9 · The Growth of an Empirical Cartography in Hellenistic Greece

PREPARED BY THE EDITORS FROM MATERIALS SUPPLIED BY GERMAINE AUJAC

There is no complete break between the development of cartography in classical and in Hellenistic Greece. In contrast to many periods in the ancient and medieval world, we are able to reconstruct throughout the Greek period—and indeed into the Roman—a continuum in cartographic thought and practice. Certainly the achievements of the third century B.C. in Alexandria had been prepared for and made possible by the scientific progress of the fourth century. Eudoxus, as we have seen, had already formulated the geocentric hypothesis in mathematical models; and he had also translated his concepts into celestial globes that may be regarded as anticipating the *sphairopoiia*.[1] By the beginning of the Hellenistic period there had been developed not only the various celestial globes, but also systems of concentric spheres, together with maps of the inhabited world that fostered a scientific curiosity about fundamental cartographic questions. The relative smallness of the inhabited world, for example, later to be proved by Eratosthenes, had already been dimly envisaged. It had been the subject of comment by Plato,[2] while Aristotle had quoted a figure for the circumference of the earth from "the mathematicians" at four hundred thousand stades.[3] He does not explain how he arrived at this figure, which may have been Eudoxus's estimate. Aristotle also believed that only the ocean prevented a passage around the world westward from the Straits of Gibraltar to India.

In spite of these speculations, however, Greek cartography might have remained largely the province of philosophy had it not been for a vigorous and parallel growth of empirical knowledge. Indeed, one of the salient trends in the history of Hellenistic cartography is the growing tendency to relate theories and mathematical models to newly acquired facts about the world—especially those gathered in the course of Greek exploration or embodied in direct observations such as those recorded by Eratosthenes in his scientific measurement of the circumference of the earth. Despite a continuing lack of surviving maps and original texts throughout the period—which continues to limit our understanding of the changing form and content of cartography—it can be shown that by its end a markedly different cartographic image of the inhabited world had emerged.

That such a change should occur is due both to political and military factors and to cultural developments within Greek society as a whole. With respect to the latter, we can see how Greek cartography started to be influenced by a new infrastructure for learning that had a profound effect on the growth of formalized knowledge in general. Of particular importance for the history of the map was the growth of Alexandria as a major center of learning, far surpassing in this respect the Macedonian court at Pella. It was at Alexandria that Euclid's famous school of geometry flourished in the reign of Ptolemy II Philadelphus (285–246 B.C.). And it was at Alexandria that this Ptolemy, son of Ptolemy I Soter, a companion of Alexander, had founded the library, soon to become famous throughout the Mediterranean world. The library not only accumulated the greatest collection of books available anywhere in the Hellenistic period but, together with the museum, likewise founded by Ptolemy II, also constituted a meeting place for the scholars of three continents. Demetrius of Phalerum (b. ca. 350 B.C.), Athenian statesman, writer, and disciple of Aristotle, had been asked to start the library, which was endowed with many scientific works

1. See chapter 8, "The Foundations of Theoretical Cartography in Archaic and Classical Greece," p. 136 and n. 33.

2. Plato (ca. 429–347 B.C.) was conscious of the relative smallness of the inhabited world on the surface of the globe; see above, p. 137.

3. Aristotle *On the Heavens* 2.14.298a.15 ff; see *On the Heavens*, trans. W. K. C. Guthrie, Loeb Classical Library (Cambridge: Harvard University Press; London: William Heinemann, 1939) and *The Geographical Fragments of Hipparchus*, ed. D. R. Dicks (London: Athlone Press, 1960), 24.

The stade, στάδιον, in origin the distance covered by a plow in a single draft, consisted of 600 Greek feet; but the length of a foot was subject to some local variation in the Greek world. Some authors take the modern equivalent of a stade to be 185 meters or 607 feet; see Jacob Skop, "The Stade of the Ancient Greeks," *Surveying and Mapping* 10 (1950): 50–55, and Dicks, *Geographical Fragments*, 42–46 (above). Other authors disagree and cite 148–58 meters; see Irene Fischer, "Another Look at Eratosthenes' and Posidonius' Determinations of the Earth's Circumference," *Quarterly Journal of the Royal Astronomical Society* 16 (1975): 152–67, and Dennis Rawlins, "The Eratosthenes-Strabo Nile Map," *Archive for History of Exact Sciences* 26 (1982): 211–19. In view of this controversy, the authors and editors have deliberately avoided using modern equivalents for the stade throughout the *History*.

and quickly increased in size. The librarians not only brought together existing texts, they corrected them for publication, listed them in descriptive catalogs, and tried to keep them up to date.[4] Thus Alexandria became a clearinghouse for cartographic and geographical knowledge; it was a center where this could be codified and evaluated and where, we may assume, new maps as well as texts could be produced in parallel with the growth of empirical knowledge.

Exploration and Discovery in the Reform of the World Map

The other great factor underlying the increasing realism of maps of the inhabited world in the Hellenistic period was the expansion of the Greek world through conquest and discovery, with a consequent acquisition of new geographical knowledge. In this process of strengthening the empirical content of maps the conquests of Alexander the Great, king of Macedon (356–323 B.C.), were especially crucial in providing the Greeks with a far more detailed knowledge of the East than previously had been possible. There is no doubt that Alexander had been influenced by existing geographical lore, some of it expressed in map form and was to contribute substantially to Greek understanding of this Eastern world. In taking up the plan originally conceived by his father Philip to organize an attack against Persia, he was certainly not unprepared. He had been taught by Aristotle and had learned from him that the inhabited world, from the Straits of Gibraltar to India, was relatively small and probably bounded by the ocean. This was clear to the geographers of the period, just as was the fact that the western part of the known world was bounded by the Atlantic Ocean. This belief explains why Alexander not only wanted to explore the whole of the inhabited world east of the Aegean, but also had a firm hope of reaching the Eastern Ocean, the existence of which had not so far been witnessed by the Greeks.

He thus instructed his secretaries to prepare a brief for the journey in great detail and to gather all available information about the countries he would cross. Xenophon had recently described Asia Minor, and Ctesias of Cnidus had described Persia and India.[5] No doubt Alexander collected all kinds of maps, general sketches of the inhabited world or regional maps indicating the main roads through the country, especially Persia, where the roads were very well organized, with posting stations at regular intervals.[6]

It is also clear that the whole expedition was planned with the deliberate aim of expanding existing geographical knowledge. Alexander took a large group of scholars with him—zoologists, doctors, historians, and surveyors—to compile a complete account of all interesting phenomena observed on the way and to verify all information that had been furnished by others. So Eumenes of Cardia (ca. 362–316 B.C.) was entrusted with keeping the daily report of the expedition and wrote *Ephemerides*, used by later historians but now lost. The so-called *bematistai*,[7] Baito and Diognetus, had to keep the record of every distance between halting places and to describe the geographical features—fauna, flora, nature of the soil, and landscape—of each country. The importance of the *bematistai* to the history of mapping is that their *Itinerary* was probably illustrated by sketches or local maps. The whole expedition, in fact, became a most important primary source of new cartographic data.[8] Its topographical notes were drawn on by such later geographers as Isidorus of Charax (fl. ca. A.D. 25).

The information collected by Alexander's expedition was of course greatly influenced by the vagaries of its progress; in no sense can it be regarded as systematic or even reconnaissance mapping—in the modern sense—of the areas traversed. In fact Alexander was prevented from carrying out his original plan by his soldiers, who refused to cross the Indus River and continue east to the external ocean. But he decided to explore at least the Indian (Southern) Ocean, so he sailed down the Indus to the sea. There he split up his troops into three contingents: one of them, under Nearchus, was to sail toward Babylon through the Indian Ocean and the Persian Gulf; another contingent, under Alexander himself, was to go by land along the coast, to support the fleet if necessary; the rest of the army was to return to Babylon by a route farther north.[9] So at least some of the country between the Aegean Sea, the Taurus Mountains, the Indus River, and the Indian Ocean was explored as a result of Alexander's expedition.

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4. This perhaps explains the complete loss of scientific works of previous periods: they were considered out of date and were replaced by more recent manuscripts. For a description of the library, see Edward Alexander Parson, *The Alexandrian Library: Glory of the Hellenic World* (Amsterdam, London, New York: Elsevier Press, 1952).

