began with God's creation of the world and opposed Aristotle's opinion to the contrary.

Although Aristotle's ideas were criticized in various ways, his cyclic theory of the Earth's history survived these criticisms. Aristotle's Meteorologica continued to be cited until the end of the seventeenth century.

Hooke's application of the cyclic theory of the Earth to his Diluvial theory became one of the frameworks for the Earth's history in the eighteenth century. J.E. O'Rourke has suggested that Hutton's theory of the Earth might have owed much to Aristotle, judging from the terminology.[68] D.R. Dean has maintained that Hutton may have had some basic grasp of Hindu and Chinese chronology, as well as the Christian chronology.[69] For Hindus, time is limitless, and we are endlessly returned within it until our personal Nirvana is attained. These suggestions indicate that Hutton upheld the natural philosophy of the ancients.

Indeed Hutton insisted on "an indefinite space of time" and on the cyclic nature of the world. He represented the system of the Earth proceeding with a certain regularity, from one world to another world:

> But if the succession of worlds is established in the system of nature, it is in vain to look for any thing higher in the origin of the earth. The result, therefore, of our present enquiry is, that we find no vestige of a beginning,-- no prospect of an end.[70]

It has been said that Hutton only completed the picture of nature presented by Isaac Newton.[71] According to Newton, the orbits of the planets were established by God's hand, and therefore their present states prove nothing about the Creation. For Hutton, in the same way, the present system of nature did not help us to know about the origin of the Earth. There had been a tendency to mechanize nature in the sciences of astronomy, physics, chemistry and biology, but miracles had not previously been completely excluded from geological speculations. Now, banishing all catastrophes and even Noah's Flood from his theory, Hutton paved the way for a reconstruction of the Earth's history.

However, it was not a mere revival of the ancients' doctrine. By the time of the publication of Hutton's theory, enormous amounts of information concerning the strata had been accumulated and the strata were thought to have been formed by degrees. Hutton seems to have absorbed up-to-date ideas of his contemporaries. For example, Hutton noted the present condition of the surface of the Earth, regarding the strata as "the most important appearances of our earth":

> We find those strata that were originally formed continuous in their substance, and horizontal in their position, now broken, bended, and inclined, in every manner and degree; we must give some reason in our theory for such a general state and disposition of things;...[72]

Like most other natural historians, Hutton attempted to base his theory on the idea that the strata had been originally continuous.

Another fundamental idea of Hutton's theory was that "our land, which is now above the level of the sea, had been formerly under water."[73] Hutton tried to prove that all the continents and islands of this globe had been gradually raised out of the ocean. In his view all the coasts of the present continents are constantly wasted by the sea, and the present continents were slowly raised from the bottom of the ocean:

> when the former land of the globe had been complete, so as to begin to waste and be impaired by the encroachment of the sea, the present land began to appear above the surface of the ocean. In this manner we suppose a due proportion to be always preserved of land and water upon the surface of the globe...[74]

As we have seen, the idea of an interchange of land and sea was widely held by natural historians of the second half of the eighteenth century.

Thirdly, Hutton believed that all geological phenomena could be explained by uniform forces. Referring to those who explained the present structure of the Earth by violent force, Hutton said that

> Philosophers observing an apparent disorder and confusion in the solid parts of this globe, have been led to conclude, that there formerly existed a more regular and uniform state, in the constitution of this earth; that there had happened some destructive change; and that the original structure of the earth had been broken and disturbed by

> some violent operation, whether natural, or from a supernatural cause.[75]

Criticizing such a view, Hutton said that "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 preternatural cause, in explaining that which actually appears." This philosophical conviction was expressed on another occasion:

> Not only are no powers to be employed that are not natural to the globe, no action to be admitted of except those of which we know the principle, and no extraordinary events to be alledged in order to explain a common appearance, the powers of nature are not to be employed in order to destroy the very object of those powers; we are not to make nature act in violation to that order which we actually observe, and in subversion of that end which is to be perceived in the system of created things.[76]

Hutton thus claimed tht the present appearance of the Earth could be explained by known principles, without referring to extraordinary powers.

Hutton's geological ideas were thus similar to those of his contemporaries. Even if Hutton owed a great deal to Hooke, Hooke's influence on Hutton could not have been exclusive. Hutton was fully aware of the current and widely accepted ideas of the Earth. However, it was exceptional to claim the infinite span of time and to neglect the Universal Deluge in geological arguments when most natural historians did not abandon the Biblical chronology. Hutton's theory was, in fact, criticized by Earth philosophers such as Jean André de Luc, Richard Kirwan, John Williams, Philip Howard and Joseph Townsend, all of whom did not agree to the philosophical and theological implications of his theory. Roy Porter has explained Hutton's unorthodoxy by his involvement in the Schotish Enlightenment, but it would not be correct to assume that "his intellectual context was not that of science." [77]

Moreover, as Porter himself has noted, contemporary geologists and mineralogists were not deeply involved in theological and philosophical arguments over the Earth's history because they had their specific problems.[78] Instead it was the origin of igneous rocks that aroused the raging controversy between Huttonians and Wernerians from the late eighteenth to the early nineteenth century. In the course of this controversy, the study of the fossiliferous strata came into contact with the study of igneous rocks which had been pursued by mineralogists. Then why did Hutton and other geologists in Britain become interested in the origin of igneous rocks at this stage? Apart from putting the question, I do not attempt to answer it because it is a topic beyond the realm of this thesis.

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