8 · The Foundations of Theoretical Cartography in Archaic and Classical Greece

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Greek civilization started in the Minoan-Mycenaean age (2100–1100 B.C.) and arguably continued to the fall of the empires of Byzantium and Trebizond in the fifteenth century. Within this span of some three thousand years, the main achievements in Greek cartography took place from about the sixth century B.C. to the culminating work of Ptolemy in the second century A.D. This seminal era can be conveniently divided into several periods around which the following chapters are shaped: the archaic and classical period (to the fourth century B.C.), the Hellenistic period (fourth and third centuries B.C.), the early Greco-Roman period (second century B.C. to the second century A.D.), and the age of Ptolemy (second century A.D.).[1]

It has often been remarked that the Greek contribution to cartography lay in the speculative and theoretical realms rather than in the practical realm, and nowhere is this truer than in the earliest period down to the end of the classical era. Large-scale terrestrial mapping, in particular, lacked a firm empirical tradition of survey and firsthand observation. Even at the end of the period, the geographical outlines of the known world or *oikoumene* were only sketchily delineated. Astronomical mapping, while clearly based on direct observation and developed for practical astrological and calendrical purposes, relied more on abstract geometry than on the systematic art of measuring.

Moreover, for the historian of cartography, the early period poses particular problems as much through the scanty nature of the evidence as through the difficulty of its interpretation. No cartographic artifacts clearly define a beginning to the period. The links, for example, with the earlier Babylonian and Egyptian cartography described in the preceding chapters can be only tentatively established, and the extent to which the early Greeks were influenced by such knowledge remains a matter for conjecture. While there is some circumstantial evidence for both the transmission and the reception of important mathematical concepts relevant to cartography—and even for the descent of the basic design of the world map—direct documentary proof for such connections is lacking.[2]

Likewise, it is not always realized that the vast majority of our knowledge about Greek cartography in this early period is known from second- or third-hand accounts. We have no original texts of Anaximander, Pythagoras, or Eratosthenes—all pillars of the development of Greek cartographic thought. In particular, there are relatively few surviving artifacts in the form of graphic representations that may be considered maps. Our cartographic knowledge must therefore be gleaned largely from literary descriptions, often couched in poetic language and difficult to interpret. In addition, many other ancient texts alluding to maps are further distorted by being written centuries after the period they record; they too must be viewed with caution because they are similarly interpretative as well as descriptive.[3] Despite the apparent continuity of some aspects of cartographic thought and practice, we must extrapolate over large gaps to arrive at our conclusions. In the account that follows, therefore, a largely empirical approach is adopted, so that the maximum amount of information about the maps, collected under the names of individual

1. For general works on this period, see G. E. R. Lloyd, *Early Greek Science: Thales to Aristotle* (New York: W. W. Norton, 1970); Armando Cortesão, *History of Portuguese Cartography*, 2 vols. (Coimbra: Junta de Investigações do Ultramar-Lisboa, 1969–71), vol. 1, chap. 2; Edward Herbert Bunbury, *A History of Ancient Geography among the Greeks and Romans from the Earliest Ages till the Fall of the Roman Empire*, 2d ed., 2 vols. (1883; republished with a new introduction by W. H. Stahl, New York: Dover, 1959); J. Oliver Thomson, *History of Ancient Geography* (Cambridge: Cambridge University Press, 1948; reprinted New York: Biblo and Tannen, 1965); H. F. Tozer, *A History of Ancient Geography*, 2d ed. (1897; reprinted New York: Biblo and Tannen, 1964); D. R. Dicks, *Early Greek Astronomy to Aristotle* (Ithaca: Cornell University Press, 1970); Otto Neugebauer, *The Exact Sciences in Antiquity*, 2d ed. (Providence: Brown University Press, 1957); idem, *A History of Ancient Mathematical Astronomy* (New York: Springer-Verlag, 1975); G. S. Kirk, J. E. Raven, and M. Schofield, *The Presocratic Philosophers*, 2d ed. (Cambridge: Cambridge University Press, 1983); W. K. C. Guthrie, *A History of Greek Philosophy*, 6 vols. (Cambridge: Cambridge University Press, 1962–81).

2. Otto Neugebauer, "Survival of Babylonian Methods in the Exact Sciences of Antiquity and the Middle Ages," *Proceedings of the American Philosophical Society* 107 (1963): 528–35.

3. Lloyd, *Early Greek Science*, 10 (note 1).

authors, can be extracted in chronological order from what are often the fragments of lost works.[4]

The earliest literary reference for cartography in early Greece is difficult to interpret. Its context is the description of the shield of Achilles in the *Iliad* of Homer, thought by modern scholars to have been written in the eighth century B.C.[5] Since both Strabo (ca. 64/63 B.C.–A.D. 21) and the Stoics claimed Homer was the founder and father of a geographical science generally understood as involving both maps and treatises, it is tempting to start a history of Greek theoretical cartography with Homer's description of this mythical shield. If this interpretation is valid, then it must also be accepted that Homer was describing a cosmological map. Although from the Hellenistic period onward the original meaning of the term geography was a description of the earth, *gē*, written or drawn (mapping and geographical descriptions were thus inseparable in the Greek world), it is equally clear that Greek mapmaking included not only the representation of the earth on a plane or globe, but also delineations of the whole universe. The shield in Homer's poem, made for Achilles by Hephaestus, god of fire and metallurgy, was evidently such a map of the universe as conceived by the early Greeks and articulated by the poet.

Despite the literary form of the poem, it gives us a clear picture of the various processes in the creation of this great work with its manifestly cartographic symbolism. We are told how Hephaestus forged a huge shield laminated with five layers of metal and with a three-layered metal rim. The five plates that made up the shield consisted of a gold one in the middle, a tin one on each side of this, and finally two of bronze. On the front bronze plate we are told that he fashioned his designs in a concentric pattern; a possible arrangement is suggested in figure 8.1.[6] The scenes of the earth and heavens in the center, two cities (one at peace and one at war), agricultural activity and pastoral life, and "the Ocean, that vast and mighty river" around the edge of the hard shield denote his intention of presenting a synthesis of the inhabited world as an island surrounded by water. Hephaestus depicted the universe in miniature on Achilles' shield, and Homer, in his poetry, only provides a commentary on this pictorial representation. As with the Thera fresco (discussed below), which is roughly contemporaneous with the subject of Homer's poem, the juxtaposition on the shield of scenes and actions that in reality could not occur at the same time shows the artist's desire to portray a syncretism of human activity.

In light of the archaeological discoveries of cultures that certainly influenced Homer's poetry, the content of Achilles' shield seems less extraordinary.[7] Homer was

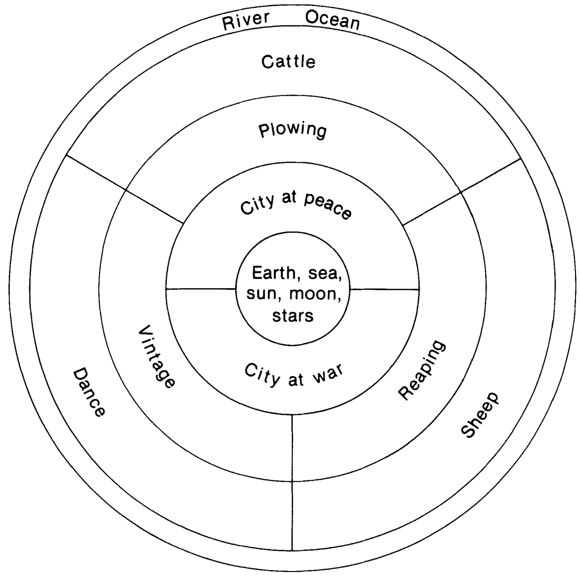


FIG. 8.1. RECONSTRUCTION OF THE SHIELD OF ACHILLES FROM HOMER'S *ILIAD*.
After Malcolm M. Willcock, *A Companion to the Iliad* (Chicago: University of Chicago Press, 1976), 210.

4. For most of the fragments, see H. Diels and W. Kranz, eds., *Die Fragmente der Vorsokratiker*, 6th ed., 3 vols. (Berlin: Weidmann, 1951–52), and an English translation of the fragments from Diels and Kranz in Kathleen Freeman, *Ancilla to the Pre-Socratic Philosophers* (Cambridge: Harvard University Press, 1948).

5. P. R. Hardie, "Imago Mundi: Cosmological and Ideological Aspects of the Shield of Achilles," *Journal of Hellenic Studies* 105 (1985): 11–31; Germaine Aujac, "De quelques représentations de l'espace géographique dans l'Antiquité," *Bulletin du Comité des Travaux Historiques et Scientifiques: Section de Géographie* 84 (1979): 27–38, esp. 27–28. The description of Achilles' shield in the *Iliad* is found in book 18, lines 480–610. For a modern translation and full commentary, see Richmond Lattimore, ed. and trans., *The Iliad of Homer* (Chicago: University of Chicago Press, 1951), 388–91, 411, and based on this translation, Malcolm M. Willcock, *A Companion to the Iliad* (Chicago: University of Chicago Press, 1976), 209–14.

6. The constellations are described thus: "He made the earth upon it, and the sky, and the sea's water, and the tireless sun, and the moon waxing into her fullness, and on it all the constellations that festoon the heavens, the Pleiades and the Hyades and the strength of Orion and the Bear, whom men give also the name of the Wagon, who turns about in a fixed place and looks at Orion and she alone is never plunged in the wash of the Ocean [never falls below the horizon]." Homer *Iliad* 18.483–89; translation by Lattimore, *Iliad*, p. 388 (note 5).

The description of the Ocean Sea and Okeanos, the god of those waters, is as follows: "Not powerful Acheloios matches his strength against Zeus, not the enormous strength of Ocean with his deep-running waters, Ocean, from whom all rivers are and the entire sea and all springs and all deep wells have their waters of him, yet even Ocean is afraid of the lightning of great Zeus and the dangerous thunderbolt when it breaks from the sky crashing." Homer *Iliad* 21.194–99; translation by Lattimore, *Iliad*, p. 423 (note 5).

7. Round shields and vases with comparable ornamentation in concentric bands have been found from this period. See Willcock, *Companion*, 209 (note 5).

writing at a time not much earlier than the first manifestations of what is considered the beginning of Greek science. His poem may be interpreted as the poetic expression of macrocosmic/microcosmic beliefs, held by a society seeking to reconcile a general view of the universe with man's activity within it. Hephaestus, the divine smith, is chosen to give a complete image of the cosmos—earth, sea, and sky together with scenes of human life. The main constellations—Orion, the Hyades, the Pleiades, and the Great Bear—are described, suggesting that a tradition had already developed of using these groupings of stars to identify different parts of the sky. The shield includes a representation of the sun and moon shining simultaneously, again in an attempt to integrate a general knowledge of the sky into one depiction. Even in this poetic form we can glimpse the use of a map, almost as a heuristic device, to bring some order into concept and observation and to codify the early Greeks' reflections on the nature and constitution of their world.

