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The Shape and Meaning of Earth History

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Archbishop James Ussher, a scholarly Irishman of the seventeenth century, has become unjustly famous as the supposed author of the claim that the creation of the world could be dated to the year 4004 B.C. More than two centuries later, when the classic histories of science and religion were being written in terms of warlike conflicts,[1] similar claims were still being made by some culturally conservative groups in Western societies. Today, routine estimates of the earth's antiquity in terms of several billion years, made by geologists on the basis of radioactivity in rocks, contrast strikingly with the assertions of the small but vocal group of creationists, who retain something like Ussher's calculation in their body of alternative knowledge. It is not surprising, therefore, that this piece of history is still commonly seen as a story of continuous conflict between Christianity and science, in which Christians—with the exception of the so-called fundamentalists—have compromised their traditional beliefs in the face of the triumphant march of scientific knowledge.

This kind of scientific triumphalism is long overdue for critical reappraisal. Its claims to serious attention have been thoroughly demolished in other areas of the history of science, but it survives as an anomaly in the historical treatment of the relation of science to religious belief.[2] This may be because the historians' own attitudes are conditioned by the immature age at which religious beliefs and practices are abandoned by many, though not all, intellectuals in modern Western societies. This common experience may explain why many historians of science seem incapable of giving the religious beliefs of past cultures the same intelligent and empathic respect that

they now routinely accord to even the strangest scientific beliefs of the past. Traditional interpretations in terms of conflict and compromise do more, however, than fail to treat religious beliefs seriously. These well-worn categories also encourage the reification of science and religion into contrasting bundles of abstract propositions. The crucial third term, society, is either ignored[3] or else invoked in the most naive form, the contents of religion and science being attributed to two similarly polarized social groups, namely religious believers and scientists.

In contrast with such simplistic treatments I suggest that specific episodes of conflict should be regarded as stories about the interaction of rival *cosmologies*—using that term, as I shall throughout this essay, in its anthropological sense.[4] In other words, they are episodes in which people on both sides appealed to some aspect of nature, such as the origin and history of the earth, in order to support and justify their attempts to propagate their own view of the *meaning* of personal and social life and of the conduct appropriate to that life, whether that meaning was formulated in religious terms or not. In historical studies there should be no place for sweeping generalizations that contrast the progressive outlook of scientists with the reactionary attitudes of Christians. We must expect to find that scientists of varying degrees of originality and competence and Christians of varying degrees of insight and orthodoxy were prominent on *both* sides of many controversies. Furthermore, there is the obvious fact that one and the same individual has frequently been both Christian and scientist (a term I use for convenience, although it is highly anachronistic before the mid-nineteenth century).

In the history of controversies about the age of the earth, few modern scholarly studies of particular episodes take the religious dimension seriously and at the same time give full attention to the social uses to which rival viewpoints were put. What I shall do in this brief essay, therefore, is simply to sketch the main outlines of the changing interpretations of earth history since the Middle Ages and to suggest how rival religious and social meanings have been expressed through those interpretations. In particular, I shall argue that the quantitative figures that have been given at various times for the age of the earth are far less significant than the qualitative patterns that have been discerned in, or attributed to, the whole history of the earth, of life, and of mankind (see fig. 12.1). I shall first summarize the tradition of biblical chronology that formed the temporal component of the geocentric picture of the cosmos. Second, I shall describe the new enterprise that was termed the "theory of the earth" and its relation to the rise of critical methods in biblical interpretation. And

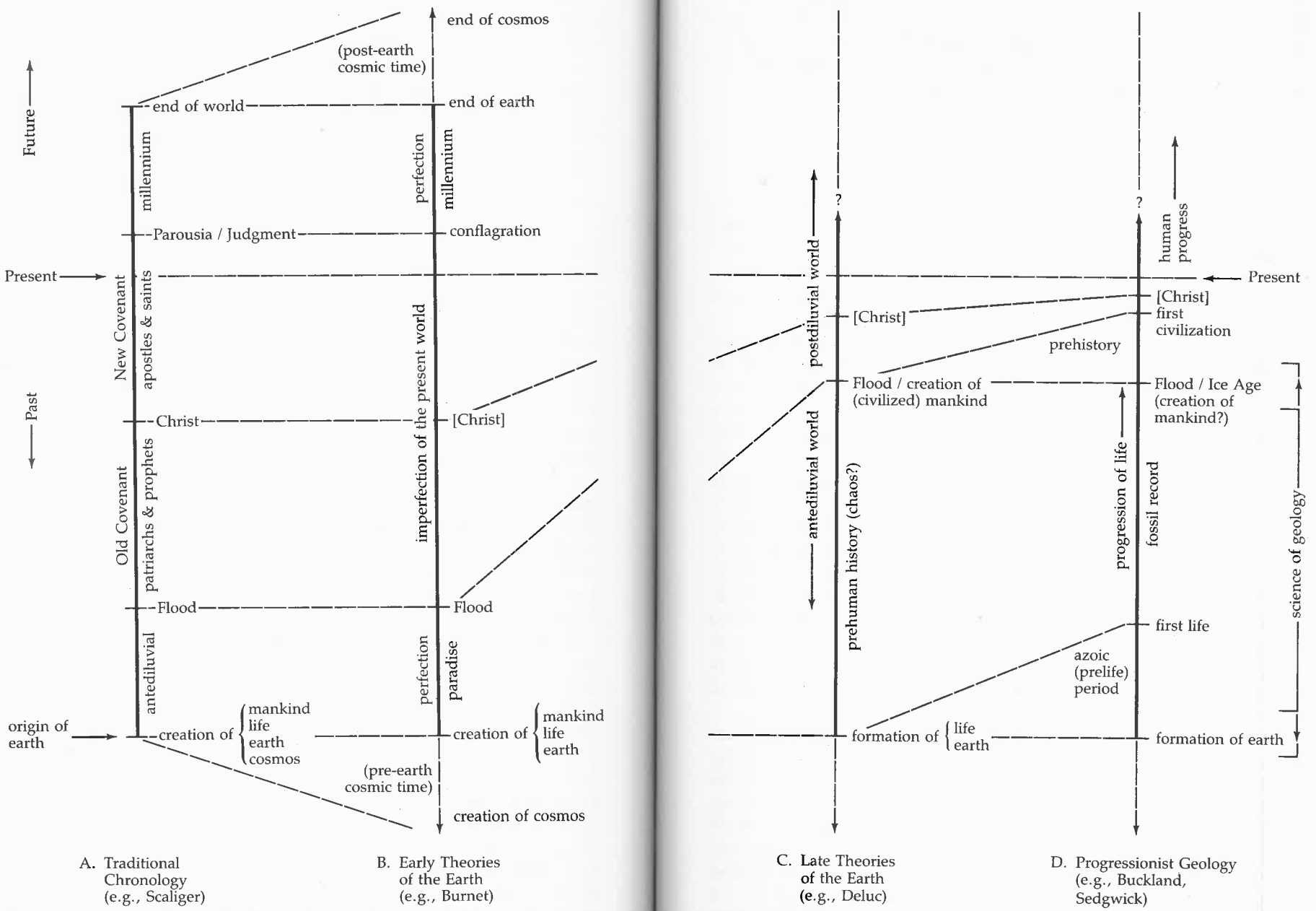

Fig. 12.1. Earth histories of the mind. Diagrammatic representations of four successive ways in which the shape of earth history and its most significant events were conceived. Time is shown flowing upward (as in classical geological diagrams). *Quantitative* estimates or calculations of the magnitudes of time involved are deliberately ignored; the span of time from the origin of the earth to the present is represented (arbitrarily) as uniform in all four diagrams, in order to highlight the qualitative changes in the conceptualized pattern of events. Note that eternalistic conceptions of earth history cannot be adequately depicted in this kind of visual representation.

