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THE SIX DAYS AND THE DELUGE: SOME IDEAS ON EARTH HISTORY IN THE ROYAL SOCIETY OF LONDON 1660-1775

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Abstract

The influence of the biblical story of Creation and the Deluge on ideas of earth history during the period 1660-1775 is examined with particular reference to papers on the subject published in the *Philosophical Transactions* of the Royal Society of London. Topics examined in more detail include the controversies over the origin of marine fossils and bones of prehistoric animals, ideas on natural causes of the Deluge and its role in shaping landforms, and the age of the earth. Despite the inhibiting effect of the Genesis account, there was considerable flexibility in interpretation of both the Creation and Deluge stories in terms of current scientific knowledge. The later papers display a good deal of uniformitarian thinking within the framework of a catastrophic deluge hypothesis.

INTRODUCTION

The centuries before Hutton are usually ignored by geologists, or dismissed as unscientific. David Page, writing in *The Philosophy of Geology* (1863) said "all that was known of it [geology] previous to the current century might be obliterated not only without inconvenience but with obvious advantage to its progress." (Quoted by Tomkeieff, 1950: p. 388.) In 1963, McIntyre remarked, "Prior to Hutton, geology did not exist, and I think it is generally agreed that the science was created in the fifty years between 1775 and 1825." (McIntyre, 1963: p. 1.) It is particularly in the field of ideas about earth history that most scorn has been cast on the pre-Huttonian period. Adams dismissed all the early theories of the earth as "wonder stories" and considered that Buffon's theory, outlined in his *Histoire Naturelle* (1749) and in greater length in *Epoques de la Nature* (1778) "marked the end of a long period of imaginative effort." (Adams, 1938: pp. 209-210.) Chorley, Dunn and Beckinsale (1964) dealt with all the centuries before Werner in a single chapter. This is all a little unfair. An enormous amount of literature in the earth sciences was published during the late seventeenth and eighteenth centuries. Eyles (1966: p. 79) quoted a bibliography, published in 1787, listing over 1600 items on geological and mineralogical subjects and this was by no means complete. Thomson recorded 251 articles on "geognosy" published in the *Philosophical Transactions* of the Royal Society of London before the end of the eighteenth century, and another 38 in mineralogy and 29 on mining. (Thomson, 1812: pp. 182, 186 and 220.) Unfortunately, Thomson's account of this geological work is too much coloured by his extreme Wernerian views to be of much value.

It must be conceded of course that geology as a science in its own right evolved in the Post-Huttonian period. It is also true that many of the earlier theorists were a little short on geological facts and allowed their imaginative speculations to carry them rather a long way sometimes. But this was the fascinating period when geology was disentangling itself from theology, particularly from the account of earth history narrated in the book of Genesis. It was a period when geological problems aroused great interest and controversy among intellectuals generally (far more so than any geological question today). It is the purpose of this paper to

examine how some of the most scientifically minded men of the late seventeenth and eighteenth centuries, namely the members of the Royal Society of London, tackled the question of the history of the earth, its theological implications, and the extent to which they were circumscribed by the authority of the six days of Creation and Noah's Deluge. The triumph of "Uniformitarianism" of Hutton, Playfair and Lyell over the "Neptunism" of Werner and his disciples and the "Catastrophism" of Dean Buckland and his "Diluvialists", was merely the final outburst in the controversy between scientific and scriptural geology which had been waged for over two centuries. The development of a science of the earth had to wait until this controversy was settled, until geologists were free to disregard theology in their scientific investigations.

THE SCIENTIFIC CLIMATE OF THE SEVENTEENTH CENTURY

The seventeenth century in Europe was the time of the profound religious upheaval of the Reformation and the time of the development of the "New Science." It was the century of the Copernican revolution, when the ancient concept of a geocentric universe was challenged and proved wanting. New planets and stars were discovered and some inkling of the vast expanse of stellar space revealed in Galileo's "optick tube." But Galileo was persecuted by the Church for his ideas. It was also the century of Bacon and Descartes, both searching for a scientific method on which to base sure knowledge; it was the century of the decline of Aristotelian authority to be replaced by mechanical and experimental philosophies (see Jones, 1965).

The Protestant Reformation was, in a sense, a purifying of religion of all the trappings of Catholicism, a return to the primitive Christian Church. And with it came an increasing dependence directly on the Scriptures, in the belief that the Divine Light would reveal the truth to one who studied the texts assiduously enough. But the texts did not always agree. Although variations had been noted by Medieval scholars, the full light of Renaissance scholarship revealed numerous variations and inconsistencies in different Greek, Latin and Hebrew versions. (Allen, 1963: ch. 3 illustrates this problem with particular reference to the Noah story in Genesis). In some ways Roman Catholic scholars who stuck to the Vulgate were better off, but then the weight of tradition was equally dangerous to the good Catholic who wandered too far from orthodox lines of thought. Even René Descartes, founder of the "mechanick philosophy" delayed publication of his ideas of the origin of the earth because of what had happened to Galileo.

Descartes, nevertheless, published his *Principia Philosophiae* in 1644. He remained a faithful Catholic and accepted God as the first cause. But Descartes' God was the Great Mechanic who had set the universe in motion. Thereafter, all natural processes, including the evolution of the earth, could be explained by mechanical laws. Descartes based his theory of the earth on scientific principles (even though these were later to be proved incorrect on mathematical and mechanical grounds). He accepted the Copernican universe and filled it with an ethereal fluid that swirled in great vortices. The earth, originally incandescent, was a cooling fixed star, caught up in the sun's vortex. It was divided into three parts: a still incandescent centre, a solidified, opaque middle layer and the outer layer, the earth's crust as we know it. Here the debris of clouds and spots, rather like sunspots, which gathered when the earth was still very hot, cooled, remelted, aggregated and consolidated into the earth's crust which contained the heaviest material. This was surrounded by the lighter water, and the lightest material of all formed the atmosphere. The heat and light of the sun could still penetrate to the centre and exert a sufficiently potent influence to rupture the crust so that land rose above the water in places. (Descartes, 1964).

This was the first scientific theory of the earth that completely ignored the Genesis account. Naturally, it was not immediately accepted as such. After the publication of Newton's work on gravitation in 1687, most English theorists preferred gravity to vortices in their theories of the earth. (See review of Isaac Newton, *Philosophiae Naturalis Principia Mathematica, Phil. Trans.* 16, (180), 1687, pp. 291-297). However, the more subtle effects of Descartes' emphasis on mechanical laws were strongly felt in England. The authority of the Bible and of the classical philosophers was no longer blindly accepted. Intelligent gentlemen were out in the field, observing the processes of nature for themselves and finding things that did not quite tally with Biblical, or Greek, writings. They were beginning to experiment, to get together, to discuss their results. It was just such a group that joined together to form themselves into the Royal Society of London in 1660, and received their charter in 1662.

By the end of the seventeenth century, "Experimental and Mechanical Knowledge" was gaining ground over the "Philosophy of Discourse and Disputation," not without some opposition and controversy. It must have been with considerable feeling that Dr John Keill, an Oxford mathematician (who was admitted to the Royal Society in 1700) wrote in 1698:

> M. Des Cartes, the great Master and Deliverer of Philosophers from the tyranny of Aristotle, is to be blamed for all this, for he has encouraged so much this presumptuous pride in Philosophers that they think they understand all the works of Nature . . . He was the first World-maker this century produced, for he supposes that God at the beginning created only a certain quantity of matter and motion, and from thence he endeavours to show how by the necessary laws of *Mechanisme* without any extraordinary concurrence of the Divine Power, the world and all that therein is might have been produced. (Quoted by Taylor, 1948: p. 105.)

Much of this sort of controversy went on outside the Royal Society. The members met regularly to discuss, experiment, and report on matters of interest to science. Religious and political topics were forbidden; nor was religious or political affiliation a bar to membership.

> Their purpose is, in short, to make faithful Records, of all the Works of Nature, or Art, which can come within their reach: that so the present Age and posterity, may be able to put a mark on the Errors, which have been strengthened by long prescription: to restore the Truths, that have lain neglected, to push on those, which are already known, to more various uses: and to make the way more passable, to what remains unreveal'd. (Sprat, 1667: p.61.)

In order to do this "they have indeavor'd to separate the knowledge of Nature, from the colours of Rhetorick, the devices of Fancy, or the delightful deceit of Fables . . ." These "Reformations in Philosophy" were to be achieved, "not by a glorious pomp of Words; but by the silent, effectual and unanswerable Arguments of real Productions." (Sprat, 1667: p. 62) Bishop Sprat, who was more the apologist for the "Experimentall Philosophy" practised by the Royal Society than its historian (it had only been in existence five years when he published his History), was also aware of the dangers of theological dogma to science. Religious dispute was the means by which

> the knowledge of Nature hath been very much retarded . . . the wit of men has been profusely pour'd out on Religion, which needed not its help, and which was onely thereby made more tempestuous: while it might have been more fruitfully spent, on some parts of Philosophy, which have been hitherto barren, and might soon have been made fertil. (Sprat, 1667: pp. 25-26).

It is in the light of current literal interpretations of the Bible and the Royal Society's avowed preoccupation with science for its own sake that some of the controversies and speculations on the history of the earth among its members will be discussed. This is of the greater interest because, on the question of earth history, science and the scriptures were farthest apart.

THE FOSSIL CONTROVERSY

"In his hand are all the deep places of the earth: the strength of the hills is his also. The sea is his, and he made it: and his hands formed the dry land."
Psalm 95: 4-5

Although a few observers in mid-seventeenth century had reached the conclusion that fossil shells were of organic origin, many learned members of the Royal Society preferred an inorganic explanation for such phenomena. Opinions on the origin of fossils ranged from planetary influence, the work of evil or occult forces, perhaps with a hidden meaning, the work of God whose meaning was hidden from man, the results of spontaneous generation which failed and never became truly animal, or discards in the process of creation, to the work of vapours and exhalations in the earth, lapidifying juices, seminal principles, or "plastick virtue" of some kind. (Adams, 1938: ch. 8). The question of the origin of fossil shells was hotly debated both in papers published in the *Philosophical Transactions* and in meetings of the members (Birch, 1756-7) or in more informal gatherings. Robert Hooke, protagonist of an organic origin, noted one such debate in 1677, "a great despute about petrifactions etc." at Jonathans, a London coffee house, with Dr. Plot who preferred to invoke a "plastick virtue." (Robinson and Adams, 1935, p. 314).

In 1665, Hooke had already published his opinion, based on microscopic examination of specimens, of the organic origin of fossils in his *Micrographia.*

From all which and several other particulars which I observed, 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 Plastick 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 hardened in those shelly moulds into those shaped substances we now find . . . (Hooke, 1665: p. 111)

It seems that Hooke's ideas were still a little advanced for his times. When he read the fossils section of the *Micrographia* as a paper before the Royal Society on 24 August 1664, "The Society approved of the modesty used in his assertions, but advised him to omit what he had delivered concerning the ends of such petrifactions." (Birch, 1756-7: Vol. I, p. 463).

