Global Visions and the Establishment of Theories of the Earth

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Abstract. During the 17th century, important conventions for the visual representation of the Earth as a whole were established by writers of Theories of the Earth. This essay examines how the emergence of visual representations contributed to the establishment of a new print tradition of multicontextual discourse and critical debate. Four vignettes contrast varying uses of global depictions: the incidental global depictions and mathematical vision of Johannes Kepler; the cosmogonic sections and chemical vision of Robert Fludd; the geogonic sections and mechanical vision of René Descartes; and the global views and classical vision of Thomas Burnet. The continuities of visual conventions and the contrasts of disciplinary perspectives and local contexts observed in these vignettes conforms well to the characterization of Theories of the Earth as an interdisciplinary print tradition.

1. Introduction

Theories of the Earth were an interdisciplinary print tradition of whole-Earth thinking that arose from the intermingling of various disciplines after the printing revolution and continued as a wide-ranging arena for critical debate until the geosciences emerged as professional disciplines in the 19th century. Theories of the Earth began to take shape in the 17th century concomitantly with the prominent deployment of visual representations of the Earth as a globe.

When contemporary readers picked up the latest '*Theory of the Earth*', they attended naturally to novel aspects of the writer's *theories* about the Earth. Similarly, historians have usually characterized these works on the basis of the *theories* they contain, their subject matter or cognitive style (Collier 1968; Roger 1973; Rudwick 2005). Yet, before any Theory of the Earth could be assessed as a *theory*, it was first distributed as a printed publication, often containing illustrations of the Earth as a globe. Theories of the Earth were a population of published works, a print tradition. They were not simply *theories*, but publications in a contested, dynamic, public tradition of critical interdisciplinary debate. (To distinguish these two meanings, I capitalize Theories of the Earth when historically delineated and use lower case for theory when cognitively defined.)

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If we select a few type-specimens in order to define what constitutes a *theory* of the Earth, we risk mis-characterizing this specific historical population as a whole and the complexity of its changes over time. Rather than defining 'theories of the Earth' in a timeless manner, the three textual criteria of self-attribution, external identification, and extensive participation will suffice to delineate a long-lived, early modern tradition of printed works as a historically continuous population of diverse texts. First, did a writer refer to his text as a *Theory of the Earth*? A criterion of self-attribution identifies works by dozens of major figures that form the backbone of the tradition (e.g. Burnet 1684; Buffon 1749; Hutton 1795). Second, was a text widely regarded by others as part of the tradition? This criterion of external identification extends the tradition to include founding figures before Burnet (e.g. Descartes 1644; Kircher 1665). Third, did a writer engage extensively with acknowledged texts in the tradition? This final criterion acknowledges that if a work was an important part of the conversation, widely citing Theories of the Earth and/or being widely cited by later Theories of the Earth, then it would be arbitrary to exclude it from consideration (e.g. Warren 1690; Keill 1698; Murray 1802). Elsewhere I have explored the ramifications of these three textual criteria for delineating Theories of the Earth as a contested textual tradition (Magruder 2000).

By these three criteria, Theories of the Earth were a long-lived inter-textual tradition of published works that took its name from the controversy over the publication of Thomas Burnet's *Theory of the Earth* in 1684. For a period of about 200 years, roughly from Descartes to Cuvier, more than 200 writers of many different nationalities and professions published Theories of the Earth. In these works, debates about the various kinds of evidence necessary to investigate the Earth's past often featured depictions of the whole Earth. Although cosmic sections, meteorological sections, and geographical maps of the Earth provided important precedents for global sections and views long before the controversy over Burnet thrust 'The Theory of the Earth' and global depictions into the limelight, the establishment of the tradition of Theories of the Earth occurred simultaneously with a sustained and prominent deployment of visual representations of the Earth as a globe.

The two major types of depictions of the Earth are global sections and global views. Global sections show a slice of the interior of the Earth, or at least a significant subsurface portion if not all the way to the center. Global views reveal conditions of the surface, either of an entire hemisphere or of a region large enough to display significant features taken as characteristic of the Earth's surface. Although the most famous example of an inference drawn from global views is Wegener's theory of continental drift, the thought experiment of imagining how the Earth would appear from a distance has a long history from Plato to the present (Cosgrove 2001).

The word 'world' (like *cosmos* in Greek and *mundus* in Latin) bears at least five different meanings: the universe as a whole; the solar system or 'vortex' of a star; the Earth as a globe; any habitable planet; or an extensive land area or region. Therefore, in a strictly literal sense one may speak of geology as cosmology or of geogony as cosmogony. In this archaic sense, for example, Hutton referred to his own fieldwork as establishing a cosmogony (Hutton 1795, 1: 286). Perhaps, for this reason, global sections and views have been called 'cosmogonic sections'. However, it is potentially misleading for an archaic meaning of 'cosmo-' to literally refer to the Earth rather than to the universe, so I will use 'cosmogonic' to describe only depictions of the origin of the universe or solar system and substitute 'geogonic' for the origin of the Earth or an Earth-like planet. As a general term, 'cosmogonic section' is not apt for an additional reason, namely that global views are not sections at all. Finally, not all cosmic sections were cosmogonic, and similarly, not all global sections depicted or implied geogonic processes. Because of these shortcomings, it is better to describe global depictions as either sections or views.

Many global depictions in Theories of the Earth are relatively well known and have been commented upon many times. In this essay, four vignettes, which together sample a variety of 17th-century global depictions, illustrate the establishment of visual conventions for depicting the Earth as a globe and show how the development of global depictions corresponds to the contested, interdisciplinary character of Theories of the Earth.

2. *Incidental Global Sections: The Mathematical Visions of Johannes Kepler*

Before whole-Earth representations became prominently deployed in Theories of the Earth, they often played incidental and sometimes ornamental roles in other works. To select one interesting example, we may begin in Prague in the early 17th century, during the reign of Holy Roman Emperor Rudolph II, when Johannes Kepler (1571–1630) joined Tycho Brahe in the Emperor's service. Most historians of geology do not immediately think of Kepler as a Theorist of the Earth. Yet 16th- and early 17th-century theorizing about the Earth was more widespread than we usually recognize, involving contributions from a significant number of diverse early-modern disciplines, and Kepler's shadow looms large over later Theories of the Earth (Kelly 1969). Kepler, therefore, may provide an instructive illustration of the incidental use of global representations before Theories of the Earth became established as a recognized tradition.

At the end of Book IV of *Harmonices mundi* (1619), Kepler penned a significant 19-page discussion of the Earth (Kepler 1619, pp. 157–176; Kepler 1997, pp. 358–385). This 'Epilogue on Sublunary Nature' was not a digression from his usual concerns, he explained, for theorizing about the Earth had long been integral to many of his writings. Kepler listed six earlier works where he already had addressed the nature of the Earth and then recapitulated aspects of each one in turn. His theorizing about the Earth, he related, developed in the context of meteorology: 'Indeed, I was moved to that, not by reading or admiration of the Platonists, but only and solely by observation of the weather' (Kepler 1997, p. 359). The classical discipline of meteorology was one of the most important sources for 17th-century Theories of the Earth because, according to Aristotle, meteorology considered all that happens beneath the Moon, including volcanos, earthquakes, tides, the changing shorelines, and location of the seas. Yet unlike Aristotle, Kepler's approach to meteorology was mathematical. Departing from the practice of many mathematical exercises, however, Kepler described his endeavor as a 'hunt for causes' (Kepler 1997, p. 361). Thus, for Kepler, the causal science of sublunar nature constituted an intersection between mathematical astrology and meteorology.