third, I shall outline the way that a new science of geology, with deliberately limited cognitive goals, pushed attributions of cosmological meanings out of the scientific study of the earth and relegated them to the social and cognitive margins of science.

THE GEOCENTRIC COSMOS

The spatial aspect of the picture of the cosmos culturally dominant around the end of the Middle Ages in the West is comparatively familiar. The universe was conceived as a bounded system, with the earth lying immobile at the center of an ascending hierarchy of ceaselessly revolving celestial spheres. The abode of mankind was central in position, but furthest from the divine presence and least in glory. This image embodied and expressed a cosmology that related mankind both to the environment and to the transcendence of God. It also reflected, and justified as natural, an analogous social order of stable hierarchical equilibrium. The temporal pattern that would have matched this spatial structure was one of merely cyclic change, without truly historical development. Up to a point this image of cyclic change was indeed incorporated into the personal and social life of Christendom, as for example in the public celebration of the cycle of the church's year. But a concept of merely cyclic change could all too easily be extrapolated into an image of a cosmos that was eternal, self-maintaining, and—above all—uncreated. This eternalism, which, like the accepted spatial picture, derived principally from Aristotle, was therefore suspect to those who saw themselves as the guardians of the order of nature and society. Conversely, an eternalistic picture of the cosmos was a valuable resource in the hands of any critics of that social order, the more so if the spatial bounds of the conventional cosmos were dissolved into boundless infinity.

Those who sought to maintain the stable order of society, as justified by the order of nature, therefore united a limited acknowledgment of cyclic change with an affirmation of the finite spatial limits of the cosmos and the underlying directional pattern of its history. In this image of world history the cosmos was bounded as much temporally as spatially: it had a clear beginning in Creation, and God's action would bring it to an equally decisive End. It was also structured as much temporally as spatially within these limits (see fig. 1A). It had a unique midpoint in the events surrounding the life of Christ, which divided the old relationship or covenant between mankind and God from the new. On either side of that divide, the particularities of patriarchs and prophets, apostles and saints, were framed by past

and future events of global significance, namely the Flood and the Parousia (or Second Coming of Christ). Beyond that frame lay only the swift prelude of the Creation, Paradise, and the Fall in the past, and the expected culmination of the final Judgment and (more controversially) the Millennium in the future. This whole temporal structure imbued the past, present, and future of the cosmos with human meaning: it attributed order to the often chaotic flux of human lives and gave social action a transcendent context and justification.

This picture of earth history was derived, of course, principally from the Bible, the diverse components of which were interpreted in terms of an underlying unity of narrative history. Spiritual methods of interpretation, such as allegory and typology, were built on a substrate of literal historical meaning. The narrative story discerned in the Bible was not simply a religious way of looking at the history of the world. For most members of Western societies it *was* the history of the world, at least in outline. Other secular events, above all the life of society and its constituent persons, received meaning by being seen in their appropriate place within the narrative structure. The brief narratives recorded in the opening passages of Genesis, the first book of the Bible, posed few problems of credibility. It seemed plausible to regard human history as virtually coextensive with earth history, and that with cosmic history; without mankind the earth and the cosmos would have seemed to lack meaning and purpose. The closely integrated Creation of cosmos, earth, and life, the swift sequence of Paradise and the Fall, and the great global action of the Flood together formed an intelligible prelude to the main historical narrative of redemption embodied in the Bible. As Sir Thomas Browne put it, "time we may comprehend; 'tis but five days older than ourselves" (*Religio Medici,* 1635).

CHRONICLES OF THE WORLD

The construction of a single narrative story of cosmic history received new impetus during the period of the Renaissance and Reformation. Improved methods of textual scholarship were used to eliminate apparent discrepancies within the Bible itself. The interest of humanist scholars in the texts and monuments of classical antiquity, later broadened to include those of other ancient civilizations, provided a new wealth of historical information that needed to be integrated into the biblical narrative. A tradition of scholarly chronology grew up, in which that narrative was given quantitative precision by the dating of its events. The scattered calendrical information in the Bible was

collated and compared with, for example, astronomical calculations on historically recorded eclipses and conjunctions. The resultant outline of datable history was then enriched by fitting into it whatever was known about the history of the world from nonbiblical sources. The result of this scholarly activity was the production of an outline of world history that had pretensions to being universal and was no longer confined to biblical sources; an example of this genre is J. J. Scaliger's *De Emendatione Temporum* (1583). At first there was little to suggest any marked deviation from traditional estimates of the scale of cosmic history, even back to the Creation. All reliable calculations, despite minor differences of scholarly opinion, could be plotted without strain within a few thousand years.[5] Ussher's famous figure of 4004 B.C., which he did not originate, was only one of many rival scholarly estimates of this kind; it has become the best known—in the English-speaking world—only through its adoption in the marginal notes of some editions of the seventeenth-century King James translation of the Bible.

This scholarly consensus was disturbed, however, by ancient records of Egyptian dynasties that implied a higher antiquity; and these were followed in the seventeenth century by reports of alleged records of Chinese civilization that pushed the history of mankind still further back in time. Moreover, problems of another kind emerged in the wake of European exploration of other continents. It became increasingly difficult to integrate what was becoming known about the distribution of exotic animals and plants—and, above all, of human beings—into the brief narrative framework of the Bible. It was not clear, for example, how the descendants of Noah and of the animal inmates of the ark could have had time to repopulate all the scattered continents after the Flood. Such problems gave rise to an extensive scholarly literature in the sixteenth and seventeenth centuries.[6] Its significance lies in the fact that these problems were used as resources for *either* the defense *or* the criticism of the established view of a temporally finite world. The consensus among scholars held that documented human history could not be carried back in any civilization more than a few thousand years; texts that implied a higher antiquity were regarded as either legendary or fraudulent. Those who claimed on the contrary that such documents were reliable used them to attack the authenticity of the biblical narrative in the interests of alternative, and generally anti-Christian, interpretations of the world. In other words, speculations about a vast antiquity for mankind, about the possible existence of human beings before Adam, and about the inadequacy of the ark as an explanation of organic distribution were

never just enlightened and disinterested scholarly inquiries. They were put forward to support specific cosmologies, as were the more literalistic interpretations to which they were opposed.