5. Xenophon (ca. 430–354 B.C.) had been in charge of the army of mercenaries after Cyrus's death in Cunaxa; he led it through Asia Minor to the Black Sea. His *Anabasis* is the story of this expedition. Ctesias of Cnidus, who was a physician at Artaxerxes' court (he was with him at Cunaxa), wrote a history of Persia, *Persica*, in twenty-three volumes and a history of India, *Indica*, now both lost.

6. Herodotus *History* 5.52–54; see *The History of Herodotus*, trans. George Rawlinson, 2 vols. (London: J. M. Dent; New York: E. P. Dutton, 1910).

7. The *bematistai* had to measure (*bematizein*) the progress of the army every day, but the word itself is not found in this context.

8. For details on Alexander's expeditions, see William Woodthorpe Tarn, *Alexander the Great*, 2 vols. (Cambridge: Cambridge University Press; New York: Macmillan, 1948).

9. Nearchus's periplus is recorded in Arrian's *Indica*, and the whole expedition in Arrian's *Anabasis*.

Later geographers used the accounts of Alexander's journeys extensively to make maps of Asia and to fill in the outline of the inhabited world. The ambition of Eratosthenes to draw a general map of the *oikoumene* based on new discoveries was also partly inspired by Alexander's exploration.[10]

Among the contemporaries of Alexander was Pytheas, a navigator and astronomer from Massalia (Marseilles), who as a private citizen embarked upon an exploration of the oceanic coasts of western Europe. In his treatise *On the Ocean*, Pytheas relates his journey and provides geographical and astronomical information about the countries he observed. This treatise is now lost and is known to us only in fragments through comments made by several later writers whom Strabo quotes. Some of these writers, among whom was Polybius, regarded Pytheas as a liar, a view shared by Strabo himself.[11] It was already well known by Pytheas's time that the continental interior of Europe just north of the Black Sea was extremely cold. Given this, the reports by Pytheas that high latitudes of the Atlantic seaboard were habitable must have been indeed hard to believe.

It is difficult to reconstruct from the fragmentary evidence exactly where Pytheas traveled. While modern scholars agree that the voyage took place, they are not in agreement on its extent, particularly north of the British Isles.[12] Neither are they agreed on exactly when it took place, although the evidence seems to point toward a date between 325 and 320 B.C.[13] It seems, though, that having left Massalia, Pytheas put into Gades (Cádiz), then followed the coasts of Iberia and France to Brittany, crossing to Cornwall and sailing north along the west coast of England and Scotland to the Orkney Islands. From there, some authors believe, he made an Arctic voyage to Thule (probably Iceland) after which he penetrated the Baltic.[14] The confirmation of the sources of tin (in the ancient Cassiterides or Tin Islands) and amber (in the Baltic) was of primary interest to him, together with new trade routes for these commodities.[15]

For the first part of his voyage, from Massalia to Tartessus, Pytheas may have used a version of an ancient Greek geographical description of these coasts known as the *Massaliote Periplus*—it was almost certainly compiled in Massalia—dating probably from about 500 B.C. We know of this periplus through the *Ora Maritima* of the Roman antiquary Rufius Festus Avienius some nine hundred years later. Avienius's work can be traced back to a second-century B.C. version associated with a person known as Pseudo-Scymnus and—from the archaic toponymy and omission of authors later than Thucydides —further back to the fifth century B.C.[16]

While Pytheas's reports of the northern lands branded him as a liar, his skill in mathematics was more widely acknowledged. Eratosthenes and Timaeus both respected his contribution to the world map, although their views are muted by Strabo's prejudiced account.[17] Pytheas was in fact a skilled astronomer who succeeded in establishing the exact position of the celestial pole, a point in the sky not marked by a star, but which, along with three faint stars, makes up a rectangle.[18] He also accurately fixed the latitude of Marseilles, indicating that at midday on the date of the summer solstice "the ratio of the index [gnomon] of the sun-dial to the shadow . . . is that of one hundred and twenty to forty-two minus one-fifth."[19] We can calculate from this the difference in latitude between Marseilles and the summer tropic as 19°12′, compared with its currently measured value of about 19°50′ (fig. 9.1).[20]

10. Strabo *Geography* 1.2.1; 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). See also Strabo, *Géographie*, ed. Germaine Aujac et al. (Paris: Belles Lettres, 1966–).

11. Strabo *Geography* 1.4.3, 2.4.1, 4.2.1 (note 10).

12. The standard edition of Pytheas is *Fragmenta*, ed. Hans Joachim Mette (Berlin: Walter de Gruyter, 1952). More recent work includes C. F. C. Hawkes, *Pytheas: Europe and the Greek Explorers*, Eighth J. L. Myres Memorial Lecture (Oxford: Blackwell, 1977), which is an excellent modern summary of the issues surrounding Pytheas's voyage with a helpful bibliography, and the articles of Roger Dion, especially his, "Où Pythéas voulait-il aller?" in *Mélanges d'archéologie et d'histoire offerts à André Piganiol*, 3 vols., ed. Raymond Chevallier (Paris: SEVPEN, 1966), 3:1315–36.

13. Hawkes, *Pytheas*, 44 (note 12) dates it 325 B.C.

14. For various views, see J. Oliver Thomson, *History of Ancient Geography* (Cambridge: Cambridge University Press, 1948; reprinted New York: Biblo and Tannen, 1965), 149, and Hawkes, *Pytheas*, 33–39 and map 9 (note 12).

15. Hawkes, *Pytheas*, 1–2 (note 12).

16. Hawkes, *Pytheas*, 17–22 and map 6 (note 12). Editions of Avienius's *Ora Maritima* include *Avieni Ora Maritima (Periplus Massiliensis saec. VI. a.C.)*, ed. Adolf Schulten, Fontes Hispaniae Antiquae, fasc. 1 (Barcelona: A. Bosch, 1922), and his companion book *Tartessos: Ein Beitrag zur ältesten Geschichte des Westens* (Hamburg: L. Friederichsen, 1922); *Ora Maritima*, ed. Edward Adolf Sonnenschein (New York: Macmillan, 1929); *Ora Maritima*, ed. André Berthelot (Paris: H. Champion, 1934); and *Ora Maritima, or a Description of the Seacoast from Brittany Round to Massilia*, ed. J. P. Murphy (Chicago: Ares, 1977). For the transmission of this periplus, Hawkes agrees with the views of Schulten, *Avieni Ora Maritima* and *Tartessos*. For references to commentaries on Schulten's work, see Hawkes, *Pytheas*, 20 n. 52 (note 12). On the influence of Carthaginian knowledge of coasts west of the Straits of Gibraltar transmitted to the Greeks at this time, see Jacques Ramin, *Le Périple d'Hannon/The Periplus of Hanno*, British Archaeological Reports, Supplementary Series 3 (Oxford: British Archaeological Reports, 1976).

17. See footnote 11 above, for example, and Strabo *Geography* 3.4.4, 4.2.1, 7.3.1 (note 10).

18. Hipparchus, *In Arati et Eudoxi Phaenomena commentariorum libri tres*, ed. C. Manitius (Leipzig: Teubner, 1894), 1.4.1. See also Dicks, *Geographical Fragments*, 171 (note 3). Hawkes, *Pytheas*, 44–45 (note 12) misinterprets Dicks in thinking that the Pole Star (α Ursae Minoris) was one of the four stars in the rectangle.

19. Strabo *Geography* 2.5.41 (note 10).

20. It is important to realize that Pytheas would not have arrived at the true value for the latitude of Marseilles using the method outlined

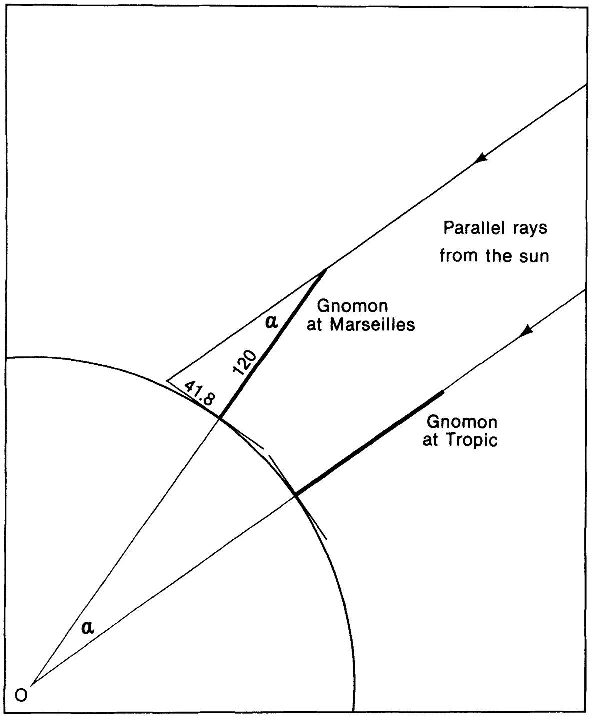

FIG. 9.1. PYTHEAS'S OBSERVATION OF THE LATITUDE OF MARSEILLES. In this diagram, O is the center of the earth and α is 19°12′.