In 1667, a book titled *Musculi Descriptio Geometrica* by Nicolaus Steno, a Dane living in Florence, was published. This work included a section titled the Dissection of a Shark's Head and in the narrative discussed the controversial "glossopetrae" or "tongue stones." (Steno, 1958)

in which controversie he [Steno] takes their part who maintain, that those and divers other substances found in the Earth are parts of the Bodies of Animals, and endeavours to prove, that such sorts of Earth may be the sediments of Water, and such Bodies, the parts of Animals carried down together with those Sediments, and in progress of time reduced to a stony hardness.

(Review in *Phil. Trans.* 1-2, (32) 1667: pp. 627-8)

Henry Oldenburg, secretary to the Royal Society and first editor of the *Philosophical Transactions,* had been in communication with Steno on the subject of fossils. (Hall, 1965-8: vol. IV, pp. 345-347, 431, 433). In 1671 he published his English translation of Steno's *Prodromus of a dissertation concerning a solid body enclosed by a process of nature within a solid* which had first appeared in Latin in 1669. This was also reviewed in the *Philosophical Transactions.* Steno affirmed that fossil shells "were once the parts of Animals living in Water and proving it by the sole inspection and consideration of those Shels themselves . . ." The occurrence of marine fossils in a stratum was evidence that that area had been formerly under the sea. Steno's basic assumptions were that strata were laid down in a fluid condition and that each stratum was laid on top of an already firm lower stratum. Although the lower level of a stratum would follow irregularities in the surface of

the layer below it, its upper surface would always be parallel to the horizon. Inequalities in the earth's surface were caused by deformation of these parallel strata, whether disrupted by subterranean exhalations which caused earthquakes, or collapse of the roofs of caverns within the earth. On the basis of these assumptions of fossil evidence of marine transgressions and superposition of strata, Steno constructed a geological history of Tuscany.

He concludeth this Prodromus with a remarkable Information, shewing, How we may from the present Face of the Earth, by an attentive view, discover the former state of it. Which he endeavours to make out by an Example taken from Toscany; in the present face of which he conceiveth, that the obvious Inequalities proclaim to an heedful Observer manifest arguments and signs of Six different Changes happened therein; the face of it having been, by his Observations, twice fluid, twice plane and dry, and twice uneven; which as he attempts to demonstrate by an Induction of many places in Toscany viewed by himself, so he confirms it of the Whole Earth by the Descriptions of various parts of the World made by several Authors; obviating the chief difficulties that may occur about each Face and particular Constitution of the Earth.

(*Phil. Trans.* 5-6 (72) 1671, p. 2190)

Steno also believed in the Deluge as the major marine transgression. His *Prodromus* was a landmark in the early development of earth science. However, the implications of his geological history were not fully realised by Royal Society members who seem to have regarded him simply among the advocates of an organic origin of fossil shells. Martin Lister was one of the chief protagonists of an inorganic origin. A letter from Lister to Oldenburg on Steno's *Prodromus* was read at the Society's meeting of 2 November 1671. "This letter 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" (Birch, 1756-7: vol. II, p. 487. Birch also reported other debates between Hooke and Lister on this subject (see especially Vol. IV, pp. 237-238). Lister wrote "that if my sentiments on this particular are somewhat different from his [Steno's], it proceeds not from a spirit of contradiction but from a different view of Nature." Lister conceded that perhaps some fossil shells found around the Mediterranean Sea, even some distance inland, could be of marine origin.

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 . . . but that these Cockle-like stones ever were, as they are at present, *Lapides sui generis*, and never any part of an Animal.

(*Phil. Trans.* 5-6, (76) 1671, pp. 2282-3)

Lister's reasons for his belief, that fossil shells were a distinct form of rocks, were based on his observation that there was considerable variety of fossils in different kinds of rock, and often the fossil did not differ in texture from the surrounding material "but that all Iron-stone Cockles are all Iron-stone; Lime or Marble all Limestone or Marble." Not only was there great variety in types of fossil but some fossils differed "from anything in nature besides, that either the land, salt, or fresh water doth yield."

The naturalist, John Ray, believed in the organic origin of fossils. He had met Steno, had read his books and frequently referred to him when discussing fossils. He had travelled widely in Europe in the 1660's and taken frequent notes on fossil deposits among his biological observations. In his notes on the fossil deposits of Malta he wrote:

that these were formed by some plastic power in the stone quarries, being nothing else but the effects or productions of Nature sporting herself in imitation of the parts and shells of these animals I can hardly be induced to believe; Nature (which is indeed nothing else but the ordinary power of God) not being so wanton and toyish as to form such elegant figures without further end or design than her own pastime and diversion.

(Quoted by Raven, 1950: p. 422)

Two of Lister's articles on fossils in the *Philosophical Transactions* in the 1670's had notes by Ray appended suggesting that an organic explanation was much more likely for the phenomena described. (*Phil. Trans.* 7-8, (100) 1673, pp. 6181-91; 9-10, (112) 1675, pp. 274-9). Ray refuted Lister's argument against an organic origin because present day species similar to the fossil had not been found "unless we will suppose them to grow at great depths under the water. And who knows but there may be such bodies growing on the rocks at this day . . . " Lister was not without support, however. An anonymous correspondent commenting on his 1675 article wrote:

> And may I suggest the Inquiry, whether those Shells which are found in the ground, and seem to argue the Sea was once there, are not such Geometrical effects of Nature, either by a Seminal principle from the Shells decaying, or the effects of the Accidental impressions from some Shells which came thither by accident.
>
> (Phil. Trans. 9-10, (122) 1675, p. 540)

The idea of a seminal principle causing growth of figured stones or fossils *in situ* was followed up in two articles by John Beaumont on the fossils of the Mendip region. His theory was that fossils "grew" in a manner analogous to the "growth" of crystals precipitated from a solution of salts.

> Thus when we find several sorts of Shell-fish 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; there being no want of Saline nor Earthy particles.
>
> (*Phil. Trans.* 11-12 (129), 1676, p. 737.)

Beaumont was applying to the growth of fossils the ancient idea of spontaneous generation without biological parents. Several articles had appeared in the Philosophical Transactions on the subject, mainly concerned with parasitic insects and those which fed on putrifying flesh. The theory had not entirely disappeared although Ray had denied such a supposition. (*Phil. Trans.* 5-6, (74), 1671, pp. 2219-20.) In his second article Beaumont raised the question of fossil species bearing no resemblance to known living species. "To answer this by saying that all these species are lost will satisfie few" particularly in view of the variety of species and their distribution; "we cannot imagine how so many species diffus'd through so many parts of the whole earth should all happen to be lost together". (*Phil. Trans.* 13, (130).) This question of "lost species" had also bothered Ray, a scientific observer of nature but also a religious man who accepted current theological teachings. In a letter to his friend Edward Lhwyd, thanking him for a box of specimens, he wrote:

> Such a diversity as we find of figures in one leaf of fern and so circumscribed in exact similitude to the plants themselves, I can hardly think to proceed from any shooting of salts or the like . . . Yet on the other side there follows such a train of consequences as seem to shock the Scripture history of the novity of the world; at least they overthrow the opinion generally received, and not without good reason, among Divines and Philosophers that since the first creation there have been no species of animals or vegetables lost, no new ones produced. (Quoted by Raven, 1950: p. 437)

Acceptance of an organic origin for fossil deposits created more problems, both theological and scientific, than an inorganic one. The whole question was most fully treated by Robert Plot in his *Natural History of Oxfordshire.* He devoted a full chapter to "the great Question now so much controverted in the World". Plot inclined toward Lister's explanation that fossils were *Lapides sui generis,* rather than an organic origin advocated by Hooke and Ray. "The latter Opinion appearing at present to be pressed with far more, and more insuperable difficulties than the former". (Plot, 1705: p. 113.) If one believed in an organic origin, then one had to accept with Steno that shells along with other plants and

animals were deposited in a watery medium, in a flood, Noah's or some other. This raised the whole question of the nature of the Flood. If it consisted of rain, this was more likely, as Ray had observed in 1671, to have washed shells down to the sea not up into the mountain tops. (Raven, 1950: p. 425.) If the Deluge were due to an overflowing sea, particularly if the flooding were gradual, why should the shellfish leave their beds? If the Deluge were violent, "such a flood would have indifferently scattered all sorts of Shells over the whole Face of the Earth". (Plot, 1705: p. 113.) Plot observed that "these Beds of Cockle-Stones (if they must needs have been Shell-fish) seem rather to have been their Breeding Places, where they had Abode for some considerable time (especially where we find them of several sizes) than brought hither in the Flood . . . " He went on to remark that the duration of the Flood was too short for shellfish to move themselves any distance and "too small a time for so many shellfish, so dispersed, as they must be by so violent a Motion, to get together and sequester themselves from all other company, and set them down, each sort, in a convenient Station". (Plot, 1705: p. 114.)

Ray also puzzled over the distribution of fossils in beds dominated by single species, indicating the breeding place of the shellfish, rather than later deposition. He noted that although earthquakes did cause some changes in the earth's surface "since the most ancient times recorded in history, the face of the earth hath suffered little change". He pondered the possibility of geological change: "if the mountains were not from the beginning, either the world is a great deal older than is imagined, there being an incredible space of time required to work such changes . . . or in the primitive times the creation of the earth suffered far more concussions and mutations . . . " (Ray, *Observations,* 1673, quoted by Raven, 1950: pp. 425-6.) Despite these difficulties, Ray advocated an organic origin of fossils "as being more consonant with the nature of the thing, and could wish that all external arguments and objections against it were rationally and solidly answered." (Quoted by Raven, 1950: p. 426.)

By the beginning of the eighteenth century an organic origin for most marine fossils was more acceptable. Certainly, after 1699, no more articles appeared in the *Philosophical Transactions* advocating a non-organic origin. Interest in fossils did not abate, however. Specimens were continually added to the Society's repository. There were still many contributions in the *Philosophical Transactions* but these were largely descriptive of individual specimens, and of the strata of the areas where they were found. Lists of fossil species published in a number of recent books served to keep up the interest in fossils. In 1708 the following advertisement appeared in the *Philosophical Transactions:*

Whereas in the perusal of the late eminent Mr Ray's Physico-Theological Discourses, Dr. Lister's Treatise de Cochlites Angliae, Dr. Robert Plot's Natural Histories of Oxfordshire and Staffordshire, Dr. Woodward's Essay, some papers in the Philosophical Transactions, and several other books, the Discourses on Formed Stones and their Origin are not so clearly understood, for want of a competent knowledge of those Bodies: Notice is hereby given, that the Curious in that part of Natural History may for one Guinea, be supplied with Specimens of all the following figur'd fossils, by Alban Thomas, Librarian of the Ashmolian Repository in Oxford.