Although 'Neoplatonism' encompassed a multitude of competing perspectives and Kepler's approach to any subject was stamped with his own distinctive natural philosophy, the 'Epilogue on Sublunary Nature' is a remarkable articulation of a Neoplatonic theory of the Earth. That is, Kepler's approach to meteorology and to the Earth was Neoplatonic in two ways: First, Kepler emphasized correspondences between the Earth as a macrocosm and the human body as a microcosm.

> For as the body puts out hairs on the surface of its skin, so the Earth puts out plants and trees; and lice are born on them as in the former case, caterpillars, cicadas, and various insects and sea monsters as in the latter. As the body displays teats, mucus, and earwax, and also in places lymph from pustules on the face, so the Earth displays amber and bitumen; as the bladder produces excrement of sulphurous odor and farts which can even be set on fire, so the Earth produces sulphur, subterranean fires, thunder, and lightning; and as blood is generated in the veins of an animate being, and with it sweat, which is thrust outside the body, so in the veins of the Earth are generated metals and fossils, and rainy vapor (Kepler 1997, pp. 363–364).

Similar macrocosm-microcosm analogies frequently appeared in later Theories of the Earth.

Second, Kepler argued that the Earth is ensouled: that the cause of processes on and within the Earth is an animating soul of the Earth. Just as the soul of an animal animates the body, so the soul of the Earth, specific to the Earth, animates geological processes in tune with its apprehension of the harmonies of the planetary motions. The soul maintains a rational sympathy with the heavens, responding to the geometries of the positions of the planets as seen from the Earth. Kepler regarded the inference to the soul of the Earth as based upon the factual observations and quantitative evidence of astro-meteorology. Kepler and his contemporaries were convinced that weather patterns and other phenomena correlate with the aspects of the planets or the angles between two planets as seen from Earth. Using techniques of mathematical astronomy, on the basis of planetary aspects, Kepler once astounded the citizens of Prague by predicting a severe thunderstorm two weeks ahead of time (cf. Jenks 1983; Field 1988, pp. 128–129; Caspar 1993, p. 172). Because aspects are perceived relative to the Earth, the soul that recognizes them must inhabit the Earth rather than the Sun, other planets, or zodiac. This soul 'detects which planet is situated at a given time in which degree of the zodiac, and measures the angles of the radiations which meet at the Earth' (Kepler 1997, p. 367). Thus, empirically determined correlations with the aspects proved that the Earth is animated by a soul that perceives the mathematical relations of the planets and responds with volcanoes, earthquakes, and diverse meteorological phenomena. This geometrical character of the soul of the

Earth also finds expression in the forms of gems and crystals generated within the Earth; Kepler explored these in the *Strena* (Prague; Kepler 1611). Additionally, for Kepler the Earth soul, akin to flame and light, is responsible for subterranean heat and contains an image of the divine ideas according to which the universe was created. The breathing of the soul of the Earth is manifest in the tides and their correlations to the influences of the Sun and Moon. Moreover, the soul of the Earth could account for the Earth's motions as required by Copernicus.

This severely truncated outline of a complex body of thought, distributed across the breadth of Kepler's work and synthesized in the 'Epilogue', suffices to show that in the essay on sublunary nature Kepler sketched a Neoplatonic Theory of the Earth in the context of the search for causes in a mathematically oriented astro-meteorology (Caspar 1993, pp. 278–281; Schwaetzer 1997; Field 1998, pp. 127–142). Fortunately, we shall soon have a nuanced account of the development of Kepler's thinking about the Earth from Patrick Boner, whose forthcoming dissertation at Cambridge will consider the entirety of Kepler's *oeuvre*. One result of Boner's work has already appeared: an examination of Kepler's defense of the Earth soul from the criticisms of Robert Fludd (Boner 2006). Yet even now we can appreciate why, although the Theories of the Earth tradition is sometimes erroneously characterized as merely an outgrowth of Cartesian mechanical philosophy, Kepler was long regarded as an influential founding figure of the tradition and an exemplar of mathematical and Neoplatonic Theories of the Earth (e.g. Cuvier 1812, p. 28).

But so far nothing has been said about Kepler's visual representations. Although Kepler's works are abundantly illustrated, and despite the central importance of many diagrams to his cosmology (particularly the regular solids), images did not play a prominent or integrated role in his theorizing about the Earth. The most detailed global diagrams occur in the *Epitome of Copernican Astronomy* (1618) where Kepler offered two small depictions of the globe. The first global section appears where Kepler explained that the Earth's axis is inclined because magnetic fibers arranged parallel to the axis of the Earth maintain its inclination in a constant direction (Kepler 1618, p. 117; Figure 1a). With the second global section, Kepler compared the physics of the Earth's diurnal motion to that of a top (Kepler 1618, p. 121; Figure 1b). Although the ideas illustrated by these global sections were not trivial, the role of the images was incidental to the exposition of the ideas. The images are not labeled, nor are their features specifically referred to in the accompanying text. Had they been omitted by the printer, no one would have noticed their absence from the text itself. Nor were these images appropriated by later writers. The merely incidental role of global depictions for Kepler is consistent with his distrust of nonmathematical images in natural philosophy. In the vast majority of cases, Kepler's images display quantitative or geometrical relations consistent with his cautionary warning, in Book V of *Harmonices mundi* (1619), that nonquantitative images often mislead a reader into chasing irrelevant analogies or inventing meaningless symbols (Westman 1984; Caspar 1993, pp. 290–293).

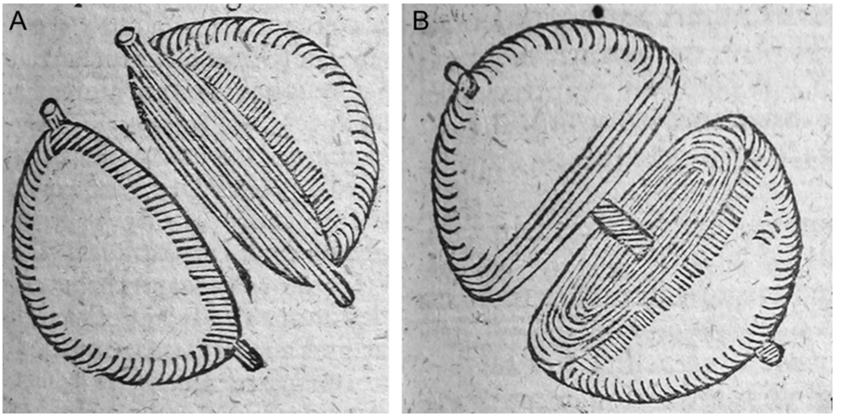

Fig. 1. Kepler (1618), global sections: (a) Fibers parallel to axis, p. 117; (b) Earth as a top, p. 121.

3. Cosmogonic Sections: The Chemical Visions of Robert Fludd

Robert Fludd (1574–1637) published the most important series of cosmogonic sections in the early 17th century. Unlike Kepler's incidental use of images, with Fludd we see theorizing about the Earth that depended on the use of images in an essential way. In contrast to Kepler's mathematical orientation, Fludd was a well-to-do London physician who advocated the chemical philosophy (Debus 1966). Like Kepler, Fludd affirmed macrocosm-microcosm analogies, or correspondences and sympathies between the universe, Earth and human body, including forces or influences acting across great distances. Yet in his hands these analogies were turned to quite different ends. Fludd's theorizing about the origin of the Earth relied upon the chemical philosophy as an esoteric key to the interpretation of creation. In his major work on the 'Macrocosm and Microcosm' (1617), Fludd's images served as shorthand to represent the mysteries of hermeticism that he would interpret for the reader. Fludd's illustrations were emblematic in the sense that one who could interpret the images using esoteric knowledge would thereby gain insight into the secrets of nature (Figure 2).

