3

The re-creation of the Earth

Historical contexts

Many theories of the Earth – and far more replies – were produced in the generation straddling the end of the seventeenth century. Early nineteenth-century geologists dismissed these as bare theological speculation, and historians of geology have generally endorsed this judgment: 'these early fables of geological science should be read by all who are in need of mental recreation and who possess the required leisure and a certain sense of humor' (Adams, 1954: 210).[1] This chapter attempts to establish a framework for understanding late seventeenth-century theories, in themselves, and within the development of Earth science.

Firstly, however, it is worth stressing their importance. For these theories were the work of the leading scientific intelligentsia. They included such first-rank natural philosophers as Hooke, Halley, Ray, Keill, Whiston, as well as the age's foremost students of the Earth, like Woodward. Newton first admired Burnet's theory ('Of our present sea, rocks, mountains, etc., I think you have given the most plausible account'), then formulated his own ideas, and finally gave his approval to Whiston's (Turnbull, 1959, ii: 329; Whiston, 1698: Preface). John Locke wrote of Whiston's theory, 'I have not heard anyone of my acquaintance speak of it, but with great Commendation, as I think it deserves' (Davies, 1969: 86). Other virtuosi, such as Samuel Pepys, Addison and Steele, gave their attention to Burnet (Davies, 1969: 72).

If these theories failed to resolve the problems of the Earth, it was not through stupidity, but because of intrinsic difficulties, and the contradictory demands made by their philosophies of Nature. The theorists generated much satire; but that proves public fascination, and perhaps the intellectual daring of the theories, not incompetence. British theories were avidly read and translated on the Continent during the eighteenth century, and naturalists such as J. J. Scheuchzer abandoned old ideas on discovering them (Zittel, 1901: 20f.; V. A. Eyles, in Schneer, 1969). Likewise, throughout eighteenth-century Britain, debate was conducted explicitly around the theories and outlooks of Burnet, Woodward and Whiston. Though dissociating themselves from them, Buffon, Raspe, Whitehurst and others nevertheless believed that *these* were the theories to be refuted in order to clear the decks.

Equally, to cast these works aside on the grounds that they were *theories* in an age supposedly of Baconian empiricism and 'hypotheses non fingo' is totally to misread both the philosophy and the practice of science in that age (cf. Buchdahl, 1969; Butts and Davis, 1970) – not least, because much theorizing about the Earth itself had a decidedly tentative tone. Burnet averred that thought was free, and that his theory was a mere hypothesis: 'there is no Chase so pleasant, methinks, as to drive a Thought, by good conduct, from one end of the World to the other' (1684: 6). Hooke argued the empirical basis of his theories, which he defended as heuristic (Oldroyd, 1972). For all his personal arrogance, Woodward offered his theories as *Essays* and *Attempts*, and stressed 'From a long train of Experience, the World is at length convinc'd that Observations are the only sure Grounds whereon to build a lasting and substantial Philosophy' (1695: 1).

The most common dismissal of these theories, however, is that they were not the outcome of empirical inquiry, but were rather amalgams of imagination and speculation, *a priori* metaphysical and natural philosophical notions, religious Revelation and uncritically regurgitated ancient wisdom, derived from books, sanctified by age and authority. This is partly true – though only partially. But it is generally stated in a form which begs the historical question. It raises three issues. How empirically based were these theories? That is, to what extent did they grow out of the natural history inquiry orchestrated by the founding of the Royal Society? This question will be discussed later.

Secondly, how should we evaluate these theories, given that they were built with many other forms of knowledge in addition to direct empirical inquiry? For all late seventeenth-century men

of science, whatever their genius or specialist discipline, believed in the multiplicity of modes and sources of inquiry after truth (Manuel, 1963; McGuire and Rattansi, 1966). Theorists of the Earth were not unusual in this respect. I shall explore below the different kinds of evidence and argument taken as valid for a theory of the Earth, and how fundamental religious and philosophical beliefs determined the form of theory which contemporaries could realize.

The third question is the simplest to resolve: were not these theories *merely* exegeses of Genesis, tailoring nature to the Scriptures, either by choice, or under pressure from public and ecclesiastical opinion? But this does not seem true. I know no evidence that any theorist – except perhaps Halley – significantly felt inhibited by any such pressure. They wrote what they believed.[2] Furthermore, they themselves discriminated between merely exegetical philosophy and empirical inquiry, and many actually chose to structure their work into separate exegeses of Scripture, philosophical discourse, and consideration of empirical evidence. Thus Thomas Burnet argued the first eight chapters of the *Theory of the earth* from rational and philosophical necessity, and then announced his intention to corroborate these points from 'Effects', in ch. ix, headed, 'The Second Part of this Discourse, proving the same Theory from the Effects and present Form of the Earth', believing that 'Truth cannot be an enemy to Truth, God is not divided against Himself' (1684: 3).

To see these theories as obediently toeing the theologically orthodox line misses the historical point. For such theological commitments were *themselves* in the melting-pot. Late seventeenth-century intellectuals had been inducted into a culture rich in theological and philosophical wisdom, natural lore, myths about man's origin and development, prophecies about the future of man and the world, allegories, symbolism, occult knowledge, mysteries. Because it was a culture overbrimming with such heterogeneous claims to truth, the critical methods, philology, sceptical temper, and sheer mushrooming of new facts of the Age of Restoration and the early Enlightenment, were shaking its foundation (Hazard, 1964; Manuel, 1959; Kubrin, 1968). Empirical natural history was espoused to resolve the narrower ambiguities of the meaning of the Earth – problems of fossils and minerals. So, in

the same way, theorists of the Earth took apart the world of traditional cosmogonical discourse, and sought to expose its flaws, resolve its ambiguities, and reconstruct it on a fit basis for a new age.

This rarely entailed anything so mechanical as putting traditional wisdom to empirical test, finding it wanting and simply discarding it, though this occasionally happened, Ray and Woodward both being scathing for instance about the 'wisdom' of the Ancients (Woodward, 1695: 56; Lankester, 1848: 229f.). Rather, empirical evidence was weighed in order to decipher the 'real' meaning of traditional wisdom. The process was one of revaluing, rather than rejecting, the components of knowledge in the world of traditional discourse. Thus, Burnet used natural necessity and the examination of effects to confirm that Genesis was not a literal account of the Creation but an allegory for the 'vulgar' (1684: Review). The evidence of strata and fossils convinced Woodward that the Deluge must have been effected by immediate miraculous agency. Investigation persuaded Hooke that Ovid's *Metamorphoses* contained a deep philosophical understanding of the Earth. It would be unhistorical of course to want to imply that these theorists open-mindedly put problems of interpretation of Scripture, traditional wisdom and philosophy to the test of Nature. Clearly, theorists largely found in Nature what they hoped to discover. (Yet not always. For example, in his *Miscellaneous discourses* Ray frequently admitted that the empirical evidence was inconclusive.) The real point, however, is that empirical natural evidence was now becoming the approved testing ground, ostensibly at least, for rival interpretations of Earth history, the destiny of mankind, the order of Nature, the mode of God's activity in the world – in short, of cosmologies and cosmogonies. Perhaps for the first time, certain fundamental beliefs were being held up for empirical confirmation at the tribunal of Nature. Of course at this stage most theories were reinterpreting, modifying and broadly reinforcing traditional cosmogony, rather than challenging it. Yet the way was opened, once the ground of debate had shifted to natural evidence, to such confutation in the future.