There followed a list of fifty-two different species.

Most contributors, particularly ecclesiastical members of the Society, were very happy to accept Noah's Flood as an explanation for the fossils. The Reverend Mr Abraham de la Pryme was rather more exuberant than most in his report on fossil shell fish observed in the quarries near Broughton in Lincolnshire. He noted different kinds of fossils in different sorts of strata and developed a theory of relationship of certain fossils to certain "soils" or strata and refuted the idea of lost species.

Just as some sorts of fish breed upon some sorts of Soils as the Cornu Ammonis, Nautili and others, upon Allum Soils . . . And if anyone would find any of those sorts of fishes

(which some Learned Men have ridiculously thought to be Species totally lost) they ought in all probability to seek for them upon Allum Soils in the Sea, and there they would undoubtedly find them. (*Phil. Trans.* 22 (266), 1700, p. 681)

The fossil species that had no modern equivalent locally no longer seemed to be such a problem, particularly as new and strange species were now frequently reported by travellers. Hans Sloane remarked quite matter of factly in a footnote to Mr Lliwd's letter describing a figured stone found in Wales :

This Stone is a sort of Coral . . . It grows in the seas adjoining to Jamaica. It is frequently found fossil in England . . . There are many other things growing in the seas about Jamaica, and not to be found in these parts, which are frequently dug up in the Inland parts of England, and elsewhere, near to which places they do not naturally grow. (*Phil. Trans.* 21, (252), 1699, pp. 107-8)

With increasing knowledge of the natural history of other regions, it was sufficient for the time being that modern species equivalent to the fossil could be found. The implication of past climatic change was a topic for later debate.

The Reverend Mr de la Pryme had also noted 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 goes on to describe how "in that Deluge the Earth suffered wonderful great violence and force, that Seas were raised into Mountains, and Mountains sunk into Seas . . . " He acknowledged the difficulties in explaining how this happened : "I know very well the great disputes and contests that are among the learned, . . . and what wonderful Systems and Theories they have formed to solve the same, all which have a great deal more of Art than Nature in them". His "notion of the Antediluvian World" was one that was not very different from the present, until God "broke the Foundations and Subterraneous Caverns and Pillars thereof with most dreadful Earthquakes" and caused the Flood. De la Pryme followed the Mosaic narrative fairly closely and quoted Plato's story of Atlantis to corroborate it.

From this happy system of the Flood, all those things are easily solved that were hard and difficult before . . . And thus it comes to pass that we find Shells and Shell-fish, and the Bones of other Fishes, and four footed Creatures and Fruits etc. petrified and lodged in Stone, Rocks, Mountains, Quarries and Pits over our whole Earth.

Discussion of the general theory of the Deluge was then applied to the countryside around Broughton, Lincolnshire, which

appears manifestly in the Antediluvian World to have been the bottom of some fresh Water Lake, because that those are fresh water Shell-fish that are found there and the bed upon which they breed was a fine blue Clay which is the colour of the Stone to this day, which Bed being elevated and lifted up (and dash'd over with other Earth in the workings of the Waters and the great hurry and confusion that then happen'd) the said Bed by the power of the subterranean Elevating heats, steams, and Effluviums were turned by Degrees into Stone, with all the Fishes therein.

The Rev. de la Pryme's paper has been considered in some detail for it illustrates how the Deluge had come to be accepted as a working hypothesis to explain past geological changes. The organic origin of fossils is assumed, and the emphasis is not on fossils as evidence of the Flood, but the occurrence of the Flood explains the fossils and strata of the quarries near Broughton. The author makes this quite clear in his concluding remarks where he compares the situation in present rivers and ponds stocked with shell fish with his observations of the fossils of the quarry. "Now if the bottom of any one of the said Rivers or Ponds was raised by Earthquakes, and turned into Stone by petrified Effluviums, they would exactly be found as these are." (*Phil. Trans.* 22, (266), 1700, pp. 677-87).

The Reverend Mr Morton followed similar lines in his report on fresh water shells dug up in a peaty marsh in Northamptonshire. "The finding of these Shells Under Ground made it very reasonable to enquire whether there were any of

the like at this time living upon the surface. I diligently searched this place, but cou'd not meet with any Live ones of any kind whatever there." Morton's fossils included both land snails and fresh water varieties, some of them similar to those found elsewhere in Northamptonshire, but in far greater numbers than they were ever found living.

It is evident that these Shells were left at the Deluge, when those from Sea were also reposited at Land; and not buryed since by Deterrations [erosion] from the Ground above. For then the upper parts of the Moor must have been cover'd with a Reddish Sand, such as the Ground [surrounding the Moor] is for the main compos'd of; but nothing like that appears near the Shells in this Moor. Besides, here are dug up several Shells that in all likelyhood never bred here, but are Inhabitants of a different Soil : Particularly the Striped Snail-Shell. For these Animals have peculiar Soils, and affect particular Regions.

The interesting feature of both de la Pryme's and Morton's papers is the uniformitarianism displayed in their thinking despite their acceptance of a catastrophic explanation for past changes in the earth's surface. Both were concerned with the details of the stratigraphy of the site, and drew on their own observations of nature in accepting that certain kinds of species thrive only in a particular habitat or "soil". Any departure from such natural laws, as a fossil striped snail found outside its "peculiar soil" required further explanation. There was an implicit acceptance that the processes of nature occured in the past in just the same way as they could be observed occurring in the present. Neither, however, was able to dissociate the hand of God from the works of Nature. And Noah's Flood, since it had Scriptural authority, was the only known way of explaining the obviously great changes that have occurred in the history of the earth.

THE MECHANICS OF THE DELUGE

"In the six hundredth year of Noah's life, in the second month, the seventeenth day of the month, the same day were all the fountains of the great deep broken up, and the windows of heaven were opened:" Genesis 7 : 11.

There was abundant evidence in the field that changes had occurred in the earth's surface since the Creation. Davies (1966 a and b) has demonstrated that scientists in the late seventeenth century were well aware of processes of erosion and deposition. There was also evidence of more dramatic changes. Several papers in the *Philosophical Transactions* before 1700 contained descriptions of mines, of strata, of faults in them, of the erratic courses of mineral veins. (See especially the account of the mines of Cornwall and Devon, *Phil Trans.* 6, (69), 1671, pp. 2096-2113). There was also the even more extraordinary evidence of marine fossils, far inland, at great depths below the surface of the land, or high in the mountains. The only possible orthodox explanation for such phenomena was Noah's Flood. This explanation had the advantage of scriptural authority and historical documentation. There was no other historical record of any world wide catastrophe, and surely there would be if one had occurred. Furthermore, most still believed the earth could be no more than about 6,000 years old. The orthodox chronology accepted widely in England was Archbishop Ussher's calculation of 4004 B.C. for Creation and the Deluge in 2348 B.C.

Despite this belief in the Deluge, there were all sorts of problems in interpreting and explaining the not very explicit text of Genesis (to say nothing of variations in Biblical texts). Theologians were concerned with such practical problems as the size of the ark, how it held all the animals, its seaworthiness, the landing place of the ark, where did the raven go since it did not return, what happened to the survivors of the Flood, if all animal and vegetable life were destroyed, how did they live, etc., etc. Such questions are not of concern here but they were considered along with the geological implications such as the nature of the flood itself; where did the water come from; how much was needed

to cover the mountain tops; where did it go to afterwards; what changes had occurred in the earth's surface; were the relations between land and sea the same now as in antediluvian times; had the climate changed? A vexing question was the universality of the Deluge. Did it flood all the land areas of the earth, or just the populated areas; to what extent was the earth populated at the time? There was plenty of food for thought and argument. There was even a minority opinion who regarded the flood as a strictly local affair. Allen (1963, chs. 4 and 5) discusses in more detail the treatment of some of these questions during the Renaissance and up to the end of the seventeenth century. The controversy in England in the seventeenth century is discussed by Taylor (1948 and 1950); the literary implications and influences are fully outlined in Nicolson (1959). Collier (1934) and Haber (1959) provide full accounts of European cosmogonical theories for the whole period, while Greene (1961, ch. 3) and Toulmin and Goodfield (1955, chs. 3, 4 and 7) provide useful summaries with implications for the later development of ideas of biological evolution and geological time. Discussion here is concerned mainly with participation by members of the Royal Society in the controversy and their contributions in the form of papers and letters published in the *Philosophical Transactions*. L

Allen said, "The progress of mankind often depends more on glorious failures than brilliant successes, and the attempt to provide a rational explanation of the Noah story is one of the glorious failures." (Allen, 1963 : p. 66) But in the seventeenth century, scientist and theologian alike still believed there was a rational explanation for the Deluge.

1) *The Special Providence of God.*

Members of the Royal Society did not generally concern themselves with theological expositions on the nature of the Deluge. In 1670 a book titled *The Divine History of the Genesis of the world* . . . (London, 1670) was reviewed. At first sight this would seem to contradict their policy to exclude theological problems. However, the anonymous author attempted to adapt science to the Mosaic account, in the process attacking the Cartesian ideas that nature can be explained in terms of "only Matter and Motion". The reviewer attacked the book, not for its theology, nor for a belief in the Deluge, but for the poor knowledge of science displayed. (*Phil. Trans.* 5-6, (60), 1670, pp. 1083-4)

Another theologian who ventured to rationalize the Deluge story and science was the Rev. Thomas Burnet who published his *Telluris Theoria Sacra* in 1681. This was soon available in English as *The Theory of the Earth Containing an Account of the Original of the Earth and of all the General Changes which it hath already undergone, or is to undergo till the Consummation of all Things.* On 2 February 1681, Dr. Gale reported briefly to the Royal Society "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". (Birch, 1756-7, Vol. IV, p. 69) On 27 April 1681 Dr. Gale read a full review "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 without a perusal of the discourse itself". (Birch, 1756-7, Vol. IV, p. 83). A short review, summarising the contents but containing no comment, subsequently appeared in the *Philosophical Collections* (No. 3, 1681, pp. 75-6).

Briefly, Burnet's theory was that the once ordered and beautiful earth had been transformed into its present ruin—mountains held no beauty and majesty for him — during the Universal Deluge by the "Special Providence of God". The antediluvian earth had been egg shaped, "the mundane egg" he called it, with its axis perpendicular to the plane of the ecliptic. There were no seasons, the climate was uniformly mild and equable. The surface was smooth and regular with no markings, no seas or oceans. During Noah's flood, "the fountains of the great

Abysse were broken open" and the earth engulfed by water from a great central reservoir. The earth's axis was tilted in the cataclysm to produce the present seasonal variation in climate and mountains and continents and oceans formed. He also predicted that the "Universal Conflagration" would again renovate the earth and a new heaven and earth would evolve. Burnet believed there was no ultimate conflict between science and religion; it was not necessary to invoke miracles every time to explain the apparently inexplicable. (Burnet, 1965).