Fludd's rich use of images established important visual conventions for representing the development of the Earth. A series of cosmogonic sections depicts, in turn, the steps of chemical creation from chaos to the cosmic section of Figure 2. At least 16 cosmogonic sections occur in the 61 pages of Fludd's first two books to depict a directional process described in the idiom of the six days of creation. As the sections sampled in Figure 3 indicate, during the first three days celestial and sublunar regions gradually emerged, followed on the fourth day by a sublimation of the Sun to the middle of the heavens. In another image Fludd depicted the Holy Spirit moving over the waters by a dove in revolution about the center during the first three days of creation (Figure 4a). Other images include a quarter section of the cosmos (Figure 4b) and two cosmogonic hemisections (Figure 4d). These

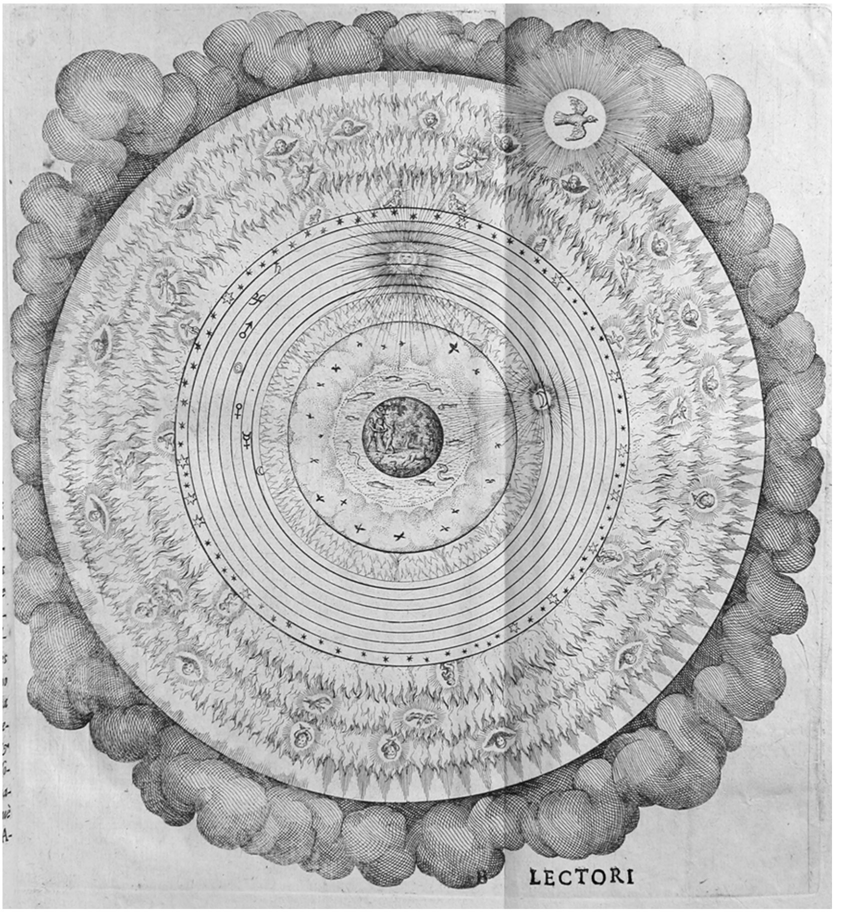

Fig. 2. Fludd (1617), p. 9; cosmic section.

and many other illustrations are described elsewhere (Westman 1984; Godwin 1991). In later works, printed with fewer illustrations, Fludd continued to refer the reader back to the illustrations printed in this volume (Fludd 1979). More than merely visual aids, for Fludd these images represented keys to the interpretation of creation.

Fludd gained notoriety in the Rosicrucian controversies. Outside of England few later figures cited him explicitly, yet contemporaries took careful notice of his works. Robert Westman has analyzed how Kepler's disparaging comments toward nonquantitative images were made in a polemical exchange with Fludd, where Kepler criticized Fludd for explaining images of the universe rather than the universe itself (Westman 1984). Mersenne, Gassendi, and others also took upon themselves the task of refuting Fludd, and some suspected even Descartes of being under his spell. Through the remainder of the century, despite the varying fortunes of Fludd's writings, chemical visions of the Earth never faltered.

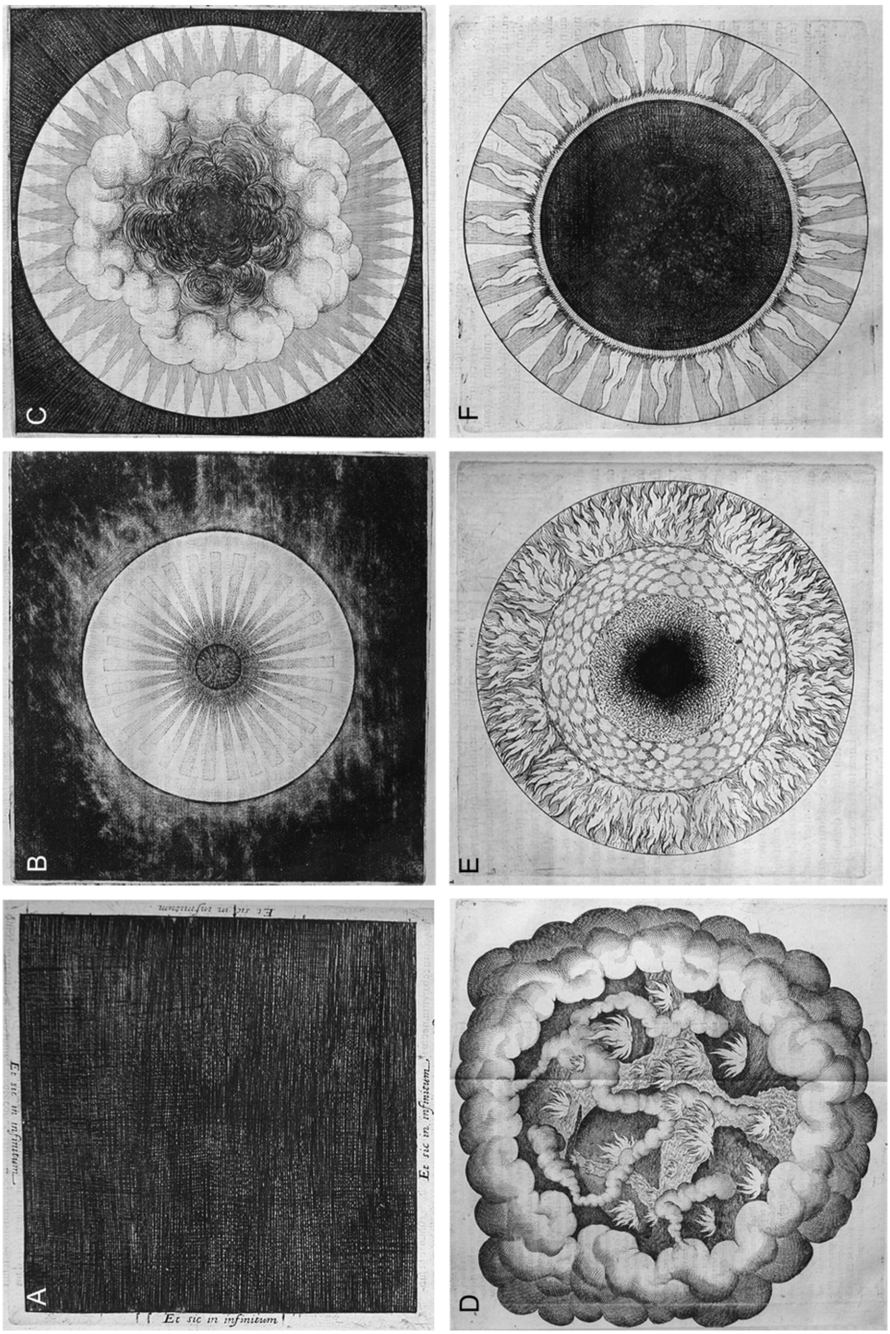

Fig. 3. Robert Fludd (1617), cosmogonic sections: (a) p. 26; (b) p. 29; (c) p. 37; (d) p. 41; (e) p. 46; (f) p. 55.