It would be wholly anachronistic to contrast the opinions of scholarly chronologists with those of contemporary scientists. Natural philosophers, as the latter generally called themselves, also worked within the taken-for-granted assumptions of their societies. For example, even the recognition of fossils as organic remains was highly problematical; the most obviously organic fossils were precisely those that could most readily be attributed to a single large-scale event.[7] The most appropriate recorded event was of course the Flood, the historicity of which seemed to be confirmed by analogous stories in other ancient literatures. For example, the Danish scholar Niels Stensen (1638–1686), better known as Steno, interpreted the rock structure of Tuscany in Italy in terms of a temporal sequence of events; but he inferred that the fossil-bearing strata must have been deposited during the Flood, and he thought they could not be much older than the monuments of the ancient Etruscan civilization that he could see in the same region. Around the same time Robert Hooke (1635–1703) in England argued likewise for the organic origin of many fossils, but he assumed that they represented organisms that would have been almost contemporary with early mankind. When, in a famous phrase, he suggested that it might be possible to "raise a chronology out of them," he meant that fossils might be used to supplement the coins and other artifacts used by antiquarians, thus amplifying the chronology of human history by charting the parallel history of the animate world.[8] Seventeenth-century naturalists such as Steno and Hooke envisaged only dimly, if at all, the possibility of a long *prehuman* history of the earth.

It is easy in retrospect to pour scorn on the tradition of chronology in biblical scholarship and the related work of naturalists such as Steno and Hooke. But its literalism was a simple consequence of the precritical approach to biblical texts, and there was little nonbiblical evidence that threw any serious doubt on the short time scale that it proposed. Chronologists were not responsible for establishing the belief in a short cosmic history; their work merely codified and lent an air of precision to an already-taken-for-granted view of the natural world. What is most significant about that view is not its short timescale by modern standards, but rather its almost unexamined assumption that the history of the cosmos must be virtually coextensive with the history of mankind—indeed, the history of civilized literate mankind. In this way the culturally dominant Christian cosmology,

although in principle centered on God, was in practice centered more on mankind. The history of the earth was seen only as the stage for the drama of human history, the drama of the creation, fall, and redemption of a unique set of rational beings.

NEW MODELS OF EARTH HISTORY

Within the traditional temporal image of the cosmos, the origin of the earth could only be regarded as an integral aspect of the creation of the cosmos as a whole. What was religiously important about that primal creation was the assertion, or alternatively the denial, that it had indeed been the work of a transcendent Creator. The origin of the earth could not become an object of inquiry on any other level until the earth could be seen as a part of the cosmos that was not wholly unique. But even the slow acceptance in the seventeenth century of Copernicus's heliostatic system of the cosmos did not have that effect, since it merely altered the position of the earth within a bounded cosmos similar in structure to the earlier geostatic system. A far more radical alternative, however, had continued a submerged existence from earlier centuries. This was the image of a cosmos without center or boundaries, a cosmos that was infinite, eternal, and possibly even uncreated. Giordano Bruno (1548–1600) described such a cosmos in the late sixteenth century, and in the mid-seventeenth century René Descartes (1596–1650) tried to rehabilitate that suspect image. In view of the recent condemnation of Galileo's work, the French philosopher felt obliged to keep a "low profile" in relation to Catholic authority and its localized secular power, and so he framed his speculations in an ambiguously hypothetical style. In *Principiae Philosophiae* (1644) he sketched a possible model of a universe of indefinite limits, within which the earth, and perhaps countless similar bodies, could have had their own origins and histories. He outlined a possible physical history of this hypothetical earth, suggesting natural explanations of its origin and of its main surface features. This account, which left aside the question of the primal creation of the cosmos, was quite compatible with the brief earth history sanctioned both by tradition and by most of the nonbiblical evidence. In this way Descartes effectively detached earth history from cosmic history (see fig. 1B). Following this new model, it became possible to conceive that the history embodied in the biblical narrative, which all agreed had been written primarily for the salvation of mankind, referred to terrestrial events directly relevant to mankind and not to the cosmos as a whole.

The implications of Descartes's model were first articulated by Thomas Burnet (ca. 1635–1715), a Cartesian scholar living in England, which was much freer from intellectual restrictions than absolutist Catholic states. In his *Sacred Theory of the Earth* (1680–1689) Burnet tried explicitly to discover the "true" interpretation of the biblical records of the great physical events of earth history by drawing on the explanatory principles of Cartesian natural philosophy. He was not reconciling Scripture with natural knowledge, for he saw no conflict there; rather, he was using natural knowledge to amplify and illuminate the biblical narrative, which he restated in physical terms (see fig. 1B). The present irregular and "imperfect" state of the earth was framed in the past by the Flood and in the future by the "Conflagration" (or burning of the whole earth) that was widely expected to bring the present order to an end.[9] Beyond those twin catastrophes were the matching "perfections" of Paradise and the Millennium, which in turn were bracketed by the Creation and the final End. The whole symmetrical scheme lay under the sovereignty of Christ as the "alpha and omega" of history, a traditional attribution that now referred only to the earth, not to the cosmos. Burnet conceived the brief and finite history of the earth as being flanked by vast "oceans" of past and future cosmic time. But in asserting the finitude of the earth he explicitly refuted the unnamed eternalists who claimed that the earth and mankind had not been created by the divine will at all.

A PROLIFERATION OF THEORIES

Burnet's work was the prototype of a new kind of writing that became known as the "theory of the earth."[10] This proved to be a highly flexible conceptual resource, in the sense that grand speculative theorizing about the shape of earth history could be, and was, used to support and justify highly diverse cosmologies. In the later seventeenth century, theories of the earth proliferated in great variety, particularly in England, where Burnet's Cartesianism was soon replaced by various aspects of the newer Newtonian natural philosophy. For example, in *A New Theory of the Earth* (1696) the Newtonian William Whiston (1667–1752) used comets to give what he claimed were better explanations of the great physical events of earth history. Above all, the older idea that the earth had decayed from an original perfection gave way to a new emphasis on the way that the harmonious equilibrium of the present earth had been derived from original chaos.[11] Of all such theories, perhaps the most influential was that of John Woodward (1667–1728), who made use of his substantial firsthand

knowledge of strata and fossils. In his *Essay towards a Natural History of the Earth* (1695) Woodward claimed that the whole sequence of strata had settled in order of specific gravity out of a chaotic global mixture at the time of the Flood. He thought this would explain the tendency for specific fossils to be embedded in particular strata. This example makes clear the way in which, in this kind of speculation, physical interpretations of events such as the Flood generally diverged far from any literal interpretation of the biblical narratives, even *before* the impact of critical methods of biblical interpretation began to be felt. The basic historicity of the narratives was not necessarily questioned; but it was assumed that behind the conventional or "vulgar" interpretation lay a true or "philosophical" interpretation, which could be discovered by the light of the latest natural philosophy. This attitude was characteristic, for example, of the latitudinarian churchmen in England, who sought to make Christian beliefs acceptable to the enlightened intellects of their age.