Although the review was noncommital, members of the Royal Society read the *Sacred Theory of the Earth* with great interest. Burnet was attacked, quite rightly, by mathematicians for his ignorance of elementary mechanics and dynamics. Robert Hooke read *The Theory* carefully and it was one of the stimuli for the later series of lectures on earthquakes delivered to the Royal Society. In 1689 Hooke produced his own "Animadversions on Burnet's Theory" to add to the score or more books and pamphlets that appeared in England and the Continent attacking both his science and his theology. (Taylor, 1948 : p. 108) Newton objected to Burnet's idea of a smooth dry earth as being contradictory to the Genesis account of the division of dry land and waters (Newton, 1959 : Vol. II, pp. 322-3) Nor was he happy with Burnet's "oval figure of ye earth . . . I am inclined to believe it spherical or not much oval" on analogy with the other planets. (Newton, 1959 : Vol. II, p. 329) Nevertheless, Newton was interested enough to write two long letters to Burnet, mainly on the creation story and its scientific interpretation. Newton had no doubt about the role of God in the processes of nature.

> Where natural causes are at hand God uses them as instruments in his works, but I doe not think them alone sufficient for ye creation and therefore may be allowed to suppose that amongst other things God gave the earth its motion by such degrees and at such times as was most suitable to ye creatures . . . (Newton, 1959: Vol. II, p. 334)

Years later, after he had published his *Principia,* Newton's views had not changed, except perhaps his concept of God, the great Geometer, had become more explicit. In 1692, in a letter to Richard Bentley on the orbits, motions and velocity of planets he wrote: "and to compare and adjust all these things together, in so great a Variety of Bodies, argues that Cause to be not blind and fortuitous, but very well skilled in Mechanicks and Geometry". (Cohen, 1958 : pp. 286-287).

This example from Newton will suffice to illustrate how even the greatest mathematical mind of the time found no difficulty in reconciling his science and his religion. It was the same with most of the members of the Royal Society. Like Newton, many of them, not only the ecclesiastical members, wrote theological works or attempts to reconcile science and religion. Examples include Nehemiah Grew's *Cosmologia Sacra* (1701), John Ray's *Physico-Theological Discourses* (1693) and William Derham's *Physico-Theology* (1713). Like most of the critiques of Burnet's theory, few such works were reviewed in the *Philosophical Transactions.* Nor does Birch record much discussion of such subjects. The Society maintained its rule to keep religion out of its activities. There were two exceptions to this general policy in the reviews of John Ray's *Physico-Theological Discourses* and J. Beaumont's *Considerations on a Book Entitled The Theory of the Earth publish'd some time since by the learned Dr Burnet.*

In his second discourse "The General Deluge, its Causes and Effects", Ray stayed close to the narrative of Genesis. The "fountains of the deep" he took literally as subterraneous waters and the opening of "the windows of heaven" supplied a great deal of water from the waters lodged above the inferior regions of air. The actual cause of the flood was a change in the centre of gravity, forcing the subterraneous water up over the land. A return to the original centre of gravity would restore the land again. He also suggested that Divine Power might have depressed the ocean surface and forced out the subterraneous waters. (*Phil. Trans.* 17, (196), 1963, p. 616; Raven, 1950 : pp. 443-4).

Although Ray depended on Divine Power to explain such things as the Deluge he was also an acute observer of nature. He saw no inconsistency in drawing on both scriptures and field observation in his discourse. His "God of the Bible and the Church was also the author and sustainer of nature". (Raven, 1950 : p. 441) Beaumont, however, considered that natural laws could not explain such events as the Deluge.

The Author of the Considerations thinks, that when things are represented in the Scriptures, as grounded on a particular Providence, as he conceives the Deluge and Paradise are, we ought not to endeavour to assign Natural Causes for them, which do but destroy the Miracle by lessening it; there being no Divine Law but must set forth God as a most free Agent, and often acting beside and contrary to the tendency and common course of any Natural Causes whatsoever (Review in *Phil. Trans.* 17, (203), 1693, pp. 888-92).

2) *Polar Mutability*

The conclusions of Robert Hooke (1635-1703), Curator of Experiments to the Royal Society, on the nature of fossils have been noted. However, Hooke went further, to consider the processes at work in the past history of the earth which might explain how marine fossils achieved their present situation. His earliest papers on the subject were delivered to the Royal Society in 1667. (Rossiter, 1935 : pp. 174-175) Birch recorded that on 27 June 1667, Hooke reported to the Society on strata seen in some cliffs. The "natural position" of these strata was horizontal, but in some places they were "much sloping and in others perpendicular". Hooke thought the strata "might fall into these odd positions by some great earthquakes; and he was of the opinion, that the great hills and mountains have been raised by earthquakes". He also quoted the shells in strata well above sea level in the cliffs of the Isle of Wight which had been raised by earthquake. In the ensuing discussion the Bishop of Exeter suggested that "the shells might be carried in by subterraneous channels". Sir Theodore de Vaux contributed the information "that a hill in Switzerland had been removed by an earthquake with the vines and some trees still growing upon it". (Birch, 1756-7 : Vol. II, p. 183) Whether Hooke expounded at length on his ideas of a shift in the earth's centre of gravity contained in his two papers on earthquakes dated 1667 and published in his *Posthumous Works* (Rossiter, 1935: pp. 175-6) this aspect was not reported by Birch. Perhaps it did not arouse so much interest at the time.

Considerable interest and debate on the question of the movement of the poles as a cause of the Universal Deluge was aroused by Hooke's series of lectures delivered to the Society in 1686-7. He began this series with lectures in December 1686, by reiterating his belief in the organic origin of marine fossils and regarding them as evidence "that there have been very great changes in the earth's surface". (Birch, 1756-7 : Vol. IV, p. 513) In discussing the structure of the nautilus and Cornu Ammonis, the fact that there was no known modern counterpart "is not a sufficient argument to evince, that there is not nor ever was any such Animal *in rerum natura*". (Birch, 1756-7 : Vol. IV, p. 516) To prove this argument fallacious "Mr Hooke produced a quotation out of Mandelslo's travels, wherein mention is made of an oister, the shells of which weighed above 400 lb; which shells were then in the Duke of Holstein's collection of rarities". (Birch, 1756-7 : Vol. IV, p. 517) On 19 January 1687, he posed three questions: "1. Whether the earth's poles are fixed in the earth or not? 2. Whether the earth's surface be truly spherical? and 3. Whether all perpendiculars pass exactly through the same point or centre?" (Birch, 1756-7 : Vol. IV, p. 521) The following week he developed his hypothesis to explain the distribution of marine fossils.

He supposed that the diurnal rotation of the earth by its *vis centrifuga* taking off part of the gravity formed the Surface of the sea into a compressed spheroid; that is, that the diameter by the poles is the shortest and those of the equinoctial greatest, with some experiments in the shortening of the pendulum near the equator seem to make out. Then,

if it may be supposed that the poles and axis are moveable, the equinoctial and greatest diameter will be likewise altered, and by consequence the parts of the land, towards which the poles approach, will be raised, and the sea retire; but, on the contrary, those parts, from which the poles recede will sink, and the water rise upon them : and that the poles may be altered, he endeavoured to prove by alledging the latitudes of several places considerably different from those assigned by Ptolemy and the old geographers. (Birch, 1756-7: Vol. IV, p. 522).

In the next three lectures Hooke amplified this hypothesis and proposed experiments and mathematical demonstrations to support it. In passing, he wondered "whether the vast sandy deserts of Africa and Arabia owe not their original to the sea?" (Birch, 1756-7: Vol. IV, pp. 523, 525 and 527).

On 15 February 1687, Edmond Halley wrote to the astronomer Wallis, describing Hooke's hypothesis, noting particularly Hooke's idea that "the superficies of the earth may have been frequently covered with water, and again dry". He went on to elaborate: "when such a shift of the Axis begins it will proceed on to make a revolution, in a greater or lesser circle, according to the manner of the impression of the force causing it so that those parts of the earth which are now near the poles may possibly here to fore have been under the Equinoctiall, or in the Torrid Zone, where the animals whose shells we find . . . may have formerly been generated". (MacPike, 1937: p. 80) On the 9 March 1687, Wallis' reply to Halley, containing "some reflexions on Mr Hooke's hypothesis of the mutability of the poles of the earth" was read to the Society. At the same meeting a paragraph from Newton's "mathematical philosophy" was read "concerning the direction and position of the axis of a globe turning about itself, and shewing that by the addition of some new matter on one side of the globe so turning, it shall make the axis of the globe change its position, and revolve about the point of the surface where the new matter is added". The members agreed that the same effect, resulting in a shift of axis, could occur in the earth "by the blowing up of mountains by subterraneous fire". (Birch, 1756-7 : Vol. IV, p. 528) This opinion was confirmed at the following meeting. (Birch 1756-7 : Vol. IV, p. 529) Halley wrote back to Wallis on 9 April 1687:

Mr. Hook seems concerned that you think his Hypothesis so slightly grounded and thinks he can fully answer the objections of your letter. For my part I conceive it reasonable, not to say demonstrative, that the Earth is of the form of the Sphaeroides prolatus, but doubt very much whether there be any ground to suppose a rotation of the Earth's poles; the latitudes of places having been ever since wee have accounts of observations much the same . . . " (MacPike, 1937 : p. 81).

