FOUR

Ptolemy's Geography: Mapmaking and the Scientific Enterprise

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A copy of Ptolemy's *Geography* from before the sixteenth century, whether it is a Byzantine codex containing the original Greek text, a western European manuscript in Latin, or a printed book, stands a good chance of being an extraordinarily luxurious object, containing a set of beautifully executed maps following a recurring pattern: one map showing Europe, Africa, and Asia, and twenty-some showing individual regions of these continents. The regional maps, always in the same order, work their way from the westernmost parts of Europe eastwards, then through Africa, and lastly across Asia, again from west to east, coming to an end with central China, southeast Asia, and Sri Lanka. The maps are the most eye-catching items in these books, although in fact many more pages are devoted to text, copied out or printed either in the original Greek or in Latin translation, and mostly consisting of names of places and numerals laid out in a more or less tabular format: a rebarbative, scarcely readable gazetteer.

It is a quirk of literary history that a book dating from the second century of our era and consisting mostly of such dry-as-dust lists should have been among the most prized of articles in fourteenth-century Byzantium and fifteenth-century western Europe. What made this possible for Ptolemy's *Geography*, of course, was the maps; for these were no mere ornaments, but showed practically as much of the world as was known to Europeans at the brink of the Age of Discovery, albeit the world as it had been peopled one thousand years and more before. No doubt Ptolemy would have been astonished that in all this time his work had still to be superseded, or at least brought up to date, but, if nothing else, it should have pleased him to know that his project had *worked*.

The *Geography* is, on the face of it, a very practical book, as its full title, *Geographical Guide*, makes evident. Its intention is to provide the reader, or it would be more accurate to say, the *user*, with everything that he or she needs to construct a map of the known part of the world. And it is very effective in attaining its object: equipped with a copy of the *Geography*, anyone living anywhere at any period who followed Ptolemy's instructions with care would produce substantially the same maps.[1] Behind this practical approach, however, are many theoretical presuppositions, not just such immediately relevant ones as the shape of the earth, but ones that go to the heart of what science is for and how it works. Ptolemy is explicit, but terse, about these assumptions in the *Geography*; it is only when we read it together with his other scientific writings that the depth, coherence, and distinctiveness of his approach become fully apparent. In short, to understand Ptolemy in his role as a cartographer, we must consider him as a scientist and philosopher.[2]

Ptolemy's Cosmology and Science

The subjects of Ptolemy's books are disparate. He wrote on the principles governing the pitches employed in music, on the process of vision and the relationship between what we see and what actually exists in the external world, and on categorizing and predicting the physical effects that the heavenly bodies exert on our environment and on our individual lives and characters; in addition, he wrote half a dozen works on astronomy.[3] Two concerns come up over and over again in these writings: how do we, or rather how *should* we, acquire the best possible knowledge of aspects of the world around us, and how should we present this knowledge, whether in graphic or pictorial form or by other means? Practically all Ptolemy's works address one or other of these concerns. Some involve both; in the *Geography* they have roughly equal prominence, as he discusses in turn how best to obtain the data for a map and how best to draw one. In fact, for him the problem of presenting or representing knowledge is really a manifestation of the epistemological problem, since the chief purpose of his modes of presentation is to impart knowledge to other people.

While historians of cartography of course know Ptolemy for the *Geography*, historians of science are most likely to be acquainted first and foremost with his astronomical works, above all with the *Almagest*, the treatise in which he deduces a detailed system of theories to explain—and allow predictions of—the apparent movements and other phenomena of the sun, moon, stars, and planets.[4] Now most of the *Almagest*, and indeed most of Ptolemy's other works on astronomical topics, consists of technical, rigorous, mathematically structured science free of terms that we would associate with philosophy. The *Geography*, while less mathematically challenging, also eschews the jargon of philosophy. Hence many people do not realize that Ptolemy had a very solid grounding and deep interest in philosophy—that in fact, like his contemporary in medicine Galen, he can claim to have been one of the most important philosophers of the second century CE.[5] This side of Ptolemy shows itself outwardly in the *Harmonics*, the *Optics*, and the astrological *Tetrabiblos*, where philosophical terminology and concepts are inextricably entwined with technical science, and in the *Criterion*, a monograph on epistemology that makes no explicit reference to scientific problems.[6] It is present in the *Almagest* and *Geography* too, but latent.