His route took him through a wide latitudinal range, and, observing how celestial phenomena and the length of day varied as he moved northward, Pytheas seems to have been the first author to relate systematically the latitude of a place to the length of its longest day, or to the height of the sun at the winter solstice.[21] Building on such observations, he also became the first to use parallels of latitude, drawn on the earth's sphere, to indicate all the places where identical astronomical phenomena could be observed. It is probable, however, that Pytheas indicated the height of the sun at the winter solstice for various latitudes not through observation, but by calculation with the help of geometry. If at least one of the results given by calculation could be empirically checked, then all results of the same series would be reliable. The very short summer nights Pytheas encountered in northern Europe made him confident about the link between latitude and the length of solstitial days. Hence the length of the solstitial day in a place became the usual way of indicating its latitude. The geometry of the sphere had also taught Pytheas that there existed on the earth a parallel of latitude where, at the summer solstice, the day lasted twenty-four hours and the sun did not disappear under the horizon. He located the island of Thule on this particular circle,[22] where—as he put it—"the [celestial] arctic circle coincides with the [celestial] summer tropic."[23] He did not hesitate to put Thule on the northern boundary of the temperate zone, that is, on our Arctic Circle.

It would appear from what is known about Pytheas's journeys and interests that he may have undertaken his voyage to the northern seas partly in order to verify what geometry (or experiments with three-dimensional models) had taught him. The result was that his observations served not merely to extend geographical knowledge about the places he had visited, but also to lay the foundation for the scientific use of parallels of latitude in the compilation of maps. But it must also be admitted, as Hawkes has suggested, that there may have been wider economic and political motives for the voyage. Detailed information on the inhabitants and resources of the northern lands would have been of interest, for example, to a campaigner of the stature of Alexander. Alexander's death in 323 B.C. would have prevented this information from being fully exploited[24] and, instead, the work became largely the target of derision for later commentators.[25]

As exemplified by the journeys of Alexander and Pytheas, the combination of theoretical knowledge with

in figure 9.1, since the trigonometric methods necessary to convert the gnomon relationship to degrees were not available until Hipparchus. Some authors have added the value of 19°12′ to the obliquity of the ecliptic as then calculated (24°), to arrive at a figure of 43°12′ for the latitude of Marseilles; but this ignores fully half a degree in the difference between the ancient and present values in the obliquity of the ecliptic. See Dicks, *Geographical Fragments*, 178–79, 188 (note 3).

21. Hipparchus is reported as noticing, for instance, that in the latitude of Celtica and the mouth of the Borysthenes (Dnieper River) the sun rose to only nine cubits (eighteen degrees, the astronomical cubit being two degrees): Strabo *Geography* 2.1.18 (note 10); cf. Dicks, *Geographical Fragments*, 188 (note 3). At that latitude, the longest day had sixteen equinoctial hours: Strabo *Geography* 2.5.42 (note 10). Strabo also reports the following observations relating the length of the longest day to the maximum height of the sun in cubits at the winter solstice:

17 hours	6 cubits	(= 12°)
18 hours	4 cubits	(= 8°)
19 hours	3 cubits	(= 6°)

Strabo *Geography* 2.1.18 and elsewhere (note 10).

22. For the Greeks of this time, since the tropics were reckoned as being roughly 24° distant from the equator, the Arctic Circle (in the modern sense) lay on the parallel 66°N. See Thomson, *History of Ancient Geography*, 153 (note 14). Oenopides of Chio was the first to mention one-fifteenth of a circle (or 24°) for the obliquity of the ecliptic; it was some time before it was applied to cartography.

23. Strabo *Geography* 2.5.8 (note 10). Translation by O. A. W. Dilke.

24. Hawkes, *Pytheas*, 44 (note 12) mentions Alexander's supposed plans discovered at his death to conquer Carthage and to explore the western part of the inhabited world, by land and by sea, to the Straits of Gibraltar (Pillars of Hercules) and the Atlantic (Western) Ocean. Other authors, including Tarn, *Alexander the Great*, 2:376 (note 8), regard these "plans" as later inventions to glorify his reputation further.

25. Hawkes, *Pytheas*, 45 (note 12).

direct observation and the fruits of extensive travel gradually provided new data for the compilation of world maps. While we can assume a priori that such a linkage was crucial to the development of Hellenistic cartography, there is no hard evidence, as in so many other aspects of its history, that allows us to reconstruct the technical processes and physical qualities of the maps themselves. Not even the improved maps that resulted from these processes have survived, and the literary references to their existence (enabling a partial reconstruction of their content) can even in their entirety refer only to a tiny fraction of the number of maps once made and once in circulation. In this case too, our generalizations are founded on the chance survival of references made by individual authors to maps.

First in this category, and roughly contemporaneous with both Alexander and Pytheas, is the map undertaken by Dicaearchus of Messana (Messina) (fl. ca. 326–296 B.C.). A pupil of Aristotle and a contemporary of Theophrastus (ca. 370–288/285 B.C.), Dicaearchus is acknowledged both by ancient writers and by modern historians of cartography and geography to have made a significant contribution.[26] Strabo puts him, with Democritus, Eudoxus, and Ephorus, among philosophers of the second age who were responsible for considerable advances in geographical science.[27] We know that he spent most of his life in the Peloponnese, especially at Sparta, and wrote various works on politics, literature, history, and philosophy.

In his *Circuit of the Earth* (*Periodos gēs*), now lost, Dicaearchus included a map and a description of the inhabited world. Like Democritus, he thought that the known inhabited world was half again as long as it was broad, a proportion of three to two.[28] Strabo, following Polybius, criticizes some distances supplied by Dicaearchus, such as the ten thousand stades from the Peloponnese to the Straits of Gibraltar, or the estimate of over ten thousand stades from the Peloponnese to the head of the Adriatic Sea.[29] Strabo, questioning these figures, criticizes Dicaearchus for having underestimated the length of the inhabited world and overestimated its breadth.

The main cartographic innovation pioneered by Dicaearchus seems to have been the insertion on a map, possibly for the first time, of two lines representing a parallel and a meridian to divide the known world.[30] According to Agathemerus, the parallel drawn by Dicaearchus, albeit somewhat imperfectly, extended eastward from the Straits of Gibraltar. It passed through Sardinia, Sicily, Caria, Lycia, Pamphylia, Cilicia, and along the Taurus range as far as Mount Himaeus (the Himalayas) (fig. 9.2).[31] Various authors have stated that Dicaearchus applied the term *diaphragma* to this arrangement in the sense of a division of the inhabited world into two parts north and south of this line.[32] It represented an attempt to give his map an east-west coordinate axis crossed by a perpendicular meridian passing approximately through Rhodes. As we shall see, Eratosthenes, working a century later, took up the idea and developed it much further.

Another step toward geographical reality reflected in Dicaearchus's map was that he sketched in the eastward extension of the Taurus Mountains along a parallel, unlike earlier terrestrial maps in which the eastern part of the chain deviated considerably to the north.[33] Eratosthenes, although wanting to make a complete revision of these early geographical maps, was to follow his idea that the Taurus Mountains stretched in a straight course on the parallel of Athens.[34]

Half a century or so later than Dicaearchus, Timosthenes of Rhodes (fl. 270 B.C.) showed the same willingness to modify the early maps rather than to copy

26. See, for example, Armando Cortesão, *History of Portuguese Cartography*, 2 vols. (Coimbra: Junta de Investigações do Ultramar-Lisboa, 1969–71), 1:76–77, and Thomson, *History of Ancient Geography*, 153–54 (note 14).

27. Strabo *Geography* 1.1.1 (note 10). Homer, Anaximander, and Hecataeus are given as representatives of the first age, and the third age comprises Eratosthenes, Polybius, and Posidonius.