And even then, quite radical pressures were creating stresses on the traditional cosmogony. Burnet did not merely find (as the popular jingle ran) that 'All the Books of Moses/Were nothing but

supposes', but allegorized the Fall, and seemingly declared that in the physical world God worked exclusively by second causes (Redwood, 1976: 110f.). Hooke and Aubrey thought 'the World is much older than is commonly supposed' (Aubrey, 1685: 112; Hunter, 1975: 59). Hooke accepted extinction. Beaumont hinted at the eternity of the Earth (Davies, 1969: 11–12). Furthermore, controversy revealed disagreement on all major issues, from microscopic facts up to total philosophies of Nature. In sum, these theories were not exercises in Biblical exegesis, but rather many-sided projects of the mind attempting to bring order out of cosmogonical chaos.

While differing in detail, late seventeenth-century theories shared certain fundamentals. All conceptualized the Earth in a context of Divine Creation, purpose, order and sustenance. All believed the Earth had been created for man, though not necessarily exclusively for him. It was, consequently, to be understood teleologically and anthropocentrically. This was the outlook of Hebraic Christianity, and also of Hellenistic philosophy and Classical culture; of rational religion and natural philosophy. Though repudiated in the strategy of physical science, teleology lost no ground in the conceptualization of the general economy of Nature until long after the sceptical attacks of Hume and Kant (Glacken, 1967; Humboldt, 1845–62). Late eighteenth-century Deistic geologists such as James Hutton and Erasmus Darwin needed to believe in the rational, man-centred purposiveness of the Earth no less than earlier Protestant Christians.

Earth history, therefore, hinged on human history. Habitat was made for inhabitant. Such a view justified another general tenet, that the Earth had not existed for many thousands of years, and quite possibly would not endure much longer.[3] Within a cosmology in which an eternal God had created Time and the world simultaneously, a long time-scale was no more plausible than a short one. Perhaps the reverse, for evidence suggested that man had not lived for long on this planet, as the Bible, taken as God's revealed Word and as one of the oldest – perhaps the oldest – relics of civil history, affirmed. ''Tis the Sacred Writings of Scripture that are the best monuments of Antiquity' (Burnet, 1684: 4). The Bible was corroborated by the chronologies of all nations with reliable records, and reaffirmed by natural evidence. Man

had not yet had time to populate – or repopulate – great expanses of the globe. Civilization was still in its infancy. Man had not subdued Nature. The earliest records of all civilizations contained memorials of the creation and youth of the Earth (Stillingfleet, 1662; Hale, 1677). Surely folk memory and recorded evidence were good testimony that man and the Earth were almost coeval. 'Time we may comprehend', wrote Sir Thomas Browne; 'it is but five days elder than ourselves'. Why should the Earth have long pre-dated man, untenanted by the one rational creature formed in God's image to conserve and understand it?

Within such fundamental background beliefs many grave tensions remained concerning the workings of Earth history – the mechanism of Creation and the Deluge, and the laws maintaining the global economy. All such questions, as well as raising physical and technical issues, possessed overt teleological dimensions relating to human perceptions of Nature and the problem of theodicy.

Such questions churned up conflicts within basic beliefs. The most critical was of the mode of God's providential operation, the higher rationality whereby God intervened miraculously as well as governing the world by natural laws. Facts, reason and Scripture supported all positions. Miraculous interventions proved that God was active and personal, but might suggest faults (or, at least, narrowness of vision) in the original design, and threatened to put an end to philosophy. Action through laws demonstrated God's wisdom but scarcely His freedom, love or wrath. Such issues were wide open for debate.[4]

In recreating the nature and history of the Earth, what kind of knowledge had to be accommodated and integrated? Accurate and well-attended facts were one agreed legitimate form of knowledge. In the next section I shall explore the use in these theories of the data built up in the previous generation. Secondly, natural theology, general philosophies of Nature, and laws from other sciences, had to be harmonized. Though certain metaphysical systems were *non grata* in late seventeenth-century England, postulates of the kind attached by Thomas Robinson to his *Natural history of Westmorland and Cumberland* (1709) were organizing principles for any theorizing of the Earth:

Such 'APHORISMS, DEFINITIONS and AXIOMS' *as we have made use of in this Treatise*

Of Nature

Nature's Productions are never in vain.
Nature's Productions are not by blind Chance.
Nature never works in haste.
Nature's Productions are not by precipitous Leaps, but by gradual Motions.
Nature never does that by Much that may be done by Less. . .(p. 114)

Nobody challenged in principle the use of rational deductions from necessary attributes of God or Nature (for example, the economy of Nature) – though some challenged particular deductions in particular cases.[5] Indeed, many theorists formally set out their own comprehensive philosophies of Nature, as Nehemiah Grew's *Cosmologia sacra* (1701), John Ray's *The wisdom of God* (1691) and John Keill's *An introduction to natural philosophy* (1720).

Thirdly, within the anthropocentric geocosm, human testimony and ancient wisdom weighed heavily as knowledge, being the savings bank of man's sagacity, and man's only eye-witness of early history (D. P. Walker, 1972; D. C. Allen, 1949). Furthermore, the Ancients were supposed wiser than the Moderns, having lived when intellect was undecayed, and knowledge less corrupted by transmission, and perhaps having received special revelation from God.

Fourthly, Scripture was knowledge, partly as a special case of Ancient Wisdom, and partly because Revealed. With the opaque corpus of Ancient Wisdom in general, but most acutely with Scripture, hermeneutic problems were labyrinthine and controversial. Could Biblical passages really be irreconcilable? Burnet for example treated the Genesis cosmopoeia as unphilosophical, but embraced the wisdom of the Book of Job, the Psalms and St Peter. The two potential extremes of interpretation – that the Bible was, with regard to the physical world, merely erroneous or fabulous, or, conversely, that it offered immediate, full and literal truth – found no favour amongst an elite accustomed to delicate and judicious classification of reality. Those like Burnet with neo-Platonic leanings tended to take the Bible rationally and philosophically. Those with stronger fundamentalist Protestant leanings, like William Whiston, favoured variants of literalism. Thus while Burnet pointed up the perils – ''Tis a dangerous thing to

ingage the authority of Scripture in disputes about the Natural World, in opposition to Reason' (1684: Preface) – Whiston retorted that Burnet contradicted the letter of Scripture (1696: 77f.), and went on in his 'Discourse concerning the Nature, Stile, and Extent of the Mosaick History of the Creation' to establish

POSTULATA

I. The Obvious or Literal Sense of Scripture is the True and Real one where no evident Reason can be given to the contrary.
II. That which is clearly accountable in a natural way is not without reason to be ascrib'd to a Miraculous Power.
III. What Ancient Tradition asserts of the constitution of Nature or of the Origin and Primitive States of the World, is to be allow'd for True, where 'tis fully agreeable to Scripture, Reason and Philosophy. (Whiston, 1696: 95)

All admitted, however, in their different ways that the matter and style of Scripture had been accommodated to the understanding of the early Jews, and that true physical meaning needed to be winnowed from the chaff.