At the same time, we should be clear that the map on Achilles' shield was not intended to communicate a literal view of geographical knowledge of the world as known to the early Greeks. The scenes from rural and urban life are arranged on the surface of the shield in no apparent geographical order. They simply present a generalized and metaphorical view of human activity and of the profound interdependence of human beings in spite of the variety and specialties of their pursuits. This human unity is emphasized by the ocean encircling the whole shield, rendering the world an island. Homer depicts no maritime activity in his social microcosm: the ocean seems to be no more than a geometric framework for the knowable inhabited world, a framework W. A. Heidel considers to be the essential feature of all maps from ancient Greece.[8]

So detailed is Homer's description that, though clearly an imaginary map, Achilles' shield represents a useful glimpse of the early history of efforts to map the world. Probably much of it is conventional, and much also is fanciful. Indeed, it was the subject of ridicule by later writers. Strabo summarized the view:

> Some men, having believed in these stories themselves and also in the wide learning of the poet, have actually turned the poetry of Homer to their use as a basis of scientific investigations. . . . Other men, however, have greeted all attempts of that sort with such ferocity that they not only have cast out the poet . . . from the whole field of scientific knowledge of this kind, but also have supposed to be madmen all who have taken in hand such a task as that.[9]

But the description no doubt reflects elements present in real maps of the time, many of which were widely used later on. Stars are named and grouped into constellations; the limits of the known world are fixed by means of the ocean, real or imaginary, that encircles the inhabited world; and there is an attempt to give pride of place to human activity in this world scene.

In comparison with Homer's poem, the earliest known graphic representation of cartographic significance to have survived from the Greek world is the Thera fresco, fragments of which were discovered in 1971 in the course of archaeological excavation in the House of the Admiral at Akrotiri, Santorini, formerly Thera (plate 3).[10] Rather than depicting the cosmos portrayed on Achilles' shield, it relates to a local area that has been thought to be situated in northern Crete. It probably dates from late Minoan times, the period of the occupation of Thera, about 1500 B.C. The fresco has a picturelike quality and can be reconstructed in detail from the surviving fragments. While its dominant purpose was no doubt decorative, it includes features that have been interpreted as parts of a map, including a coastline, a harbor, a seaside village, a mountain with cattle and wild animals, and a winding river with plants and animals on its banks. Ships and fish are shown in the sea. But besides these geographical features, episodes are also included from what may be the historical past of that society. There are processions of notables going up the hillside, boats in attacking positions along the shore, and battles being fought inland; and there is the departure of the navy and its subsequent triumphal entry into its home port amid general rejoicing. As in Egyptian narrative drawings, events are depicted as occurring simultaneously that are in fact successive in time.

Circular Maps and the Flat Earth: Anaximander and His Successors in the Sixth Century B.C.

With the emergence of Greek science in the sixth century B.C., the context for descriptions of the world changed. It is of course difficult to say how far the greater frequency of allusions to maps in Greek society by this time is due to a fuller survival of literary texts as opposed to real changes and technical advances in the theory and

8. William Arthur Heidel, *The Frame of the Ancient Greek Maps* (New York: American Geographical Society, 1937).

9. Strabo *Geography* 3.4.4; see *The Geography of Strabo*, 8 vols., ed. and trans. Horace Leonard Jones, Loeb Classical Library (Cambridge: Harvard University Press; London: William Heinemann, 1917–32).

10. Peter Warren, "The Miniature Fresco from the West House at Akrotiri, Thera, and Its Aegean Setting," *Journal of Hellenic Studies* 99 (1979): 115–29, and Lajos Stegena, "Minoische kartenähnliche Fresken bei Acrotiri, Insel Thera (Santorini)," *Kartographische Nachrichten* 34 (1984): 141–43. The fresco was first published by Spyridon Marinatos, *Excavations at Thera VI (1972 Season)*, Bibliothēkē tēs en Athēnais Archaiologikēs Hetaireias 64 (Athens: Archailogikē Hetaireia, 1974).

practice of mapmaking. Yet despite the fact that our conclusions must still rest on literary sources (often at several removes from the practices they describe) rather than on map artifacts of the period, there are strong grounds for believing that for the first time natural philosophers were asking more systematic questions about the world in general and trying to give naturalistic rather than supernatural explanations for the phenomena they observed. Thus it may be that the Milesian natural philosophers were the first Greeks to attempt to map the

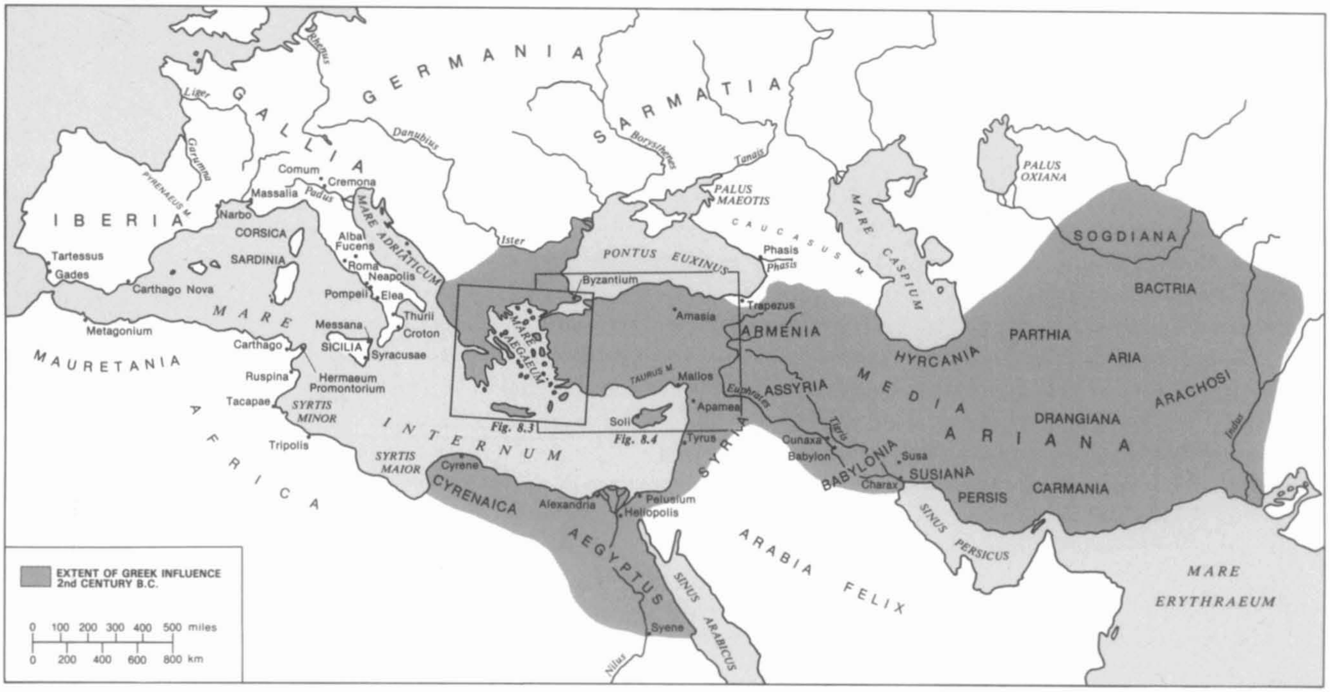


FIG. 8.2. PRINCIPAL PLACES ASSOCIATED WITH MAPS IN THE GREEK WORLD.

FIG. 8.3. THE AEGEAN. Detail from the reference map in figure 8.2.

FIG. 8.4 ASIA MINOR FROM THE THIRD CENTURY B.C. Detail from the reference map in figure 8.2.

earth and sky according to recognizable scientific principles.

As viewed through the later Greek authors—who tended to adopt a heroic rather than a contextual view of the development of knowledge—much of the credit for these innovations was given to Anaximander (ca. 610–546 B.C.), who had been a disciple of Thales at Miletus, a city in Asia Minor (see figs. 8.2–8.4). Thales (ca. 624–547 B.C.), one of the Seven Sages of Greece, was considered by later commentators to be an excellent astronomer.[11] It was said he could predict eclipses and calculate the length of the solar year and the lunar month so as to fix the interval between solstices and equinoxes.[12] According to one legend, Thales was so preoccupied with the heavens that he ignored what was beneath his feet, and fell into a well while looking at the stars.[13]

Anaximander, who was also known as a fine astronomer, was particularly interested in the technical aspect of this science. He is alleged to have invented the gnomon and introduced it into Sparta as part of a sundial.[14] In fact, as Herodotus suggests, he may only have borrowed the idea for this instrument from the Babylonians.[15] Whether Anaximander taught that the earth was spherical or cylindrical has also been a point of contention among classical and modern authors—the indirect evidence on his cosmology is contradictory.[16] In any case, according to Diogenes Laertius, the third-century A.D. compiler from whom we derive much of our biographical information about ancient Greek philosophers, Anaximander "was the first to draw the outline of land and sea and also to have constructed a globe."[17] Similarly, Agathemerus, the author of a third-century A.D. geographical treatise and a source of many otherwise lost works, claims that Anaximander was the first "to venture to draw the inhabited world on a map [*pinaki*],"[18] and Strabo calls him the author who "published the first geographical map [*geographikon pinaka*]."[19] It is clear that Anaximander was the first recorded of that long line of Greek craftsmen-philosophers who tried to express concepts in graphic form. The construction of spheres and the drawing of maps were to become characteristic products of the mechanical mind of the Greeks, and their regular occurrence reveals perhaps a more practical side than has traditionally been presented.

It is not certain that Anaximander wrote a commentary on his map or on the construction of his sphere. Hecataeus (fl. 500 B.C.), historian, statesman, and native of Miletus, is thought to be the author of the first *Circuit of the Earth* (*Periodos gēs*).[20] It was divided into two parts: one concerns Europe and the other Asia and Libya (Africa). Hecataeus's treatise is believed to have improved greatly on Anaximander's map; Agathemerus considered it excellent and even preferred it to the later one of Hellanicus of Lesbos.[21] Figure 8.5 is a reconstruction of Hecataeus's world view.

The materials used for these early maps were probably substantial. The word *pinax*, as defined by later authors, could mean a wooden panel used for writing inscriptions

11. The Seven Sages were statesmen, tyrants, and others who lived between 620 and 550 B.C., each of whom was recognized for a wise maxim. Thales is consistently included among the seven. See John Warrington, *Everyman's Classical Dictionary* (London: J. M. Dent; New York: E. P. Dutton, 1961).

12. Since our evidence of Thales' astronomy is indirect, it must be regarded with caution. Neugebauer, *Exact Sciences in Antiquity*, 142 (note 1), argues that if Thales did predict the solar eclipse of 584 B.C., it was not done on a scientific basis, since the Babylonian theory on which it was supposedly based did not exist in 600 B.C. Legends about Thales are sometimes contradictory, emphasizing either his theoretical or his practical abilities.

13. The story about the well is found in Plato *Theaetetus* 174A; see James Longrigg, "Thales," in *Dictionary of Scientific Biography*, 16 vols., ed. Charles Coulston Gillispie (New York: Charles Scribner's Sons, 1970–80), 13:297, especially n. 7.

14. Diogenes Laertius *Lives of Famous Philosophers* 2.1; see *Vitae philosophorum*, ed. Herbert S. Long, 2 vols. (Oxford: Clarendon Press, 1964); or, for an English translation, *Lives of Eminent Philosophers*, 2 vols., trans. R. D. Hicks, Loeb Classical Library (Cambridge: Harvard University Press; London: William Heinemann, 1925–38).