Perhaps the most direct entry to Ptolemy's philosophy is by way of his geocentric cosmology, which is something about Ptolemy that "everyone knows," and for once what everyone knows is reasonably accurate—up to a point! To him, the cosmos is, for all intents and purposes, an immense but finite sphere; what, if anything, lies beyond the outer surface of the sphere he nowhere speculates. The cosmic sphere has two distinct parts. At its center is an inner sphere, composed of the four elements earth, water, air, and fire, which are more or less stratified from the heaviest at the center out to the lightest around the outer surface of this inner sphere. We, of course, live upon those parts of the surface of the earthy mass that are not covered by water. Enclosing this domain of the four elements is a spherical shell, composed of a fifth element, aether, which is lighter than the other four and, unlike them, is not liable to transformation or alteration, generation or decay. The aetherial shell is not a single body, but has a number of distinct pieces, one enclosing another, shaped in such a way that the pieces can slide against one another freely in various kinds of rotation. Most of this aether is invisible, but some parts are either visible or luminous, and these are in fact the stars, planets, moon, and sun. The moon and the bodies of transparent aether connected with it are innermost, whereas the stars and their aetherial setting are outermost.

Where the popular idea of Ptolemaic cosmology often goes astray is with respect to its dimensions. When we make diagrams to show the layout of Ptolemy's cosmology, we usually assign sizes to its parts in such a way as to make everything visible, and the result is that the earth beneath our feet looks fairly significant on the cosmic scale. But when Ptolemy wrote the *Geography*, he had already concluded that the boundary between the fiery periphery of the four-elements part of the cosmos and the aetherial shell was thirty-three times as far from the center of the cosmos as the surface of the solid earth, while the sun—which is by no means the furthest object in the cosmos—was 1,210 earth radii from the center. Eventually, though this may have come after the composition of the *Geography*, Ptolemy worked out a complete scheme of cosmic distances, according to which the distance from the center to the outermost surface of the aetherial shell was close to six hundred times the distance from the center to its inner surface, and twenty thousand times the solid earth's radius (fig. 4.1).[7] Thus the portion of the cosmos allotted to the four elements was a mere speck relative to the whole, and our earth was a speck within that speck (fig. 4.2).

The cosmic insignificance of the terrestrial globe (with us on it) is not just a matter of relative bulk. Ptolemy believes that the cosmos as a whole, like an individual human being, has an intellective soul with a governing faculty, a *hēgemonikon*, in the jargon of the Hellenistic philosophers, that drives and coordinates the movements of its parts with exquisite rationality. And this governing faculty does not

FIGURE 4.1 Diagram of the heavenly spheres from Peter Apian, *Cosmographia* (Antwerp, 1540), a typical schematic representation of an early modern European version of Ptolemaic cosmology. The innermost three spheres are the "solid" earth (elemental earth and water), air, and fire. The Newberry Library, Gift of Edward E. Ayer. Reproduced with permission.

reside at the center, the "bottom" of the cosmos, any more than a human soul resides in the soles of one's feet: its seat is at the top, the outer periphery of the celestial sphere.[8]

It is commonly supposed that the physical framework of Ptolemy's cosmology—with its discontinuity between the sphere of the four elements and the celestial shell of aether—was ultimately traceable to Aristotle, which is true, and that it was the conventional cosmology of Greek antiquity, which is false. Within his own Peripatetic school, Aristotle's theory that there is a celestial fifth element was received at best with doubt and at worst with hostility. Stoics and Epicureans, who agreed on little else, agreed that the heavens were composed of the same materials as our immediate environment, though in different proportions. So, initially, did the so-called Middle Platonists, starting with Antiochus of Ascalon, notwithstanding their reliance on Aristotle's works as a window on Platonic verities.[9] However, it was not long before Ptolemy that some Middle Platonists, such as Adrastus of Aphrodisias and Theon of Smyrna, embraced the five-element cosmology and adapted it to render it more compatible with recent astronomical theories, according to which heavenly bodies vary in their distance from the center of the cosmos.