The age fervently sought unity of knowledge, for unity promised stability. In particular, natural and evidential theology, both of fundamental significance within late Stuart vindications of Christianity, specifically encouraged integration of natural and scriptural knowledge (Cragg, 1964; Pattison, 1859). Bacon had earlier urged that one could not 'search too well in the Book of God's Word or the Book of God's Works, Divinity or Philosophy' – adding only the proviso that one should not 'unwisely mingle and confound these distinct learnings' (1605, i: 3). The great late-century natural theologies, such as Ray's *The wisdom of God* (1691) and Grew's *Cosmologia sacra* (1701), were less cautious about mingling and confounding. Boyle himself had specifically urged that natural philosophers should become natural and evidential theologians, corroborating Genesis:

> And indeed so far is God from being unwilling that we should pry into His works, that by diverse dispensations He imposes on us little less than a necessity of studying them. For first He begins the Book of Scripture with the description of the Book of Nature. We may next observe that God had some knowledge of His created Book both conducive to the belief and necessary to the understanding of His written one. (Boyle, 1774, ii: 19)

Within this powerful tradition, theorists claimed that Nature corroborated the Mosaic accounts of the Creation and the Deluge.

Woodward wrote that as a result of 'freely' comparing the Mosaic account and natural evidence he had proved 'the Fidelity and Exactness of the Mosaick Narrative of the Creation' (1695: Preface). For Whiston,

> Whatever incompetent Judges may say, nothing will so much tend to the vindication and honour of reveal'd Religion as free enquiries into, and a solid acquaintance with, (not ingenious and precarious Hypotheses but) true and demonstrable principles of Philosophy, with the History of Nature, and with such ancient Traditions as in all probability were deriv'd from *Noah* and by him from the more Ancient Fathers of the World. (1696: 63)

Similarly, Burnet claimed that sacred history had been 'confirmed anew' 'by another Light, that of Nature and Philosophy', and John Ray hoped that he could 'confirm the Truth of the History of the Deluge'.[6] All these traditions of knowledge had to be integrated into a total theory which would respect the internal logic and criteria of each: one which would embody a usable cosmic myth while also satisfying the standards of objective scientificity upon which the credit of the project now depended.

The structure of theories of the Earth

The cosmogonies of the late seventeenth century were attempting to project a *myth* of the Earth, in the sense of a total, self-justifying framework, which would weave all knowledge together, and explain each partial facet – whether the role of volcanoes or the diaspora – in respect of its position within the whole. But significantly – and here they are unlike, say, *Paradise lost* – these were *scientific* myths, or *realizations*, which aimed to have the strength of being rational and empirical achievements of objective truth, hence also of being open to debate and correction.

Though differing in myriad details, certain constellations of structures appeared.[7] One characteristic way of seeing the Earth was that which informed Thomas Robinson's *The anatomy of the earth* (1694) and William Hobbs's *The earth generated and anatomized* (1715). The Earth was taken as a living body, or animal, and explained in terms of its structures and functions within a fully articulated macrocosm–microcosm correspondence theory. Anatomy and physiology provided the teleological and functional explanatory schema. Theories of this kind were rooted

in the Hermetic, alchemical and mystical currents associated with Paracelsus, Fludd, Gabriel Plattes and Kircher. But by the end of the seventeenth century they were ignored or rejected, and uninfluential in the further growth of the science.[8]

The dominant way of realizing the Earth came to be one in which significance hinged upon logical and chronological sequence. Most theories – those for example of Hooke, Burnet, Ray, Woodward, Whiston, Keill, Arbuthnot – presupposed that understanding the Earth entailed a historical account of its origin and development, relating its present nature to past events, and perhaps to its future state. Confidence in such *historical* explanations followed from certain Christian, and especially Protestant, modes of thought, which attributed the significance of particular events to their place in a providential sequential chronology determined by God.[9] Theorists aimed to find 'the Cause and Reason of the present Figure, Shape, and Constitution of the Surface of this Body of the Earth, whether Sea or Land, as we now find it presented unto us, under various and very irregular Forms and Fashions and constituted of very differing Substances' (Hooke, 1705: 334).[10]

They could agree the Earth had not eternally been in its present condition. The testimony of disputed rocks proved that past changes had occurred. Human evidence told of change. In any case, present processes, however slight, were modifying the Earth, however slowly. Hence no theory sought to 'explain' the Earth by trying to prove that it had always existed in its current state. The problem, in other words, was to explain change.

Fundamental, then, was whether past changes could fully be assimilated in terms of those with which contemporaries were familiar. Two theorists staked claims for the size and scope of present change: Burnet and Hooke (and, probably derivatively from Hooke, Aubrey). It is no accident that they were among the most senior theorists. Burnet in particular was much influenced by Cartesianism, and especially by Descartes' emphasis in his *Principia philosophiae* (1644) upon the development of the Earth by natural regular causation (Farrell, 1973: ch. ii). They grew up at a time when the decaying Earth still compelled assent. Yet Burnet did not believe that current decay, due to weather, sea and rivers, could account for what *he* conceived the evidence of past

terrestrial change – the original separation of land and sea, mountains and valleys, highland and lowland. His championing of the potency of current processes rather served to prove that the Earth could not be eternal – in fact, could not be immensely old.[11]

For Hooke, however, the power of known present causes was the precise scientific guarantee of the plausibility of his philosophy of past revolutions. He re-echoed Ovid's view that 'All things almost circulate and have their vicissitudes' (1705: 313). He believed in the Earth's decay, being impressed by evidence for volcanoes, earthquakes, new islands, subterranean caverns, landslips, tidal waves and denudaton. His commitment to the New Science led him to seek explanations within known processes of Nature, and he shunned miraculous or extraordinary causation. Being empirically and metaphysically convinced that figured stones could not be other than organic relics petrified while entombed within sediment on the sea-bed, he looked to the land-consolidating and uplifting powers of earthquakes and volcanoes as the only credible explanations of revolutions of land and sea (1705: 295f.). Hooke, however, believed that though such past forces were of the same kind as existing causes, they had diminished as the Earth approached senescence.

Burnet and Hooke could place change at the centre of the stage, because decay articulated their theodicy. Their bid for scientificity depended utterly upon the rationality of Nature. Later theorists, however, possessed deep intellectual and emotional investments in the sovereignty of God and the order and stability of Nature, and they used their radical scepticism to bludgeon hypothetical, unsubstantiated notions of change and to sanctify Nature's *status quo*. By the 1690s Newtonianism for similar reasons was also lending its authority to a highly passive view of the globe.[12] Newton's vision of the solar system – indeed, the whole universe – as a stable system of forces was readily applied by analogy to the terrestrial economy. His conception of matter as hard, inert and impenetrable, not essentially possessed of force, motion or life, was explicitly used to guarantee a passive Earth, especially in his protégé William Whiston's geometrically arranged *New theory of the earth* (1696: Bk i, Lemmata). Newton's matter theory and Whiston's theory of the Earth express the same intellectual convictions. Whiston believed that to see matter or Nature as endowed with

life or 'tendencies' was a vulgar, unphilosophical error. He feared that concessions to any kind of hylozoism, hylarchic principles or to Cartesianism, must lead to atheism.