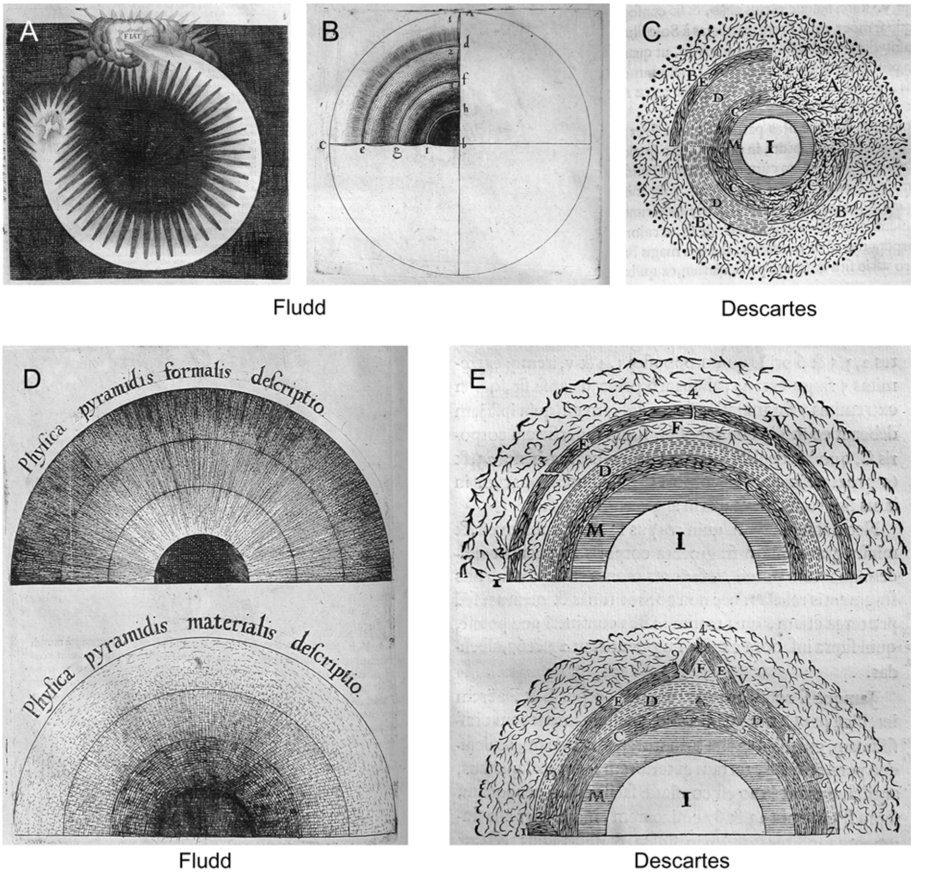

Fig. 4. Visual conventions, Robert Fludd (1617) and René Descartes (1644): (a) Fludd, p. 49, rotating figure. (b) Fludd, p. 76, quarter-section. (c) Descartes, p. 206, quarter-sections (wheel of time). (d) Fludd, p. 166, double-hemisection. (e) Descartes, p. 215, double-hemisection.

The works of subsequent chemical geogonists, many of which included global depictions, established a foundation for the emergence of mineralogy (Debus 1975; Laudan 1987).

4. *Geogonic Sections: The Mechanical Visions of René Descartes*

In the *Principia Philosophiae* (1644), René Descartes (1596–1650) transformed the use of cosmogonic sections into a didactic rather than esoteric form of illustration to serve the rational vision of the mechanical philosophy. In opposition to Fludd's emblematic chemical vision, Descartes sought to substitute the clarity of mechanical explanations invoking only matter and motion, dispensing with macrocosm-microcosm sympathies and forces acting across distances. In a well-known global section, Descartes explained magnetism as

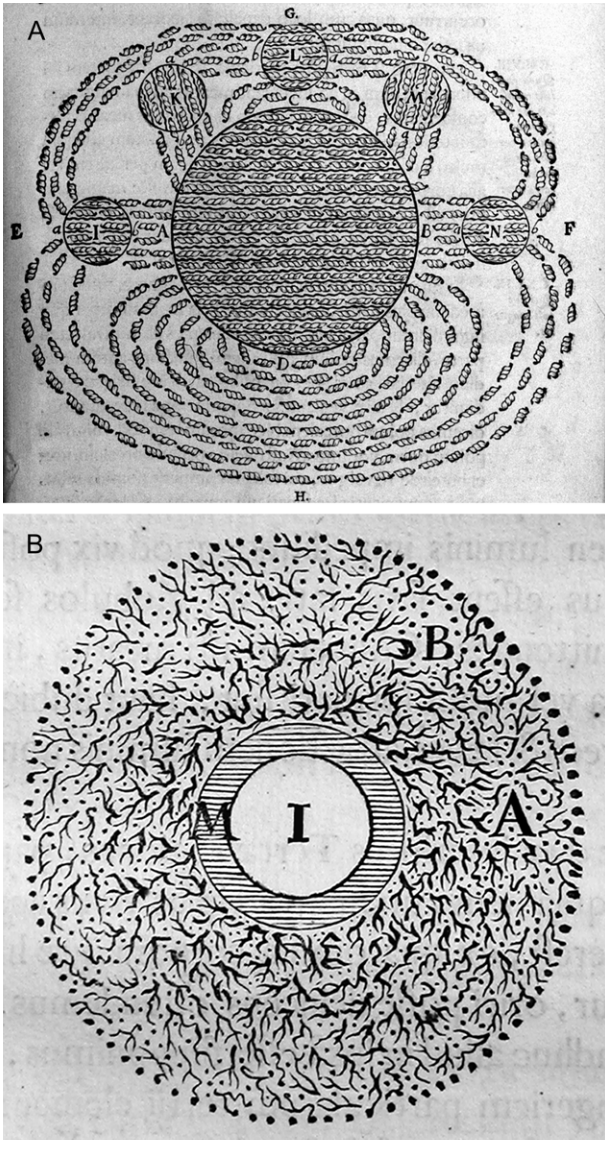

Fig. 5. Descartes (1644): (a) magnetic global section, p. 271; (b) geogonic section, p. 191.

the result of the motion of spiral-shaped particles through and around the Earth (Figure 5a). If even magnetic attraction could be explained by mechanical principles, then why would one need to invoke souls like Kepler or mysterious hidden sympathies like Fludd?

Descartes' (1983) *Principles of Philosophy* held two far-reaching consequences for the emerging tradition of Theories of the Earth in that: (1) Descartes divided the discipline of meteorology into separate discourses on the atmosphere and on the Earth, and (2) he raised the stature of theorizing about the Earth to a position of prominence in natural philosophy. In the *Principia*, Descartes offered a comprehensive mechanical vision of knowledge and the universe. After setting out to explain all of cosmology in part 3, Descartes significantly concluded the work by giving the Earth its own separate section (the longest of the work) in Part 4, entitled simply 'De Terrâ' or 'on the Earth'. In Part 4, Descartes addressed in one place the topics of Aristotle's *Meteorology* not already covered in his essay on the atmosphere (*Les Météores*; Descartes 1637). Moreover, in this concluding section of the *Principia*, Descartes bestowed a high status upon Theories of the Earth by claiming that a natural philosophy fails if it can explain the cosmos, but not the Earth which is more accessible to us. This assertion offered a direct point of contrast to Aristotle, who had conceded that demonstrative knowledge of causes is often impossible in meteorology due to the very nature of the subject matter (Descartes 1644, articles 204–206; Aristotle *Meteorology* 339a20–21).