Ptolemy was not a Middle Platonist in the narrowest sense, but his idiosyncratic

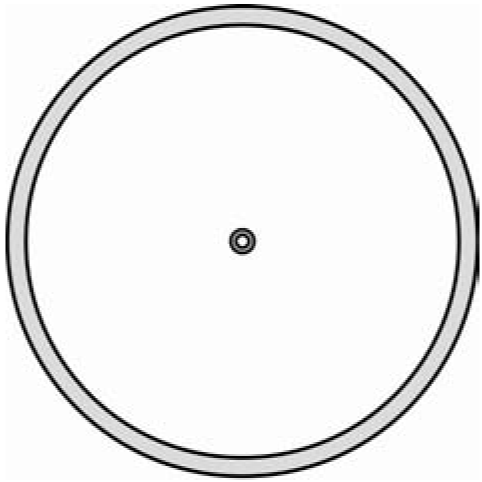


FIGURE 4.2 The cosmic dimensions of Ptolemy's *Almagest* represented to scale. The outer ring represents a cross section of the spherical aetherial shell comprising the sun and the invisible bodies that govern its motion. The inner, dark gray ring represents a cross section of the shell for the moon. The white space within this ring is the sphere of the four mundane elements. The solid terrestrial globe at the exact center, with its diameter less than a thousandth of the diameter of the solar shell, is too small to portray. According to the theory of Ptolemy's later *Planetary Hypotheses*, the space between the lunar and solar shells is filled by shells for Mercury and Venus, while the solar shell is enclosed by shells for the remaining planets and the fixed stars. The diameter of the outermost shell is nearly 170 times the diameter of the solar shell. Drawing by the author.

brand of Neoaristotelianism is best understood as an offshoot of that tradition; what is more, he seems to assume that his readers will already be committed to a cosmology incorporating the aetherial fifth element and the discontinuity between the sublunary and superlunary regions. For him it is axiomatic that the only temporal processes conceivable in the heavens are spatial motions of the aetherial bodies, and these motions must be limited to unhindered spinning that goes on with perfect regularity through eternity. Our lower world of earth, water, air, and fire, on the other hand, is characterized by perpetual but irregular changes involving qualities as well as spatial positions.

This physical cosmology underpins Ptolemy's conception of science, which he delineates in the opening chapter of the *Almagest* and book 3 of the *Harmonics*. Consider an object in our sublunary world, compounded of some or all of the four mundane elements. It has certain attributes, some of them essential to its nature and some contingent on its situation with respect to other things. For instance, a lump of strawberry ice cream has attributes such as coldness, sweetness, moistness, and pinkness, as well as a certain shape and volume, which are partly determined by the shape of the bowl, and it is so many feet away from us and is being carried towards us at a certain speed by a waiter. So much for the objective, external reality. Our perception of the ice cream, which is the foundation of any knowledge we have of it, is coming at this stage through our sight alone; only later will touch and taste and smell come into play. Now, our faculty of sight can register one kind of attribute directly, namely color, though together with this detection of the pinkness it is aware of the directions from the eye in which the pinkness lies as well as, to a limited extent, the distance. Hence by means of the color, the sight indirectly perceives attributes such as size, shape, position, and motion.

So far all this is straight out of Aristotle's theory of sense perception. Ptolemy, however, introduces a new twist by observing that the qualities that our senses directly apprehend, such as color, hot or cold, sweet or sour, are associated with the irregular processes of change and transformation to which the four elements are subject. Because they are irregular, exact generalized knowledge of them is unattainable. On the other hand, the attributes that are perceived by way of the directly sensed qualities—size and shape, number, position, and motion—can be reasoned about using the methods of mathematical demonstration, and thus are knowable. Even so, this knowability is subject to two limitations. First, since the qualities are perceived only by way of the irregular attributes such as color, an element of unknowability or uncertainty adheres to any observation or experiment. Second, the object that we are studying is itself mutable because of the inherent instability of its constituent elements.