Theorists like Woodward, Whiston and Arbuthnot of course accepted that the Earth had undergone changes.[13] Their causes, however, could be seen as not inherent in Nature itself, but dependent upon God's immediate intervening will. Nature's passivity proved God's Omnipotence. Whiston's 'The *Idea* and Nature of God includes *Active Power*. . .the *Idea* and Nature of matter supposes *Intire Inactivity*' (1696: 222) crystallized the intimate intellectual links of Protestantism and Newtonian metaphysics in contemporary theories of the Earth (Hooykaas, 1972). In response to the Cartesian sufficiency of Nature ('Give me extension and movement and I will remake the world'), Ray accused Descartes of trying 'to solve all the *Phoenomena* of Nature, and to give an account of the Production and Efformation of the Universe, and all corporeal Beings therein, both celestial and terrestrial, as well animate as inanimate, not excluding Animals themselves, by a slight *Hypothesis* of Matter so and so divided and mov'd' (1701: 44). He reasserted his faith in the active finger of God, to pinpoint his programmatic conclusion that mere natural forces were not competent to account for the phenomena.

Thus, most theorists believed that such forces as volcanoes, earthquakes, the effects of climate and of sea on coastlines, were not sufficiently universal or powerful to solve the chief explicanda – fossils, strata, the distinction between land and sea, mountains and valleys. In taking this stance, they sought to vindicate both Design and the rigour of their own investigation. Hence there must have been periods of extraordinary forces operating during Earth history. This is not to say that all fell back upon miracles, for some theorists such as Burnet insisted that extraordinary events, such as the Deluge, nevertheless lay within the regular course of natural causation. But all sought to explain Earth history in terms of the two great formative epochs, related to them in the Bible, in the mythology of the East, and in much Classical literature: the Creation and the Deluge.

Theorists were adamant that empirical evidence, philosophy and religion proved that the Earth could not have existed from eternity, and that it could not be self-creating or self-sustaining (e.g.

Stillingfleet, 1662). The Earth itself had been created. Furthermore, no known, natural process was creating massive areas of consolidated land, was differentiating land from sea. Most agreed that no current processes were raising up high mountains, producing fossils deep within strata, sculpting valleys, shaping the coast-lines of entire continents. Practically all theorists, in other words, attributed such events to some special period of creative activity in the youth of the Earth, during which either by divine fiat or by laws not operative subsequently the Earth had emerged from Chaos into a form somewhat akin to its present one.

But they were also aware that one such creative revolution alone could not explain the Earth's physical face. If Creation left the Earth a smooth paradise without seas (as Burnet believed), how had inequalities of land, and the boundary between land and sea, arisen? If strata had been formed at the Creation before the origin of life, how had organic fossils become deeply embedded in the rocks? If the strata had originally been created in a horizontal condition, how had they come to be raised and lowered, faulted, disrupted, displaced?

Once again, theorists' realizations of Earth history made actual processes seem incompetent to account for these changes. Seeking the origin of petrifactions, John Woodward methodically examined all hypothetical natural causes: that they were 'kitchen refuse'; that they had become lodged in rocks via subterranean channels leading from the sea; that they were debris of local floods, tidal waves, or the original covering of the land by the sea, or had been left by supposed retreats of the sea. He eliminated all of these because 'scarce any of all these alledged, had the least countenance either from the present face of the earth, or any credible and authentick Records of the ancient state of it' (1695: 40). Thus, fossils could only be the product of a unique and miraculous Deluge.[14]

Hence most theorists attributed the great revolutions of the Earth subsequent to the Creation to the Noachian Deluge. This explanation had much plausibility. Deluges on a smaller scale were well-attested events. Most cultural traditions included major widespread deluges. A universal Deluge could account for global phenomena such as fossils and strata disruption. Furthermore, deluges were likely instruments for the kind of changes in question – especially gouging out deep valleys, shifting coast-lines, and fossils strewn over the land. Of course, each theorist had his own view of the Deluge, interpreting Genesis differently, and offering different mechanisms. Woodward and Keill invoked a miracle; Whiston, the approach of a comet; Halley, a shift in the Earth's centre of gravity; Burnet, a contracting of the Earth's crust. Likewise, they attributed different effects to the Deluge. Woodward believed that the Deluge had taken apart the Earth's total fabric, which then needed to be reformed in a second Creation. Ray thought the Deluge's effects essentially superficial. Interpretation of the Deluge varied according to what it needed to explain.

Most theorists agreed that, since the Deluge, Nature had operated according to familiar principles and actual causes. For Burnet this meant continual decay, but for later theorists it entailed a regular and well designed economy which maintained the habitable Earth in stability. Whiston described the present system of Nature as 'regular, beautiful, permanent' (1696: 286). Woodward saw the world existing in 'the most excellent and beautiful order' (1695: 60). Providence's intention was that present causes should preserve, not destroy, the world. Whereas Burnet had believed natural forces would in time destroy the Earth, Ray, Woodward and Whiston all argued that the Earth would maintain its present order until God decreed.

John Woodward's *Essay* (1695) epitomized this pattern of Earth history. He conceived the Earth's economy as a stable, ordered and benevolent system, with minimal forces producing minimal change. The ante-diluvial Earth 'was not much different from *this* we now inhabit' (1695: 248). It 'hath been in much the same condition that it is at this day, ever since the time of the Deluge' (47); and 'the Earth, Sea and all natural things will continue in the state wherein they now are, without the least Senescence or Decay, without jarring, disorder or invasion of one another' (61). He explained the presence of fossils in rocks by invoking a universal Deluge, during which all rocks disintegrated as a result of loss of gravitational cohesion, the reliquiae of creatures were introduced, and the rocks resettled much as before, in order of specific gravity. The Deluge was immediately occasioned by a sudden miraculous influx of water 'wherever it may be now hid' (163), for 'the Deluge did not happen from an accidental Concourse of

Natural Causes, as the Author above-cited [Burnet] is of Opinion. That very many things were then certainly done which never possibly could have been done without the Assistance of a *Supernatural Power*' (1695: 165). For Woodward, the Deluge explained almost the whole range of terrestrial problems, in context of man's physical and moral condition (cf. Lyell, i, 1830: 37). Its evidences were daily proof of 'the Fidelity and Exactness of the Mosaic Narrative of the Creation'. Since this supernatural event, the history of the Earth had been a history of quiescence (93).

Strategically, these theories presented a most apt schematization of Earth history. They impressed it with defined order, by dividing it into a sequence of significant states (before the Creation of life; the Creation of life, and of man; the Deluge; post-Deluge), separated by great revolutionary events of human significance – Creation, Deluge, Conflagration. Burnet thus declared that he would only deal with such 'great revolutions of the globe', as did the Bible, for these were 'truly the hinges upon which the Providence of this world moves' (1684: Preface).