15. Herodotus *History* 2.109; see *The History of Herodotus*, 2 vols., trans. George Rawlinson (London: J. M. Dent; New York: E. P. Dutton, 1910). See also Herodotus *Histoires*, 10 vols., ed. P. E. Legrand (Paris: Belles Lettres, 1932–39). The actual level of Anaximander's scientific knowledge was probably far less than the secondary and tertiary sources suggest; see D. R. Dicks, "Solstices, Equinoxes, and the Presocratics," *Journal of Hellenic Studies* 86 (1966): 26–40.

16. Dicks, *Early Greek Astronomy*, 45–46 and n. 50 (note 1).

17. Diogenes Laertius *Lives* 2.1 (note 14). See also William Arthur Heidel, "Anaximander's Book: The Earliest Known Geographical Treatise," *Proceedings of the American Academy of Arts and Sciences* 56 (1921): 237–88.

18. Agathemerus *Geographiae informatio* 1.1, in *Geographi Graeci minores*, ed. Karl Müller, 2 vols. and tabulae (Paris: Firmin-Didot, 1855–56), 2:471–87, esp. 471, translation by O. A. W. Dilke; the Greek words rendered here as "on a map" are ἐν πίνακι. The two most common words for a map, *(gēs) periodos* and *pinax*, can have other meanings, respectively "circuit of the earth" and "painting." As a result, modern writers have tended to be somewhat cautious in their assessment of Greek cartography, and a proportion of the material presented here is not to be found in published accounts; yet it should be seriously and scientifically considered.

19. γεωγραφικὸν πίνακα. Strabo *Geography* 1.1.11 (note 9), translated by O. A. W. Dilke. See also Strabo, *Géographie*, ed. François Lasserre, Germaine Aujac et al. (Paris: Belles Lettres, 1966–).

20. περίοδος γῆς. The title of Hecataeus's work is sometimes given simply as *Periodos* or *Periegesis*. Most of the extant fragments are from Stephanus of Byzantium, and these are largely lists of placenames. From the fragments in Strabo and Herodotus, however, it is evident that the original work was more extensive. See D. R. Dicks, "Hecataeus of Miletus," in *Dictionary of Scientific Biography*, 6:212–13 (note 13), and Tozer, *History of Ancient Geography*, 70–74 (note 1).

21. Agathemerus *Geographiae informatio* 1.1 (note 18). Hellanicus (ca. 480–400 B.C.), a contemporary of Herodotus, was more a historian than a geographer.

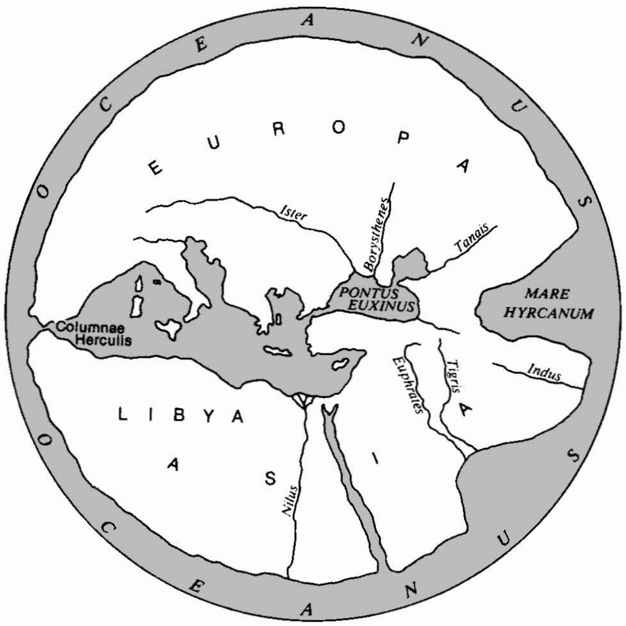


FIG. 8.5. RECONSTRUCTION OF THE WORLD ACCORDING TO HECATAEUS.
After Edward Herbert Bunbury, *A History of Ancient Geography among the Greeks and Romans from the Earliest Ages till the Fall of the Roman Empire*, 2d ed., 2 vols. (1883; republished with a new introduction by W. H. Stahl, New York: Dover, 1959), vol. 1, map facing p. 148.

or painting portraits, landscapes, or maps.[22] Herodotus, on the other hand, speaks of a bronze tablet (*pinax*) with an engraving of the circuit (*periodos*) of the whole earth with all the rivers and seas that Aristagoras of Miletus took with him when he went to Greece about 500 B.C. in search of allies against the Persians.[23] Herodotus's reference is important in showing that maps could be engraved on portable bronze tablets, that general maps of the inhabited world were frequently made in Ionia, and that they were more informative than the simple geometric plans such as the Babylonian clay tablet of the same era. Aristagoras had in fact been able to show on that map the regions to be crossed on the way from Ionia to Persia, comprising Lydia, Phrygia, Cappadocia, Cilicia stretching to the sea opposite Cyprus, Armenia, Matiena, and Cissia with the town of Susa. All these places were inscribed on the "circuit of the earth" engraved on the tablet. The map Aristagoras carried was probably originally derived from Anaximander's map, so much admired in antiquity. But we may presume that it also drew on road measurements compiled by the Persians for their imperial highways.[24]

We have almost no details of Anaximander's map, but it is traditionally accepted that "ancient maps" (which are probably those from Ionia) were circular, with Greece in the middle and Delphi at the center.[25] Herodotus confirms the regularity of the form of these maps: "For my part, I cannot but laugh when I see numbers of persons drawing maps of the world without having any reason to guide them; making, as they do, the ocean-stream to run all round the earth, and the earth itself to be an exact circle, as if described by a pair of compasses, with Europe and Asia just of the same size."[26] It is significant that Herodotus refers here to *periodoi gēs* (circuits of the earth), probably similar to that of Hecataeus. These works were supposed to be illustrated with diagrams or were accompanied by maps engraved on bronze or painted on wood.[27]

Aristotle ridiculed his contemporaries who, in their "circuits of the earth," drew the inhabited world as circular, which he said was illogical.[28] In the first century B.C. Geminus, the Stoic philosopher and pupil of Posidonius, complained of the artificiality of circular maps still in use and warned against accepting relative distances in maps of this sort.[29] His use of the word *geographia* in reference to maps illustrates the double meaning of the word. Thus the simple circular maps continued to be in use long after it was known that the inhabited world was greater in length (west to east) than in breadth (south to north).

The Impact of New Theories on Cartography from the Sixth to the Fourth Century B.C.: Pythagoras, Herodotus, and Democritus

Although the tradition of world maps drawn as flat disks, reflecting a theory that the earth was also a plane

22. πίνακι. These wooden panels were used for public exhibitions, inserted into the walls of monuments or in porticoes where they were prominently displayed.

23. Herodotus *History* 5.49 (note 15). Here the word paraphrased as "circuit," *periodos*, literally means "a going round" and may therefore suggest a roughly circular shape for the map engraved on the tablet.

24. The description of the Persian Royal Road is in Herodotus *History* 5.52–54 (note 15). See also Robert James Forbes, *Notes on the History of Ancient Roads and Their Construction*, Archaeologisch-Historische Bijdragen 3 (Amsterdam: North-Holland, 1934), 70–84.

25. At Apollo's oracle in Delphi there was an omphalos (navel), a stone that symbolized the center of the world. The origin of the notion of the centrality of Delphi (from Greek mythology) and a general discussion of the omphalos at Delphi are found in *Oxford Classical Dictionary*, 2d ed., s.v. "omphalos." See Agathemerus *Geographiae informatio* 1.2 (note 18).

26. Herodotus *History* 4.36 (note 15).

27. See note 22.

28. Aristotle *Meteorologica* 2.5.362b.13; see *Meteorologica*, trans. H. D. P. Lee, Loeb Classical Library (Cambridge: Harvard University Press; London: William Heinemann, 1952).

29. Geminus *Introduction to Phenomena* 16.4.5; see *Introduction aux phénomènes*, ed. and trans. Germaine Aujac (Paris: Belles Lettres, 1975).

surface, had been entrenched since the time of Homer, the sources indicate that the concept of the heavens and earth as spherical, eventually leading to cartographic representation in the form of celestial and terrestrial globes, came much later. It is very doubtful that the theory of sphericity of the earth can be dated earlier than Pythagoras, a native of Samos who moved to Croton in southern Italy about 530 B.C. The statement by Diogenes Laetius that Anaximander constructed a celestial sphere is unsubstantiated.[30]

The observation that fixed stars seemed to turn around a fixed point (later to be identified as the celestial pole) in regular procession led to the concept of a spherical sky rotating on an axis whose extremities were the celestial poles.[31] Recognition of the spherical nature of the heavens in turn may have led to the supposition that the earth too was a sphere. This concept appears to have been first diffused and taught in the southern Italian cities of Magna Graecia by the Pythagoreans; the first description of a spherical earth has been attributed sometimes to Pythagoras himself (fl. 530 B.C.) and sometimes to Parmenides, a native of Elea (Velia) in southern Italy (fl. ca. 480 B.C.). It was first proposed as a simple hypothesis, not verified scientifically but justified theologically. In the eyes of the Pythagoreans, the geometric perfection of the circle and the sphere was sufficient reason for adopting these ideas. They imagined all parts of the cosmos to be spheres (the stars, the sky in which they were fixed, the terrestrial globe) and all the movements in the sky to be circular (the rotation of fixed stars, the combined circular motions for the movements of the planets). These theories did not, however, have an immediate or dramatic impact on cartography. Since the representation of a sphere on a single plane is a circle, it is probable that the hypothesis of a spherical earth could reinforce, by an understandable misinterpretation of the figure, the idea of a flat, circular inhabited world and perpetuate this kind of representation.

The teachings of Pythagoras (who left no writings) are known only from what was said by his disciples or his successors, who tended to attribute to him all the ideas of the later school. As for Parmenides, he was the author of a philosophical poem, *Concerning Nature,* of which only fragments remain. Posidonius, who four centuries later described the process leading to the division of the sky and the earth into five zones, considered Parmenides the originator of this division also, and he saw the division itself as the direct result of the hypothesis of the spherical nature of the sky and the earth.[32]

There are no documents to prove whether the Pythagoreans in general and Parmenides in particular, other than producing simple geometric diagrams, put their hypotheses into material representations in the form of globes. But it must be remembered that the making of mechanical spheres or *sphairopoiia* flourished in the third century B.C. in this general region, especially Sicily, reinforced by the inventive genius of Archimedes, and that this may represent the continuation of a longer tradition.[33]

It was not until the fifth century B.C. that the traditional Homeric disk-shaped view of the world was systematically challenged by Herodotus (ca. 489–425 B.C.). A native of Halicarnassus (Bodrum) in Caria, but living in Thurii in southern Italy after 444, Herodotus was a friend of Pericles and Anaxagoras and had denounced, as we have seen, the traditional circular maps he viewed as so misleading. According to him, it had not been proven that the inhabited world was surrounded by water on all sides. It was clear to him that Africa was surrounded by sea except on the side where it adjoined Asia, because the Phoenicians sent by Necos (Necho), king of Egypt 609–594 B.C., had been able to go around it by boat in three years.[34] Asia was inhabited only as far as India, and farther to the east there was only a desert about which nothing was known.[35] Similarly for Europe, no one knew "whether any sea girds it round either on the north or on the east."[36] Thus Herodotus refused, in the name of scientific caution, to make a general map of the inhabited world when the outlines were so uncertain. He attacked the theoretical cartographers who based their ideas on geometry alone and seems to have urged a return to empirical cartography founded on exploration and travel. Theory, in his view, should give way to experience.