It is easy to see how this conception of a privileged interpretation, dependent on scholarly or philosophical knowledge, could lead to a total inversion of the traditional task of biblical interpretation. Traditionally, nonbiblical sources, whether natural or historical, had received their true meaning by being fitted into the unitary narrative of the Bible. This relationship now began to be reversed: the biblical narrative, it was now claimed, received its true meaning by being fitted, on the authority of self-styled experts, into a framework of nonbiblical knowledge. In this way the cognitive plausibility and religious meaning of the biblical narrative could only be maintained in a form that was constrained increasingly by nonbiblical considerations.

The same inverted relationship could equally well be used, however, to promote radically anti-Christian cosmologies. If the biblical narrative were to be interpreted in the light of nonbiblical resources, it could be claimed that it had no validity whatever, except as a record of the superstitions of an unenlightened primitive people. This was the strategy characteristically adopted by the early Enlightenment *philosophes* in France. They generally used the theory of the earth as a means with which to attack Christian orthodoxy and the secular cultural power that it still wielded in many of the Catholic states. For example, Voltaire (1694–1778), in order to remove any evidential foothold for the historicity of the Flood, went so far as to deny the natural emplacement of fossils altogether. He failed to win support for that view, however, since anyone who had observed fossils in strata could see at once that it was untenable. Later theorists in this tradition therefore focused their attention on denying the validity of the supposed evidence for the Flood, claiming, for example, that it had been merely local or that, if universal, it had mysteriously failed to leave any traces and therefore could be ignored for all scientific purposes.

Another line of argument with similar cosmological goals involved reviving the older eternalistic model of the cosmos and applying it to the earth. The earth, it was claimed, had always been and would always be under the dominion of the same purely natural laws. Its history stretched indefinitely or even infinitely into past and future and involved no unique and unexplained events such as the Flood; indeed, earth history was "without vestige of a beginning, without prospect of an end." That famous phrase appeared in James Hutton's *Theory of the Earth* (1795), but the sentiment had often been foreshadowed earlier, particularly in continental Europe, in such works as the Baron d'Holbach's *Système de la nature* (1770). Writers such as Holbach and Hutton generalized the present relative stability of the earth into a permanent feature of the terrestrial system, past and future. This was often given meaning in deistic terms by being attributed to a wise and providential design directed toward the permanent well-being of mankind. Most significantly, the virtual eternalism of such theories was extended, often explicitly, to the history of mankind—for example, in George Toulmin's *The Antiquity and Duration of the World* (1780). Mankind could thus be claimed as uncreated and therefore not subject to any of the traditional moral and social constraints.[12] These theories were far from anticipating modern geology, despite their casual references—for example, in Jean-Baptiste Lamarck's *Hydrogéologie* (1802)—to "millions of centuries" for the history of the earth. Such vast spans of time were invoked primarily as an essential component of eternalistic theories that had clear and generally overt cosmological goals.

PREHUMAN EARTH HISTORY

Meanwhile, however, the bulk of empirical studies of the earth was taking a different direction. Such studies were not necessarily integrated into any high-level theory of the earth. Rather, they were often directed toward more mundane and practical goals, such as the discovery of mineral resources. In such work the implausibility of Woodward's explanation of the strata soon became clear, but his emphasis on the strata as a temporal sequence was retained and enlarged. It became commonplace among eighteenth-century naturalists to distinguish the most ancient, or "Primary," rocks, having no fossils, from the regular sequences of "Secondary" fossil-bearing strata; these were

distinguished in turn from irregular and patchy superficial deposits containing the bones of exotic animals such as elephants. The record of the biblical Flood or Deluge was now identified only with these relatively recent deposits. Admittedly they did not suggest the kind of episode recorded in Genesis, and they contained no human remains; but they did seem to be the product of some exceptional catastrophe, and they were difficult to explain away in terms of ordinary observable processes. Since these superficial deposits were identified as "diluvial" (that is, dating from the Flood), the regular sequence of Secondary strata was necessarily described as "antediluvial" or pre-Flood. Since it too contained no human remains, it gradually came to be accepted as a record of *prehuman* earth history (fig. 1C).

This implicit separation of the origin of the earth from the origin of mankind had profound consequences. It created a new kind of history, a history without human documents, which required new conceptual tools. These were borrowed by naturalists from human historiography.[13] Antiquarians had already concluded that "monuments"—a term that covered artifacts such as coins as well as architectural remains—were more trustworthy as historical evidence than textual documents, and in the eighteenth century this term was appropriated by naturalists. They argued that fossils and strata should be more reliable monuments than human artifacts, since Nature could hardly be suspected of historical bias or forgery. In this way, natural monuments were transformed from being merely a source of evidence to supplement the annals of human history, as they had been for Steno, into evidence for a long history that predated mankind altogether. By the late eighteenth century, fossils and strata were routinely described as monuments or as "Nature's archives"; they helped to define "epochs" of local validity, which gave greater precision to the global categories of Primary and Secondary. The naturalists who pioneered this new kind of earth history rarely attempted to quantify its time scale. On occasion this may have been a matter of prudence, to avoid disturbing readers who still took the traditional biblical chronology for granted.[14] But a more general reason was the scarcity of evidence to go on, beyond the impression given by thick piles of strata that seemed to have been deposited slowly on a former seafloor. Nonetheless, such evidence was sufficiently compelling by the late eighteenth century for many naturalists to assume implicitly—and sometimes explicitly, if only in passing—that prehuman earth history must be reckoned at least in tens or hundreds of thousands of years.

This view of a prehuman earth history of inconceivable duration was seized upon for diverse cosmological purposes. For example, the posthumous publication of Gottfried Wilhelm von Leibniz's theory of

the earth *Protogaea* (1749), which had originally been intended as a prelude to a conventional human history of his patron's territories, provided a useful model for interpretations of earth history that stressed natural causes but were not eternalistic.[15] Thus the French naturalist Georges Louis Leclerc, Comte de Buffon (1707–1788), abandoned the virtual eternalism of his earlier theorizing and worked out a directional model based on analogical experiments with cooling globes. This led him to date the successive "epochs of nature," past and future, with an impressive air of precision; in his *Epoques de la nature* (1778) he gave a total of about a hundred thousand years.[16]