28. Agathemerus *Geographiae informatio* 1.2, in *Geographi Graeci minores*, ed. Karl Müller, 2 vols. and tabulae (Paris: Firmin-Didot, 1855–56), 2:471–87, esp. 471.

29. Strabo *Geography* 2.4.2 (note 10). A criticism by John of Lydia, that Dicaearchus made the Nile "flow uphill" from the Atlantic, may be due to a slight misunderstanding. John of Lydia *Liber de mensibus* 4; see the edition by Richard Wünsch (Leipzig, 1898), 147. For an explanation of the controversy concerning the modern value of the stade, see note 3.

30. Despite the view of Aubrey Diller, "Dicaearchus of Messina," in *Dictionary of Scientific Biography*, 16 vols., ed. Charles Coulston Gillispie (New York: Charles Scribner's Sons, 1970–80), 4:81–82, there is no hard evidence for either Dicaearchus or Eudoxus as measuring "a long arc north from Syene (Aswan) and observing the zenith points at the ends." He is referring, no doubt, to the passage by Cleomedes concerning the distance between Syene and Lysimachia (near the Hellespont, or Dardanelles): Cleomedes *De motu circulari* 1.8.44–43; see *De motu circulari corporum caelestium libri duo*, ed. H. Ziegler (Leipzig: Teubner, 1891). But William Arthur Heidel, *The Frame of the Ancient Greek Maps* (New York: American Geographical Society, 1937), 113–19, summarizes the question thoroughly, pointing out that Cleomedes "gives no intimation to whom we should credit this estimate" (p. 115).

31. Agathemerus *Geographiae informatio* 1.5 (note 28).

32. Cortesão, *History of Portuguese Cartography*, 1:77 (note 26); Thomson, *History of Ancient Geography*, 134 (note 14). Bunbury, as Cortesão points out, finds no evidence that Dicaearchus used the term; see 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), 2:628 n. 6.

33. Strabo *Geography* 2.1.2 (note 10).

34. Strabo *Geography* 2.1.1–2 (note 10).

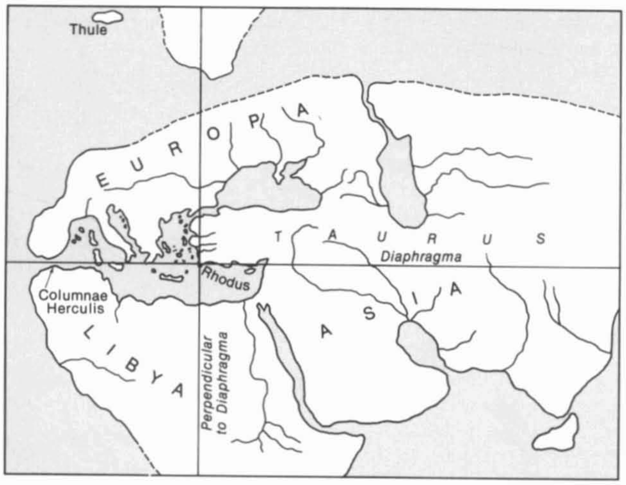

FIG. 9.2. RECONSTRUCTED WORLD MAP OF DICAEARCHUS, THIRD CENTURY B.C. The inhabited world is divided by the diaphragm (approximately 36°N) and a perpendicular to this at Rhodes.
After Armando Cortesão, *History of Portuguese Cartography*, 2 vols. (Coimbra: Junta de Investigações do Ultramar-Lisboa, 1969–71), vol. 1, fig. 16.

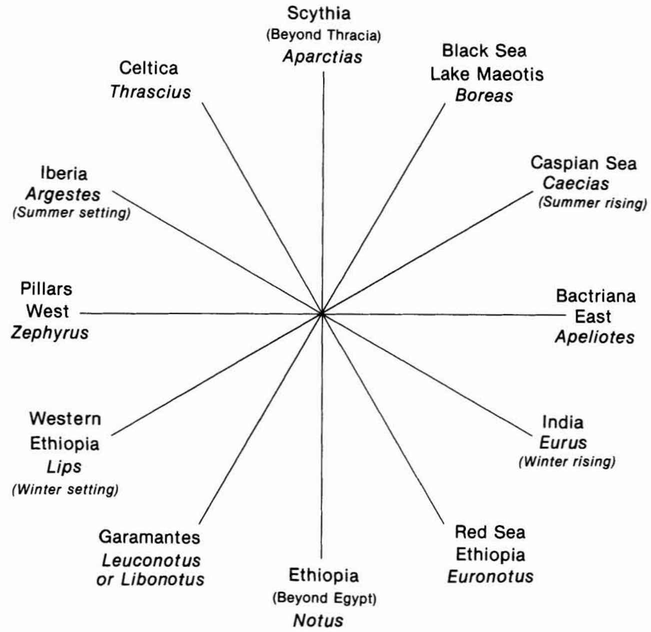

FIG. 9.3. TIMOSTHENES' SYSTEM OF THE WINDS. The relationship between winds, regions, and peoples as proposed by Admiral Timosthenes of Rhodes (third century B.C.).

them slavishly. Timosthenes, as an admiral of Ptolemy II Philadelphus, certainly traveled widely beyond his own island, and he is well known in the history of geography. He wrote a treatise *On Harbors* in ten books (lost), which was used and criticized by Eratosthenes, Hipparchus, and Strabo.[35] Timosthenes, who was later considered an authority on winds (i.e., on directions or rhumbs), added two winds or directions to the ten already mentioned in Aristotle's *Meteorologica*[36] and obtained twelve directions, at regular intervals, based on what would later be recognized as the twelve points of the compass.

According to Agathemerus, Timosthenes used these twelve directions to locate remote peoples or countries of the inhabited world (fig. 9.3).[37] Rather like Ephorus before him, he drew a kind of schematic map of nations, probably imitating the diagram of the winds in Aristotle's *Meteorologica*. The positioning of the Straits of Gibraltar and Bactria on the east-west line and of Scythia beyond Thrace and Ethiopia beyond Egypt on the north-south line suggests that the wind directions were drawn with Rhodes as a center. Thus, between north and east lie the Black Sea and the Sea of Azov (NNE), then the Caspian Sea (ENE); between east and south, India (ESE) and the Red Sea and Ethiopia (SSE); between south and west, the Garamantes (north-central Africa) (SSW) and western Ethiopia (northwestern Africa) (WSW); between west and north, Iberia (WNW) and Celtica (NNW).

Timosthenes probably also drew more detailed maps to illustrate his treatise. Strabo accuses him of being totally ignorant of Iberia, France, Germany, and Britain, and even of Italy, the Adriatic, and the Black Sea, pointing out at least two gross mistakes in his work.[38] First, he mentioned forty islands instead of twenty in the channel between Lesbos and Asia Minor.[39] Second, he put Metagonium (Melilla) opposite (i.e., on the meridian of) Massalia (Marseilles) when in Strabo's opinion it was on the same meridian as Nova Carthago (Cartagena),[40] which is closer to, if not actually, the true location. Timosthenes' treatise and accompanying map, though possibly useful to sailors, seem to have lacked scientific accuracy. But his idea of taking Rhodes as the center of the map was generally adopted by his successors.

The Measurement of the Earth and the World Map by Eratosthenes

Few would dispute that in both a theoretical and a practical sense Hellenistic cartography reached its apogee in

35. Strabo *Geography* 9.3.10 (note 10).
36. Aristotle *Meteorologica* 2.6.363a.21 ff.; see *Meteorologica*, trans. H. D. P. Lee, Loeb Classical Library (Cambridge: Harvard University Press; London: William Heinemann, 1952), and pp. 145–46 above.
37. Agathemerus *Geographiae informatio* 2.7 (note 28).
38. Strabo *Geography* 2.1.41 (note 10).
39. Strabo *Geography* 13.2.5 (note 10).
40. Strabo *Geography* 17.3.6 (note 10).

the work of the polymath Eratosthenes (ca. 275–194 B.C.). His was a lasting contribution to the development of mapping, and with some justification he has been variously assigned a founding role in geography, cartography, and geodesy.[41] Although we are acquainted with his contribution only through later writers rather than through his original texts,[42] it is absolutely clear that in two scientific endeavors he surpassed both his predecessors and his contemporaries. The first of these was his measurement of the circumference of the earth, which was methodologically simple but brilliant.[43] The second was his construction of a world map based on both parallels and meridians, which was of seminal importance not only in the subsequent development of map projections but also in the eventual scientific and practical use of maps. Such a cartographic invention was equally applicable in chorographical or regional mapping and in geographical or world mapping, so that its key significance for the history of the map needs to be fully described.