The difficulty of a hypothesis of polar mutability was the question of changing latitudes of places. On 18 May 1687 Hooke read another discourse on polar mutability which he thought confirmed by an observation of Bartholinus and Picart at Uraniburg of "the angles of position of the neighbouring places with the meridian." These were said to be very different from Tycho Brahe's observations a hundred years earlier. (Birch, 1756-7 : Vol. IV, p. 539) However, on 9 November 1687, Edmond Halley read a letter he had received from Mr Wurtzelbaur of Nuremburg, "containing his observations of the eclipse on the 1st May 1687". (Birch, 1756-7 : Vol. IV, p. 551) It seems to have been Halley who wrote up the anonymous account which appeared in the *Philosophical Transactions,* "shewing that the latitude of that place has continued without sensible alterations for 200 years last past; as likewise the obliquity of the ecliptick; by comparing them with what was observed by Bernard Walther in the year 1487. (*Phil. Trans.* 16, (190), 1687, pp. 403-6) Here was experimental evidence on the subject. The very slight discrepancy in the reading could be attributed to defective instruments "but what I shall necessarily conclude from hence is, that if there be such a motion of the Poles, it is either very slow, or else nearly at right angles to the meridian at Nuremberg". If the latter, then one could expect much faster changes in eastern Asia or the Americas "but I have never heard of any such thing by any of our navigators". This evidence did not invalidate Hooke's idea

that the earth was a prolate spheroid. The author acknowledged that this part of Hooke's hypothesis and marine transgressions resulting from polar change was the most logical explanation for marine fossils. But if the hypothesis of regular polar motion were true, "it would require a prodigious number of Ages to effect those changes we may be certain to have been". But Halley was not prepared to abandon a Deluge catastrophe for a more gradual cycle of marine transgressions. Such gradual "Inundations could never be fatal in the Inhabitants . . . But the Holy Scriptures and Pagan Tradition do unanimously agree, that the last great Deluge was brought to pass in a few days, with no previous notice, so that the account we have thereof, could not by this Hypothesis be made out" (*Phil. Trans.* 16, (190), 1687, pp. 403-6) Halley delivered another paper on the same subject before the Society in February 1688 "whence he concluded that so graduall a motion of the Poles could not account for the Phaenomena of the Universall Deluge". (MacPike, 1937: pp. 210-211)

3) *Comets and Gravitation*

The work of Halley and Newton on the orbits of comets attracted wide interest in the 1680's. It was to be expected that the appearance of what was later known as Halley's Comet in 1682, would stimulate a cometary hypothesis of some kind. Halley was toying with the idea in his 1687 paper on Wurtzelbaur's Nuremburg observations. He wondered "whether we should have recourse to the Intelligent Powers that first imprest this whirling motion on the Ball, or leave it to be performed naturally, by the casual Choc of some transient body, such as a Comet or the like," to explain the sudden shift in the earth's axis, revolution and orbit that would cause a flood. (*Phil. Trans.* 16, (190), 1687, p. 406).

In two papers delivered before the Society in December 1694 he elaborated on the idea of "the casual Choc of a Comet, or other transient Body, as an Expedient to change instantly the Poles and Diurnal Rotation of the Globe". Halley believed that the account of the Deluge was incomplete. "This we may, however, be fully assured of, that such a Deluge has been". He went on to quote fossil evidence but admitted the difficulty in explaining either, how the sea got to the level of fossil strata or, how land containing marine fossils was raised above sea level. He dismissed rainfall to account for the Deluge. Supposing it to rain all over the globe at the rate of 40 inches per day, the total annual rainfall of one of the wettest counties in England, in 40 days the earth would be covered by a mere 22 fathoms of water. He considered a change in the earth's centre of gravity but dismissed this on realising "that this Center of Gravity was the necessary Result of the Materials of which our Globe consists and not alterable whilst the Parts thereof remained in the same Position". He quickly dismissed Burnet's hypothesis as "jarring as much with the Physical Principles of Nature, as with the Holy Scriptures". He did not regard Hooke's explanation as a complete solution either for it only accounted "for drowning two extream opposite Zones of the Globe" and raising the middle zone correspondingly higher out of the water. Nor could he see how Hooke's theory could be accounted for "from Physical Causes, but require a preternatural *digitus Dei*".

Halley, therefore, by process of elimination, reached his theory of a cometary shock. The force of impact would be sufficient to cause the sea to run to the area where the blow was received, taking the bottom of the ocean along and depositing it on the land, heaping the deposits into mountains. In "those Places where the opposite waves balance each other . . . those long continued Ridges of Mountains" were probably formed. Waters recoiling and "reciprocating many times, would at last come to settle in such a Manner as we now observe in the Structure of the superficial Parts of the Globe". (*Phil. Trans.* 33, (383), 1724, pp. 118-124)

William Whiston, Newton's successor as professor of mathematics at Cambridge, but who was never a member of the Royal Society, had also been following

the work of Halley and Newton on orbits of comets. He used Newtonian ideas of gravitational attraction in developing his *A New Theory of the Earth from its Original to the Consummation of All Things* (1696). He believed that the earth had been created out of a chaos of matter from a comet attracted into a circular path about the sun. The near approach of another comet to the earth explained the Universal Deluge. The gravitational pull of this comet reopened fissures in the earth to free the waters of the abyss and changed the earth's orbit from a circle to an ellipse. In addition, this new comet provided enormous rainfall from its own atmosphere. Some parts of the earth dried quickly, as the water drained back into the abyss, but many lowland areas remained submerged for hundreds of years where strata were slowly deposited. Some of these strata were later broken up, raised or lowered, as the earth's crust resettled into shape. (Taylor, 1948 : pp. 111-112; Collier, 1934 : pp. 109-124)

The chief difficulty with Whiston's theory was how to dispose of all the extra water from the comet. Whiston's explanation that all the water drained into the pores and fissures of the earth did not satisfy John Keill, another mathematician, who calculated that this would take 1786.4 years. (Taylor, 1948: p. 112) The publication of Keill's critique of Burnet and Whiston was noted in the *Philosophical Transactions* (20, (240), p. 202) but no review was included. It is certain, however, that many of the members read this, and similar works, with interest and very critically. John Ray wrote, "the new theory seems to me pretty odd and extravagant and is borrowed of Mr. Newton in great part". (Raven, 1950 : p. 434)

Another theory, which was written about the same time as Whiston's gained a much greater following. This was Woodward's *An Essay toward a Natural History of the Earth and Terrestrial Bodies especially Minerals: as also of the Seas, Rivers and Springs; with an Account of the Universal Deluge and of the Effects that it had upon the Earth* (1695). John Woodward, F.R.S., was a physician who had become interested in geology while visiting friends in Gloucestershire. He was already interested in botany and had conducted some experiments in plant nutrition. He was intrigued by the marine fossils of the Jurassic rocks of the area. The question of their origin "was a Speculation new to me; and what I judg'd of so great moment that I resolved to pursue it through the other remoter parts of the Kingdom; which I afterwards did . . . " (Eyles, 1965 : pp. 869-870) He collected an enormous number of minerals and fossils, later bequeathing them to Cambridge University and endowed the Woodwardian chair of geology there.

Woodward was convinced of the organic origin of fossils. He also noted that different fossils occurred in different kinds of strata. His reviewer in the *Philosophical Transactions* described his *Essay:* "The Author of this Book having with great Industry, and no less success, made Enquiry into many considerable Parts of Nature, hath thought fit here to set forth an Account of several of his Observations, and of certain Conclusions which he hath drawn from them, whereof many are indeed of great weight and moment . . . " The most interesting of these conclusions was the relationship of various kinds of "Terrestrial Strata" including fossiliferous ones "down to the very bottom of the deepest Quarries and Mines : That they lye according to the order of their Specifick Gravity, the heavier kinds deeper, the lighter nearer the surface of the Earth . . . " (*Phil. Trans.* 19, (215), 1965, pp. 115-116)

Despite his extensive field observations, Woodward remained circumscribed by the Genesis story. He dismissed suggestions of successive changes in relations of land and sea, earthquakes, shifting of earth's centre of gravity, erosion and deposition. "But to these Opinions our Author replys that they are destitute of all true Foundation and repugnant to Observation". The reviewer went on: "There is not any Reason to believe that such Changes did ever happen, they having not the least Countenance either from the present face of the Earth, or any Credible or Authentick Records of the Ancient state of it, but that the Globe is to this day

nearly in the same condition that the Universal Deluge left it". Woodward also postulated a subterranean abyss of water, connected to the oceans. Woodward's Deluge consisted of a complete dissolution of the material of the earth into particles "together with Sea-shells and other Animal and Vegetable Bodies : That at length all these subsided from the Water, according to the order of their Gravity . . . " and consolidated into horizontal layers, "the Globe at first even and Spherical, the water lying above all . . . " Gradually the water drained back into the abyss, some of it to be vapourized by subterranean fires, elevating parts of the crust and causing earthquakes which ruptured and dislocated some of the strata, and raised continents and mountains. "This great Revolution was brought about by the Hand of Almighty God". The reviewer concluded : "There are many very Curious and uncommon Remarks in the several Parts of this Book, concerning the Wisdom and Contrivance that is evident in the Mechanisme and Fabrick of the Globe . . . but . . . we cannot do better than refer the Reader to the Book itself." (*Phil. Trans.* 19, (215), 1695, pp. 117-122; see also Collier, 1934 : pp. 125-134).

John Ray was very caustic about Woodwards *Essay* on two grounds : firstly that "if he had modestly propounded it as a plausible conjecture it might have passed for such : but to go about so magisterially to impose it upon our belief is too arrogant and usurping"; secondly, his ideas on specific gravity were doubtful. Woodward "had no proof that those bodies must be thus lodged and disposed but the negative one that they could not possibly be so otherwise". (Raven, 1950 : p. 434) Nevertheless, Woodward's ideas on specific gravity of strata were attractive. He was quoted in an "improved and corrected" edition of Varenius' *Geography,* edited by Newton and Jurin, both members of the Royal Society. (Varenius, 1736: Vol. 1, pp. 93, 97-8, 132-3) The Rev. Mr Holloway wrote to Woodward about the strata he had observed in pits dug for fullers earth in Bedfordshire. He sent the account "because it confirms what you say of the regular Disposition of the Earth into like Strata, or layers of Matter, commonly through vast Tracts, and from whence I make a Question whether Fullers-Earth may not be found in other Parts of the same Ridge of Sand Hills, among other like Matter". (*Phil. Trans.* 32, (379), 1723, pp. 419-21)

Not every member was convinced, however, and in the true experimental tradition of the Royal Society, Mr Fettiplace Bellers, F.R.S., studied the composition and thickness of thirty different strata in a coal pit in Staffordshire. Mr. F. Hauksbee provided a table of specific gravity for 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". (*Phil. Trans.* 27, (336), 1712, pp. 541-4) John Strachey probably had Woodward's ideas on strata in mind in his two classic papers on stratification in coal mines in Somerset. In his 1719 paper, illustrated by a cross section diagram, he noted: "For all coal lies shelving like the Tyle of a House, not perpendicular nor horizontal, unless it be broken by a Ridge, which is a parting of Clay, Stone, or Rubble; as if the Veins by some violent Shock were disjointed and broken, so as to let in Rubble etc. between them." (*Phil. Trans.* 30, (360), 1719, pp. 968-73) In his 1725 paper, after visiting some Scottish coal mines, he developed his observations of inclined coal strata into a general theory of all the strata of the globe. He postulated strata, including the ones he described,

or perhaps, of ten thousand other different Minerals, all originally, whilst in a soft and fluid State tending towards the Center. It must mechanically, and almost necessarily follow, by the continual Revolution of the crude Mass from West to East, like the winding up of a Jack, or rolling up the leaves of a Paper Book, that everyone of these Strata, 'tho they each reach the Center, must in some Place or other, appear to the Day; in which case there needs no Specifick Gravitation to cause the lightest to be uppermost etc. for every one in its turn in some place of the Globe or other will be uppermost. (*Phil. Trans.* 33, (391), 1725, pp. 395-8).