Another objection Herodotus made to the maps of his day was the way they divided the inhabited world into continents: "I am astonished that men should ever have divided Libya, Asia, and Europe as they have, for they are exceedingly unequal. Europe extends the entire length of the other two, and for breadth will not even (as I think) bear to be compared to them."[37] Herodotus would thus have given the general map of the inhabited world, had he been willing to draw it, a form similar to the T-O maps of the late classical period and Middle

30. Kirk, Raven, and Schofield, *Presocratic Philosophers*, 104 (note 1).

31. The position of the celestial pole relative to the stars has changed since that time because of the precession of the equinoxes. Our Pole Star, at the end of the tail of the Little Bear, was twelve degrees distant from the pole in Hipparchus's time. See *The Geographical Fragments of Hipparchus*, ed. D. R. Dicks (London: Athlone Press, 1960), 170.

32. Strabo *Geography* 2.2.1–2 (note 9).

33. *Sphairopoiia* means the making of a sphere; it was considered a branch of mechanics that studied the rotation of the sphere. See Hans Joachim Mette, *Sphairopoiia: Untersuchungen zur Kosmologie des Krates von Pergamon* (Munich: Beck, 1936).

34. Herodotus *History* 4.42 (note 15).

35. Herodotus *History* 4.40 (note 15).

36. Herodotus *History* 4.45 (note 15).

37. Herodotus *History* 4.42 (note 15).

Ages,[38] except that Europe (and not Asia), would have taken up the transverse part, while Asia and Libya would have been on each side of the vertical line.[39] Yet despite his awareness of the deficiencies of contemporary "geometric" maps, whether originating in Ionia or elsewhere, and perhaps because of his failure to express his ideas in graphic form, Herodotus was never considered a geographer—still less a mapmaker—by his successors.

This was far from the case with his contemporary Democritus (ca. 460 to ca. 370 B.C.), widely acknowledged for his formulation of the concept that the inhabited world was oblong and that the world map could be better accommodated in an oval rather than a circular frame. Born at Abdera in Thrace, Democritus was a great traveler with an inquiring mind. A philosopher and atomist like his master Leucippus, he studied with the Babylonian magi, the Egyptian priests, and even the Indian gymnosophists, at least according to the tradition.[40] He was a prolific writer, but his *Cosmology* (considered a work of physics), *Uranography*, *Geography*, and *Polography* (these three considered mathematical works, the last being perhaps a description of the pole) are all now lost.

The observational work of Democritus is known from the fragments of his calendar preserved in Geminus's *Isagoge* and Ptolemy's *Phaseis*, which gave the dates of the heliacal risings and settings of the chief constellations (the Pleiades, Lyra, Eagle, and Orion) and weather prognostications connected with these.[41] The description and drawing of these constellations was perhaps the main subject of his *Uranography*. In geography and cartography, however, Democritus can be assessed only through the testimony of his successors rather than the substance of his works. Strabo puts him immediately after the Ionians Anaximander and Hecataeus on his list of those who had most served geography and mentions him together with Eudoxus of Cnidus, Dicaearchus, and Ephorus.[42] He considered all four the most distinguished predecessors of Eratosthenes. It is likely that Democritus provided a map, or at least a plan, showing the shape he ascribed to the world in his *Geography*. As already noted, it is probable that this was oblong, its length one and a half times its breadth.[43] This proportion was accepted 150 years later by Dicaearchus. Democritus can thus claim a place in the history of cartography—as among the geographers of the Greek world—on the basis of this new idea of an oval rather than a circular inhabited world, one that by the third century B.C. was to be incorporated in the design of the world map.

While not directly concerned with geography or with the description of Greek maps of the time, Plato (ca. 429–347 B.C.) alluded in his writings to matters broadly associated with cartography in both the *Phaedo* and the *Republic* (both ca. 380 B.C.). In the *Phaedo*, Socrates is made to comment on the shape of the earth:

> Now there are many wondrous regions in the earth, and the earth itself is of neither the nature nor the size supposed by those who usually describe it, as someone has convinced me. . . . I've been convinced that if it is round and in the centre of the heaven, it needs neither air nor any other such force to prevent its falling, but the uniformity of the heaven in every direction with itself is enough to support it, together with the equilibrium of the earth itself.[44]

Whether the word περιφερής (*peripheres*, translated as "round") means circular or spherical has been the subject of a controversy not wholly understandable in view of Plato's obvious spherical analogy of the earth as a ball in a later passage.[45]

He then reveals his view of the earth's size: "And next, that it is of vast size, and that we who dwell between the Phasis River and the Pillars of Heracles inhabit only a small part of it, living around the sea like ants or frogs around a marsh, and that there are many others living elsewhere in many such places."[46] There then follows the passage where he likens the earth to a leather ball made up of twelve pentagonal pieces. This is an allusion to the Pythagorean theory of the dodecahedron, considered in classical times especially significant as the solid most nearly approaching a sphere.[47] In this, Plato also emphasizes the variety of colors of the earth when viewed from above:

> First of all the true earth, if one views it from above, is said to look like those twelve-piece leather balls,

38. The T-O maps were circular maps (hence the O), divided geometrically into three parts by two lines (hence the T). See Marcel Destombes, ed., *Mappemondes A.D. 1200–1500: Catalogue préparé par la Commission des Cartes Anciennes de l'Union Géographique Internationale* (Amsterdam: N. Israel, 1964); see also below, pp. 296–97 and 301.

39. As illustrated in a manuscript of Bede's *De natura rerum*, Bayerische Staatsbibliothek, Munich (Clm. 210, fol. 132v), and in figures 18.38 and 18.55 below.

40. For a general review of the various traditions surrounding Democritus, see G. B. Kerferd, "Democritus," in *Dictionary of Scientific Biography*, 4:30–35 (note 13).

41. Dicks, *Early Greek Astronomy*, 84–85 (note 1).

42. Strabo *Geography* 1.1.1 (note 9).

43. Agathemerus *Geographiae informatio* 1.2 (note 18).

44. Plato *Phaedo* 108e–109a; see the translation by David Gallop (Oxford: Clarendon Press, 1975). Both the *Phaedo* and the *Republic* date to Plato's middle period when he was in close contact with the Pythagorean Archytas, who was called by Horace the "measurer of land and sea"; see Tozer, *History of Ancient Geography*, 169 (note 1).

45. On the controversy, see page 223 of the Gallop translation (note 44). For the reference to the earth as a ball, see below, note 48.

46. Plato *Phaedo* 109b (note 44).

47. Plato, *Phaedo*, ed. John Burnet (Oxford: Clarendon Press, 1911), 131 (110b6).

> variegated, a patchwork of colours, of which our colours here are, as it were, samples that painters use. There the whole earth is of such colours, indeed of colours far brighter still and purer than these: one portion is purple, marvellous for its beauty, another is golden, and all that is white is whiter than chalk or snow; and the earth is composed of the other colours likewise, indeed of colours more numerous and beautiful than any we have seen. Even its very hollows, full as they are of water and air, give an appearance of colour, gleaming among the variety of the other colours, so that its general appearance is of one continuous multi-coloured surface.[48]

In the *Republic*, Plato briefly describes the skills of the navigator. He was illustrating the need for government to be in the hands of skilled "pilots" (philosophers). We can perhaps interpret this as confirmation that the art of navigation was fully understood by his readership: "The true pilot must give his attention to the time of the year, the seasons, the sky, the winds, the stars, and all that pertains to his art if he is to be a true ruler of a ship."[49] More directly cartographic in its allusion is Plato's description of a model of the universe within a passage known as the myth of Er. Er is depicted as a Pamphylian warrior who returned from the dead to describe the afterlife. Plato believed in a geocentric universe with the fixed stars on a sphere or band at the outside, and the orbits of the sun, moon, and planets between the earth and the stars. In his description of it, he used a spindle (the Spindle of Necessity) and whorl to symbolize, somewhat imperfectly, its workings.[50] The rims of the whorl—illustrated in figure 8.6—are intended to represent, from the outside in, the fixed stars and the orbits of Saturn, Jupiter, Mars, Mercury, Venus, the sun, and the moon.

Despite the theoretical nature of much of Greek cartography in the fifth and fourth centuries B.C., and though it was mainly the subject of debate among the philosophers rather than the object of much practical mapmaking, it does seem likely that the Greeks' awareness of the place of maps in their society grew in this period. There are even a few fragments of evidence to suggest that a knowledge of maps may have filtered into the experience of ordinary citizens. Three examples show the role maps or plans played in everyday life. Most remarkable, perhaps, is that in a fifth-century comedy by Aristophanes, *The Clouds*, we encounter a stage map that, just as surely as the many cartographic allusions in Shakespeare, suggests that the audience was familiar with the form and content of maps. Strepsiades, an old farmer compelled by war to take up residence in Athens, is intrigued with the paraphernalia of philosophy and questions a student:

> STREPSIADES (pointing to a chart): "In the name of heaven, what's *that*?"
>
> STUDENT: That's for astronomy.
>
> STREPSIADES (pointing to surveying instruments): And what are those?
>
> STUDENT: They're for geometry.
>
> STREPSIADES: Geometry? And what's that good for?
>
> STUDENT: Surveying, of course.
>
> STREPSIADES: Surveying what? Lots?
>
> STUDENT: No, the whole world.
>
> STREPSIADES: What a clever gadget! And as patriotic as it is useful.

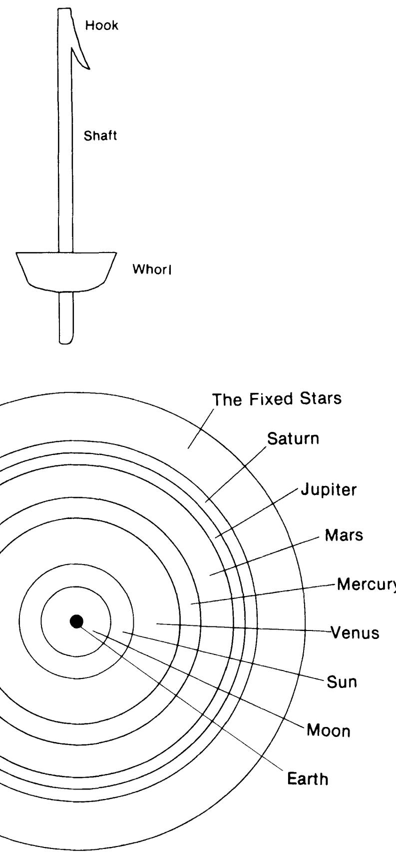


FIG. 8.6. RECONSTRUCTION OF PLATO'S SPINDLE OF NECESSITY. Plato used a spindle as an analogy for the universe, which he believed to be geocentric.
After Plato, *The Republic of Plato*, 2 vols., ed. James Adam (Cambridge: Cambridge University Press, 1902), book 10, figs. iii and iv.

48. Plato *Phaedo* 110b–d (note 44).

49. Plato *Republic* 6.4; see *Plato's Republic*, 2 vols., trans. Paul Shorey, Loeb Classical Library (Cambridge: Harvard University Press; London: William Heinemann, 1935–37).

50. Plato *Republic* 10.14 (note 49). H. D. P. Lee's translation, *The Republic* (London: Penguin Books, 1955), has a description and diagram of the "Spindle of Necessity" on pages 402–5. The diagram is taken from *The Republic of Plato*, ed. James Adam, 2 vols. (Cambridge: Cambridge University Press, 1902), book 10, figs. iii and iv.