Eratosthenes was born a Greek, in Cyrene (North Africa); going to Athens as a young man, he took lessons at one time from the Stoics and at another from the Academicians, among whom he was particularly influenced by Arcesilas of Pitane (Candarli), who had been a disciple of the mathematician Autolycus. In the work of Eratosthenes, as in that of his predecessors, the importance of his mastery of the geometry of the sphere and of the geocentric hypothesis cannot be overemphasized as providing the point of departure—as well as the theoretical framework—for the development of his cartographic ideas.[44] Eratosthenes' scientific distinction later attracted the attention of Ptolemy III Euergetes, king of Egypt 246–221 B.C. The king asked him to come to Alexandria as tutor to his son Philopator (born ca. 245 B.C.) and to take over the direction of the library when Apollonius left for Rhodes after adverse criticism of his poem *Argonautica*. At Alexandria, Eratosthenes was to compose two works on geographical subjects: one, *Measurement of the Earth*, explained the method used to find the circumference of the earth; the other, entitled *Geographica*, in three books, gave instructions for making a map of the inhabited world. Both works are lost, but Strabo, who begins his own work by a criticism of the *Geographica*, affords us fairly clear knowledge of its contents, and Cleomedes of the second century A.D. gives a brief summary of the *Measurement of the Earth*.[45]

From Cleomedes we learn that the method Eratosthenes used to evaluate the circumference of the earth was based on the geometry of the sphere.[46] According to the geocentric hypothesis, by which the earth was reduced to a point,[47] the sun's rays are parallel when falling on any point of the earth. It was known that Syene (Aswan) in Egypt was situated under the tropic; at midday on the summer solstice there was no shadow,

41. Cortesão, *History of Portuguese Cartography*, 1:78–79 (note 26); D. R. Dicks, "Eratosthenes," in *Dictionary of Scientific Biography*, 4:388–93 (note 30).

42. R. M. Bentham, "The Fragments of Eratosthenes of Cyrene" (typescript for Ph.D. thesis, University of London, 1948—author died before thesis was submitted); see also *Die geographischen Fragmente des Eratosthenes*, ed. Hugo Berger (Leipzig: Teubner, 1898). We know of Eratosthenes' *Geographica* mostly through Strabo.

43. Gerald R. Crone, *Maps and Their Makers: An Introduction to the History of Cartography*, 5th ed. (Folkestone, Kent: Dawson; Hamden, Conn.: Archon Books, 1978), 3.

44. In this respect Eratosthenes was heir to a continuous tradition of mathematical learning that can be traced back at least as far as Eudoxus, from whose day onward it is likely that treatises entitled *Sphaerica* had existed. Autolycus of Pitane (fl. 310 B.C.) was clearly a link in this chain of writers influencing Eratosthenes. Although Autolycus's textbook *On the Sphere in Motion*, composed about 330 B.C., was not an original work, it was a competent summary of a number of basic theorems concerning celestial phenomena for given places of observation, and it explained clearly the geometric relationship between the sky and the earth and the need for astronomical knowledge to define the position on the earth of any place of observation. See Autolycus of Pitane, *La sphère en mouvement*, ed. and trans. Germaine Aujac, Jean-Pierre Brunet, and Robert Nadal (Paris: Belles Lettres, 1979). It is also likely that the writings of Euclid (fl. Alexandria ca. 300 B.C.) were known to Eratosthenes. The *Elements* had been completed about 300 B.C., but Euclid was also the author of a small treatise entitled *Phaenomena*, which applied specifically to the celestial sphere the conclusions Autolycus drew for rotating spheres in general. After establishing the geometry of the rotating celestial sphere, Euclid examined the rising and setting of stars as a means of measuring time at night; to do this he had to analyze the relationship between the observer's horizon and the ecliptic on the celestial sphere, which is different for each parallel on the earth. A brief summary of this work is given by Pierre Chiron, "Les Phénomènes d'Euclide," in *L'astronomie dans l'antiquité classique*, Actes du Colloque tenu à l'Université de Toulouse–Le Mirail, 21–23 Octobre 1977 (Paris: Belles Lettres, 1979), 83–89. For early spherical astronomy, see Otto Neugebauer, *A History of Ancient Mathematical Astronomy* (New York: Springer-Verlag, 1975), 748–67.

45. Cleomedes *De motu circulari* (note 30). The original Greek title is Κυκλικὴ Θεωρία τῶν Μετεώρων.

46. Cleomedes *De motu circulari* 1.10 (note 30). An English translation of book 1, chap. 10, appears in Cortesão, *History of Portuguese Cartography*, 1:141–43 (note 26).

47. In the geocentric hypothesis, as explained in Euclid's *Phaenomena*, the sky of the fixed stars was compared to a sphere rotating around one diameter called the world axis. In the middle, the earth was reduced to a point that acted as center to the sphere; the fixed stars moved along parallel circles (being on a rotating sphere, they were all circles of the sphere perpendicular to the axis of rotation). The greatest of these parallel circles Euclid recognized as the celestial equator. But two other great circles were important: the oblique circle of the ecliptic (called the "zodiac" by Euclid; see Chiron, "Phénomènes d'Euclide," 85 [note 44]), and the circle of the visible horizon (the astronomical horizon dividing the visible celestial hemisphere from the invisible one), which remained motionless during the apparent motion of the celestial sphere (fig. 8.8). Euclid *Phaenomena* 1 and prop. 1, see Euclid, *Opera omnia*, 9 vols., ed. J. L. Heiberg and H. Menge (Leipzig: Teubner, 1883–1916), vol. 8, *Phaenomena et scripta musica [and] Fragmenta* (1916).

the sun being exactly at the zenith.[48] Supposing Alexandria to be on the same meridian as Syene (the difference is only 3°), Eratosthenes measured the angle between the direction of the sun and the vertical in Alexandria at midday on the summer solstice. This angle, one-fiftieth of a circle, was equal to the angle at the earth's center subtended by the arc of the meridian defined by Syene and Alexandria. Estimating the distance between the two towns at roughly 5,000 stades, Eratosthenes calculated the total circumference as 250,000 stades (fig. 9.4). He later extended the value to 252,000 so as to make it divisible by sixty.[49]

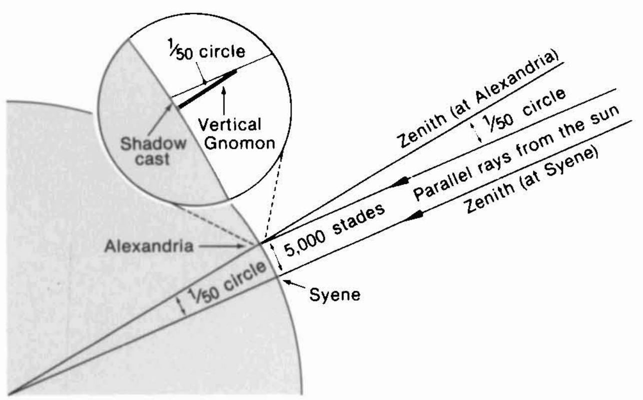

FIG. 9.4. ERATOSTHENES' MEASUREMENT OF THE EARTH. Eratosthenes worked with four assumptions: that Syene was on the tropic (at the summer solstice, the sun was thus directly overhead); that both it and Alexandria were on the same meridian; that the distance between them was 5,000 stades; and that the sun's rays were parallel. He knew that the difference in latitude between Alexandria and Syene was equivalent to the angle between the sun's rays and the zenith at Alexandria. From the lengths of a vertical stick (gnomon) and its shadow, he calculated this angle to be one-fiftieth of a circle. Thus the earth's circumference was estimated at 250,000 stades.
After John Campbell, *Introductory Cartography* (Englewood Cliffs, N.J.: Prentice-Hall, 1984), fig. 1.7.