Although Buffon's work could seem like a secular parody of the Creation narrative, other naturalists sought to harness recent empirical results to the cause of defending the plausibility of the traditional Christian viewpoint. For example, the Swiss naturalist Jean-André Deluc (1727–1817) conceded the vast time-scale of prehuman earth history; and, even though he regarded it as peripheral to the main issues of religious concern, he absorbed it into the biblical narrative at least to his own satisfaction. He criticized eternalistic theorists like Hutton, above all for implicitly denying the biblical account of the origin and early history of mankind. In *Lettres physiques et morales* (1779) he focused his attention on the detailed evidence of "natural chronometers" derived from the observable rates of natural processes, believing these indicated that an exceptional physical disturbance—which he identified with the biblical Flood—had affected many areas of Europe only a few thousand years ago, turning seafloors into land areas. In effect, Deluc believed that in the study of the earth the issues of concern to Christians could be narrowed down to those affecting the creation and history of mankind. Within that narrowed limit, the tradition of biblical chronology remained in his opinion valid; outside it, for the epochs before the Flood and before mankind, a more symbolic interpretation of Genesis was quite acceptable (see fig. 1C). This was no simplistic compromise between Christianity and science; rather, Deluc, in seeking to defend traditional Christian beliefs from the skeptical attacks of openly antireligious *philosophes*, was trying to define just what areas of natural philosophy were of legitimate concern in maintaining those beliefs as valid guides to the meaning and conduct of life.

The inference that earth history as a whole had been inconceivably lengthy, even if human beings were relative newcomers to the scene, was not very widespread outside the small circles of naturalists engaged in this kind of study. Such conclusions certainly remained suspect among some conservative religious groups in Western societies; but this was at least partly because high estimates of the earth's

antiquity were tainted by their long association with eternalistic cosmologies. Some social groups, however, found it possible to accept the idea of a high antiquity for the earth without rejecting the religious authority of the biblical writings. This was due above all to the emergence of the new critical school of biblical scholarship centered in the German cultural area. Unlike much earlier work of biblical criticism, this was not necessarily directed toward rationalistic or antireligious goals. Its conclusions could indeed be used to argue reductively that the Bible was now more worthless than ever. But alternatively it could be claimed that the new critical perspective gave even the "legendary" parts of the Bible their truly religious meaning. They could now be regarded as a precious record of early *religious* insights into the relation between mankind, the created world, and God. In any case, since the new methods treated the biblical texts as the products of diverse periods and cultures, the early chapters of Genesis, bearing a close relation to physical and historical events for which there was nonbiblical evidence, became a natural early focus of debate, as for example in J. G. Eichhorn's *Die Urgeschichte* (1779).[17]

But even if the new biblical criticism was not used in the service of antireligious cosmologies, it altered profoundly the traditional concerns of theories of the earth, because the search for physical evidence that would confirm, or undermine, the more or less literal meaning of the opening biblical narratives became irrelevant from this perspective. The Flood could be taken to have been a purely local event, and the narrative of Creation could be regarded as a prescientific story designed primarily to express in religious terms the creaturehood of the natural world and mankind. Above all, the time scale of earth history became religiously irrelevant. For those who abandoned the traditional precritical approach to the biblical texts, and with it the idea of a total earth history of only a few thousand years, it made no difference to religious belief and practice whether naturalists estimated that history in tens of thousands or hundreds of millions of years. The only religious problem was now that of finding some human meaning in those vast spans of prehuman history.

THE NEW SCIENCE OF GEOLOGY

Toward the end of the eighteenth century many naturalists engaged in the study of the earth tried to dissociate themselves from the use of their work by rival cosmological interests. In the three main cultural areas of Europe, the preferred terms for the study of the earth became *Geognosie*, *géographie physique*, and (somewhat later) *geology*. Such

terms marked a firm rejection of large-scale theorizing and a new emphasis on the value of cumulative observation, at a time when the economic value of mineral surveying was becoming apparent. The new empiricist rhetoric was therefore not socially neutral. It expressed an attempt to establish the study of the earth as a practical pursuit that would be free of cultural pressures from *either* side: from the traditional concerns of biblical chronologists *and* from the secularizing concerns of eternalistic theorists. Empiricism was justified at the time on the grounds that earlier theories of the earth had signally failed to lead to any clear progress in knowledge. But after the revolution in France in the late eighteenth century it was strongly reinforced by widespread political suspicion of the naturalistic speculations of the *philosophes* and their antireligious cosmological goals.[18]

The new science of geology therefore emerged in the early nineteenth century as a strongly bounded field of knowledge, conspicuous for what it did *not* contain. Geologists (as they may now at last be called without anachronism) excluded as unscientific almost all that had previously made the earth rich in cosmological meaning: the origin of the earth, its ultimate fate, and, above all, the origin and early history of mankind (see fig. 1D). Within its self-imposed frontiers, however, geology developed its cognitive heartland with great practical success. Local sequences of strata were classified in terms of a programmatically global sequence of Systems (Carboniferous, Silurian, etc.), which were accepted as the records of a sequence of corresponding Periods of literally immeasurable length. Deluc's unique, recent diluvial event was generalized into a notion that such catastrophes had been a repeated feature of the earth's history; and this was used by the French zoologist Georges Cuvier (1769–1832) and others to account for the apparently abrupt changes in fossil animals and plants between adjacent sets of strata. Far from bringing the supernatural into geology, this so-called catastrophism turned even the puzzling Flood or Deluge into one of a series of natural events, as can be seen, for example, in Léonce Elie de Beaumont's *Sur les révolutions du globe* (1829–1830). Geology, with its carefully maintained cosmological neutrality, was prized as a science in which Christians of all denominations, together with freethinkers and those who were later termed agnostics, could cooperate amicably. At least in Europe, if not in America, those geologists who regarded themselves as Christians generally accepted the new biblical criticism and therefore felt the age of the earth to be irrelevant to their religious beliefs. The more sensitive issue of the origin of mankind—and, by implication, the nature of human beings as creatures in God's image—was effectively excluded by the newly drawn boundaries of geology.

It should be added, however, that this did not seem at the time to be avoiding the issue, because human remains were conspicuously absent from even the geologically recent diluvial deposits.

In the early nineteenth century, therefore, geologists opened up with increasing self-assurance an astonishing drama of vanished worlds that had been inhabited by strange, extinct organisms. They set this drama within an assumed time-scale that dwarfed even the whole history of civilization (see fig. 1D). In popularized form this new drama of earth history was eagerly absorbed by many among the wider public. But not all were prepared to accept on trust what ran so strongly counter to both tradition and common sense.

MOSAIC GEOLOGY

In conscious opposition to the self-styled philosophical (i.e., scientific) geologists, a so-called scriptural or Mosaic geology emerged, in which the cognitive validity of the biblical narrative was reasserted in terms inherited from the biblical chronology of the sixteenth and seventeenth centuries. Mosaic geology was so called because its proponents retained the precritical view that Genesis and the rest of the Pentateuch had been written under divine inspiration by Moses himself. It flourished more in the English-speaking world, including the United States, than in continental Europe, probably because critical methods of interpretation were accepted earlier and more widely among intellectual Christians on the Continent. Mosaic geologies ranged from work by erudite, though precritical, biblical scholars down to the most unsophisticated popularizations, from theories supported by at least some empirical fieldwork down to books by those who had never studied a rock or a fossil at first hand. What united all these writers was the conviction that Genesis, if rightly interpreted, embodied an authoritative narrative account of the origin and history of the earth and mankind. But the contrast that they frequently expressed between the "fanciful" theories of the geologists and their own "commonsense" conclusions shows that more was involved than simple religious or social conservatism. The geologists' startling assertions about earth history were indeed derived from increasingly esoteric inferences that the ordinary person could no longer follow easily. Mosaic geology was, therefore, in part a cultural reaction to the social and cognitive exclusion of all but self-styled experts from an area of speculation that, in the heyday of theories of the earth, had been open to all.