STUDENT (pointing to a map): Now then, over here we have a map of the entire world. You see there? That's Athens.

STREPSIADES: *That*, Athens? Don't be ridiculous. Why, I can't see even a single lawcourt in session.

STUDENT: Nonetheless, it's quite true. It really is Athens.

STREPSIADES: Then where are my neighbors of Kikynna?

STUDENT: Here they are. And you see this island squeezed along the coast? That's Euboia.

STREPSIADES: I know that place well enough. Perikles squeezed it dry. But where's Sparta?

STUDENT: Sparta? Right over here.

STREPSIADES: That's MUCH TOO CLOSE! You'd be well advised to move it further away.

STUDENT: But that's utterly impossible.

STREPSIADES: You'll be sorry you didn't, by god.[51]

The passage demonstrates that large-scale cadastral maps and maps of the world were known to an audience of fifth-century Athens, and that the power of the map as a metaphor was realized (Strepsiades thinks he can lessen the threat from Sparta by moving it farther away on the map). The map is thus employed to focus attention on the geography of contemporary issues, and it has also become a vehicle for social criticism of that particular society.

A briefer allusion—this time to the value of maps as propaganda—is found in Plutarch's life of Nicias, in which Alcibiades, the notorious Greek statesman and general of the fifth century, is seeking to persuade the Athenians to undertake an expedition against Sicily:

> Before the assembly had met at all, Alcibiades had already corrupted the multitude and got them into his power by means of his sanguine promises, so that the youth in their training-schools and the old men in their work-shops and lounging-places would sit in clusters drawing maps of Sicily, charts of the sea about it, and plans of the harbours and districts of the island which look towards Libya.[52]

A story in Aelian of Socrates and his rich pupil Alcibiades shows that any Athenian could consult a world map. Seeing Alcibiades blinded by wealth and boasting of his big estates, Socrates took him to a place in the city (Athens) where a world map [*pinakion*, diminutive of *pinax*] was set up. He told Alcibiades to look for Attica; and when he had found it, he told him to look carefully at his own fields. Alcibiades replied: "But they are not drawn in anywhere." Socrates: "Why then, you are boasting of fields which are not even a part of the earth."[53]

Other roles were defined in less ambitious terms. At Thorikos, Attica, on the edge of the horizontal rock face immediately above the adit to mine 3, is what seems to be a small incised plan of the mine (fig. 8.7).[54] The latter was explored to a distance of 120 meters in 1982 by members of the Belgian Archaeological Mission, and the part explored is said to correspond to the diagram. It may date to the fourth century B.C. While this isolated example is hardly impressive, this and the other glimpses of the practical uses of maps perhaps indicate that some caution should be exercised when defining Greek cartography as a largely theoretical pursuit.

FIG. 8.7. MINE DIAGRAM FROM THORIKOS, ATTICA. Perhaps dating to the fourth century B.C., this seems to be a plan of the mine in front of which it was found incised in the rock.
Length of the original: 35 cm. By permission of the Mission Archéologique Belge en Grèce, Ghent.

Another indication of the Greek bent in practical drawing is afforded by the discovery of detailed architectural plans for parts of Greek buildings. It was thought until recently that no such plans had survived,[55] but a considerable set of incised drawings from the temple of Apollo at Didyma, south of Miletus, has recently

51. Aristophanes *The Clouds* 200–217; see *The Clouds, by Aristophanes*, trans. William Arrowsmith (New York: New American Library, 1962), 30–32.

52. Plutarch *Nicias* 7.1–2 and *Alcibiades* 17.2–3, both in *Plutarch's Lives*, 11 vols., trans. Bernadotte Perrin, Loeb Classical Library, (Cambridge: Harvard University Press; London: William Heinemann, 1914–26).

53. Claudius Aelianus (Aelian) *Varia historia* 3.28, translated by O. A. W. Dilke; see the edition edited by Mervin R. Dilts (Leipzig: Teubner, 1974); cf. Christian Jacob, "Lectures antiques de la carte," *Etudes françaises* 21, no. 2 (1985): 21–46, esp. 42–44.

54. H. F. Mussche, *Thorikos: Eine Führung durch die Ausgrabungen* (Ghent and Nuremberg: Comité des Fouilles Belges en Grèce, 1978), 44 and 48, fig. 53. We may compare another, undated inscription the first words of which may be translated "Boundary of house and shop" and that ends thus: ΓΗ, in H. W. Catling, "Archaeology in Greece, 1979–80," *Archaeological Reports 1979–80*, no. 26 (1980): 12, col. 2.

55. J. J. Coulton, *Ancient Greek Architects at Work: Problems of Structure and Design* (Ithaca: Cornell University Press, 1977), 53.

been analyzed.[56] This very large temple, planned after 334 B.C., had much work carried out on it about 250 B.C., but it was never completed. The incisions concerned were in fact known earlier but were dismissed by guides as builders' doodles.[57] Perhaps they were ignored for so long because, though one can easily see late Christian incisions on the stylobate, the earlier drawings are in a dark passage near a tunnel.

They include straight lines up to 10 meters long and circles up to 4.5 meters in diameter, originally filled with red chalk. The incisions, mostly full size, represent measurements of the temple and its *naiskos* (interior miniature temple) or their parts. A comparison between the plan of a column base and the actual base shows that the correspondence was very exact, that at two points the drawing was corrected, and that the fluting was not inserted on the plan, evidently because it was carved in situ.[58] The full-scale plans for large architectural members were incised horizontally, not vertically, since only the former gave sufficient length on a suitable flat surface. But in one case we find a column, about 18 meters high, drawn upright but with an unusual type of scale. Half the width only is shown, but at full scale, while the height is at 1/16 size, or one digit (finger's breadth; Greek *daktylos*, 1.85 centimeters) to one Greek foot (29.6 centimeters). Each foot of height was represented by parallel lines one digit apart. The object was to show a regular Greek feature, entasis or gradual curve on the column, whose diameter is indicated by the end of the line at each foot of height. In this case, to draw the curve, first a straight line was incised between the top and the bottom of the column shaft on the plan, then an arc of a circle was drawn with this line as chord and with a radius thought to be about 3.2 meters.[59] To the left of this diagram is a semicircle showing a half-section of a column, and overlapping both of these is the top quarter of a column drawn horizontally with the entasis shown. On other drawings the only major discrepancy discovered is between the plan of the *naiskos* and its actual dimensions. As to the drawing of the foundations, thin lines were found to have been engraved on the surface of successive layers of them. Although such lines do not reveal great mathematical skill, unlike the others, nevertheless they constitute a closer parallel with cartographic plans than do architectural elevations.

Similar incisions, though far fewer, have been found at two other Greek buildings in Asia Minor—the temple of Athena at Priene and the temple of Artemis at Sardis. They imply a far more systematic concern with scaled drawings in classical Greece than had hitherto been supposed.

Theory into Practice: New Celestial Globes and Maps in the Fourth Century B.C.

The ideas that had been expressed in largely theoretical terms in the fifth century B.C. began to be modified empirically in the fourth century. Significant advances were made both in celestial mapping—especially in the construction of celestial globes—and to a lesser extent in the terrestrial mapping of the inhabited world. Once again, however, the original sources reflect a bias toward the scientific achievements of individuals (which has, moreover, been perpetuated by many modern commentators on the cartographic significance of the texts).[60] In the present state of our knowledge, therefore, the cartographic history of this period still has to be understood in terms of these individuals and their works rather than of the wider social and intellectual milieu in which their ideas were rooted.

Eudoxus of Cnidus (ca. 408–355 B.C.),[61] whom Strabo placed in his long line of philosophers from Homer to Posidonius,[62] apparently initiated great progress in the mapping of both sky and earth. There is some controversy about the sources of Eudoxus's inspiration. He attended lectures of Plato—although apparently not his school—and is said to have spent more than a year in Egypt, some of it studying with the priests at Heliopolis.[63] In any event, Eudoxus of Cnidus is famous for his theory of geocentric and homocentric spheres (twenty-six concentric spheres centered on the earth), which was designed to explain the motion of the planets. His greatest cartographic achievement, however, was that he was the first to draw the stars on a globe representing the sky seen from the outside looking in, rather

56. Lothar Haselberger, "The Construction Plans for the Temple of Apollo at Didyma," *Scientific American*, December 1985, 126–32; idem, "Werkzeichnungen am jüngeren Didymeion," *Mitteilungen des Deutschen Archäologischen Instituts, Abteilung Istanbul* 30 (1980): 191–215.

57. Information from Mrs. J. Lidbrooke of the *Geographical Magazine*.

58. Haselberger, "Temple of Apollo," 128B (note 56).

59. Haselberger, "Temple of Apollo," 131 (note 56), gives 3.2 meters, but this may be an underestimate. The curve is not, as often, parabolic; but care is evidently taken, by substituting a straight line for part of the arc, that the diameter at no point exceeds the diameter at the base.

60. For example, Cortesão, *History of Portuguese Cartography*, 1:74–76 (note 1).

61. Some scholars prefer ca. 400–347 B.C. For example, G. L. Huxley, "Eudoxus of Cnidus," in *Dictionary of Scientific Biography*, 4:465–67, esp. 465 (note 13).

62. Strabo *Geography* 1.1.1 (note 9).

63. Huxley, "Eudoxus," 466 (note 61). But see Heidel, *Frame of Maps*, 100–101 (note 8), and Dicks, *Geographical Fragments*, 13 (note 31), for words of caution on the classical attribution of knowledge to the Egyptian priests.

than as seen by an observer on the earth, together with the positions of the main celestial circles: the equator, the tropics, the arctic (ever-visible) circles, the ecliptic and zodiac, and the colures (fig. 8.8).[64] See also appendix 8.1.

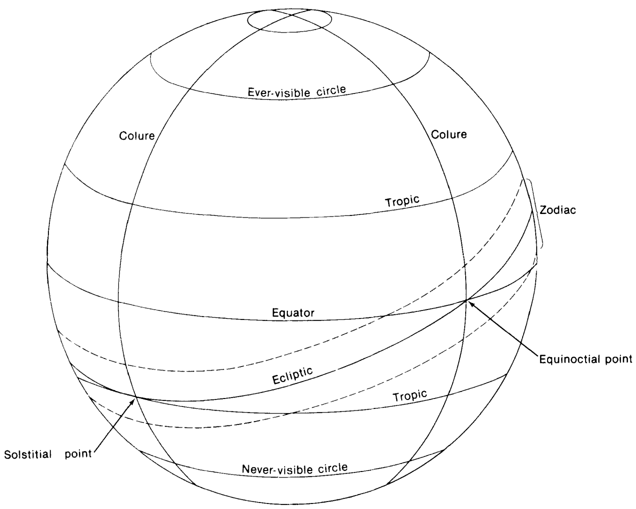


FIG. 8.8. THE CELESTIAL CIRCLES. The arctic circle is constructed for an observer's location at 37°N (see also fig. 10.6).