Eratosthenes' method for calculating the circumference of the earth was sound, but its reliability depended on the accuracy of his base measurements and other assumptions. The angular distance between the two cities is quite accurate (7°12′ instead of the actual 7°7′), but Syene is not directly on the Tropic of Cancer but about 35′ to the north (using the modern figure for the obliquity of the ecliptic), and Alexandria and Syene are not on the same meridian. Furthermore, the distance between Alexandria and Syene is given in stades, the value of which has sparked considerable debate[50] quite apart from the question of the empirical source of the distance thus recorded.[51] Regardless of the actual value for the stade that Eratosthenes used or of the distance he arrived at—he knew that the distance between the two cities was a very rough estimate, as was his evaluation of the terrestrial circumference—the importance of his calculation lies in its influence. It is probable that after he had measured the circumference of the earth, Eratosthenes henceforth first established any distance in latitude by astronomical means, or by reference to the geometry of the sphere (the distance between equator and tropic being fixed at four-sixtieths of the great circle, for instance), and then evaluated this distance in stades. Thus the distance between equator and tropic, which had never been measured by surveyors, was said to be 16,800 stades.

The availability of knowledge of this estimate of the earth's circumference had three outstanding consequences. First, it was now possible to work out through geometry the length of every parallel circle on the earth. The parallel of Athens, for example, was "less than two hundred thousand stadia in circuit."[52] Second, differences of latitude, found by gnomonic methods and expressed in fractions of the circle, could easily be converted into stades. Third, it was now also possible to define the size of the inhabited world and its position on the surface of the terrestrial globe.

This third issue—the size and location of the inhabited world—was of intense and continuing interest to the Greeks, and having devised a method to answer this question, Eratosthenes was to return to its exposition in his *Geographica*. This work in three books is known to us mainly through Strabo. It was intended to provide a review and solution of all known problems involved in drawing a map of the earth (*gē-graphein*) or, more precisely, a map of the inhabited world on the surface of the terrestrial globe.[53] Starting from the theoretical premise that the earth is spherical, albeit with "certain irregularities of surface,"[54] Eratosthenes located the inhabited world completely in the Northern Hemisphere occupying the northern half of the distance between the Tropic of Cancer and the equator and the entire distance

48. Strabo *Geography* 17.1.48 (note 10).

49. Eratosthenes divided the earth into sixtieths; the use of 360° comes with Hipparchus.

50. On the matter of the modern value of the stade, see note 3 above.

51. Cortesão, *History of Portuguese Cartography*, 1:82 (note 26), speculates that Egyptian cadastral surveys may have been available to Eratosthenes in his calculation of the distance between the two points of observation.

52. Eratosthenes, in Strabo *Geography* 1.4.6 (note 10).

53. Eratosthenes was the first author to attempt this. His work began with a short history of geographical science from the time of Homer and the first mapmakers.

54. Strabo *Geography* 1.3.3 (note 10).

between that tropic and the polar circle. He calculated its width from north to south along the meridian that runs through Meroë, Alexandria, and Rhodes, resulting in a distance of 38,000 stades. Strabo described the overall shape of the *oikoumene* as somewhat like a chlamys, a Macedonian cloak perhaps resembling the shape in fig. 9.5.[55] Its length from west to east, however, he determined in accordance with an established concept, that its length was more than double the known breadth.

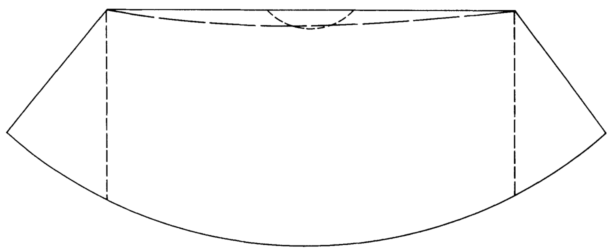

FIG. 9.5. THE CHLAMYS. This is the possible form of a common style of Macedonian cloak used by Strabo to illustrate the shape of the *oikoumene*. The top could be either straight or slightly curved.
Reconstructed from the description in *The Geography of Strabo*, 8 vols., ed. and trans. Horace Leonard Jones, Loeb Classical Library (Cambridge: Harvard University Press; London: William Heinemann, 1917–32), 2.5.6 and p. 435 n. 3.

Eratosthenes first described the distance from the capes of India to the extremities of Iberia as roughly 74,000 stades. Then (according to Strabo) Eratosthenes added 2,000 more stades to both west and east to keep the breadth from being more than half the length.[56] The total length thus became 78,000 stades.

The determination of the length of the inhabited world from India to Iberia was reckoned along the parallel of Athens. Eratosthenes believed this was less than 200,000 stades in circuit, "so that, if the immensity of the Atlantic Sea did not prevent, we could sail from Iberia to India along one and the same parallel over the remainder of the circle, that is, the remainder when you have subtracted the aforesaid distance, which is more than a third of the whole circle."[57] In fact, using a value for the circumference of the earth of 252,000 stades, 78,000 stades on the parallel in question is approximately equivalent to 138° of longitude, which is roughly the distance between the western coast of Spain and Korea rather than India.

It is not surprising that for many centuries to come values representing latitude were always much more reliable than those for longitude. Familiar with the geometry of the sphere, the Greeks were fairly well equipped to derive latitudes from direct observations of the sun and stars. In this respect, straightforward calculations could be undertaken to test the information of travelers. For longitudes the results were much less reliable, since it was necessary to observe an eclipse of the moon or other celestial body simultaneously from different places to obtain exact distances between them. Instead, the Greeks had to accept distances given by the itineraries without being able to verify them astronomically.

According to Strabo, it was in the third book of *Geographica* that Eratosthenes explained how to draw a map of the world:

> Eratosthenes, in establishing the map of the inhabited world, divides it into two parts by a line drawn from west to east, parallel to the equatorial line; and as ends of this line he takes, on the west, the Pillars of Heracles [Straits of Gibraltar], on the east, the capes and most remote peaks of the mountain-chain that forms the northern boundary of India. He draws the line from the Pillars through the Strait of Sicily [Straits of Messina] and also through the southern capes both of the Peloponnesus and of Attica, and as far as Rhodes and the Gulf of Issus [Gulf of Iskenderun, Turkey]; . . . then the line is produced in an approximately straight course along the whole Taurus Range as far as India, for the Taurus stretches in a straight course with the sea that begins at the Pillars, and divides all Asia lengthwise into two parts, thus making one part of it northern, the other southern; so that in like manner both the Taurus and the Sea from the Pillars up to the Taurus lie on the parallel of Athens.[58]

We can see from this passage that Eratosthenes had adopted the idea of the *diaphragma* (if not the term) introduced by Dicaearchus to divide the known world by means of a line parallel to the equator, drawn from west to east, beginning at the Straits of Gibraltar and running through Athens and Rhodes to India. It is also clear from other passages in Strabo that Eratosthenes drew a central perpendicular meridian through Rhodes, for he lists the places through which this passes and the distances between them.[59] Eratosthenes used very rough estimates and round numbers. The south-north distances (in stades) he provided between the following regions or towns were:

Between	*Stades*
Cinnamon country and Meroë	3,400
Meroë and Alexandria	10,000
Alexandria and Hellespont	about 8,100
Hellespont and river Borysthenes	5,000
River Borysthenes and parallel of Thule	about 11,500
Total	38,000

(Strabo *Geography* 1.4.2).

55. Strabo *Geography* 2.5.6 (note 10).
56. Strabo *Geography* 1.4.5 (note 10).
57. Eratosthenes, in Strabo *Geography* 1.4.6 (note 10).
58. Strabo *Geography* 2.1.1 (note 10).
59. Strabo *Geography* 2.5.42 (note 10).

It must be remembered, however, that these figures are not consistently given by Eratosthenes (the cinnamon-producing country, for instance, was often located 3,000 stades south of Meroë); but here Eratosthenes wanted to put the southern limit of the inhabited world halfway between the equator and the tropic.

The intermediate east-west distances used by Eratosthenes between the following regions or towns were:

Between	*Stades*
Far eastern capes and eastern India	3,000
Eastern India and river Indus	16,000
River Indus and Caspian Gates	14,000
Caspian Gates and river Euphrates	10,000
River Euphrates and river Nile	5,000
River Nile and Carthage	15,000
Carthage and Pillars of Hercules	8,000
Pillars and Hercules and far western capes	3,000
Total	74,000

(Strabo *Geography* 1.4.5).