Descartes prepared a sequence of geogonic images to show the progression of an Earth-like planet through time. The series begins with a section of a star composed of three areas, including a central fiery core (I, *ignis*), an outermost atmosphere (A and B), and a hard rind or shell (*crustis*) that developed from sunspots as they thicken and spread (M, *macula*; Figure 5b). In a striking wheel of time, Descartes combined four geogonic sections into one diagram (Figure 4c). The upper right quarter of the wheel is the same as the previous star section, with three divisions. Then the atmosphere divides, yielding four divisions (lower right). Next there are five, because water has condensed to form layer D (lower left), and finally six divisions, with the layer of water sandwiched between a superficial hard shell E and an inner hard shell C (upper left). This rotating wheel of quarter sections is an abstract diagram, unlike Fludd's emblematic figures. To understand it does not require a seer who unveils secret mysteries. Rather, it represents the intelligibility of a rational process, which it helps to clarify. More than a pedagogical visual aid, it is an instrument for thinking, a cognitive tool, a didactic abstraction (Baigrie 1996; Hall 1996). In the first of two global hemisections (Figure 4e), Descartes depicted fissures that developed as the outer shell of earth dried out. In the second, lower hemisection, the dried outer earth has fractured and its fragments have tilted, creating mountains and ocean beds. With his quarter section and rotating figure, Fludd provided the visual precedents for Descartes' rotating wheel of time. With his double cosmogonic hemisections, Fludd provided a visual precedent for the two geogonic hemisections of Descartes.

Descartes' illustrations accounted for any Earth-like planet and not just the universe as a whole. His use of geogonic sections, in addition to cosmogonic sections, reflects his strong assertion that explaining the cosmos is not enough, that the Earth provides a crucial test-case for evaluating competing natural philosophies. Descartes' model of a changing Earth invoked the mechanism of crustal collapse, widely known from the *locus classicus*, the Atlantis myth of Plato. This mechanism, like the geogonic sequence as a whole, confirmed the directionalist character of the Earth's changes over time, in accordance with Fludd's hexameral cosmogenesis but in contrast to the endless cycles of Aristotelian meteorology. Finally, Descartes' geogonic sections showed what must inevitably happen, not only for the Earth but also for any Earth-like planet, offering what has been called a genetic explanation rather than an account of the Earth in particular (Oldroyd 1979; Roger 1982). Cartesian visions were sustained by many followers whose global sections continued to advance the mechanical philosophy and closely followed the visual conventions of Descartes (e.g. Gadroys 1675; Barin 1686; Hartsoeker 1706).

5. Global Sections and Views: The Classical Visions of Thomas Burnet

Thomas Burnet, royal chaplain, classical scholar, and Cambridge Platonist, published *Telluris theoria sacra* in 1681, with an English translation, *The Theory of the Earth*, appearing in 1684. Burnet's works were frequently revised and added to until his death, and they were reprinted in authorized and unauthorized editions throughout the next 150 years (Magruder 2003). Burnet founded his ideas on the three pillars of Reason, Scripture, and Antiquity: 'This Theory being chiefly Philosophical, Reason is to be our first Guide; and where that falls short... we may receive further light and confirmation from the Sacred writings' (Burnet 1684, p. 6). For Burnet, a theory of the Earth was based on Reason, but not Reason alone: '...we take more faithful Guides, THE unanimous reports of Antiquity, Sacred and Profane, supported by a regular Theory' (Burnet 1684, p. 202). As is manifest from the images, Burnet's chief guide in Reason or natural philosophy was Descartes: Burnet employed a geogonic sequence of didactic abstractions derived very closely from the *Principia* (Figure 6a–e). However, Burnet added a feature of interest not seen in Descartes: a global view corresponding to a global section (Figure 6f). In another global view, Burnet cut away part of the outer crust to disclose the layer of water within (Figure 7a).

Burnet's famous frontispiece, which first appeared in the English translation of 1684, depicts a circle of seven globes (Figure 8). These are not global sections but global views, each portrayed as if viewed from a distance, perhaps from the Moon or another planet; or rather, all seven global views represent the Earth completing its journey through time. These are views of the Earth not merely from far away but from eternity, through the eyes of an apocalyptic vision which animated Burnet's treatise. Thus in the theater of the world, the Earth is the location of three successive scenes of habitation: the paradise that was lost (Figure 8b), the present world of wreck and ruin (Figure 8d), and the millennium or paradise regained (Figure 8f). The transitions between these scenes are four 'Revolutions of our natural world', accomplished through natural causes: chaos (Figure 8a), Noah's universal deluge (Figure 8c), a future conflagration (Figure 8e), and a final consummation (Figure 8g) when the Earth will be transformed into a fixed star (Gould 1987). Burnet's sequence of geogonic sections (Figure 6) connects chaos and paradise, the first two global views in the frontispiece. But there are no global views in Descartes. In contrast to Descartes' manner of presentation in the *Principia*, where he uniformly appeared to be

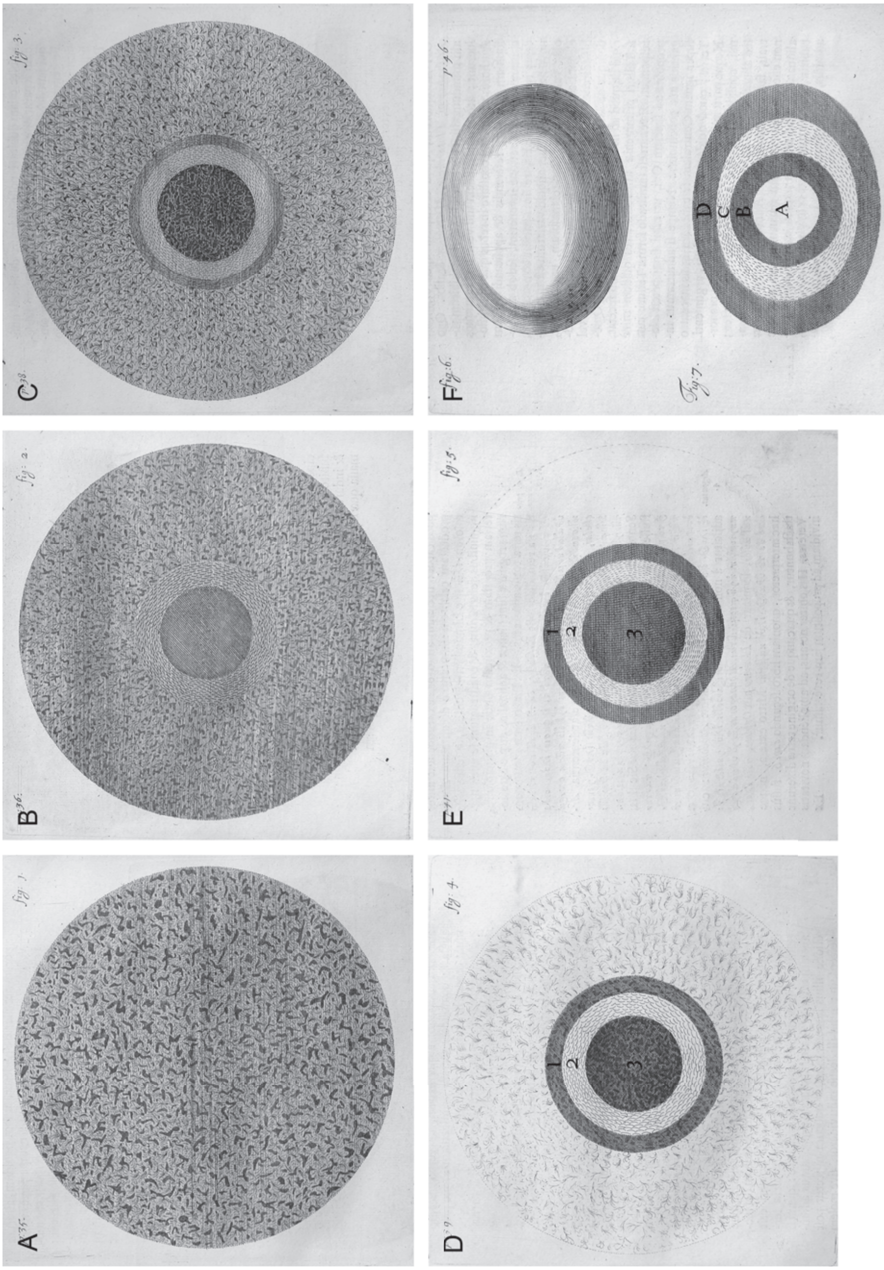

Fig. 6. Burnet (1681), geogonic sequence. (a) p. 35; (b) p. 36; (c) p. 38; (d) p. 39; (e) p. 41; (f) p. 46.