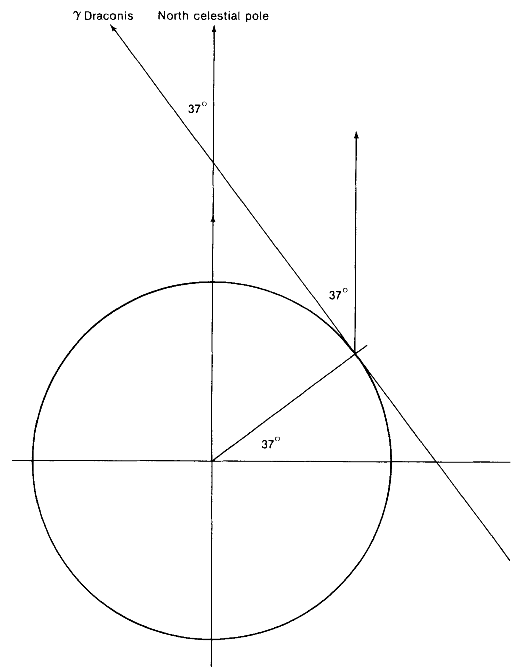


FIG. 8.9. RECONSTRUCTION OF LATITUDE OF OBSERVER. The latitude of intended users of Eudoxus's globe is based on the observation of γ Draconis as it touches the horizon of the observer.

Eudoxus wrote two works, *Phaenomena* and *The Mirror*, to accompany his celestial globe and to help in its interpretation, but both are lost. Fortunately a verse rendering of the *Phaenomena* has survived. It was written by the poet Aratus of Soli (ca. 315–240/239 B.C.) at the request of the Macedonian king Antigonus Gonatas (ca. 320–239 B.C.), a keen patron at his court of scholars, poets, and historians.[65] Aratus undertook this during his stay at Pella, adding to the text of Eudoxus a short prelude in honor of Zeus that has a strong flavor of Stoicism. That the poem accurately reflects the original text is decisively proved in the *Commentary* by Hipparchus.[66]

From Aratus's description of the constellation Draco (the Dragon), it appears that the observer is situated at about 37°N. The southernmost star, γ Draconis, the head of the Dragon, is seen to touch the horizon as the constellation appears to revolve around the heavens.[67] Since the declination of this star at that time was +53°, the angular distance of this star from the pole—37°—is equal to the latitude of the observer, in this case 37°N, the latitude of Athens according to Hipparchus (fig. 8.9).

In his versification of Eudoxus's *Phaenomena*, Aratus not only describes the geometry of the heavens with respect to the visible constellations but also compares the celestial circles to belts that could be linked together on a physical model.[68] Aratus presents the human figures and animals of the constellations in action and in motion

64. Aratus, *Phaenomena* in *Callimachus: Hymns and Epigrams; Lycophron; Aratus*, trans. A. W. Mair and G. R. Mair, Loeb Classical Library (Cambridge: Harvard University Press; London: William Heinemann, 1955), 185–299. See also Aratus, *Phaenomena*, ed. Jean Martin, Biblioteca di Studi Superiori: Filologia Greca 25 (Florence: Nuova Italia, 1956).

65. See G. R. Mair's introduction to his translation of Aratus's *Phaenomena* in *Callimachus: Hymns and Epigrams; Lycophron; Aratus*, 185–89 (note 64).

66. Hipparchus (ca. 190–post 126 B.C.) wrote a commentary on Eudoxus's and Aratus's *Phaenomena*; see *In Arati et Eudoxi Phaenomena commentariorum libri tres*, ed. C. Manitius (Leipzig: Teubner, 1894).

67. Aratus, *Phaenomena*, Mair edition, 211 (note 64). For the declination of γ Draconis see U. Baehr, *Tafeln zur Behandlung chronologischer Probleme*, Veröffentlichungen des Astronomischen Rechen-Instituts zu Heidelberg no. 3 (Karlsruhe: G. Braun, 1955), 58. For Hipparchus's commentary, see *In Arati et Eudoxi Phaenomena* 1.3.12 (note 66), and Dicks, *Geographical Fragments*, 134 (note 31).

68. Aratus, *Phaenomena*, Mair edition, 249 (note 64). A general discussion of celestial globes in antiquity appears in Edward Luther Stevenson, *Terrestrial and Celestial Globes: Their History and Construction, Including a Consideration of Their Value as Aids in the Study of Geography and Astronomy*, 2 vols., Publications of the Hispanic Society of America, no. 86 (New Haven: Yale University Press, 1921; reprinted New York and London: Johnson Reprint Corporation, 1971), 1:14–25. Stevenson's book is based largely on Matteo Fiorini, "Le sfere cosmografiche e specialmente le sfere terrestri," *Bollettino della Società Geografica Italiana* 30 (1893): 862–88, 31 (1894):

like living creatures, and their positions on the globe—and indeed their detailed outlines—are not pure fantasy: they provide a means of identifying the stars and personifying the sky.[69] A close knowledge of the constellations lies behind the poetic language of Aratus. The detailed description of the Dragon, for example, suggests that the stars had been precisely observed in the sky; the constellations are set in relation to one another, and their alignments are clearly explained.[70] We must conclude that the celestial globe of Eudoxus, accompanied by the treatise that described it, was an authentic instrument. It probably helped to conventionalize the figures of the constellations, which have been only slightly modified since Eudoxus's time, and it also gave the Greeks a taste for a mechanical interpretation of the universe.

Although Eudoxus's globe no longer exists, our understanding of its contribution to the development of celestial cartography, as transmitted to later cultures by the poem of Aratus, is enhanced through what is almost certainly a direct descendant. This is the celestial globe resting on the shoulders of a sculptured figure preserved in Naples, known as the Farnese Atlas (figs. 8.10 and 8.11). Although the actual statue dates from the late second century A.D., the style of execution of both the statue and the constellations shows that it is a copy of a Hellenistic original. Forty-three constellations are shown in the form of bas-relief figures (humans, animals, and objects) derived from the Aratus poem; their iconography has not substantially changed since. No individual stars are indicated. The southern sky—invisible from the Mediterranean world—is hidden by the supporting Atlas. At the same time, a cavity in the globe has obliterated the most northerly constellations. The globe was designed to be viewed from the exterior, so that the figures all face in toward the center. As in the Aratus poem, there is also a series of circles: the equator, the two arctic (ever-visible and never-visible) circles, and the two colures. Three oblique parallel circles represent the ecliptic and the zodiac, equally divided into twelve dodecatemories or signs. The intended positions of the arctic circles on this globe, and hence the inferred latitude at which the globe was designed to be used, have been the subject of controversy. The positions of the circles have been precisely measured, but at issue are the intended precision of a statue of this type, the positions of the certain stars (especially Draconis and Canopus) relative to the arctic circles, and the location of constellations in the zodiac relative to the solstitial and equinoctial points. A critical review of existing studies of the globe, together with its detailed reproduction and careful analysis, is urgently needed to resolve these questions.[71]

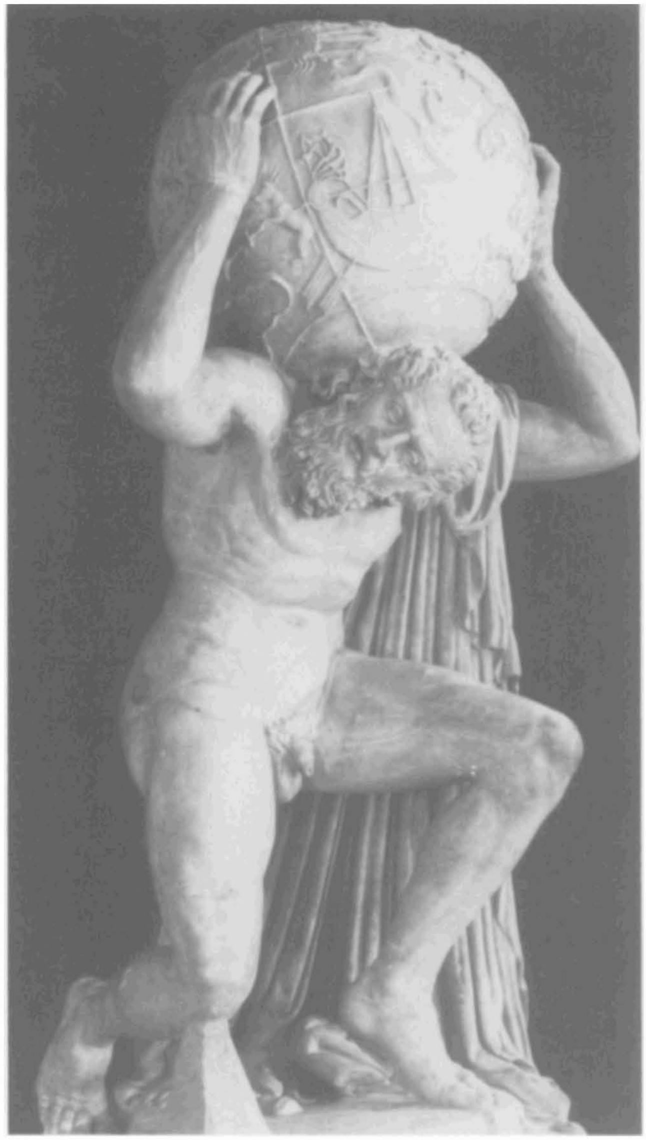


FIG. 8.10. THE FARNESE ATLAS. Originally belonging to the Farnese family, this is the best surviving example of a genre of statues depicting the mythical figure.
Height of the original: 1.9 m. By permission of the Museo Archeologico Nazionale, Naples.

121–32, 271–81, 331–49, 415–35, and Fiorini's *Sfere terrestri e celesti di autore italiano oppure fatte o conservate in Italia* (Rome: Società Geografica Italiana, 1899). A detailed analysis of Aratus's *Phaenomena* is given in Manfred Erren, *Die Phainomena des Aratos von Soloi: Untersuchungen zum Sach- und Sinnverständnis* (Wiesbaden: Franz Steiner, 1967), 159–200.

69. Dicks, *Early Greek Astronomy*, 158 ff. (note 1).

70. Aratus, *Phaenomena*, Mair edition, 211 (note 64).

71. Costanza Gialanella and Vladimiro Valerio, "Atlas Farnèse," in *Cartes et figures de la terre*, exhibition catalog (Paris: Centre Georges Pompidou, 1980), 84, cite several measurements based on an unpublished photogrammetric study by Valerio, as follows: The tropics are marked at 25°30′ on either side of the equator, the band of the zodiac is 13°30′ wide, and the arctic circles are 58° distant from the equator,

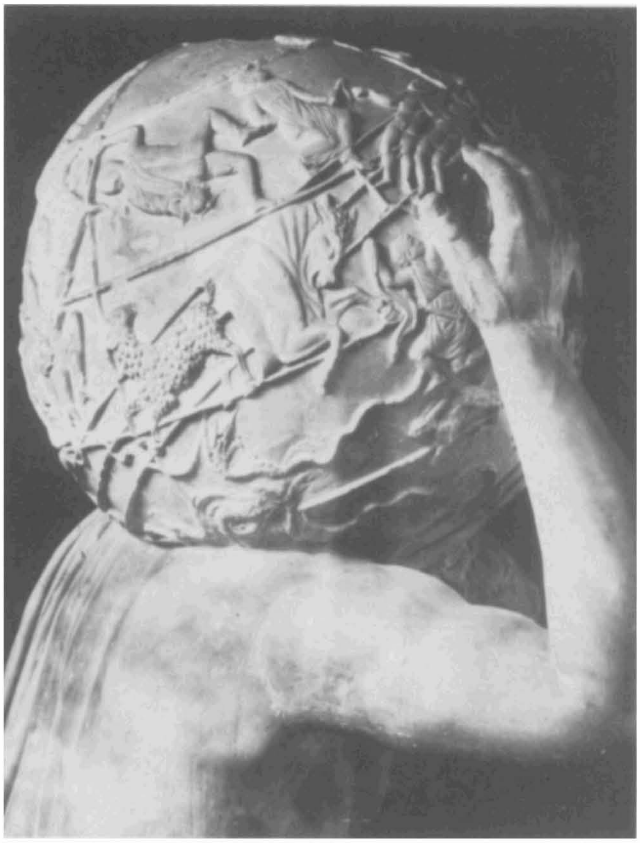


FIG. 8.11. DETAIL OF THE FARNESE ATLAS. The globe is probably an imitation of Eudoxus's globe and could have been used as an illustration of Aratus's poem.
Diameter of the globe: ca. 64 cm. By permission of the Museo Archeologico Nazionale, Naples.