The next stage in drawing the map suggested by Eratosthenes was to subdivide the northern and southern halves of the map into smaller sections called *sphragides*, literally "seals" but meaning irregular quadrilaterals similar to the shape of document seals. The first two of those in the southern division, with their boundaries, are shown in figure 9.6.[60] Strabo describes only the first three sections of the southern half of the map, but it is enough to show us how Eratosthenes proceeded. It is clear that he had tried to identify the geometric figure characterizing each country, so as to be able to measure the sides (or the diagonals) of each figure and then to insert each in the right position, like the pieces of a jigsaw puzzle. He had to make the boundaries and size of each section fit the general outlines and size of the inhabited world. This was fairly easy with India, the shape of which was rather clear; it was much more difficult with other countries less well known and not bounded by the sea, a range of mountains, or a river.

The northern half of the map, at least as far as Europe was concerned, Eratosthenes divided on the basis of the three promontories projecting southward into the Mediterranean and enclosing both the Adriatic and the Tyrrhenian seas: the Peloponnesian (Greece), the Italian (Italy), and the Ligurian (Corsica and Sardinia).[61] But Hipparchus and Strabo sharply criticized Eratosthenes for overgeneralization, pointing out, for example, that the Peloponnesian promontory was actually made up of a number of smaller capes.

Reconstructions of Eratosthenes' map from Strabo's text, such as those by Bunbury and Cortesão, may be misleading.[62] Eratosthenes' drawing of the central parallel and meridian is not in doubt. Furthermore, he could certainly have drawn other parallels and meridians where stade distances of places from the reference lines through Athens and Rhodes were the same or almost the same.[63] But Strabo does not say that these were actually shown on Eratosthenes' map, nor can we infer from the evidence in Strabo, as Cortesão does, that "he prepared the ground for the cartographic projection, as developed by Hipparchus, Marinus, and Ptolemy."[64] The apparent precision of these reconstructed maps should therefore be evaluated with care.

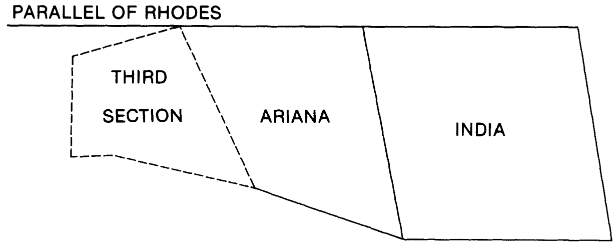

FIG. 9.6. RECONSTRUCTION OF ERATOSTHENES' *SPHRAGIDES*. The seal-like subdivisions for South Asia are part of a system that covered the *oikoumene* described by Strabo in his *Geography*. The dashed lines are the boundaries between geographical areas that Eratosthenes was unable to define properly.
Developed from the description in *The Geography of Strabo*, 8 vols., ed. and trans. Horace Leonard Jones, Loeb Classical Library (Cambridge: Harvard University Press; London: William Heinemann, 1917–32), 2.1.22–23.

The Dissemination of Cartographic Knowledge

On first inspection, the sources for the development of cartography in Hellenistic Greece strongly convey the impression that its knowledge and practice were confined to relatively few in an educated elite. Certainly the names associated with the history of mapping are largely drawn from a handful of outstanding thinkers traditionally associated with the history of Greek science in general. From other sources, however, albeit fragmentary, a broader picture can be drawn in which both the theories underlying mapping and the maps themselves were more widely experienced by the educated class and among the citizens of the major towns. Three-dimensional models of the universe as well as globes and maps were used in schools and sometimes displayed in public places; and considering the maps engraved as emblems for the face of coins, it could even be said that the cartographic image was being popularized.

60. Strabo *Geography* 2.1.22–23 (note 10).

61. Strabo *Geography* 2.1.40 (note 10).

62. Bunbury, *History of Ancient Geography*, facing p. 660 (note 32), and Cortesão, *History of Portuguese Cartography*, 1:83–84 and fig. 19 (note 26).

63. Dicks, *Geographical Fragments*, 159 (note 3).

64. Cortesão, *History of Portuguese Cartography*, 1:84 (note 26).

An interesting pointer to the popularity of maps in Athens at the beginning of the third century B.C. is provided by Theophrastus, disciple and successor of Aristotle and a contemporary of Dicaearchus. He requests in his will "that the small portico adjoining the shrine of the Muses shall be rebuilt no worse than before, and that the panels (*pinakas*) showing maps of the earth (*gēs periodoi*) shall be put up in the lower cloister."[65] This will, transcribed verbatim by Diogenes Laertius, suggests that the custom of drawing maps on wooden panels and showing them in public or semipublic places for information was well established.[66] The maps described were existing fixtures, easily movable like other paintings; they could be displayed with other types of pictures, in the company of which they became a familiar type of image.

Nor was this the sole example of such public cartographic displays. Although the allusion is literary and refers to an earlier period, a passage in the epic of Apollonius Rhodius (fl. ca. 267–260 B.C.) extends the practice outside Athens, claiming that the Colchians, on the southeast coast of the Black Sea, were originally colonists from Egypt. "They preserve," he says, "the engravings of their fathers on pillars, on which are marked all the ways and the limits of the sea and land as you journey on all sides round."[67] The word rendered as "engravings" means "scratchings" in Homer—from whom Apollonius often drew his vocabulary—so the poet is implying roughly incised lines.

A different medium for the dissemination of miniature map images is found in the Ionian coins (fig. 9.7) probably struck by Memnon of Rhodes, who acted as a Persian general in Ephesus until the arrival of Alexander in 334 B.C. In this series of Rhodian-weight tetradrachms, the obverse type is the figure of the Persian king, running or kneeling right. The reverse is a rectangular incuse with irregular raised areas, recognizable as a map depicting the physical relief of the hinterland of Ephesus. It is described thus by Johnston:

> The feature most clearly recognisable is the central loop, with the Tmolus range in the north and the Messogis range in the south, divided by the valley of the Caÿster (now the Küçük Menderes) running towards the sea to the West. Also running east-west are the rivers Hermus (the modern Gediz) to the north of the Tmolus range and the Maeander (Büyük Menderes) to the south of the Messogis range. The tributaries of the Maeander, the Harpasus (Ak) and the Morsynas (Vandalas), divide the southern mountain block into three ridges, visible in the lower part of the reverse.

And Johnston adds:

> If such an accurate and detailed map could be conceived of as a coin type, the maps for ordinary use must have been the products of a highly developed technique. . . . The whole conception is remarkably close to that of a modern plastic relief map.[68]

FIG. 9.7. IONIAN COIN MAP. This design is found on the reverse of many Ionian silver tetradrachms, one of which is shown, ca. 330 B.C. It depicts an area in Asia Minor near Ephesus.
Diameter of the original: 2.3 cm. By permission of the Trustees of the British Museum, London (BMC Ionia, 323 no. 1).

Although other Greek coins with maps or plans are not of this period, it is convenient to group them here.[69] The map images, of course, serve no practical purpose, but they have a symbolic or propaganda value. Thus the people of Messana chose to give thanks, by a map emblem struck on their coins, for a natural feature that had helped their city develop. This was the sickle-shaped sandspit that protected their harbor and was said to have given the city its original name of Zankle.[70] Some coins of Messana show this; on a few of them are found interior rectangular projections that have been thought to represent harbor buildings.

65. Diogenes Laertius *Lives of Famous Philosophers* 5.51; translation by O. A. W. Dilke. See Diogenes Laertius, *Vitae philosophorum*, 2 vols., ed. Herbert S. Long (Oxford: Clarendon Press, 1964); for an English translation see *Lives of Eminent Philosophers*, 2 vols., trans. R. D. Hicks, Loeb Classical Library (Cambridge: Harvard University Press; London: William Heinemann, 1925–38). See also H. B. Gottschalk, "Notes on the Wills of the Peripatetic Scholarchs," *Hermes* 100 (1972): 314–42; John Patrick Lynch, *Aristotle's School: A Study of a Greek Educational Institution* (Berkeley: University of California Press, 1972), 9 ff. and map, p. 217.

66. Désiré Raoul Rochette, *Peintures antiques inédites, précédées de recherches sur l'emploi de la peinture dans la décoration des édifices sacrés et publics, chez les Grecs et chez les Romains* (Paris: Imprimerie Royale, 1836).

67. Apollonius Rhodius *Argonautica* 4.279–81, translation by O. A. W. Dilke; see *Argonautique*, 3 vols., ed. Francis Vian, trans. Emile Delage (Paris: Belles Lettres, 1974–81), vol. 3.