The aetherial bodies in the heavens, by contrast, are immutable. Hence any knowledge we can obtain of them through our sight (the only sense faculty that can perceive them at all) has a permanence that is impossible for mundane objects. A certain degree of imprecision is unavoidable in our perceptions and resulting knowledge of the heavenly bodies, arising from the fact that these perceptions must take place through the mediation of our unstable bodies and the unstable surrounding air or other matter. Thus for Ptolemy there is a hierarchy, beginning with the lowest level of unreliable, probabilistic knowledge (or as he once calls it, "guesswork"), to which we are limited concerning the qualitative attributes of mundane bodies; then ascending first to the valid though unstable knowledge we can have of the quantitative attributes of mundane bodies, next to the secure albeit slightly fuzzy knowledge we can have of the attributes of heavenly bodies; and finally to a secure and perfect knowledge of the heavenly bodies that no human being can attain. All the first three kinds of knowledge, however, are aimed at in Ptolemy's works. His designation for the lowest kind is "physics," and it provides the causal framework for the astrology of his *Tetrabiblos*. The others he calls "mathematics." His *Harmonics* is an exercise in the mathematics of mundane objects, the relations among musical pitches made by human voices and instruments. The *Almagest* is celestial mathematics.

In Ptolemy's view, a human being acquires knowledge not passively through an automatic process arising from sense perceptions, but by judgment exercised by reason cooperating with sense perceptions. In other words, it is a way of thinking that one must acquire, and one can do it in a wrong way or in the right way. In scientific contexts such as harmonic theory and astronomy, one must have an appropriate strategy involving successive approximations: an initial sense perception provides reason with a basis for setting up conditions under which further sense perceptions can yield more exact information. In other words, Ptolemy's scientific methodology relies on progressive stages of experiment, each of which presumes and seeks to refine a preexistent theory that ultimately can be traced back to certain naive but unambiguous sense perceptions.[10]

Wherever possible, Ptolemy's preferred form of reasoning is mathematical deduction from reliable empirical data. When confronted with questions that cannot be settled directly in this way, Ptolemy accepts other types of reasoning of a more metaphysical or dialectical character, among which the two most important are analogy, the assumption that structures and relations in nature tend to follow similar patterns in different contexts, and simplicity, the assumption that structures and relations tend to be the least complex ones that are compatible with the phenomena. Underlying these arguments is Ptolemy's confidence that a fundamental orderliness, rationality, and goodness subsist in the cosmos.

Ptolemy and the Greek Cartographic Tradition

While Ionian Greeks were said to be making maps representing the world already in the sixth century BCE, a genre of texts that offered a rational and critical argument for the layout and content of a world map began only in the third century with Eratosthenes's *Geographica*. As the previous chapter has shown, through the geographer Strabo we gain some insight into this work, as well as into the treatise that Hipparchus composed about a century later to castigate its author's faults. The next author of works along the same lines as Eratosthenes's is Marinus of Tyre, who was active around the first decade of the second century of our era. It appears doubtful that the gap of more than two centuries between Hipparchus and Marinus represents a total lapse of this kind of research and writing. We should keep in mind that we would not know that Hipparchus wrote a polemic against Eratosthenes were it not for a single surviving witness, Strabo, and again that the very existence of Marinus would have been forgotten if we did not have Ptolemy's *Geography*. It is in fact the only instance of this genre of cartographic literature to have come down to us—so tenuous are the threads on which hangs the remembrance of ancient scientific writers.

In the *Geography* Ptolemy assumes the stance of a reformer coming to the cartographic tradition from outside; and like a reformer, he begins with fundamental issues.[11] At the outset he offers a definition of the subject of the book: *geōgraphia* is an imitation, a *mimēsis*, of the known part of the world by means of drawing. This may appear a strange definition to us, since we tend to think of the word *geōgraphia* as equivalent to our term "geography," which is how Strabo uses it. But Ptolemy is actually adhering to an older tradition, going back to Eratosthenes, who may have coined the word and who evidently meant it to signify mapmaking.[12]

Immediately, however, Ptolemy refines his definition by contrasting *geōgraphia*, the pictorial imitation of the whole known world, with something called *chōrographia*, a pictorial imitation of smaller regions. This does seem to be an innovation of terminology, since both before and after Ptolemy the accepted meaning of *chōrographia* is a *text* describing geographical regions, and such a text could in fact cover the entirety of the known world. I believe that Ptolemy is not only inventing a new meaning for *chōrographia*, but also introducing for the first time the contrast that he wishes to delineate between two kinds of mapmaking. He is not describing what the mapmakers up to his time actually did, but what they *should* do.