It is possible that the globe carried by the Farnese Atlas was consciously sculpted as an illustration of Aratus's poem. The cartographic concepts developed by Eudoxus certainly appear to have had wide influence in the classical world: the globe was frequently copied, as was the poem itself, which was translated several times into Latin verse.[72] Both poem and sculpture must have helped to codify the iconography of the various constellations; the legends explaining their presence in the sky served as a mnemonic device, as did the solid graphic representation of the globe.

Eudoxus also wrote a *Circuit of the Earth* (*Periodos gēs*), now lost except for small fragments.[73] He was considered an authority, according to Strabo, in figures (σχημάτων) and in climata (κλιμάτων; latitudes);[74] this praise of his mathematical training and his astronomical skill was no doubt fully justified. The clue to his cartographic contribution lies in the word rendered as "figures," which suggests that his text was accompanied by outline maps of a geometric nature. As a result of these deliberations, and by modifying the estimate of Democritus, Eudoxus was led to consider the length of the inhabited world to be double its breadth.[75] It is perhaps a measure of his influence that this proportion was adopted in most of the maps in the ancient world that succeeded him.[76]

That a new cartographic image of the inhabited world was being adopted in some quarters by the fourth century B.C. is also suggested by the evidence we have for the map of the historian Ephorus (ca. 405–330 B.C.). His only known contribution is the compilation of a map to illustrate a theoretical geography of the world's peoples, but though he was a contemporary of Eudoxus, the exact nature of his map's construction and content remains partly conjectural. Ephorus was born in Cyme in the Aeolis, and he became a disciple of Isocrates (436–338 B.C.) and an accomplished writer. It is clear that he discussed many geographical questions in his *History* in thirty books, but these are now lost. Once again our knowledge of his cartographic ideas is filtered through the texts of later writers, in this case Strabo (ca. 64/63 B.C. to A.D. 21 or later) and, much later, in the writings of Cosmas Indicopleustes, a Nestorian Christian author of the sixth century A.D.[77]

indicating to them that the globe was designed for an observer at 32°N (the latitude of Alexandria). Other scholars believe that the tropics are intended to be 24°, and the arctic circles 54°, from the equator, pointing out that the star Canopus—at the tip of the rudder (steering oar) of the ship *Argo*—just touches the never-visible circle. This would suggest that the globe was intended for an observer at 36°. For a summary of earlier views of the globe, see Fiorini, *Sfere terrestri e celesti*, 9–25 (note 68).

72. The poem was translated by Cicero, Germanicus, and Avienius: Cicero, *Les Aratea*, ed. and trans. Victor Buescu (Bucharest, 1941; reprinted Hildesheim: Georg Olms, 1966), and *Aratea: Fragments poétiques*, ed. and trans. Jean Soubiran (Paris: Belles Lettres, 1972); Germanicus, *Les Phénomènes d'Aratos*, ed. André Le Boeffle (Paris: Belles Lettres, 1975); *The Aratus Ascribed to Germanicus Caesar*, ed. D. B. Gain (London: Athlone Press, 1976); and Avienius, *Les Phénomènes d'Aratos*, ed. and trans. Jean Soubiran (Paris: Belles Lettres, 1981.

73. Eudoxus *Die Fragmente*, ed. F. Lasserre (Berlin: Walter de Gruyter, 1966).

74. Strabo *Geography* 9.1.2 (note 9).

75. Agathemerus *Geographiae informatio* 1.2 (note 18).

76. This is shown by Geminus, writing in the first century B.C.: "The length of the inhabited world is just about twice its breadth; those who compose geographies according to scale make their drawings on oblong tablets"; translation by O. A. W. Dilke from Geminus *Introduction*, 16.3–4 (note 29).

77. Wanda Wolska, *La topographie chrétienne de Cosmas Indicopleustès: Théologie et science au VI^e siècle*, Bibliothèque Byzantine, Etudes 3 (Paris: Presses Universitaires de France, 1962), and Cosmas Indicopleustes *Topographie chrétienne*, ed. Wanda Wolska-Conus in

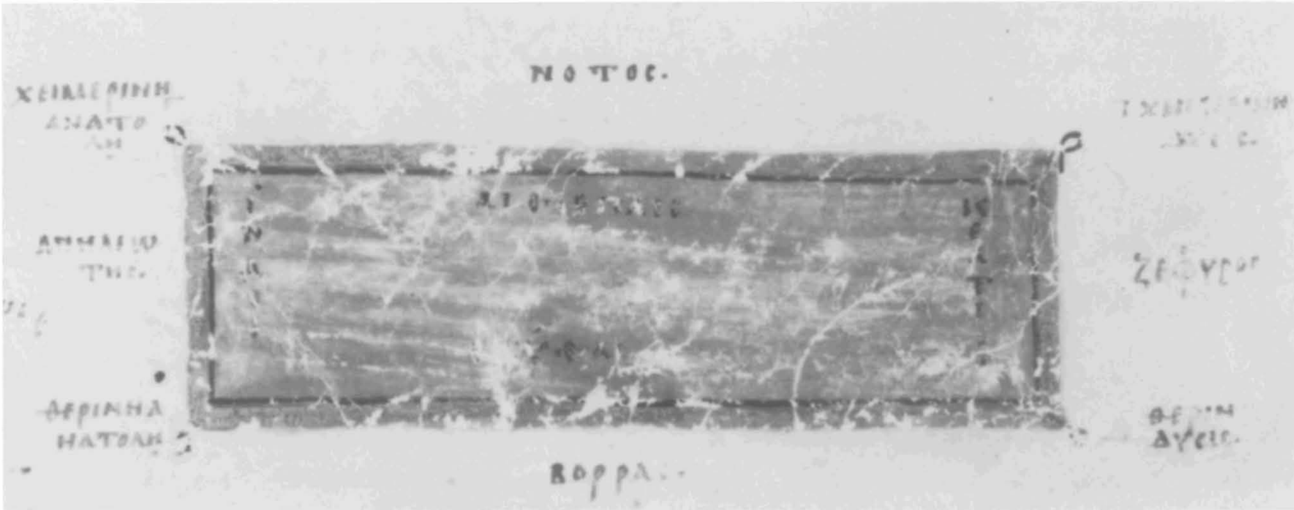


FIG. 8.12. COSMAS'S SCHEMATIC REPRESENTATION OF THE EARTH. An eighth/ninth-century version of a map drawn by Cosmas Indicopleustes (sixth century A.D.) according to the principles explained by Ephorus (ca. 405–330 B.C.).

Photograph from the Biblioteca Apostolica Vaticana, Rome (Vat. Gr. 699, fol. 19r).

It is thus from Strabo's *Geography* that we begin to glimpse the possible map of the world developed by Ephorus. In book 4 of Ephorus's *History*, the part dealing with Europe, says Strabo, we find the opinions of the ancients concerning Ethiopia: "Ephorus, too, discloses the ancient belief in regard to Ethiopia, for in his treatise *On Europe* he says that if we divide the regions of the heavens and of the earth into four parts, the Indians will occupy that part from which Apeliotes blows, the Ethiopians the part from which Notus blows, the Celts the part on the west, and the Scythians the part from which the north wind blows."[78] Ephorus had apparently added that Ethiopia and Scythia were the largest areas, because the Ethiopians seemed to extend from the winter rising to the winter setting, and the Scythians occupied the area from the summer rising to the summer setting.[79]

Cosmas Indicopleustes also quoted the passage of Ephorus from book 4 in full, adding a very interesting detail: Ephorus had stated his opinion "with the help of the enclosed drawings."[80] Indeed, the manuscript of Cosmas is illustrated by a rectangle showing the earth according to the principle explained above (fig. 8.12): the south is in the top part of the length of the rectangle, showing the Ethiopians; the north is in the lower part of its length, showing the Scythians; to the right on its breadth are Zephyrus and the Celts; and to the left are Apeliotes and the Indians. In this map it is clear that the center of such a rectangle—with the positions of summer and winter sunrise and sunset at its corners—must be Greece or the Aegean.

In summary, then, Ephorus included peoples peripheral to the known world in his theoretical geography. Their distance from the Aegean, or the climate in which they were thought to live, had rendered them mysterious and almost mythical. The map supplied by Ephorus, as reconstructed by Cosmas (although we cannot be quite sure how faithfully), similarly portrays the remote parts of the inhabited world. It is little more than a geometric sketch revealing a general ignorance of these regions. And it also brings home to us to what extent the Mediterranean basin had long remained the best-known part of the inhabited world and the most exactly drawn: distant lands were only vaguely delineated and were inserted into world maps by guesswork.

The culmination of the classical Greek period—at least in terms of a contemporary synthesis of cartography—is seen in the works of Aristotle (384–322 B.C.), teacher of Alexander the Great and founder of the Peripatetic School. Although Aristotle is rarely considered a geographer or a cartographic thinker, he had very definite ideas about the shape of the earth and the outline of the inhabited world. His teaching was ultimately significant for the development of cartography insofar as it not only rationalized the arguments for the sphericity of the earth, but also certainly encouraged the enlargement of the knowledge of the *oikoumene*, particularly

Sources Chrétiennes, nos. 141 (1968), 159 (1970), and 197 (1973). See also pp. 261–63.

78. Strabo *Geography* 1.2.28 (note 9).

79. With mainland Greece or Rhodes as the traditional place of observation, the equinoctial rising and setting of the sun are due east and due west; its summer rising is ENE; its summer setting, WNW; its winter rising ESE; its winter setting, WSW.

80. Cosmas *Topographie chrétienne* 2.80 (note 77), translation by O. A. W. Dilke.

through the Asian journeys and conquests of Alexander the Great.