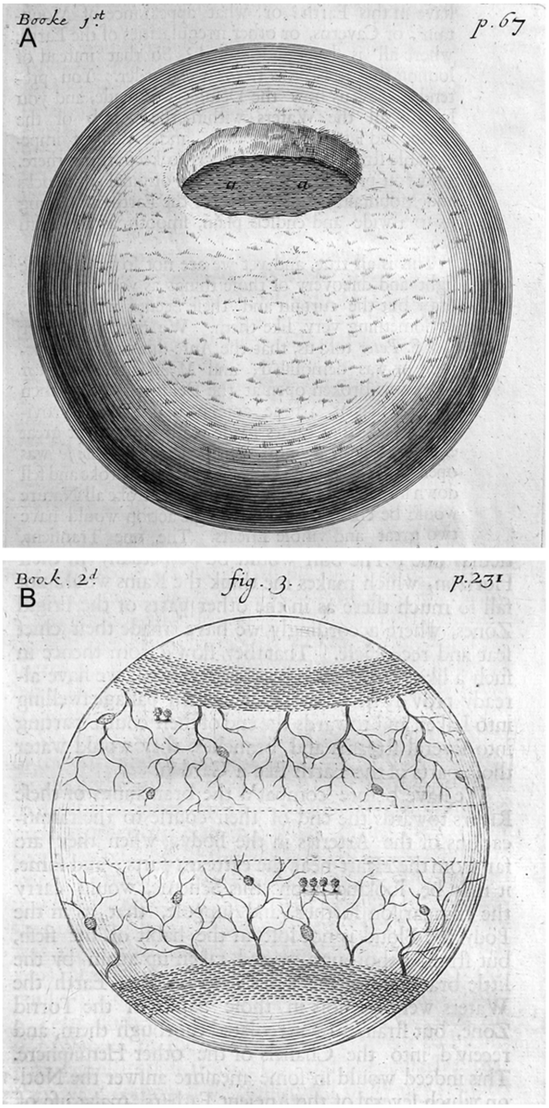

Fig. 7. Burnet (1684), Paradisiacal Earth: (a) p. 67; (b) p. 231.

reasoning from causes, Burnet spent much of his book reasoning from effects. Burnet was emphatic about this contrast to Descartes: ‘I judg’d it more useful and expedient to lay aside the Causes at present, and begin with the Effects, that we might have some sensible matter to work upon. Bare Idea’s of things are lookt upon as Romantick till Effects be propos’d, whereof they are to give an account...’ (Burnet 1684, p. 134). Burnet insisted that, unlike Descartes, he did not offer a ‘Romantick’ account, because he

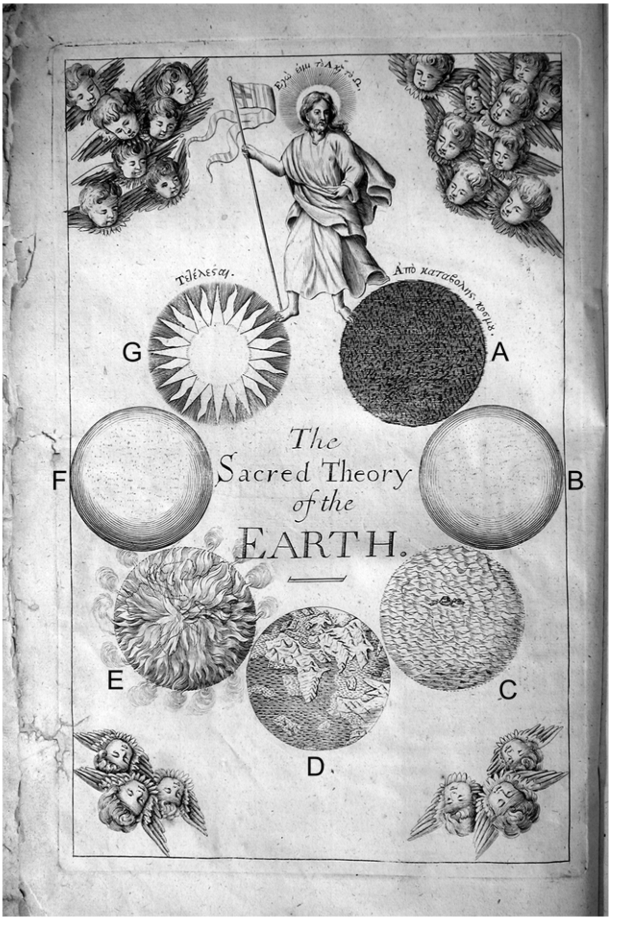

Fig. 8. Thomas Burnet, *Theory of the Earth* (1684), frontispiece. (a) Chaos; (b) Paradise; (c) Deluge; (d) the present world; (e) Conflagration; (f) Millennium; (g) Consummation.

offered reasonings from effects and not just deductions from causes. And while global sections served Descartes' purposes well in reasoning from causes, Burnet used global views to depict the reconstruction of causes from the effects. Going beyond Descartes, Burnet deployed global sections in combination with global views and an abundance of other depictions in diverse styles (geometrical and naturalistic, ornate and symbolic), at times incorporating local phenomena as well.

Figure 7b is another look at the Paradisiacal Earth viewed from afar. Burnet's theory of the primeval water cycle underlies this image in several interesting ways, but the chief purpose of the image was to suggest that the primeval paradise would have appeared banded to an observer on the Moon or a nearby planet. As a classical humanist scholar, Burnet compiled much evidence from ancient texts that the primeval globe was banded, containing a torrid zone that was impassable in the first age of the world. Contemporary observations of Jupiter as a banded planet therefore suggested that it might still remain in an unfallen state; telescopic drawings of Jupiter were included in some editions (e.g. Burnet 1693). In addition to considering evidence from antiquity and observational astronomy for the bandedness of antediluvian planets, Burnet also used this global view to address New World discoveries. The two sets of trees in Figure 7b indicate two homes of Adam and Eve. After they left descendants in the southern hemisphere, Burnet suggested that Providence transported them across the impassable torrid zone to populate the northern hemisphere. North-south migration became possible after the crustal collapse created the modern continents. Thus, Adam could be the father of all humanity, including those races discovered in the Americas who must be a remnant from the southern stock, but not through Noah. The southern races, and distinctive animals in the western hemisphere, must have been delivered through the Deluge by another Noah unknown to Europeans. Descartes never adjusted his theories to accommodate this kind of historical reconstruction! Unlike Descartes, but very much like a Cambridge Platonist, Burnet explicitly attempted to reason from the evidence provided by ancient texts and scripture, as well as from planetary observations and biodistribution patterns in the New World. The effects to be explained in this image arose from all three of Burnet's guides (Reason, Antiquity, and Scripture), but the key point is that Burnet used effects rather than causes alone to construct global views.