Strachey had failed to appreciate the significance of the unconformity shown in his cross section diagram of coal strata. (Tomkeieff: 1962)

ANTEDILUVIAN MONSTERS

"There were giants in the earth in those days . . . . " Genesis 6 : 4

Giant bones had been found, and used, mainly for magical or medicinal purposes, in Europe for many centuries, but few scientists had taken much interest in these curios. The first mentioned in the *Philosophical Transactions* was Thomas Molyneux's report of a giant *os frontis* that he had seen in the medical school in Leyden in 1684. Molyneux was sceptical of giant bones generally, but the similarity of this bone in all respects except size to the human forehead bone made him conclude "there's not the least Question to be made, but this formerly belonged to a Man, and that of a most extravagant large size". Molyneux calculated that the "Giant" would have been between eleven and twelve feet tall. Unfortunately the professor of anatomy at Leyden did not know where it came from, having "found it among the rest of the bones and Skeletons when he first came into that place." (*Phil. Trans.* 15, (168), 1685, pp. 880-1)

Some years later, Molyneux wrote "An Essay Concerning Giants" published in the *Philosophical Transactions*. He was still cautious, acknowledging that many of the so-called "Giants Remains" were either frauds or the remains of elephants or other large animals. The Leyden *os frontis*, which had appeared quite normal and not diseased, had impressed him, but this was one isolated example. If further real evidence could be found of giant human bones

we must not only determine a point that is some use for the Information of the Philosopher and Naturalist, by shewing how far the power of Nature may reach, and does sometimes exert itself in the Production of Humane Bodies beyond her usual bounds : but at the same time likewise do service in relation to the Divine by confirming the truth of several passages in Holy Writ, where there is mention made of Giants, and men of extraordinary strength, as well as bulk of body. (*Phil. Trans.* 22, (261), 1700, pp. 487-508)

Cotton Mather, the New England divine, took up the idea of antediluvian giants in several letters to John Woodward and Richard Waller, the secretary of the Royal Society. In these letters, Mather "confirms the Opinion of there having been in the Antediluvian World, men of very large and prodigious Stature, by the Bones and Teeth of some large Animals lately found in Albany", New York in 1705. He described a thigh bone seventeen feet long and a large molar tooth weighing four and three quarter pounds and another weighing two pounds four ounces which he takes to be "the Eye Tooth of a Man". Another heavier tooth was

found under the bank of Hudson's River, about fifty leagues from the Sea, a great way below the Surface of the Earth, where the Ground is of a different colour and substance from the other Ground for about seventy five foot long, which they suppose to be from the Rotting of the Body, to which these Bones and Teeth did . . . once belong."

Cotton Mather was somewhat carried away by this apparent confirmation of Genesis 6 : 4. The editor, however, was unimpressed and added the laconic footnote: "It were to be wished the writer had given an exact figure of the Teeth and Bones". (*Phil. Trans.* 29, (339), 1714, pp. 62-71)

Other contributors were much more cautious than the credulous Cotton Mather. The same Molyneux who provided the Essay on Giants, also reported on large deer horns found in the ground in Ireland and concluded that the "great American Deer call'd a Moose, was formerly common in that Island". Molyneux's chief concern was to explain why the creature no longer lived in Ireland because he believed "That no real Species of Living Creatur is so utterly extinct, as to be lost entirely out of the World, since it was first Created, is the Opinion of many Naturalists, and 'tis grounded on so good a Principle of Providence taking Care in general of all its Animal Productions, that it deserves our Assent." Despite his acceptance of the scriptural idea that no species had been lost since creation, he was not happy to explain these bones in terms of Noah's flood "which, I confess is a ready and short way to solve this Difficulty, but does not at all satisfy me".

Apart from unanswerable arguments against the universality of the Deluge, Molyneux could not see that the "fragil, slight and porous Substance" of these bones could "be preserv'd entire and uncorrupt" during and since the flood some four thousand years ago. "And therefore it seems more likely to me, this kind of Animal might become extinct here from a certain ill Constitution of Air in some of the past Seasons long since the Flood, which might occasion an Epidemick Distemper . . . " He quoted a contemporary report of the destruction of whole herds of reindeer in Lapland by "a Raging Distemper" to support this theory. The few that survived in Ireland would have been killed off for venison by the increasing number of local inhabitants. However, the species survived in North America. Thus, a natural explanation for extinction of these deer in Ireland could be found without invoking the question of lost species or resorting to the Deluge.

A discovery on the property of Mr. John Sommers, near Canterbury, was reported in the *Philosophical Transactions*. A well was being dug "through gravelly and chalky ground" when, at about seventeen feet deep, the diggers came upon "a parcel of strange and monstrous Bones, some whole, some broken, together with four Teeth, perfect and sound". The writer went on to suggest that this might be the remains of a hippopotamus but wondered whether it were a sea or land creature. If it were a sea creature, how did it get there ? This would assume the sea once covered the region, but since fossil oyster shells were also found in the same locality then a flood of some kind must have occurred. He remarked on the historical evidence of earlier floods such as Deucalion's flood which had separated Sicily from Italy and wondered whether a similar explanation could be found for the separation of Spain from Africa and the United Kingdom from continental Europe. He realised that the Low Countries had arisen from the sea and regarded the whole question as one requiring further investigation. (*Phil. Trans.* 22, (272), 1701, pp. 882-893)

Dr John Wallis was moved to speculate on the implications of Sommers' find, particularly concerning a possible former land connection between Dover and Calais.

And many such alterations (no doubt) have been of the face of the Earth, all the World over, of which we have no particular Histories. For the World was of a great Age, before the Writing of any Histories (except the Bible) now extant.
And who knows but that (in former Ages) even amidst the Alps, there may have been large Lakes which in process of time (by Earthquakes or other Accidents) may have been drained of their Water, and become fruitful Vallies: of which it is said divers symptoms have been discovered, even amidst the Alps, in later Ages.
And something of the like nature hath happened within some few years last past, in Jamaica, in Sicily, and in other places . . ." (*Phil. Trans.* 22, (275), 1701, pp. 967-79; see also ibid. 22, (276), 1701, pp. 1022-1038)

Mr. John Luffkin also reported finding some large bones which he identified as elephant in a gravel pit near Colchester. He suggested that Sommers' finds were also "the Bones and Teeth of some Elephant, buryed there by their Loving Masters the Romans". The depth of the bones could be explained by subsequent deposition of soil washed down by rain and snow from adjacent hills, and vegetative growth. (*Phil. Trans.* 22, (274), 1701, pp. 924-6.)

Leaving aside the possibility of antediluvian human giants, the enormous size of these remains of animal monsters was wondrous indeed. In 1715, the Bishop of Clogher reported Francis Nevile's discovery of some large teeth and pieces of bone dug up in Northern Ireland. The site was described in some detail and the assumption made that the "Monster" had "been buried, or that it had lain there since the Deluge". The Bishop went on to speculate on the nature of the creature and how it got there.

if Human there was some reason for the interrment, and for that Preparation of the Bed it was laid on; if Animal it was not worth the Trouble : if Human, it must be larger than any Giant we read of; if Animal, it could be no other than an Elephant, and we do not find that those Creatures were ever the Product of this Climate. And considering how long it must have lain here, I do not believe the Inhabitants then had any Curiosity or conveniency to

bring such into this Kingdom: for I suppose the best of their Ships could not carry one. Then if an Elephant, or some other Beast which must have proportion to the Teeth, it must have lain there ever since the Flood; and if so, then the Bed on which it lay must be of its own making : whence it will follow that the Flood coming on him while he lay in his Den, he was there drown'd, and covered with Slime or Mud . . . (*Phil. Trans.* 29, (346), 1715, pp. 367-70)

Another find, "the Impression of the Almost Entire Sceleton of a large Animal" was reported by William Stukely from Nottinghamshire :

I am persuaded it cannot be reckon'd Human, but seems to be a Crocodile or a Porpoise. We should impose upon our Senses to question, whether these be the real Reliques of an Animal; for the very Bones themselves are now to be seen as plainly as if preserv'd in an Egyptian Mummy.

Stukely went on to attribute such phenomenon to the changes the earth "suffer'd at the Universal Cataclysm". He also regarded marine fossils as "Proofs of that great Catastrophe". (*Phil. Trans.* 30, (360), 1719, pp. 963-8). Reports of discoveries of giant bones were reported regularly in the *Philosophical Transactions:* deer in Ireland (34, (394), 1726, pp. 122-3) and Yorkshire (44, (479), 1746, pp. 124-7); elephants and rhinoceros species in the lower Thames valley (48, 1753-4, pp. 626-7 and 51, 1759-60, pp. 506-14) and near Oxford (50, 1757-8, pp. 524-7); reptile remains were discovered also in Oxford and Gloucestershire (48, 1753-4, pp. 117-123) and in Yorkshire (50, 1757-8, pp. 688-91 and pp. 1786-90). Similar finds were also reported from the Continent and North America.

Although the destruction of these animals was usually attributed unsatisfactorily to the Deluge, the theological problems of "lost species" no longer seemed so important to contributors for they rarely mentioned them. Perhaps they would have agreed with William Hunter's comments on the Ohio *incognitum*, "And if this animal was indeed carnivorous, which I believe cannot be doubted, though we may as philosophers regret it, as men we cannot but thank Heaven that its whole generation is probably extinct." (*Phil. Trans.* 58, 1768, p. 45)

ELEPHANTS IN A COLD CLIMATE

"Behold now behemoth, which I made with these . . . " Job 40 : 15

With so many discoveries of fossil remains of antediluvian monsters, and the identification of some with modern species, particularly the elephant, a creature of tropical regions rather than cool northern Europe and Siberia, speculation on the reasons for this distribution mounted. The Bishop of Clogher first set out the problem when reporting Nevile's find in Northern Ireland. "If Animal, it could be no other than an Elephant, and we do not find that those Creatures were ever the Product of this Climate".

In 1728 Sir Hans Sloane published two articles which summarised the state of knowledge concerning fossil elephant remains. He remarked on "the vast variety of extraneous Substances lodged and found in several layers of the Earth, at considerable Depths, where it is impossible that they should have been bred". He noted elephant remains found in Britain, Italy, Sicily and Siberia and added the belief that something similar was "thought to be still alive in some remote and unfrequented Parts of the Continent of America". It was the Siberian remains which created most interest, however.

The old Siberian Russians . . . are of Opinion that there were Elephants in this Country before the Deluge, when this Climate was warmer, and that their drowned Bodies floating on the surface of the Water of that Flood were at last washed and forced into subterranean Cavities. But that after the Noachian Deluge, the Air, which was before warm, was changed to cold, and that these Bones have lain frozen in the Earth ever since . . .