Aristotle had no doubt at all that the earth was spherical.[81] He proved it by observations that we might make today: the shadow of the earth on the moon in eclipses of the moon is invariably circular, and one sees the celestial pole rising more and more above the horizon as one goes from south to north. Overarching is the idea that it is in the nature of earth and water to move to the center of the universe, since they are the heavy elements (as opposed to air and fire, which are light). He thus saw the natural shape of the earth as spherical.[82]

He also described the system of five zones on the earth that had earlier been introduced by Parmenides,[83] comparing each inhabitable zone on the sphere to a drum and ridiculing his contemporaries who held the earth to be circular: "For there are two habitable sectors of the earth's surface, one, in which we live, towards the upper pole, the other towards the other, that is the south pole. These sectors are drum-shaped—for lines running from the center of the earth cut out this shaped figure on the surface"[84] (fig. 8.13). He goes on to say: "The way in which present maps of the world are drawn is therefore absurd. For they represent the inhabited earth as circular, which is impossible both on factual and theoretical grounds."[85] He believed this view was theoretically impossible because of the geometry of the sphere and empirically impossible because of the proportions between the length of the inhabited world (from the Straits of Gibraltar, or Pillars of Hercules, to India) and its breadth (from Ethiopia to the Sea of Azov, ancient Palus Maeotis), which were more than 5:3. The breadth of the inhabited world, he believed, could not be extended by exploration because of climatic conditions, excessive heat or cold, while between India and the Straits of Gibraltar "it is the ocean which severs the habitable land and prevents it from forming a continuous belt around the globe."[86]

In the next chapter of the *Meteorologica*, which also helps us to understand in summary form some of the principles underlying the construction of the maps of that age, Aristotle uses a diagram (fig. 8.14) to show the relative positions of the winds: "The treatment of their position must be followed with the help of a diagram. For the sake of clarity, we have drawn the circle of the horizon; that is why our figure is round. And it must be supposed to represent the section of the earth's surface in which we live; for the other section could be divided in a similar way."[87] The circle represents the northern temperate zone; the circular horizon has a center where the observer stands, probably in Greece or the Aegean, as in the case of Ephorus's rectangular map. On its circumference are marked the points of the compass as he envisaged them: the equinoctial rising and setting (east

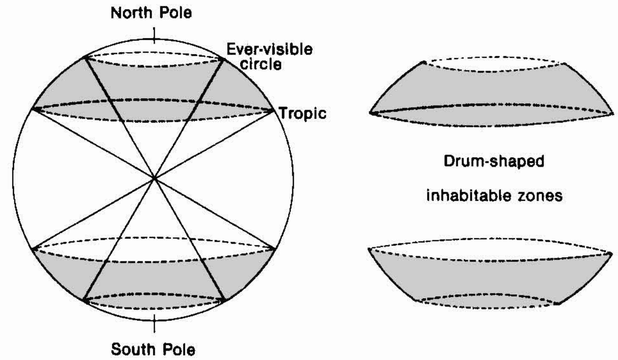


FIG. 8.13. ARISTOTLE'S CONCEPT OF THE POSITION AND SHAPE OF THE INHABITED WORLD. Reconstruction showing the five zones and the corresponding "drums."
After Aristotle, *Meteorologica*, ed. H. D. P. Lee, Loeb Classical Library (Cambridge: Harvard University Press; London: William Heinemann, 1952), 181.

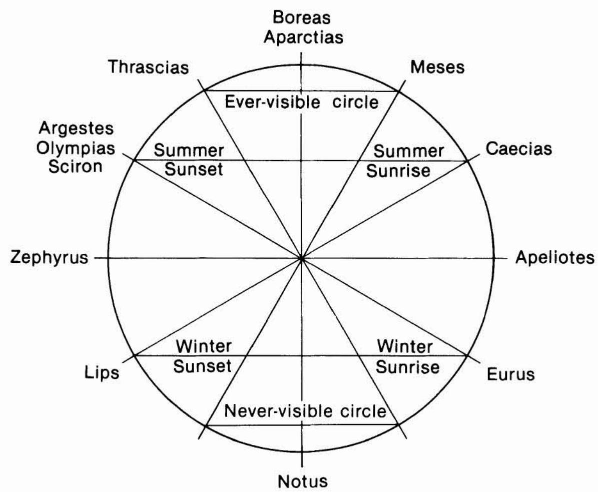


FIG. 8.14. ARISTOTLE'S SYSTEM OF THE WINDS. Reconstruction from the *Meteorologica* 2.6, showing the position of the winds at the summer and winter sunrise and sunset and the ever- and never-visible circles for an observer in Greece or the Aegean.
After Aristotle, *Meteorologica*, ed. H. D. P. Lee, Loeb Classical Library (Cambridge: Harvard University Press; London: William Heinemann, 1952), 187.

81. References are made to Aristotle's *Meteorologica* (note 28), and *De caelo*; see *On the Heavens*, trans. W. K. C. Guthrie, Loeb Classical Library (Cambridge: Harvard University Press; London: William Heinemann, 1939). See also Thomson, *History of Ancient Geography*, 118–21 (note 1).

82. Aristotle *On the Heavens* 2.14 (note 81).

83. According to Dicks, *Geographical Fragments*, 23 (note 31), there is some doubt about Parmenides' division of the earth into zones.

84. Aristotle *Meteorologica* 2.5.362a.33 (note 28).

85. Aristotle *Meteorologica* 2.5.362b (note 28).

86. Aristotle *Meteorologica* 2.5.362b (note 28).

87. Aristotle *Meteorologica* 2.6.363a (note 28). Modern editions of Aristotle reconstruct this diagram from his text rather than from a Madrid manuscript of the twelfth century, for which see Charles Graux

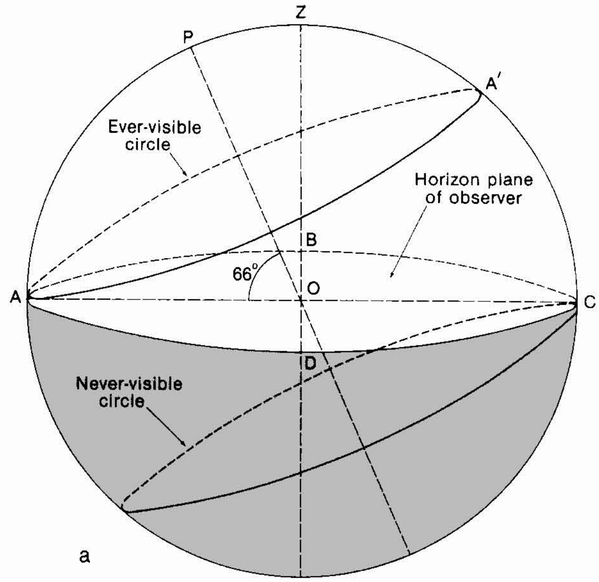
and west), the summer and winter risings and settings (about ENE, WNW, ESE, WSW), north and south. The winds are named according to the directions from which they blow and are diametrically opposed. But Aristotle adds two more winds (about NNE and NNW) that have no named opposites; the chord between them almost corresponds to the "ever-visible circle." Such a schema for the winds, with many modifications, was later to find its way into the paraphernalia of the navigator and cartographer even into the Renaissance period, as chapters 18 and 19 demonstrate.

It is clear that Aristotle's teaching was based on a geocentric hypothesis: the sphere of the fixed stars turns in regular motion on an axis going through the earth, which serves as the center of the celestial sphere. He maintained this hypothesis against others already formulated, which he claimed gave less satisfactory results.[88] Like Eudoxus, he subscribed to the theory of homocentric spheres to explain the apparently irregular movements of the planets, yet his attribution of a physical reality to Eudoxus's general system was to raise as many questions as it answered in the attempt to understand the celestial mechanism.

APPENDIX 8.1
DEFINITIONS OF SOME BASIC TERMS RELATING TO THE CELESTIAL SPHERE

The celestial equator is the celestial great circle whose plane is perpendicular to the axis of the earth; it is the path that the sun seems to describe in its diurnal revolution at the equinoxes. The tropics are two circles parallel to the equator and tangent to the ecliptic; they are the apparent path of the sun in its diurnal rotation on solstitial days.

The zodiac was—for the ancients—an oblique band twelve degrees wide in which the planets appear to move; the ecliptic, the median circle of the zodiac, is the great oblique circle that the sun seems to describe in its annual motion. The colures are two great circles drawn through the poles and the equinoctial or solstitial points; they are perpendicular to one another (see fig. 8.8).



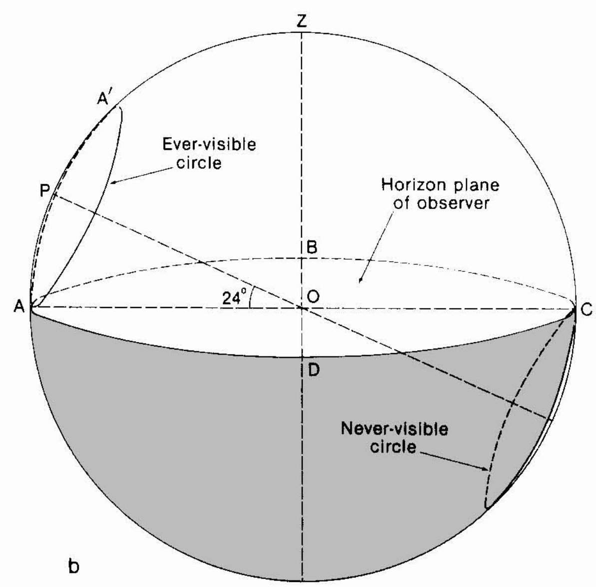


FIG. 8.15. THE "EVER-VISIBLE CIRCLE" AT 66°N (*a*) AND AT 24°N (*b*). The terrestrial globe is an infinitesimal point, O, which also corresponds to the position of the observer. Z is the observer's zenith, ABCD the observer's horizon. The shaded portion of the sky is invisible to the observer. As the stars on the celestial sphere rotate about the celestial pole, P, those above the circle AA′ do not intercept the horizon and thus do not appear to rise or set. In (*a*) the circle AA′ is the ever-visible circle for an observer on the Arctic Circle, latitude 66°N. In (*b*), the circle AA′ is the ever-visible circle for an observer at latitude 24°N (see also fig. 10.6).
After Geminus, *Introduction aux phénomènes*, ed. and trans. Germaine Aujac (Paris: Belles Lettres, 1975).

and Albert Martin, "Figures tirées d'un manuscrit des *Météorologiques* d'Aristote," *Revue de Philologie, de Littérature et d'Histoire Anciennes*, n.s., 24 (1900): 5–18. For the connection between this reconstruction and the Pesaro anemoscope see p. 248 and n. 81.

88. Aristotle *On the Heavens* 2.13.293a ff. (note 81). The Pythagoreans had imagined a cosmic system with fire in the center; the earth and the sun moved around it. But the geocentric hypothesis allowed men to study the terrestrial globe geometrically, by reference to the celestial sphere. See Germaine Aujac, "Le géocentrisme en Grèce ancienne?" in *Avant, avec, après Copernic: La représentation de l'univers et ses conséquences epistémologiques*, Centre International de Synthèse, 31ᵉ semaine de synthèse, 1–7 June 1973 (Paris: A. Blanchard, 1975), 19–28.

The arctic circle in the ancient Greek sense is different from our Arctic Circle and varies according to the latitude of the place of observation. It is defined as the limit of the ever-visible stars for a particular latitude. By corollary, the antarctic circle for any given latitude is the limit of never-visible stars. It can be shown that the angular distance of both these circles from the pole is equal to the angular distance of the terrestrial equator from the place of observation (i.e., the latitude). At the terrestrial equator, the ever-visible or arctic circle has no radius; thus all stars rise and set for an observer there. At the North Pole the ever-visible circle is coincident with the observer's horizon; one-half only of the celestial sphere is thus always visible. To an observer on the Arctic Circle (66°N), the arctic circle coincides with the summer tropic of the celestial sphere (fig. 8.15*a*). To an observer at the tropic (24°N) the arctic circle is 24° distant from the celestial pole and coincides with the polar circle on the celestial sphere (fig. 8.15*b*).[1]

1. On the arctic circles, see *The Geographical Fragments of Hipparchus*, ed. D. R. Dicks (London: Athlone Press, 1960), 165–66.

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Chapter 8 The Foundations of Theoretical Cartography in Archaic and Classical Greece

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