Figure 9 displays another example of Burnet's use of global views to reason from effects and not just from causes. The hemisection at the top ('fig. 1' in 9b) combines both of the hemisections of Descartes (compare Figure 4e). Descartes' first hemisection resembles the lighter hatching at the top of Burnet's, which depicts a central fissure before the crustal collapse. Burnet's darker portion corresponds to Descartes' second hemisection and shows the crust after its collapse. Particular details in Burnet's hemisection more obviously correspond to their referents in the actual Earth, such as coastal islands and cliffs, because of the two accompanying global views. A local section (Figure 9a, below), which resembles an image published by Athanasius Kircher in 1665, acknowledged contemporary evidence that coastal islands are separated from nearby shores by relatively shallow depths. In contrast, Descartes' sections were abstracted to the point of obscuring their correlations with the actual Earth. It is striking that Descartes' verbal account reflects the abstraction of his diagrams, for to create a rhetorical 'aha!' effect, he revealed the correspondences with the actual Earth only after the processes depicted by his diagrams were derived by deduction from first causes. Burnet's *Theory* is quite different, despite his clear appropriation of Cartesian precedents. Just as Descartes transformed the visual rhetoric of Fludd, so Burnet transformed that of Descartes. The addition of global views and local illustrations, not just global sections, emphasized that Burnet was not reasoning from causes alone. Indeed, global depictions appearing in many other Theories of the Earth were frequently associated with regional and local depictions.

As a final example, Burnet's global views of the eastern and western hemispheres show the present form of the Earth (Figure 10a and b). Burnet wished to present the appearance

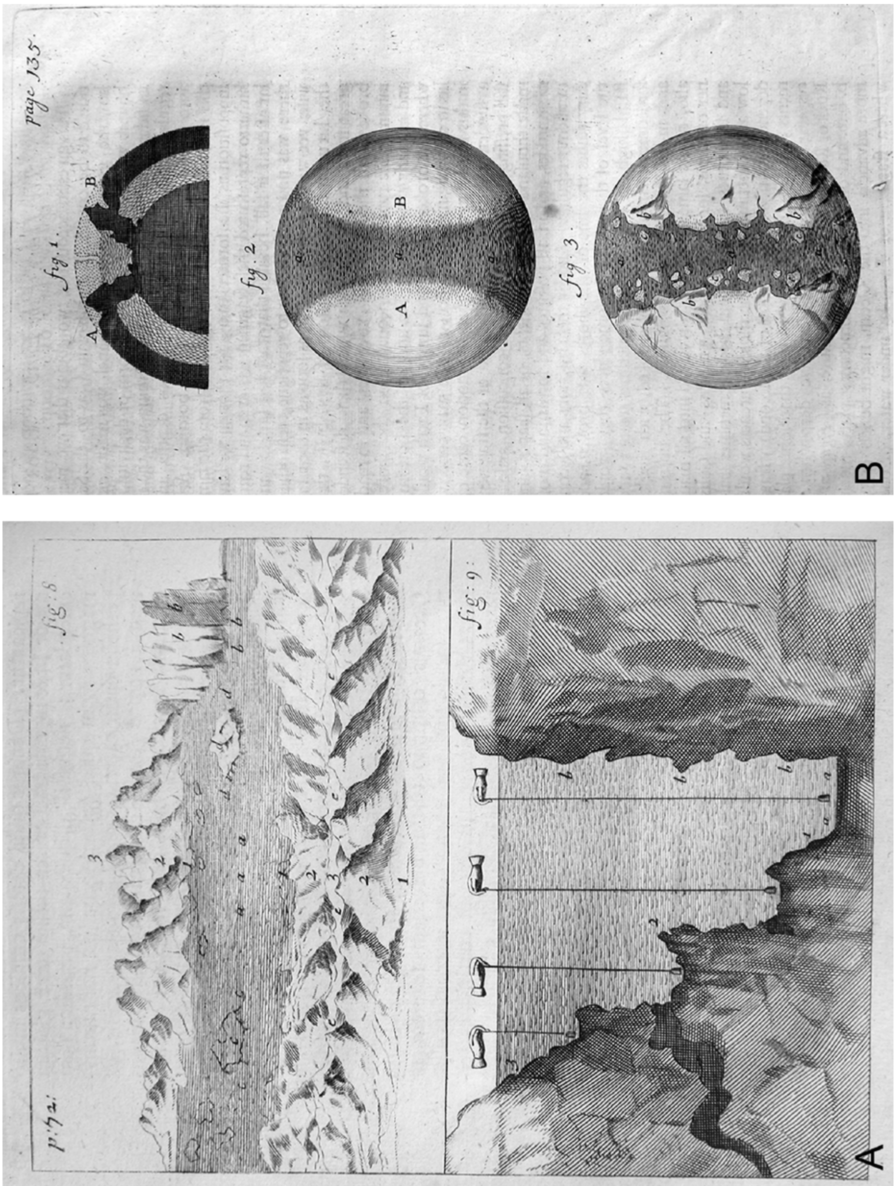

Fig. 9. Crustal collapse: (a) Burnet (1681), local section, p. 72. (b) Burnet (1684), global section and views, p. 135.

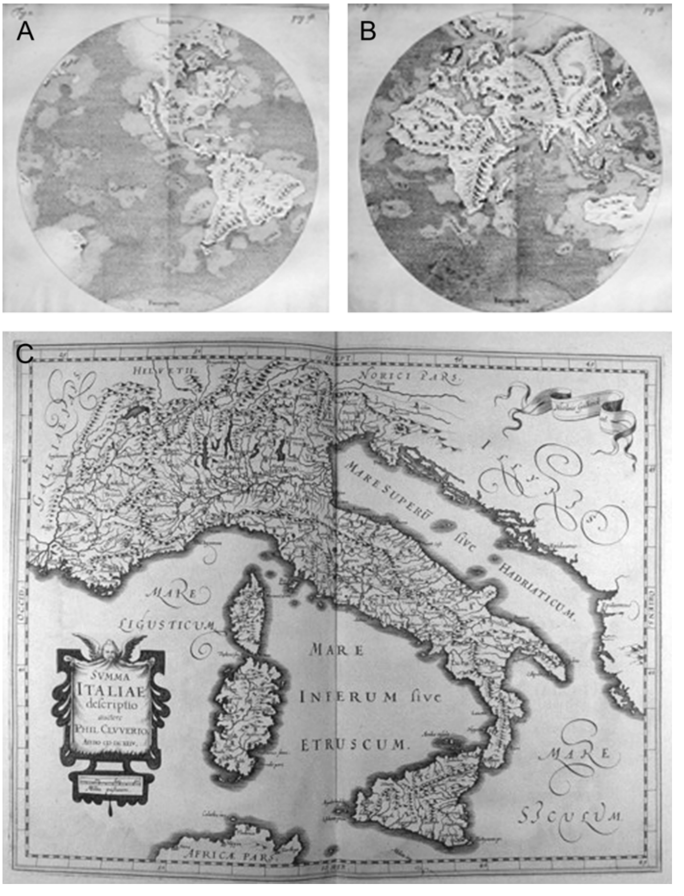

Fig. 10. (a) and (b) Burnet (1681), Present world, western and eastern hemispheres, inserted after p. 98. (c) Clüver (1624), Italy in the classical era, map inserted before p. 1.

of the Earth without cities, in order more memorably to impress its mountainous character upon his readers. In doing so, he again drew upon classical scholarship, citing the natural maps of Philipp Clüver (1580–1622), which represented regions of the Earth as they existed in antiquity before human settlement changed the face of the Earth (Figure 10c). Such maps took into account the textual evidence of classical scholarship, including reports of the changing shorelines of the sea.