There is an echo here of Burnet's theory of climatic change from the eternal spring of the antediluvian world to the present seasonal extremes. Burnet's ideas were

derived from Descartes' view of an originally molten earth which was cooling down, a view to be taken up by Buffon later. However, Sloane did not consider this was necessarily proof of a warmer climate before the Flood "since the Carcasses of drowned Elephants were very likely to float from other Places several hundred Miles distant . . . " (*Phil. Trans.* 35, (403), 1728, pp. 457-71).

In his second article, Sloane summarized European writers on the subject and made a plea for more detailed anatomical study of fossil bones. He noted that many of the teeth displayed as evidence of a former race of giants "have been found upon a more accurate Inspection to be only the Bones and Teeth of Elephants . . . " Although in his first article he suggested that some of the finds near the Don were the remains of Alexander the Great's Elephants, in his second article he discussed the question of Roman army elephants more fully and argued from the condition of the remains and disposition of the strata where they were found, "they must be of much greater Antiquity". (*Phil. Trans.* 35, (404), 1728, pp. 497-514).

Two letters to Hans Sloane from John Breyne, published in 1737, added more information on the "Mammoths of Siberia". Breyne concluded that the so-called "Mammoth's, or Mammut's Teeth and Bones" were firstly, "True Bones and Teeth of some large Animals once living", secondly, the animals were elephants by analogy with the teeth and bones of modern elephants, and thirdly, "that they were brought and left here by the universal Deluge". The remains, sometimes almost complete skeletons, were found chiefly in northern Siberia when exposed by large slips on the river banks and there was quite a lively local trade in the fossil ivory tusks. Breyne, like Sloane, was happy to explain the distribution of the remains in terms of a universal Deluge.

> because we know nothing of any particular extraordinary Deluge in those countries but of the universal Deluge of Noah . . . In such Manner, not only the Holy Scripture may serve to prove Natural History; but the Truth of the Scripture, which says that Noah's Flood was universal, a thing which is doubted by many, may be proved again by natural History".

Breyne avoided the real issue of explaining the remains of a tropical animal in a cooler climate. He noted the discovery of similar remains in Poland, Germany, Italy, England and Ireland and other regions, where they were not so well preserved "without doubt by the greater Warmth of those Climates". He failed—or was afraid—to see the implications of a much wider distribution of a tropical animal in a former period. (*Phil. Trans.* 40, (446), 1737, pp. 124-138)

However, Henry Baker, reporting a find of a fossil elephant tooth eleven pounds in weight and a six foot long thigh bone, in a cliff on the Norfolk coast, was not afraid to follow through the implications of his discovery. He dismissed a possible Roman origin because it was buried too deep. Rather, he regarded it as

> a convincing Demonstration that the Earth has undergone some very extraordinary Alterations : For the remains of Animals of quite different Climates and Regions, and of Kinds, which in the present situation of the World, could never possibly come over hither, must either imply their having been placed here by Providence, originally, or, that this Island must, heretofore, have been contiguous to the Continent. But, since we find these Creatures in very hot Countries only, it is highly probable they were never placed here by Providence; unless we can suppose the Temperature of our Climate, as to Heat and Cold, to have been greatly alter'd. And without such a Supposition, it would be no less unreasonable to imagine they would wander hither from warmer Regions, though even all the Quarters of the Globe should have been contiguous.

Baker drew upon Hooke's hypothesis to explain this apparent climatic change in terms of a shift of "but a few Degrees" in the "Polar Points or Axis thereof" involving a shift in the earth's centre of gravity.

> What Convulsions in Nature, what an universal Change in the Face of Things, must thereby have been occasioned ! What inundations or Deluges of Water, bearing everything before them ! What Breaches in the Earth, what Hurricanes and Tempests, must have attended such an Event ! For the waters must have been roll'd along, till, by them, an Equipoise was pro-

duced—In short, all Parts of the World would thereby acquire different Degrees of Heat and Cold than what they had before. Seas would be formed where Continents had been : Continents would be torn in sunder, or perhaps split into Islands. The antient Bed of the Sea would be changed into dry land, and appear covered at first with Shells and other Marine Bodies . . . .

The surface shells and animal remains would have mouldered away under the action of "nitrous salts" in the air, but those buried deep would be preserved. Most animal life would have been destroyed except those that escaped by swimming or were left "on rising lands, where if they met with proper food, and an agreeable Climate, they would continue and increase, or otherwise would wander until they found such a Country . . . " Although Baker admitted that "All this is indeed barely Conjecture" he was convinced of past geological and climatic change. His "inundations" could be interpreted by the orthodox as Noah's Flood but he does not state this himself and his attempt to explain past changes is influenced more by Hooke than the Mosaic narrative of the Deluge. The fossil evidence "seems to prove, that such Animals formerly inhabited these Countries, not withstanding the Mouse-Deer [i.e. Moose] is known at present only in America, and Elephants are not found except in Africa and Asia". (*Phil. Trans.* 43, (475), 1745, pp. 331-5)

Not all observers were prepared to be scientific about Noah's Flood. E. Mendes da Costa, writing "an account of the impressions of plants on the slates of coals" was convinced that these curious botanical specimens had been "buried in the strata of the earth at the time of the universal deluge recorded by Moses". He regretted the attitude of those who rejected Noah's deluge "but substitute partial deluges" to account for such phenomena as fossil deposits and broken and contorted strata.

Were local or partial deluges the cause, we should find only the animals and plants of the climates or places, where such deluges have happened; whereas in these fossil remains it is quite the contrary : the remains of those plants and animals, we know, are of animals and plants, the inhabitants of the most remote climes from those where they now lie buried. (*Phil. Trans.* 50, 1757-8, pp. 228-35)

No possibility of past climatic change is admitted here at all.

The discovery of fossil remains of elephants and other large animals in the Americas added a new dimension to the argument. Early in the eighteenth century large fossil bones had been found in New York and the Ohio Country. (The background to the American discoveries is outlined in Greene, 1961 : ch. 4) In 1767 Peter Collinson reported to the Royal Society on George Croghan's finds of "a prodigious number of bones and teeth" and fine ivory tusks at the Great Buffaloes Lick near the Ohio River, below the confluence of the Miami River. These were thought to be elephant remains but no elephants were known in North America and it was highly unlikely that the inhabitants had imported them from Asia or Africa; "and as it is impossible that elephants should inhabit the country where these bones and teeth are now found, by reason of the severity of the winters, it seems incomprehensible how they came there". The common explanation of Siberian remains, that they were floated there by the Deluge from warmer southern regions was not sufficient. "But what system or hypothesis can, with any degree of probability, account for these remains of elephants being found in America, where those creatures are not known ever to haxe existed, is submitted to this learned Society". (*Phil. Trans.* 57, 1767, pp. 464-7)

By the late 1760's, with more detailed study and comparison of fossil teeth and bones with those of modern elephants, it was gradually realised that the fossil species were not identical to their modern counterparts, but perhaps some other member of the elephant family. William Hunter reported further on the Ohio finds to the Royal Society in 1768. "From all these observations I was convinced that the grinder tooth, brought from the Ohio, was not that of an elephant; but of some carnivorous animal, larger than an ordinary elephant . . . " The American bones

were similar to the Siberian ones, and larger, but not the same as modern Asian or African elephants. Hunter did not feel that identification of a distinct fossil species necessarily altered the argument that such remains

> seemed to concur with many other phenomena, in proving, that in former times some astonishing change must have happened in this terraqueous globe; that the highest mountains, in most countries now known, must have lain for many ages in the bottom of the sea; and that this earth must have been so changed with respect to climates, that countries, which are now intensely cold, must have been formerly inhabited by animals which are now confined to the warm climates. (*Phil. Trans.* 58, 1768, pp. 34-45)

R. E. Raspe summarized the problem of bones and teeth of elephants and other large animals found in cool northern regions of America, Europe and Siberia. He noted that these remains were never found in hard rock strata, or mixed with marine fossils, or calcined, or changed in any way. They were less deeply buried, usually singly, often in caves or swamps. The unusual accumulation of a large number of skeletons at Great Buffaloes Lick in Ohio, Raspe explained was because this was swampy ground, the great beasts stumbled into it, became mired there, and died. Raspe was convinced that these creatures had been born, lived, and died in the same region where they were now extinct. The fact that no marine fossils were found with them ruled out Noah's or anyone else's flood. If Woodward's theory were correct, such heavy bones should be much more deeply buried. They could not be ancient Roman or other army pack animals, for they were found in the Americas, separated from other land by ocean, and the inhabitants had no vessels large enough to carry them.

The conclusion that these creatures were indigenous to the regions in which their remains were found implied that the climate had changed in some way. Perhaps this could have been caused by a variation in the earth's orbit, the obliquity of the ecliptic had become more inclined toward the plane of the equator. Or a change had occurred in the location of the earth's axis and centre of gravity. The other aspect of the argument was the possibility that these were remains of an unknown species, distinct from any modern one. If so, how did they survive in the Arctic? Did they die out, or were they exterminated? There was no doubt in Raspe's mind that these creatures had died where they had lived, even though there were still many unanswered questions. (*Phil. Trans.* 59, 1769, pp. 126-137). A great deal more work indeed was required in identifying the various denizens of Quaternary Europe, Siberia and North America. But by the 1770's, it was obvious to a scientific mind that a Deluge hypothesis was quite inadequate to explain the phenomenon of elephant bones in a cold climate.

THE AGE OF THE EARTH

> Some drill and bore
> The solid earth, and from the strata there
> Extract a register, by which we learn
> That he who made it, and reveal'd its date
> To Moses, was mistaken in its age.
>
> William Cowper, 1785: The Garden, Book III of The Task.

The relative chronology of earth history was clearly set out in the book of Genesis, and consisted of the six days of Creation and a seventh day of rest, the fall of Adam, and Noah's flood. There was considerable variety of opinion on the time periods involved. Collier (1934: p. 142) noted over a hundred different chronologies, mainly calculated by working through the genealogies provided in Genesis, and quoted another reference giving 140 different opinions on the date of Creation with a total discrepancy of 3194 years. The most widely accepted date in England was Ussher's 4004 B.C. for Creation and 2348 B.C. for the Deluge.

Although there was general agreement on relative chronology there was considerable variety in interpretation of the Creation story. Some, of course,

accepted the literal six days and regarded the whole event as a miracle wrought by God. Others, including Burnet, preferred an allegorical interpretation believing that Moses only told as much of the story to the ancient Israelites as they could understand at the time. Burnet's later work *Archeologia Philosophicae* was reviewed at length in the *Philosophical Transactions* (17, (201), 1693, pp. 796-812). His reviewer accused him of collecting "all such passages amongst them [the ancient writers] as seemed most consonant to, and confirming of the Doctrines delivered in the first part of his Theory where he had omitted taking notice of them . . ." The reviewer had less of a quarrel with an allegorical interpretation of Genesis, or that "Moses accommodated his History to the Capacity of those for whom he writ" than with Burnet's audacity in believing his version to be the true account.