The scientific geologists claimed to regard Mosaic geology as marginal to science and worthy only of derision. But in fact they took very seriously its threat to the cognitive and social status of their own enterprise. This is shown particularly by their reaction to any work from within their own social circle that transgressed the tacit boundaries of the science. Early in the century, for example, Cuvier's extension of Deluc's arguments for the historicity of a recent Flood event was widely criticized on just these grounds. Cuvier argued for the low antiquity of civilization—and, by implication, of mankind—by comparing the records of all ancient civilizations. Although he was probably no orthodox Christian, and although he used the biblical records with all the scholarly impartiality of the German biblical critics, his excursion into chronology seemed to others to imperil the cosmological neutrality of geology.[19] This was particularly the case because, when imported into the English-speaking world in Robert Jameson's edition of the *Theory of the Earth* (1813), Cuvier's work was used openly to reassert the literal authority of the Bible. Cuvier's English follower William Buckland (1784–1856) met with a similar critical response, when he argued in *Reliquiae Diluvianae* (1823) for the historicity of a recent, though nonmiraculous, Flood event, basing his case in large part on a detailed study of a supposedly antediluvial hyena den. Such episodes seem, however, to reflect highly specific social circumstances. Buckland's diluvialism, for example, was evoked by a local situation at Oxford, in which he felt he had to defend the new science of geology from the old charge that such speculations encouraged religious skepticism. Once that social threat receded, he quietly dropped his claim that geology gave evidence of a universal Flood event, and later became one of the first geologists to support Louis Agassiz's (1807–1873) theory of a recent Ice Age as a better explanation of the puzzling diluvial phenomena.[20]

The famous remark by the British geologist Charles Lyell (1797–1875) that he was determined to "free the science from Moses" therefore needs to be interpreted in its proper context. Other geologists, whether Christians or freethinkers, agreed with Lyell that the cognitive boundaries of geology needed to be maintained in order to exclude Mosaic geology and its practitioners. They also agreed that scientific geologists such as Buckland, who—for whatever reason—transgressed those boundaries, did the science a disservice. But this exercise in boundary maintenance reflected a conflict not between science and religion but between one social group and another. The geologists were struggling for a cultural place in the sun, for greater social recognition of their cultural authority, in competition with older

elites. In the early nineteenth century they did not represent antireligious interests but rather those of a pragmatic alliance between liberal Christians, whom even Lyell accepted as "enlightened saints," and a varied assortment of freethinkers; both groups valued geology especially for its potential practical utility.

SCIENTIFIC NATURALISM

Within the cognitive boundaries of early-nineteenth-century geology, one cosmological gloss won widespread acceptance because it was not socially divisive. This related not to Genesis but to natural theology. Geology, or more particularly the analysis of extinct organisms preserved as fossils, gave a new temporal dimension to the sense of divine design in the world. The traditional static concept of design was dramatically enlarged by the understanding that divine providence had underlain equally all the successive phases of earth history, even before the existence of mankind, a view expressed, for example, in Buckland's Bridgewater treatise on *Geology and Mineralogy Considered with Reference to Natural Theology* (1836). In this way cosmological meaning could be attributed to the vast prehuman history that geology had opened up. Rather than being socially divisive, this perspective, because it was so broad, acted as a social cement between conflicting religious groups.[21] It was acceptable to a deistically inclined geologist like Lyell, with his uniformitarian or virtually eternalistic theory of earth history, as well as to a quite explicitly Christian geologist such as Adam Sedgwick. And any geologist privately inclined to a more materialistic viewpoint, like the young Charles Darwin (1809–1882), could simply omit the rhetoric of design, leaving his geology unimpaired in the eyes of others.

A second cosmological interpretation of geology was, however, more debatable and had more divisive implications. The general belief among geologists that the earth had cooled gradually in the course of its history seemed at first to be an adequate explanation of an observed directional change in the character of its faunas and floras. This could readily be assimilated within the new sense of a dynamic providential design. In the middle decades of the century, however, evidence began to emerge that could be made to support the view that the history of life had been not only directional but progressive, moving from "lower" to "higher" forms independently of environmental change.[22] Indeed, it was possible for geologists such as Agassiz and Richard Owen (1804–1892) to attribute this to the progressive unfolding of an overarching divine design, by which the living world

had slowly been prepared for its culmination in the creation of mankind. But this kind of progressionist interpretation could be radically transformed into a strictly naturalistic image of earth history. This possibility first became apparent in the *Vestiges of the Natural History of Creation* (1844) by the Scottish writer Robert Chambers (1802–1871), notwithstanding his substantial use of providentialist arguments. Chambers used the nebular hypothesis of Pierre Simon Laplace (1749–1827), in a new context of progressionist geology and evolutionary biology, to provide a naturalistic explanation of the origin of the earth and the progressive evolution of life toward mankind. It is significant that such reinterpretations of geology (and biology) in terms of the cosmology of scientific naturalism first arose among generalists like Chambers, outside the social circle of the geological specialists; for of course any such theory transgressed the cognitive boundaries that had been defined by that circle. Because such theories could not simply be ignored—Chambers's work was extremely popular among the general public—they forced open the tacit boundaries of the science and obliged geologists to respond to them in kind. If those with an ax to grind in the interests of scientific naturalism claimed that the latest geological discoveries supported that cosmology, then those concerned to defend a Christian cosmology were obliged to show how the same evidence could be interpreted differently, and to do so on the same popular level; Hugh Miller's *Footprints of the Creator* (1847) exemplifies such an effort.