68. A. E. M. Johnston, "The Earliest Preserved Greek Map: A New Ionian Coin Type," *Journal of Hellenic Studies* 87 (1967): 86–94, quotation on 91.

69. For coins of Cnossos, however, see p. 251 below.

70. George Francis Hill, *Coins of Ancient Sicily* (Westminster: A. Constable, 1903), 38–39 and pl. I.2; Charles Theodore Seltman, *Greek Coins: A History of Metallic Currency and Coinage down to the Fall of the Hellenistic Kingdoms* (London: Methuen, 1933; revised 1955), pl. 14.5 (upper).

A more doubtful example is on a coin of Phocaea (Foca), north of Smyrna (Izmir) in Ionia; this has a drawing of the common seal (the animal; Greek *phoke*, origin of their city name) on the obverse.[71] On the reverse, however, is what could be a city plan, showing three-quarters of a square, with a possible harbor and river. Other coins of Phocaea have a complete square, although the layout differs somewhat from Livy's later description of the town plan.[72]

Another factor contributing to this wider understanding of maps was, as already noted, that the early Greek astronomers and philosophers had a well-developed mechanical flair. Rather than confining their geometric hypotheses solely to diagrams drawn on flat surfaces, they expressed them in three-dimensional models, whether globes or mechanical representations of the workings of the celestial system. In particular, the study of *sphairopoiia* (σφαιροποιία)—a branch of mechanics the object of which was to represent celestial rotations[73]—while serving as a method of research into the laws of cosmic motion through the construction of models of the cosmos, also helped bridge the gap between purely theoretical speculation and its wider understanding in a more tangible form. Pappus, a distinguished Alexandrian mathematician (fl. A.D. 320), defines experts in mechanics as "those who know *sphairopoiia*, a technique used to construct representations of the moving sky through the regular and circular motion of water."[74]

One of these experts was Archimedes (287–212 B.C.), a contemporary and friend of Eratosthenes, exerted an influence on astronomical and geographical thinking, and hence on the maps and models that represented these theories. Born in Syracuse, Archimedes was the son of Pheidias, an astronomer. He visited Alexandria, where he mixed in the intellectual circle of astronomers and philosophers such as Conon of Samos (fl. 245 B.C.) and his pupil Dositheus of Pelusium (fl. 230 B.C.),[75] and where he also met Eratosthenes, with whom he later conducted a scientific correspondence. Archimedes was a favorite at the court of Hieron II (ca. 306–215 B.C.), ruler of Syracuse, becoming famous for the various machines he invented, especially those used to repulse Roman assailants at the siege of Syracuse.[76]

Among numerous other works, Archimedes composed a treatise (lost) on *sphairopoiia*, which led to a greatly improved representation of the universe. His project was indeed ambitious—an attempt to build a model of the "terrestrial system" based on the geocentric hypothesis and to make it work as in reality. The design was such that the celestial sphere, the planets, and the earth were all parts of one intricate mechanism, which could be set in motion so as to simulate the apparent rotation of the stellar sphere and the various motions of the main planets. From this work, as well as from other contemporary and later sources, it becomes clear that in the time of Archimedes it was quite usual to make all kinds of models imitating the various movements in the universe. Furthermore, celestial globes, like the ones introduced by Eudoxus and made familiar by Aratus, were exhibited frequently in schools or in public places. And armillary spheres such as that reconstructed in figure 8.8, in which the sphere of the fixed stars was reduced to its main circles (equator, tropics, ever-visible and never-visible circles, zodiac, colures) and the earth could be envisioned in the center, helped demonstrate to a wider audience the effects of latitude on celestial phenomena.

Archimedes also constructed a number of globes. At least two of them were taken to Rome by Marcus Claudius Marcellus after the fall of Syracuse in 212 B.C.; they are described enthusiastically (but rather vaguely) by Cicero.[77] One of them, apparently of striking appearance, was well known to the people of Rome and had been put in the temple of Virtue. It was probably a solid celestial globe, showing the whole series of constellations, or rather the characters and animals representing them. These kinds of globes were usually elegantly drawn and then brightly colored. A second globe, which

71. William Smith, *Dictionary of Greek and Roman Geography*, 2 vols. (London: J. Murray, 1870), 2:603; S. W. Grose, *Fitzwilliam Museum: Catalogue of the McClean Collection of Greek Coins* (Cambridge: Cambridge University Press, 1929), 3:143 and pl. 285.22. There is, however, some resemblance to the plan given by F. Sartiaux, "Recherches sur le site de l'ancienne Phocée," *Comptes Rendus des Séances de l'Académie des Inscriptions et Belles-Lettres* (1914): 6–18, esp. 6–7.

72. Livy [*History of Rome*] 37.31.7–10; see *Livy*, 14 vols., trans. B. O. Foster et al., Loeb Classical Library (Cambridge: Harvard University Press; London: William Heinemann, 1919–59).

73. The word σφαιροποιία is mentioned by Geminus, in Proclus *Commentary on the Elements of Euclid*; see *In primum Euclidis Elementorum librum commentarii*, ed. G. Friedlein (Leipzig: Teubner, 1873), p. 41, l. 16, and also in Geminus *Introduction to Phenomena* 12.23, 12.27, 14.9, 16.19, 16.27, and 16.29; see *Introduction aux phénomènes*, ed. and trans. Germaine Aujac (Paris: Belles Lettres, 1975).

74. Pappus of Alexandria *Synagoge* (Collection) 8.2, translation by O. A. W. Dilke; see *Collectionis quae supersunt*, 3 vols., ed. F. Hultsch (Berlin: Weidmann, 1867–78), vol. 3.

75. Both were astronomers: Conon of Samos identified a new constellation that he named the Lock of Berenice; Dositheus constructed an astronomical calendar. See Ivor Bulmer-Thomas, "Conon of Samos," and D. R. Dicks, "Dositheus," in *Dictionary of Scientific Biography*, 3:391 and 4:171–72, respectively (note 30).

76. Archimedes' inventions are discussed in Aage Gerhardt Drachmann, *The Mechanical Technology of Greek and Roman Antiquity: A Study of Literary Sources*, Acta Historica Scientiarum Naturalium et Medicinalium, 17 (Copenhagen: Munksgaard, 1961).

77. Cicero *The Republic* 1.14; 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), 1:15–17.

was held to be the masterpiece of Archimedes, at first glance did not seem extraordinary. Marcellus kept it in his own house. It was not a celestial globe, but a kind of planetarium. While it lacked the beautiful drawing and attractive colors that probably gave the globe in the temple of Virtue its charm, it was a major contribution to mechanical science, modeling the motions of the sun, the moon, and five planets. Marcus Fadius Gallus, when presenting it to Cicero, declared: "What is admirable in the invention of Archimedes is this: he caused a single rotation to put into constant action bodies moving in various and unequal orbits, at different speeds." And Cicero goes on: "When Gallus put this sphere in motion, the moon placed itself under the sun after as many rotations as days are needed for doing so in the sky itself; so that an eclipse of the sun took place in the artificial sphere, as in the sky. And the moon also went into the shadow thrown by the earth when the light of the sun came from exactly the opposite direction."[78] The construction of this planetarium made Archimedes famous among educated Romans, who were impressed by the high level of knowledge and skill it had required.[79] Later on, some people—to Cicero's indignation—even expressed the view that the model was better than reality: "that Archimedes, in his imitation of the rotations of the celestial sphere, was a better constructor than Nature itself . . . whereas (Cicero asserts) natural movements are very much better planned than imitated ones."[80]

It is clear that the construction of such models—like their representation in two dimensions—could raise fundamental questions, going beyond the purely astronomical and geographical and expressing concern about man's place in the universe in relation to its very purpose and plan.

78. Cicero *The Republic* 1.14.22, translation by O. A. W. Dilke; see *La République*, 2 vols., trans. Esther Bréguet (Paris: Belles Lettres, 1980), vol. 1.

79. Cf. also Cicero *Tusculan Disputations* 1.25.63; see *Tusculan Disputations*, trans. J. E. King, Loeb Classical Library (Cambridge: Harvard University Press; London: William Heinemann, 1933).

80. Cicero *De natura deorum* 2.35.88, translation by O. A. W. Dilke; see also *De natura deorum [and] Academica*, trans. H. Rackham, Loeb Classical Library (Cambridge: Harvard University Press; London: William Heinemann, 1924).

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