John Ray's *Miscellaneous discourses* likewise illustrate the imposition of ordered purpose. Ray wrote the *Discourses* in a hurry, partly out of old notes (1692: Preface). They consist of a major discourse, showing that no natural terrestrial forces appear to be advancing that general Conflagration prophesied by St Peter which will give the earth its quietus; broken up by two long digressions, the first on the Deluge, the second on the Creation – hence the apt title 'Miscellaneous'. Revising for a second edition, however, Ray systematized them into a full history of the Earth, entitled *Three physico-theological discourses*, the first now on the Creation, the second on the Deluge, and the last on the Conflagration (1693: 5of.). The full title of Whiston's theory equally reveals the same ordered structure of Earth history: *A new theory of the earth, from its original to the Consummation of all things wherein the creation of the world in six days, the universal deluge, the general conflagration as laid down in the Scriptures are shown to be perfectly agreeable to reason and philosophy* (1696). The theorists succeeded in conceptualizing the Earth as an object, distinct from man and possessing its own laws, while at the same time retaining a powerful notion of it as a habitat, subject, by God's will, to human needs and purposes.

Furthermore, this theoretical structure had the attractive quality of orchestrating – rather than challenging, as *geology* did later – contemporary educated common sense. The Earth's history, thus interpreted, confirmed the Biblical and rational perception that rocks antedated life; that sea creatures had preceded land animals; that plants and animals antedated man. Englishmen crossing the Alps could fully appreciate Burnet's view that such mountains had not been created by everyday processes.

Lastly, these theories absorbed within themselves the concepts of contemporary physical science. Newton's *Principia* had solved the celestial system: the terrestrial system now demanded its Newton. Whiston, Newton's protégé, significantly set out his *New theory* (1696) rather in the form of Newton's *Principia*. John Hutchinson revealingly called his counterblast *Moses's Principia* (1724–7). Most of these theories strove to integrate Newtonian physico-chemical mechanisms to explain the great events of the world. Newtonianism offered theories prestigious quantification, and validated them within the range of simple universal laws of the physical world (cf. Kubrin, 1967).

Woodward's whole theory hung on Newtonian gravity, which, like Newton, he insisted was not essentially inherent in bodies, but was 'Intirely owing to the direct Concourse of the Power of the Author of Nature, immediately in his hands, . . .the prime hinge whereon the whole frame of Nature moves'. Gravity produced the cohesion of the original chaotic particles to form distinctive rocks, whose specific gravities precisely determined their position in the order of strata (1695: 51, 75). Furthermore, for Woodward, the Deluge was occasioned by *suspension* of the laws of gravity. Burnet, Hooke and Halley used gravity in a different way, showing that the Deluge had been caused, or at least accompanied, by shifting of the Earth's centre of gravity – a conception which appealed to Ray, and to Whiston before Newton himself voiced his disapproval.[15] Explanations of the Deluge through the mechanism of land collapse derived some of their popularity from the central role they gave to gravity. Newton's own suggestions for the Deluge hinged upon it (Turnbull, ii, 1959: 329).

The scheme most strikingly derived from natural philosophy was Whiston's *New theory*. This was set out *modo geometrico*, as a series of deductions from Newton's metaphysics of matter,

his laws of motion, and his physical astronomy (1696: Lemmata). For Whiston, as for Newton, the Genesis account of Creation out of Chaos referred only to the Earth. Its oblate spheroid figure, as proved by Newton, demonstrated its original chaotic state (1696: 53, 72). The Earth's transition from a chaotic to an ordered condition had a cosmic rather than a strictly terrestrial explanation (viz., the Earth was once a comet). So stable was Whiston's view of the terrestrial economy that subsequent changes, the Deluge and Conflagration, had to be effected by external means, by comets passing close to the earth (1696: 73, 437).

Certainly, there were alternative general physical explanations, such as Burnet's mixture of Aristotelian and Cartesian physics, or Robinson's neo-Platonic organicism. A few, such as Ray – significantly, chiefly a natural historian – held back from all-embracing causal physical accounts of Creation and Parousia. But by 1710, the Earth had fallen firmly within the attractive field of Newtonian explanatory models.

That so many competing and contradictory theories vied against each other is no mark of incompetence. Each strategically focused upon a few key problems without being able to weave all other outstanding issues into an overall fabric with the power to convince others. Newton had his principate, but of Earth science there was no king. Yet if no individual theory triumphed, the broad structure of the realization of Earth history was becoming well-established for the future.

Boundaries and bridges

The seventeenth century saw no unification of Earth science. A tradition of geocosmic physics flourished, expressing itself in the genre of the theory of the Earth (Roger, 1973–4). Similarly a natural history practice steadily gathered strength, hingeing on Baconian fieldwork and issuing in the *catalogue raisonnée* of terrestrial objects. But these traditions strongly fortified their boundaries against each other, and there was generally little common ground between them. At this time most theorists of the Earth were not – nor were seeking to be – fieldworkers. Burnet, Hooke, Whiston, Warren, Croft, Halley, Keill had not in any real sense

personally practised fieldwork. For Burnet, the certainties of Cartesian mechanism, for Whiston the truths of Newtonian celestial physics, transcended the uncertain world of empirical evidence from the ruins of the Earth. *Per contra*, fieldworking naturalists like Lhwyd set their face against all contemporary forms of theorizing. Those who sought to realize an interpretation of the Earth which integrated fieldwork and theory, a concern for objects, interpreted *within* an ambition to schematize total Earth history, were the exception: Woodward, Ray and Hooke perhaps come to mind.

But to speak of the resilient independence of isolated traditions of scientific practice is not to deny that there were levels at which those diverse practices deeply interacted – and thereby produced the conditions for their own transcending. For there was important interplay between fieldwork and theorizing. The theories of the 1690s would hardly have been possible without the generation of intense fieldworking launched in the 1660s. In Ray's and in Beaumont's case, early fieldwork produced a later readiness to generalize, deploying the mounds of empirical research published in the interim.

Of course, other kinds of interplay between theories and observation grew up. Fieldwork came to be undertaken to confirm or challenge particular theories. Morton investigated Northamptonshire in the light of Woodward's belief that strata lay in order of specific gravity. Hauksbee used vertical sections of strata to test the same hypothesis (1712). Halley proposed experiments on the salinity of seas to determine the Earth's age (1715). Theories could themselves open up observation programmes. And of course, controversies around theories deployed data in the cut-and-thrust of assertion and denial of fidelity to nature.

Under pressure from specific criticisms and new evidence, the succession of theories demonstrates tangible intellectual progression. It is in part a trivial but necessary story of error being recognized and corrected. For example, Burnet still believed with the Ancients that the Earth was egg-shaped, but Newton subsequently convinced theorists it was rather an oblate spheroid (cf. Whitehurst, 1778: 2). But more important was a broadening consciousness of important criteria. In 1681 Burnet could publish his *Telluris theoria sacra* showing no apparent awareness of

stratification, or that fossil evidence might bear in some way upon his thesis. Burnet's controversy with Warren (1690; 1691) brought the fossil issue out into the open. Woodward's *Essay* (1695) irreversibly required that all future theories address themselves to the facts of stratification. But at a more fine-textured level, Woodward himself had not 'read' various problems which could be posed by fossils and strata – e.g. the meaning of the fact that most known fossils were exuviae of *sea*-creatures – for Woodward's Newtonianism led him to differentiate fossils according to specific gravity not zoological type. Shortly afterwards, however, Abraham de la Pryme grasped this as a problem, and argued on the strength of it that land and sea had changed places at the Deluge (1700).