Some of the books which attempted to reconcile scientific principles with the Creation story were reviewed. One example was Edmund Dickinson's *Physica vetus et vera, sive Tractatus de Naturali veritate hexameri Mosaici* . . . (1702) "Many persons having cavill'd at the Mosaical Cosmopaeia as unphilosophically written, this learned Author here takes upon him to shew, that Moses, in his History of the Creation, has briefly deliver'd both the principles of true Philosophy, and the method and manner of all generation." Dickinson believed that the true Philosophy which prevailed in the time of Moses was "Atomic" or "Corpusculary, holding that whatsoever was contain'd within the Heavens and Terraqueous Globe, was made of most subtle Particles." It was these particles which were created to form the original matter of chaos, then, "since Matter existing, nothing was wanting but motion for the formation of the Heav'ns and Earth." God provided this motion, "he created that power which we call Nature, this being nothing but the motion of Matter, made according to the Laws, which the prime Author of Nature establisht in the beginning." But these laws alone were not sufficient, "it pleas'd God among those works which he put under the Laws of Nature, from the beginning to institute some great Miracles here and there, above the power of Nature, more signally to show he was Lord of the frame of the World, and that the Divine Mind is always to give rule to Nature . . ." (*Phil. Trans.* 23, (277), 1702, 1083-91).

Dickinson was typical of the intelligent man's attempt to reconcile science with the creation story. There were few men in England prepared to go as far as Descartes, accepting God as the first cause but explaining all further earth history in terms of natural laws, ignoring the Mosaic account. Newton possibly went nearest in his view of God, the great Geometer who set the planetary system in motion. One of the issues in interpretation of the Creation story was the amount of time involved in the six days. Most accepted the literal twenty-four hours per day, but a few, of more practical turn of mind, considered this rather too short a time for everything described by Moses to be done, even by God. Newton suggested to Burnet that "at first wee may suppose ye diurnal revolutions of ye Earth to have been very slow, soe yt ye first 6 revolutions or days might containe time enough for ye whole Creation" (Newton, 1959: vol. II ,p. 319). Burnet objected to this on two grounds: first, if the revolutions were so slow how did they become quicker and, second, such a long day implied a long "dolefull night" that "would undoe all yt was done on ye day time." (Newton, 1959: vol. II, p. 325.) Newton in reply, quoted the animals of Greenland which managed to endure a long night successfully. He made an alternative suggestion for the problem of days: "you may make the first day as long as you please, & ye second day too if there was no diurnal motion till there was a terraqueous globe . . ." (Newton, 1959: vol. III, pp. 333-334). Whiston had regarded a day as one year since he believed the earth did not yet have diurnal motion, but moved in a perfectly circular orbit around the sun. (Collier, 1934: pp. 109-124).

The debate ranged from scientific to purely mystical explanations of the time required for Creation. Edmond Halley summed up the problem for the practical man of science. Although there was scriptural evidence that man had

been on the earth about six thousand years and his making had been the last act of Creation,

'tis nowhere revealed in Scripture how long the Earth had existed before this last Creation, nor how long those five Days that preceded it may be to be accounted; since we are elsewhere told, that in respect of the Almighty a thousand Years is as one Day, being equally no part of Eternity. Nor can it well be conceived how those Days should be to be understood of natural Days, since they are mentioned as measures of Time before the Creation of the Sun, which was not till the Fourth Day . . . .

Halley, in the Royal Society tradition, proposed an experiment which must be regarded as the first scientific attempt to estimate the age of the earth. He based his proposal on his observations that lakes with no outlet "are found to be Salt." Evaporation consisted of pure water "so that the saline Particles that are brought in by the Rivers remain behind, whilst the fresh evaporates; and hence 'tis evident that the Salt in the Lakes will be continually augmented . . ." The same thing happens in the ocean "and we are thereby furnished with an Argument for estimating the Duration of all Things from an Observation of the Increment of Saltness in their waters." He proposed "a certain weight of water" be taken from the Caspian Sea and its salt content determined. The same should be done again "after some Centurys of Years." If a greater amount of salt is found the second time "we may by the Rule of Proportion take an estimate of the whole time wherein the Water would acquire the Degree of Saltness we at present find in it." Halley regretted very much that the Ancient Greeks had not thought of doing it. (*Phil. Trans.* 29, (344), 1715, pp. 296-300).

During the seventeenth century, belief in a senescent deteriorating earth was widespread. The earth had a beginning, described in Genesis, and it must have an end, as described in Revelation. This was a remnant of the medieval idea that the earth had deteriorated since the fall of Adam. On analogy with organic life, the earth had been born, and was now decaying with old age. Burnet (1965: p. 120) regarded the earth as "a ruine . . . a broken globe," which would ultimately be renovated to its former smooth paradisiacal state, in the Universal Conflagration. (Ogden, 1947; see also Davies, 1966b and Nicolson, 1959). Although this was not a field into which members of the Royal Society ventured in their scientific discussions, this sort of millennial thinking was implicit in much seventeenth and early eighteenth century writing about the earth. John Ray's third physico-theological discourse was titled "The Dissolution of the World" (reviewed in *Phil. Trans.* 17, (196), 1693, pp. 615-617; see also Tuveson, 1949).

By the end of the seventeenth century the stern God of puritan theology was becoming a more beneficient deity. In the movement which became known as physico-theology "Nature is now to be contemplated as the finished and unimprovable product of divine wisdom, omnipotence, and benevolence." (Willey, 1962: p. 39). The title of one of John Ray's books, a discourse on natural history, was *The Wisdom of God Manifested in the Works of Creation.* (1692, reviewed in *Phil. Trans.* 17, (196), 1693, pp. 611-614). Halley's argument for hills in his account of the circulation of the watery vapours of the sea and the cause of springs illustrates well this attitude

This, if we may allow final Causes, seems to be the design of the Hills, that their Ridges being placed through the midst of the Continents might serve as it were for Alembicks to distil fresh Water for the use of Man and Beast, and their heights to give a descent to those Streams to run gently, like so many veins of the Macrocosm, to be the more beneficial to the Creation. (*Phil. Trans.* 16, (192), 1691, p. 473)

Mountains created by God for the use of man were not likely to be eroded away in a hurry. The processes of denudation therefore assumed less importance during the eighteenth century. (Davies, 1966b and c; see also Nicolson, 1959).

Despite this changing attitude towards "the everlasting hills" it was still obvious that changes were occurring in the landscape. There were frequent reports in the *Philosophical Transactions* of changes wrought by earthquakes and volcanoes, especially after the Lisbon earthquake of 1755. (See especially john Michell's

Conjectures . . . *Phil. Trans.* 51, 1759-60, pp. 566-634, and Hamilton, 1774). The Rev. Borlase's "Account of the great Alterations which the Islands of Sylley have undergone since the Time of the Antients" was a fine example of detailed observation of geological processes at work.

The sea is the insatiable monster, which devours these little islands, gorges itself with the earth, sand, clay and all the yielding parts, and leaves nothing, where it can reach, but the skeleton, the bared rock. The continual advances which the sea makes upon the lowlands, at present, are plain to all people of observation, and within these last thirty years have been very considerable. What we see happening every day may assure us of what has happened in former times . . .

This is also a fine example of uniformitarianism but Borlase would probably have admitted too, that the earth was about six thousand years old and the major outlines of the land were shaped by Noah's Flood.

CONCLUSION

By the 1770's, a great deal more was known about land form processes and there was abundant evidence of extraordinary changes that had occurred in the past history of the earth. The book of Genesis still provided a framework for earth history in its account of the six days of Creation and the Deluge. No longer, however, was it taken literally by men of science. Indeed, there was considerable flexibility in interpretations of the scriptural account. The Deluge had come to be regarded as a working hypothesis to explain disrupted strata and fossil deposits. And grave inadequacies in the Deluge hypothesis had been detected already, particularly in explaining deposits of giant bones. Nevertheless, probably one of the last efforts in a serious scientific journal to justify the Deluge hypothesis appeared in the *Philosophical Transactions* in 1767, in Edward King's "An Attempt to Account for the Universal Deluge."

King was aware of the problems of framing hypotheses, "where we cannot arrive at demonstration we must be content with probability." In a discussion of the Deluge even the smallest degree of probability had its use "as it tends to remove those objections that are made to the truth of the fact, by persons who may not think the mere relation of it in the Mosaic writings a sufficient proof of the reality of it; or who may be led from the difficulty there appears in accounting for such an event to doubt of the authority of those sacred books." King was on the defensive but plunged in with comments on the "Many ingenious hypotheses" on the subject which "all seem liable to most insuperable objections." He justified another attempt to explain the Deluge in the evidence of marine fossils as proof that the earth had "been at some time or other entirely covered with water, however fallible any attempt to account for the deluge may be."

The details of King's theories which involved a raising up of parts of the bottom of the sea by subterraneous fires (he referred to Michell's paper on earthquakes here . . . *Phil. Trans.* 51, 1759-60, pp. 566-634) and sinking of antediluvian land masses, a shift in the earth's centre of gravity and consequent climatic change, are not so important. The most interesting feature is the uniformitarianism displayed in his method of explaining the processes involved in this catastrophe in terms of processes known and observed at present.

For as I imagine the shells and other marine bodies which are now found on various parts of the dry land, to have been placed there gradually during a succession of ages, whilst it was the bottom of the sea; it will follow that they must be found just as the sea, by its washings and motion, laid them; which would of course first wash many of them together and then wash gravel, or sand, or clay, or other substances over them; after which more shells or other bodies would be deposited, and then more stones, or gravel etc. according to the nature of the soil . . .
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 . . .

This passage would be quite acceptable to the modern reader — until the flood is mentioned. King was circumscribed still by the theological climate of his times and his own religious beliefs. He also predicted that the earthquakes would "in the end break forth with redoubled violence and destroy it [the earth], in the manner foretold in the Scriptures." (*Phil. Trans.* 57, 1767, pp. 44-57).

We may smile at the naivety of King and his contemporaries who were still seeking a rational explanation of the Noah story. It was James Hutton's great contribution in his *Theory of the Earth* free earth history from the bounds of the book of Genesis, to extend the time span of six thousand years indefinitely — "no vestige of a beginning, no prospect of an end." On the other hand, it would not be out of place to wonder whether these eighteenth century scientists who sought out and reported on evidence of the Deluge were any more misguided by an inadequate hypothesis than those individuals who roamed the countryside earlier this century, searching for peneplains.

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