In the middle decades of the nineteenth century, therefore, the frontiers of geology were reopened, as it were, at both ends of the time scale (see fig. 1D). The question of the origin of the earth was forced back into scientific discourse, though it is significant that this opening was first exploited not by geologists themselves but by physicists such as William Thomson, later Lord Kelvin (1824–1907). At the other end of their temporal territory, geologists at last accepted the evidence that human beings must have coexisted with extinct mammals in a geologically recent (but humanly remote) period, because stone implements were found with those animals' bones in circumstances that could no longer be doubted. These discoveries opened up a new conceptual space of prehistory, between the relatively well-established history of civilized literate mankind and the strictly geological history of prehuman periods (see fig. 1D). The question of the origin and antiquity of mankind could thus no longer be tacitly cordoned off from scientific geology. Yet that question, like the origin of the earth, was debated in the later nineteenth century not in terms of conflict between science and religion but between rival cosmologies. The naturalistic interpretation of human origins was neither

neutral nor disinterested: it was generally used in the service of the often strident cosmology of scientific naturalism. And scientific naturalism was itself the cosmology of specific social groups, including the self-consciously professionalizing scientists, who used it as a means of wresting cultural power from the hands of older social elites, particularly, of course, the clergy.[23]

These conflicts in the later nineteenth century were more directly concerned with the relation of mankind to the rest of the animal world than with the earth as such. At this point, therefore, they pass beyond the strict limits of this essay. The specific question of the age of the earth did arise once more in the mid-nineteenth century, but only in this biological context was it of cosmological significance. Ever since the rise of geology with its self-imposed cognitive limitations, there had been a tacit embargo on quantitative estimates of geological time. As the Prussian naturalist Alexander von Humboldt (1769–1859) had put it in his *Essai géognostique* (1823), such estimates belonged to "géologues hebraizans," that is, to Mosaic geologists. Geologists got on very well without quantitative estimates; and by the middle of the century Lyell's explanatory use of unquantified but virtually limitless time had been assimilated into much routine geological practice. The quantitative magnitude of the time scale reemerged into scientific discourse only after Darwin in *The Origin of Species* (1859) hitched his concept of natural selection to a Lyellian concept of geological time and used natural selection in the service of a far-reaching naturalistic theory of species change and, implicitly, of the origin of mankind. Darwin rashly committed himself in print to a "guesstimate" of geological time that even modern geologists would find extravagant.[24] This gave his contemporaries the opportunity to attack his theory at a weak point on impeccably scientific grounds, though in reality their reasons for doing so were no more disinterested cosmologically than his. On the basis of observed rates of sedimentation, for example, geologists such as John Phillips (1800–1874) estimated the total age of all preserved strata to be on the order of a hundred million years. They found this estimate gratifyingly compatible with those proposed by Kelvin for the total age of the earth, using the quite independent evidence of the thermodynamic history of the sun.[25] In the face of such a consensus on the relatively limited time scale of earth history, natural selection seemed to be eliminated from being a plausible motor for evolutionary change. But the dynamic behind this criticism lay in opposition not to evolutionary theories in general but to the particular form of Darwin's theory, in which "blind chance" seemed to play such a crucial role and providential design was apparently excluded from organic nature. Still less was the scientists' opposition to Darwin's

geological time scale rooted in any desire to reinstate the time scale of precritical biblical chronology. Such an attempt did indeed continue throughout the nineteenth century, but only in the tradition of Mosaic geology, not among those whose work was accepted within the circle of scientists. And even Mosaic geology was pushed inexorably into an increasingly marginal position, both cognitively and socially, as the intellectual spokesmen for Christian opinion, even in the English-speaking world, abandoned precritical forms of biblical interpretation and restated their beliefs in terms that took account of the newer critical methods.

CONCLUSION

Soon after 1900 Kelvin's ever more restrictive estimates of geological time were burst open by the discovery of radioactivity in rocks. But by then the question had lost all its earlier associations with rival religious and secularist cosmologies. The great expansion of estimates of the age of the earth during the twentieth century (to their present level of several billions of years) facilitated the revival of Darwinian interpretations of evolutionary theory, but it had no new religious implications. For Christians who accepted critical methods of interpretation in their understanding and practical use of the biblical documents, the religious meaning of texts such as the Creation narrative remained undisturbed by changing estimates of the quantitative magnitude of earth history or the history of mankind. Some individual scientists did assert that those histories bore a deeper cosmological meaning; the Catholic priest and paleontologist Pierre Teilhard de Chardin (1881–1955), for example, argued for a religious interpretation, while the French biologist Jacques Monod (1910–1976) favored an antireligious one. But neither assertion found general support among scientists; to most of them, either conclusion seemed evidently imposed on the scientific evidence rather than derived from it. More clearly than ever, any such cosmological gloss could be seen to represent an individual decision to attribute a certain set of values to a scientific story of earth history that in itself was geared to far more limited cognitive goals.

Yet this modest and perhaps tame conclusion continues to be challenged from two opposed directions. On the one hand there are the successors of the strident nineteenth-century proponents of scientific naturalism, such as Monod, who insist that the scientific story does carry an intrinsic cosmological implication, namely an atheistic one. And on the other hand there are the successors of the equally strident

nineteenth-century proponents of biblical literalism, who insist that the scientific story is radically false because it is incompatible with their own "scientific" evidence and with a precritical method of interpreting the Bible. Such Christian fundamentalism, including its component strand of creationism, has become in recent years a powerful cultural force in some Western societies—for example, in the United States and the Netherlands (see chapter 16). But it has been evoked, at least in part, by the way that a few scientists have made well-publicized and often arrogant claims to a privileged monopoly in the attribution of human meaning to the natural world.

Late-twentieth-century Christians who reject the precritical assumptions of the fundamentalists find it necessary to steer a difficult middle course between this Scylla and Charybdis. But so do late-twentieth-century agnostics who reject the arrogant scientistic pretensions of the new scientific naturalists. Being in the same boat, those two groups can probably agree about the present outcome of the earlier debates on the origin and history of the earth and of mankind's place in it, namely that Christian beliefs about the meaning and conduct of human lives have no legitimate point of contact of any significance with the modern scientific story of earth history. This is not because mainstream Christian theology has compromised with atheistic secularism, as the fundamentalists claim. Nor is it because orthodox Christianity has been defeated in a conflict with science, as the new scientific naturalists claim. The true reason, I suggest, is twofold. First, earth scientists as a social group have *collectively* chosen the historical option of abandoning any cosmological ambitions, as the most effective route to the achievement of more limited cognitive and technical goals. And second, mainstream Christian theologians have recognized that the religious meaning of biblical texts is to be found in terms of whatever input from a "God-labeled" source (that is, in traditional language, revelation) may be embodied in the religious insight of the ancient cultures that produced those texts.[26] Of course the Christian and the agnostic are likely to differ profoundly in their estimate of the cognitive and practical value of that insight for the construction of individual and social lives in the modern world. But that is another story.

NOTES

I am under an obligation to state that the work for this paper was begun while I was still Professor of the History and Social Aspects of Science at the Vrije Universiteit, Amsterdam, the Netherlands. Preliminary versions of the paper were given to colloquia at the Science Studies Unit, Edinburgh University, and the Department of History and Philosophy of Science, Cambridge University; I am grateful to those who made helpful comments and suggestions on these earlier occasions, as well as at the conference at Madison. Neal Gillespie and Jim Moore made valuable written comments on the draft discussed at the conference.

1. James R. Moore, *The Post-Darwinian Controversies: A Study of the Protestant Struggle to Come to Terms with Darwin in Great Britain and America, 1870–1900* (Cambridge: Cambridge Univ. Press, 1979), part 1, gives a valuable account of the polemical contemporary context of these works.