Thus a fruitful dialectic could be set up between data and interpretation, with limitations of vision being successively superseded, and better-directed observation opening horizons onto new problems. In this way the age's achievement was not a paradigmatic theory. It lay rather in a growing grasp of the *agenda* of any theory adequate to bear the load of the manifold functions it had to serve. The pressing *questions* – rather than the *answers* – for a theory of the Earth were becoming more clearly defined. I shall now examine in greater detail three examples of accumulating factual knowledge and expanding vistas.

Graduating from St John's College, Cambridge, in 1694, Abraham de la Pryme became curate of Broughton, near Brigg, in Lincolnshire. From then to his early death in 1704 his diary shows him as a diligent natural history observer (1869). He read the *Philosophical transactions*, was familiar with the theories of Hooke and Woodward, corresponded with Sloane, and used Lhwyd's *Lithophylacii* for identifying fossils (1869: 235f.; 1700: 682). He listened to folklore of fossils and landforms, but was sceptical (1869: 89, 106).

His attention focused on the problem of buried objects – fossils, skulls, ships' timbers found inland, coastal villages encroached on by sands (1869: 89, 91, 122, 137, 142, 148). This concern possibly sprang from his family's involvement with fen drainage, and certainly harmonized with his own antiquarian pursuits. His diary observations show a keen eye for evidence of migrations of land and sea (1869: 155).

The theoretical problem in natural history that puzzled him was the location of fossils. He had no doubt of their organic origin. His solution sprang from his own observations. The features which caught his eye were that fossils were frequently found in a damaged and broken condition; that fresh-water fossil shells were found embedded in different strata from marine remains; and that the strata containing them, consisting of silts, clays and sands, bore close resemblance to the materials in which shell creatures presently bred (1700: 677, 681f.). The former observations could not be accounted for by Woodward's theory. De la Pryme evidently thought Hooke's theory of continuous interchange of land and sea due to earthquakes and volcanic action was fanciful and lacked hard proof (1869: 106). Hence he advanced a theory in which at the Deluge much of the former sea-bed had been transformed into land and vice versa. This accounted for his three major observations. In modified form it became one of the most popular eighteenth-century integrations of fossils within Earth history (1700: 684f.).

John Ray's career presents the clearest example of a lifelong naturalist venturing a theory in his mature days. Ray had been successively severed from the pulpit, essentially by the Restoration religious settlement, and from fieldwork, by illness, family commitments, old age and poverty. Hence his theory was both substitute for, and completion of, his religious mission and his natural history. Whereas Abraham de la Pryme's theory flowed essentially from personal observations, Ray's life shows theory as the mature distillation of many kinds of experience, reading and reflection on the possibilities and limits of a scientific realization of the Earth. Raven having already established an excellent chronological description of Ray's thought, I shall merely draw threads together (1950: ch. xvi).

Ray's first known thoughts about the Earth are a sermon on the dissolution of the world, delivered in Cambridge in the 1650s (Raven, 1950: 442). It drew essentially upon theological learning. On his travels round England in the 1660s, he listed fossils and their locations, but chiefly with a collector's interest (1950: 421). On his subsequent Continental travels his more graphic experience of strata (at Bruges) and fossils (glossopetrae on Malta: 1738: 96–110; 251–7), provoked him to further thought, and

stimulated the lengthy digressions, especially on fossils, in his *Observations topographical, moral and physiological* (1673). From the 1670s to his death, Ray corresponded with friends such as Lister, Tancred Robinson and Lhwyd, identifying fossils and particularly rehearsing, probing and revising the arguments used in the *Observations* for the organic origins of fossils. In 1692 he published his *Miscellaneous discourses.* This had for its core the above-mentioned sermon. Its theological learning remained much as in the 1650s, but its theme was now illustrated by extensive natural observations of changes in landforms. It included a digression on the Deluge, which debated fossils at greater length than before, and another on the Creation.[16] It discussed most of the important British and Continental writing in this area published over the previous thirty years, as well as many *Philosophical transactions* articles, and some from the *Acta eruditorum* (Raven, 1950: 442–3). It was recast as *Three physico-theological discourses* in the next year, when discussions of Creation, Deluge and Dissolution were now arranged in that order to form, for the first time in Ray's work, a comprehensive theory of the Earth. The two subsequent editions which Ray published before his death were further enlarged and revised with newly available evidence (Raven, 1950: 432–40).

Thus Ray's own observations, and those of his times, became woven into a theory in the 1690s. Yet though he formulated a total interpretation, Ray, the natural historian, remained deeply aware of the ambivalence of the evidence on such major issues as the origin of fossils. Furthermore, he believed that while Creation and Deluge were crucial hinges of Earth history, experience offered no unambiguous account of them – neither their causes, nor effects. Nor did observation provide a basis for a physical understanding of the Dissolution. Ray's *Discourses* are actually an *anti*-theory. While purporting to biographize the Earth, they demonstrate how such a project was impossible.

My last example of the interface of empirical and theoretical traditions is Robert Hooke. With de la Pryme and Ray, fieldwork was private, theory a public offering. In Hooke's case, however, form and audience were constant, but ambitions changed over time. Like his *Micrographia* (1665), his early 'Discourse of earthquakes', delivered to the Royal Society (1668, published 1705),

began with a close empirical examination of figured stones (1705: 279–328) from which he inferred their organic origin (280–90). He argued on empirical, rational and Scriptural grounds that only successive operations of earthquakes could account for such fossils becoming embedded in the strata. Hooke's speculations on earthquakes were at this stage a bold, essentially *ad hoc* device introduced to justify his interpretation of fossils (1705: 290–328).

By the time of his lectures of the 1680s and 1690s, however, Hooke had incorporated the new empirical findings of the intervening twenty years – above all, reports of earthquakes and the discovery of giant fossil bones – within the ambition of a synoptic theory of the Earth (1705: 329–450; cf. Kubrin, 1968). He now saw the deep role of earthquakes within a structured, integrated Earth history, stretching from a pristine golden age up to the present, undergoing a continuing process of old age and decay (1705: 378f.). He investigated geo-physical causation for earthquakes and integrated the physics of the Earth's adopting its oblate spheroid form and of its changing centre of gravity (1705: 350f.; 372f.). He sought to legitimate his pattern of Earth history within the traditional wisdom of the Ancients (1705: 402f.). Davies has written 'Hooke's later geological writings display little of the perspicacity that is evident in his earlier work' (1964: 497), but this is to miss the point: his explanatory ambitions had changed.