Burnet's openness to reconstructing causes from effects correlates with his rejection of Cartesian determinism. For Burnet, the history of the Earth was contingent in that the present form of the Earth might have been otherwise. Unlike Descartes, for Burnet the state of the Earth could not simply be deduced from initial conditions: 'the present form of the Earth... is not deducible from a Chaos, by any known laws of Nature, or by any wit of Man. . . ' (Burnet 1684, p. 227). Because it might have been otherwise, as a survey of other planets in the solar system confirmed, one needs to reason from effects and not just from causes. Burnet opened the door to reasoning from effects, and once opened, knowledge of these effects might potentially come from any evidential source, whether classical texts, astronomy, natural history, or local observations. Burnet's use of global views in addition to global sections reflects his willingness to take into account a variety of kinds of evidence as starting points for reconstructing a theory of the Earth.

After Burnet, global sections and views were prominently associated with Theories of the Earth. They served as instruments to clarify thinking, and they became a common currency of debate. Burnet's diagrams were repeatedly appropriated by rivals and successors, sometimes without modification. Once Burnet established the visual conventions, similar images were used by different writers to support rival claims. For example, Thomas Beverley reproduced Burnet's global view of the Deluge to represent not the era of Noah, as Burnet would have it, but the first chapter of Genesis when the waters covered the Earth (Beverley 1699). This brief survey of global depictions is far from thorough, but these four vignettes suffice to show that global sections and views came to play a prominent role in constructing a dynamic, interdisciplinary tradition of Theories of the Earth.

6. Conclusion

The 'Global Visions' table summarizes many of the divergent characteristics of these early Theorists of the Earth and their global depictions. Kepler's theorizing about the Earth was oriented in the context of astro-meteorology, a science of sublunar nature at the intersection between mathematical cosmology and the Earth, consistent with a Neoplatonic natural philosophy. His incidental use of global depictions reflected his strong preference for mathematical diagrams and his distrust of other kinds of images. Fludd's images were emblematic figures that required esoteric knowledge derived from hermeticism and chemical philosophy to understand. Most importantly, Fludd set a precedent of explaining the Earth and cosmos by a close and sustained reference to cosmogonic sections. Descartes transformed the emblematic cosmogonic sections of Fludd into didactic abstractions that, more than mere pedagogical aids, were instruments to clarify conceptions of the structure of the Earth and its temporal changes. Their abstract character matched his attempt to substitute clear, mechanical explanations for the emblematic, esoteric explanations of chemical philosophers. Descartes' mechanical vision of the Earth was rooted in meteorology and featured geogonic rather than merely cosmogonic sections. Finally, Burnet's disciplinary orientation was that of a classical scholar; his natural philosophy fused Cartesian causal science with the Cambridge Platonist respect for ancient sources. Burnet used a range of less abstract images, especially global views and corresponding local illustrations, to serve an evidential as well as a didactic function.

The continuities and contrasts observed in visual representations provide a valuable portrait of a print tradition. Neither Descartes' use of Fludd nor Burnet's use of Descartes were

Table 1. Global visions.

	Primary discipline	Natural philosophy	Characteristic images	Uses of images
Kepler	Astro-meteorology	Neoplatonism	Mathematical diagrams	Incidental
Fludd	Physician	Chemical philosophy	Emblematic figures	Cosmogonic sections
Descartes	Meteorology	Mechanical philosophy	Didactic abstractions	Geogonic sections
Burnet	Classics	Cambridge Platonism	Evidential representations	Global sections and views

explicitly acknowledged in the texts. Moreover, images may reveal unexpected features to a modern reader, such as Burnet's trees, which reflect contexts that were tacitly appreciated by contemporary readers, but are no longer as obvious from an explication of texts.

Given the diversity of writers and illustrations surveyed in these four vignettes, it is perhaps not surprising that many historians of geology have found Theories of the Earth perplexing. Roy Porter expressed a typical view from the standpoint of disciplinary history, for example, when he raised the question 'why this scientific genre had such a chequered career. For theorists of the Earth were constantly feuding amongst themselves, and the discipline itself was to be ignominiously superseded by 'geology' at the turn of the 19th century. Why then was the theory of the Earth a failure as regulator of thought and action?' (Porter 1979, pp. 97–98). Such attempts to cast Theories of the Earth as an emerging scientific discipline, as if they should have constituted an incipient form of geology, fail to take into account the interdisciplinary character of a print tradition. On the other hand, to characterize Theories of the Earth as an interdisciplinary print tradition comports well with the simultaneous establishment of Theories of the Earth and of visual conventions for depicting the Earth as a globe.

The multiplication of images prepared for dissemination in printed texts, and their reuse and modification in subsequent contexts, are frequently examined aspects of the printing revolution (e.g. Ivins 1953; Eisenstein 1979; Johns 1998). Global depictions were 'boundary objects' which served as interfaces between multiple contexts and facilitated reciprocal translations (Star and Griesemer 1989). That is, global depictions served as mobile boundary objects linking diverse individuals, each possessing various disciplinary, natural philosophical, religious, institutional, and national and ideological identities, in a public conversation. Images and visual conventions migrated between different disciplines and intellectual contexts, often carrying associated questions or approaches to diverse kinds of evidence along for the ride.

If global depictions were boundary objects, so too on another level were Theories of the Earth when understood as printed texts. To appreciate Theories of the Earth as an interdisciplinary print tradition does not seal them away in a 'placeless and timeless' print culture, such as that critiqued by Adrian Johns (Johns 1998, p. 19), but cuts them loose as boundary objects that traversed gaps between diverse places and varied contexts over a sustained length of time (thus making Porter's criticism moot). These four vignettes illustrate how out of many early-modern disciplines (e.g. meteorology, medicine, classics, chemistry, astronomy, cosmology, chronology, biblical commentary, mining, and mineralogy), some of which no longer exist, 17th-century Theories of the Earth developed as a multidisciplinary discourse that enabled participants with a variety of disciplinary perspectives and cognitive styles to debate the nature and history of the Earth. Published 'Theories of the Earth' were not isolated 'theories', but participants in a new tradition of critical debate in a public, interdisciplinary forum created by the printed medium. The concomitant emergence of a visual tradition of global depictions that was well suited for bringing a variety of different kinds of evidence to bear on common questions facilitated this debate. By incorporating a variety of topics from older disciplines, eventually the new discourse allowed for the emergence of new ways of investigation, the consideration of new kinds of evidence, and an ongoing adjustment to new disciplinary boundaries. Eisenstein pointed to the emergence of novel conversations that cut across established disciplinary lines as one of the chief effects of the printing revolution: 'Not only was confidence in old theories weakened, but an enriched reading matter also encouraged the development of new intellectual combinations and permutations.... Once old texts came together within the same study, diverse systems of ideas and special disciplines could be combined' (Eisenstein 1983, p. 44). One could not hope to find a more appropriate example of disciplinary reshuffling than the establishment of Theories of the Earth as a contested print tradition. Global visions—whether depictions of the Earth as a globe or Theories of the Earth understood as printed texts in a public forum—bridged remarkable disciplinary divides.

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Note

Much of the material addressed in this essay is treated more thoroughly in my dissertation (Magruder 2000). Since references to the dissertation are minimized, to access places where the dissertation extends material presented here see pp. 366–379 on the thought experiment of viewing the Earth from a distance; pp. 631–633 on Kepler as a founding figure for Theories of the Earth; pp. 602–615 on Fludd's cosmogonic sections; p. 604 on reactions to Fludd; pp. 234–236 and 620–621 on contrasting epistemic claims for meteorology made by Aristotle and Descartes; pp. 388–394 on didactic and evidential types of visual representations; pp. 24–25 and 614–621 on genetic vs. historical conceptions of the Earth's past; chapter 5 on Burnet's frontispiece; pp. 212–220 on the frequent association of global and local depictions in Theories of the Earth; and pp. 92–94 on Theories of the Earth as boundary objects.

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