2. For further discussion of this point of view see Martin Rudwick, "Senses of the Natural World and Senses of God: Another Look at the Historical Relation of Science and Religion," in *The Sciences and Theology in the Twentieth Century*, ed. A. R. Peacocke (London: Routledge & Kegan Paul, 1981), pp. 241–261.

3. This point is well made by Mary Hesse, "Criteria of Truth in Science and Theology," in her *Revolutions and Reconstructions in the Philosophy of Science* (Hassocks: Harvester Press, 1980), chap. 10.

4. For work that explores the extension of the term *cosmology* beyond its original anthropological setting see, for example, Mary Douglas, *Implicit Meanings* (London: Routledge & Kegan Paul, 1975). The same notion is used in the context of the history of science in Barry Barnes and Steven Shapin, eds., *Natural Order: Historical Studies of Scientific Culture* (Beverly Hills, Calif.: Sage Publications, 1979). I deliberately avoid the contentious term *ideology* in this context.

5. See Anthony T. Grafton, "Joseph Scaliger and Historical Chronology: The Rise and Fall of a Discipline," *History & Theory* 14 (1975): 156–185; and J. D. North, "Chronology and the Age of the World," in *Cosmology, History, and Theology*, ed. Wolfgang Yourgrau and Allen D. Breck (New York: Plenum Press, 1977), pp. 307–333.

6. See Don Cameron Allen, *The Legend of Noah: Renaissance Rationalism in Art, Science and Letters* (Urbana: Univ. of Illinois Press, 1949); Arnold Williams, *The Common Expositor: An Account of the Commentaries on Genesis, 1527–1633* (Chapel Hill: Univ. of North Carolina Press, 1948); and Janet Browne, *The Secular Ark: Studies in the History of Biogeography* (New Haven: Yale Univ. Press, 1983).

7. See Martin Rudwick, *The Meaning of Fossils: Episodes in the History of Palaeontology*, 2d ed. (New York: Science History Publications, 1976), chaps. 1 and 2.

8. On the close relation between naturalists and antiquarians see Cecil J. Schneer, "The Rise of Historical Geology in the Seventeenth Century," *Isis* 45 (1954): 256–268; and Paolo Rossi, *The Dark Abyss of Time: The History of the Earth and the History of Nations from Hooke to Vico* (Chicago: Univ. of Chicago Press, 1984).

9. The political context of Burnet's chiliastic expectation of an imminent millennium is explored in Margaret C. Jacob and Wilfrid A. Lockwood, "Po-

litical Millenarianism and Burnet's *Sacred Theory*," *Science Studies* 2 (1972): 265–279. Burnet's scheme is elegantly summarized in visual form in the frontispiece of his book, which is reproduced in Rudwick, *Meaning of Fossils*, p. 79.

10. See the important interpretative synthesis in Jacques Roger, "La theorie de la terre au XVII[e] siècle," *Revue d'histoire des sciences* 26 (1973): 23–48. See also Roy Porter, "Creation and Credence: The Career of Theories of the Earth in Britain, 1660–1820," in *Natural Order*, ed. Barnes and Shapin, pp. 97–123; and "The Terraqueous Globe," in *The Ferment of Knowledge: Studies in the Historiography of Eighteenth-Century Science*, ed. G. S. Rousseau and Roy Porter (Cambridge: Cambridge Univ. Press, 1980), pp. 285–324.

11. See Marjorie H. Nicolson, *Mountain Gloom and Mountain Glory: The Development of the Aesthetics of the Infinite* (Ithaca, N.Y.: Cornell Univ. Press, 1959); and Gordon L. Davies, *The Earth in Decay: The History of British Geomorphology* (London: Macdonald, 1969).

12. Roy Porter, "George Hoggart Toulmin's Theory of Man and the Earth in the Light of the Development of British Geology," *Annals of Science* 35 (1978): 339–352.

13. I am grateful to Dr. Rhoda Rappaport for allowing me to draw on her unpublished research in this section.

14. On the absence of any consensual view see Rhoda Rappaport, "Geology and Orthodoxy: The Case of Noah's Flood in Eighteenth-Century Thought," *British Journal for the History of Science* 11 (1978): 1–18.

15. Bernhard Sticker, "Leibniz' Beitrag zur Theorie der Erde," *Sudhoffs Archiv* 51 (1967): 244–259.

16. Jacques Roger, ed., "Buffon: Les epoques de la nature, edition critique," *Mémoires du Muséum d'histoire naturelle*, n.s., ser. C, 10 (1962). Privately, Buffon suspected that the true time scale was even longer.

17. My interpretation of the precritical concept of biblical narrative, and of the way it was supplanted by critical methods of interpretation, is much indebted to Hans W. Frei, *The Eclipse of Biblical Narrative: A Study in Eighteenth and Nineteenth Century Hermeneutics* (New Haven: Yale Univ. Press, 1974).

18. See Roy Porter, *The Making of Geology: Earth Science in Britain, 1660–1815* (Cambridge: Cambridge Univ. Press, 1977).

19. See Dorinda Outram, *Georges Cuvier: Vocation, Science and Authority in Post-Revolutionary France* (Manchester: Manchester Univ. Press, 1984).

20. See Nicolaas A. Rupke, *The Great Chain of History: William Buckland and the English School of Geology, 1814–1849* (Oxford: Clarendon Press, 1983); Martin Rudwick, "The Glacial Theory," *History of Science* 8 (1970): 136–157.

21. See John H. Brooke, "The Natural Theology of the Geologists: Some Theological Strata," in *Images of the Earth: Essays in the History of the Environmental Sciences*, ed. L. J. Jordanova and Roy S. Porter (Chalfont St. Giles: British Society for the History of Science, 1979), pp. 39–64.

22. For the earlier interpretation of progression see Martin Rudwick, "Uniformity and Progression: Reflections on the Structure of Geological Theory in the Age of Lyell," in *Perspectives in the History of Science and Technology*, ed. Duane H. D. Roller (Norman: Univ. of Oklahoma Press, 1971), pp. 209–227; for the later or true progressionism see Peter J. Bowler, *Fossils and Progress: Paleontology and the Idea of Progressive Evolution in the Nineteenth Century* (New York: Science History Publications, 1976).

23. See, for example, Frank M. Turner, "The Victorian Conflict between Science and Religion: A Professional Dimension," *Isis* 69 (1978): 356–376.

24. J. D. Burchfield, "Darwin and the Dilemma of Geological Time," *Isis* 65 (1974): 300–321.

25. See Joe D. Burchfield, *Lord Kelvin and the Age of the Earth* (New York: Science History Publications, 1975).

26. For a reinterpretation of revelation framed in these terms see John Bowker, *The Sense of God: Sociological, Anthropological and Psychological Approaches to the Origin of the Sense of God* (Oxford: Clarendon Press, 1973).