Theories, controversy and their audience

Theories of the Earth triggered off volleys of ripostes and counterblasts. Burnet's *Sacred theory of the earth* induced Erasmus Warren's *Geologia*, to which Burnet immediately replied in his *Answer to the late exceptions* (1690). Warren's further counter, his *Defence of his exceptions*, provoked his *Short consideration of Mr Erasmus Warren's defence of his exceptions* (1691). Opposition did not stop there. In 1693 John Beaumont added his own demolition of Burnet, *Considerations on...the Theory of the earth*, and Archibald Lovell donated his mite in 1696, in his *Summary of material heads.* To neither of these did Burnet deign to reply, but when John Keill entered the lists, with his powerful

Examination of Dr Burnet's Theory of the earth (1698), Burnet answered with his *Reflections upon the Theory of the earth* (1699). Woodward and Whiston elicited the same frenzy of theory and counter-theory.[17]

This controversy was no mere dispute within a narrow scientific community. It was markedly public scientific debate because its science operated within common-sense concepts. The debate drew in a wide range of 'outsiders', such as Herbert Croft, Bishop of Hereford, and Erasmus Warren, rector of Worlington in Suffolk, taunted by Burnet for his 'country philosophy' (1691: 16) – as well as those from other areas of science and scholarship. Furthermore, the theory of the Earth became a talking point for the educated. The age of William and Mary, and of Anne, was one of bitter polemics on the entire spectrum, from religion and politics to medical remedies (Holmes and Speck, 1967). In such a climate men readily seized pens to defend their theories, or to attack others', and the town eagerly bought tracts hot from the press to read and debate. In 1696 the Deluge stood as 'the Subject of most of the Philosophical Conversations of the *Virtuosi* about the Town' (Wotton, 1697: 66).

In this section I shall explore from two angles how controversy over theories of the Earth characterized and shaped the state of the science: relations amongst the theorists themselves, and between them and their social audience. The problems of interpreting controversies are immense, and I can no more than scratch the surface. I shall examine two examples, the debate between Burnet and Warren, and that concerning Woodward's *Essay*, in the light of D. C. Allen's interpretation of the Renaissance humanist–scholarly debate on the Noachian Deluge. Allen established the high quality of historical and philological scholarship in this querela, but showed that in the course of two centuries the debate was neither resolved nor even focused upon a particular difficulty, because of the intractability of the written records and the impossibility of achieving agreement on a common method (1949). Would scientific debate, with an appeal to the objective tribunal of Nature, be any different?

Between 1690 and 1691 Erasmus Warren produced two attacks on Burnet's *Theory* and Burnet two defences. Warren's *Geologia* (1690) did not rise to any comprehensive assessment of

the problems which Burnet had addressed, or any general review of Burnet's solutions. His was rather a string of *ad hoc* criticisms – many *ad hominem* – against particular parts of the theory, not all consistent with each other (1690: 23f.). The tone of Warren's attacks was polemical and forensic – Burnet called them 'wrangling and scolding' (1691: 1–2). Warren admitted 'my pen growing warm, quite out-run the bounds of my first Intentions' (1690: 'To the Reader'). The whole dispute was a characteristically logic-chopping, 'witty' altercation between scholars, with mutual censuring for their immoderate language and tone.

Though Burnet had adumbrated specific physical mechanisms, controversy largely bypassed these. Warren was chiefly concerned with refuting Burnet's interpretation of Scripture and classical authors, and Burnet of course replied on these issues. '. . .the *Theorist* has assaulted *Religion* and that in the very *foundations* of it', wrote Warren (1690: 'To the Reader'). The aspect of the *Theory* which most rattled Warren was its implication for man. For example, he was less at pains to refute on physical grounds Burnet's notions of original enclosed seas than to deny this was consistent with the dominion God had given over the animal kingdom (including fish).

In broad perspective, the controversy was fruitless. Warren had failed to grasp many of Burnet's original conceptions. Burnet accepted none of Warren's criticisms; nor did he modify his theory at all. Warren's second *Defence* and Burnet's reply danced the same steps with greater exasperation. Yet the dialectic of the controversy was highlighting certain real problems, though neither combatant might have recognized this. Warren castigated Burnet's physical extravagance over the Universal Deluge. But when Warren tried to explain it, denying himself a generous creation of water and Burnet's utter destruction of the Earth, he found that the waters failed to cover the mountains, and concluded that it had killed off mankind by starving, rather than drowning (Burnet, 1691: 13f.). Such an impasse generated a heightened awareness amongst their audience that the problem needed to be reconstituted. Likewise, Burnet and Warren clashed on whether mountains were beautiful, functional or mere ruins (Burnet, 1690: ch. x). This also sensitized opinion to an issue which was to become fundamental in the next century. The

Burnet–Warren controversy indicates that the chief passions sparked by theories were overtly religious, moral and humanistic, rather than physical. Men with incommensurable convictions were talking past each other, and using debating techniques which banished detailed and dispassionate technical examination of physical evidence.

John Arbuthnot's critique of Woodward's *Essay* is interestingly different. Arbuthnot and his friends were later to be scathing critics of Woodward as a man (Beattie, 1935; Nokes, 1975), but his *Examination* (1697) avoids *ad hominem* attacks, and presents itself as a constructive attempt to evaluate which aspects of Woodward's theory might be of lasting value to understanding the Earth. Thus, even though he established that Woodward plagiarized from Steno, Arbuthnot's point was not simply to condemn his intellectual pilfering, but rather to make a lengthy (and judicious) comparison between their ideas, showing where Woodward had improved on Steno, and the points at which Steno remained more plausible.

Arbuthnot began by summarizing Woodward briefly but accurately (1697: 1–10). Instead of wrangling over the details of the *Essay*, he launched into a methodological and philosophical critique (10–28). He showed that Woodward's theory appealed to events outside the present laws of Nature. But, except where miracles were specifically sanctioned by Scripture, he argued, philosophy should not go beyond known laws of Nature to explain the phenomena (8). Steno's theory was preferable in requiring fewer breaches in the laws of Nature than Woodward's. Furthermore, Woodward's theory seemed empirically dubious. The testimony of the rocks suggested that different strata were formed gradually over a period of time, not simultaneously, as Woodward insisted (24–5).

Arbuthnot's *Examination* shows that criticism which was perspicacious from the viewpoint of the advancement of scientific knowledge and methods was possible. It was, however, exceptional. The other writings in the Woodward controversy, especially the pseudonymous *Two essays* by L.P. (1695) and John Harris's *Remarks* (1697), were all fine words and invective, casting aspersions upon the character and scholarship of their targets rather than examining physical and methodological problems.

Whereas for Arbuthnot, Woodward's alleged plagiarism from Steno initiated constructive comparison, from the *Two essays* it drew personal attack. Harris sycophantically lambasted Woodward's detractors as 'invidious and morose', 'the Pest and Complaint of all Ages', 'Discouragers and impeders of Learning and Knowledge'. They had not 'offered one Objection of any weight', or 'invalidated so much as one Single Article of any of the numerous Propositions the Doctor hath advanc'd' (1697: Preface). The period of controversy was fruitful, though at one remove. Though not producing a victorious theory, it did expose the inadequacies of existing ones.

The theories aroused public interest, as is evident from the number of editions published, and also from the apparently large number of copies in some editions – Whiston claimed that 1500 copies of the first edition of his *New theory* were printed (1753: i, 38; V. A. Eyles, in Schneer, 1969). Those who did not read the tracts themselves were brought face to face with their authors as popularized in the *Spectator* (1911 ed.: i, 240; ii, 231), or as anatomized by the wits and writers of the day. The theory of the Earth became so well established in contemporary mythology that Swift saw to it that the ivory-towered Laputans in *Gulliver's travels* were discussing Whiston's Deluge theory (1906 ed.: 152f.). The audience at John Gay's *Three hours after marriage* encountered Woodward elevated into demonology as Dr Fossile, and found a play within the play on the Noachian Deluge (Beattie, 1935: 232). The public clamoured to see fossil shells and giant's bones in raree shows, and paid to hear Whiston lecture on the end of the world.

Theories of the Earth had been almost unknown in mid-century, but were popular science by its end. What does this mean? It shows an impressively rising general interest in grasping the natural world, particularly the human environment, through scientific investigation. This in part represents a displacing of Christian millennial expectation from political and eschatological dimensions onto Nature (Jacob and Lockwood, 1972). With very few exceptions, the reaction of the literate public to these theories was not one of horror. The Scottish Church apparently burnt Whiston's *New theory* – but that was mainly because of his Arian theology (de la Pryme, 1869: 159). There was no equivalent to

the belief rampant in the age of the French Revolution that Earth science was set fair to undermine religion and society. For the late seventeenth-century theorists were essentially working *within* the common-sense assumptions of popular cosmology. The Boyle Lectures show that the main bogeys were philosophical materialism, determinism and atheism, not theories of the Earth (Jacob, 1976). Fossil collectors were sometimes ridiculed as neglecting human life for their collections, and theorists were satirized as grandiose system-builders. But satire was directed more against over-enthusiastic indulgence than against the science *eo ipso*, and was festooned over the eminently parodiable personal characteristics of Woodward and Whiston, and the sitting target of the wealthy, fashionable physician Sir Hans Sloane (Stimson, 1948: 130f.). Scientific satire in the period before the Glorious Revolution – e.g. in Shadwell and Butler – was almost silent on study of the Earth, whereas Woodward and Whiston became two prime targets after 1700.

Theories captured the imagination because they naturalized and rendered scientific the central topics of human life, integrating basic issues of cosmology, theodicy, and the nature and place of man. They encouraged pious cosmic meditation. At this stage – contrast the early nineteenth century – the impact of theories of the Earth upon the public was to open up edifying religious and moral vistas. Public interest was not in minutiae. Theories did not send *Spectator* readers scurrying out classifying fossils or charting the strata.

Let us take stock of developments in the direction of Earth science to the early eighteenth century, which marks something of a watershed. No unanimity had been achieved on a theory – or even on the particular issues within one: at most, a growing, if inexplicit, agreement on the agenda for solutions to the problems of the Earth.

Active investigation had grown from negligible origins in the mid-seventeenth century into lively scientific and public controversies early in the eighteenth. Every quantitative index shows growth. Although no immediate, direct and special social *stimulus* generated this increased preoccupation with the Earth, nevertheless society seems to have been becoming more *receptive* to natural

knowledge. Religious disputes were being taken before Nature's tribunal.

The intelligentsia was gradually but perceptibly redefining the criteria of wars of truth, away from scholarly techniques and the authority of books towards the norms of science and the objectivity of Nature, as is marked by the Ancients versus Moderns debate. Communities – albeit precarious and unstable – had arisen with shared interests in investigating the Earth. Natural history techniques, expanded into fieldwork on the mineral kingdom, were opening up new perspectives such as problems of strata. Field observation, especially in county natural histories, was beginning to make the *relations* between traditionally distinct fields of investigation study objects in their own right.

Theories of the Earth at the end of the century still bore strong family resemblance to the older cosmological and cosmogonical foci of natural philosophy and Biblical scholarship. But the subject was being dissolved and reintegrated. Burnet, Woodward, Whiston and Keill chose to discuss only the Earth itself rather than the whole system of Creation. The Earth's *future* was, perhaps, being hived off into entirely different study. Natural evidence was becoming far more central. Tenuous relationships had been forged between observation and theory. How the essentially local, agglomerative natural history tradition might relate in future to the analytical, theoretical aims of the geophysical sciences, or how description of a timeless Creation might dovetail with the historical explanatory ambitions of the theorists – these were open issues (Greene, 1959).

Furthermore, the theoretical structures which had been developed themselves posed paradoxical contradictions. New constraints – observational rigour, Newtonianism, natural theology – had been militating against acceptance of a naturally active Earth. Hence theorists – perforce and by choice – came to explain past Earth change by unactualistic, and even miraculous, catastrophic events or periods. Stringent methodology and the desire to disenchant and disinfect Nature were dissolving the major acts of Earth history into mysteries. This view of the Earth's destiny as involving 'revolution and stasis' emphasized *history*, but almost spirited that history beyond the bounds of possible inquiry. At this time there was not only no agreement, but also no obvious

way forward, on many of the fundamental issues. A major high-level reorientation of philosophy of Nature would be necessary before such dilemmas could be reconceived.

But investigation of the Earth had developed its own new momentum, in the field and in the mind. Greater integration of particular studies – fossils, minerals, landforms – within an overall view of the Earth had begun. The meaning of fossils was assuming historical dimensions. The mechanical philosophy and the very aspirations of theories were generating confidence that the Earth's form and processes were regular, orderly and capable of being understood within natural laws: both as a conclusion of scientific inquiry and as the very condition of that inquiry. Empirical study of fossils and topography was beginning to repay that confidence by revealing empirical conjunctions. Even in the absence of theoretical consensus, patterns of meticulous work-practice were being established which became normative for the future.

4

A deepening base: *c.* 1710–1775

Disintegration and reintegration

Investigation of the Earth in Britain in the first three-quarters of the eighteenth century is generally said to have been in decline and is frequently ignored.[1] This is part of a wider view that the gamut of the sciences – indeed, almost all intellectual life – was suffering a dark age in Britain at this time. In British natural philosophy, until the recent work of Schofield (1970), Heimann and McGuire (1971), and Thackray (1970a), the period has been stigmatized as a sterile interval between Newton and Dalton. Philip Ritterbush became exasperated at English investigations of life – at best, 'overtures' to biology (1964). D. E. Allen has traced a lull in natural history between about 1710 and 1745 (1976: 18f.). David Douglas believed the eighteenth century a fallow period in English antiquarian and historical scholarship (1939: ch. xiii). Stuart Piggott, studying the leading antiquary and archaeologist William Stukeley, explicitly confirmed this view (1950: Preface). Historians of the Enlightenment, such as Peter Gay, have been harsh on currents of intellectual life in England, beyond self-styled cosmopolitans such as Edward Gibbon (1967–70). A powerful historiography has seen eighteenth-century England as benightedly Christian, while Enlightened Europe was throwing off its theological shackles; as irrationalist, conservative, preoccupied more with arid theological wranglings and Classical literature than with modern humanities and the sciences; an England enshrined in the trinity of Dr Johnson, William Blackstone and Edmund Burke (e.g. Schilling, 1950; Stephen, 1876).

Prima facie, investigation of the Earth may seem simply to have suffered decline. Institutions such as the Oxford and the