Ptolemy's argument depends on a concept that he frequently invokes across his whole literary production, *symmetria*, which should not be rendered in English as "symmetry" but as something like "commensurateness." *Symmetria* means having the parts of something scaled appropriately to the whole entity, or having the entity scaled appropriately for its setting or application; in particular, the things that we make ought to have the right size and proportions for human use. It has often been remarked, for example, that Ptolemy never specifies the actual dimensions of the various instruments for astronomical observations that he tells us how to make in the *Almagest*, but he regularly says that they should be *symmetra*, "of appropriate size." When drawing a map, therefore, we should keep in mind that the purpose of the map is for people to look at it, and so we should consider the task in terms of optics. The map as a whole should be of such a size that it neither greatly exceeds the field of view of a spectator at whatever distance the situation calls for nor occupies too tiny a part of the field of view. And again, the level of detail on the map should be commensurate with the resolution of the spectator's sight.

At issue is not merely the number of features per square inch marked on the map, but the character of their portrayal: in *chōrographia*, the imitation of a small region, it is reasonable to aim for a kind of pictorial realism that would be entirely inappropriate in a map of the entire known world. Again one suspects that this is not an account of the way people actually make maps, but of how Ptolemy believes that they should make them. Since he is not really concerned in the *Geography* with how to make pictures of small regions, the target of his remarks would appear to be world maps that incorporate realistic images of physical features, towns and cities, and other monuments. His aim is to impose a clear separation of art from science, such that the world map becomes a strictly scientific object, constructed, as he says, "purely by means of lines and labels."

Indeed, Ptolemy now emphasizes that a world map is a mathematical object, in the strong sense that he has of mathematics as a means of grasping truths about the quantitative and spatial attributes of a body, in this instance the terrestrial globe and its features. In short, the map is mathematical because of the geometrical structure of the cosmos. Having brought up in a preliminary way the mathematical mode in which the map should represent reality, he turns now to the appropriate strategies for acquiring the knowledge to be embodied in the map, namely the absolute and relative locations of terrestrial features on the globe.

The importance of this part of Ptolemy's argument is not that he has new methods of acquiring positional information; the methods that he refers to had been known to Greek geographers for centuries. His contribution is a criterion for evaluating these methods. One method, or perhaps it would be better to say one class of methods, Ptolemy characterizes as *geōmetrikon*, a term that in this context does not mean "geometrical," but reflects its etymological sense of "pertaining to land measurement." Briefly, this is a deduction of the location of one place relative to another from an empirical datum of the kind, "*B* is so many distance units from *A* in such-and-such a direction." In principle Ptolemy envisions such a datum as having been obtained by first finding the direction of north at *A*, then establishing the direction from *A* to *B* relative to this north, and finally traveling in a perfect straight line from *A* to *B* while measuring the traversed distance. (This is obviously meant as an idealization of the messy processes actually underlying such geographical data.) The second method is *meteōroskopikon*, "pertaining to observation of the heavens," by which he means any procedure for extracting positional information regarding a locality from observations of the heavenly bodies made at that locality.

Ptolemy contrasts the methods according to two standards, by both of which the second, astronomical method is found superior. He tells us that an astronomical determination of a location can be performed without recourse to distance measurements, whereas any determination of the relative position of two places by distance measurement requires an astronomical observation to establish which way is north. But besides this matter of dependence, he tells us that the astronomical method is "more indisputable" (*adistaktoteron*, a favorite word with Ptolemy), while the distance-measurement method is "rougher" (*holoscheresteron*, again a favorite word). He illustrates his point by observing that the journey from *A* to *B* is seldom rectilinear, and (if it is across water) the speed of sail, on which the estimate of distance depends, is seldom uniform. But he has not really evaluated the relative accuracy of the two methods objectively. He is ready to rely, for example, on reports of the local times when a lunar eclipse is observed in two different places to obtain their longitudinal separation, without worrying about the difficulty of obtaining accurate reports of these times. One cannot help concluding that astronomical measurement is superior in Ptolemy's eyes on *a priori* grounds, because knowledge of the heavens is more secure than even mathematical knowledge relating to mundane objects.

If Ptolemy had been engaged in another scientific project (the analysis of pitch systems in the *Harmonics*, say, or the deduction of planetary systems in the *Almagest*), which reached the conclusion that method *X* is in all ways superior to method *Y*, he would then have proceeded to a complete rejection of method *Y*. In cartography this is not possible, however, because, as he has earlier remarked, the earth cannot be inspected part by part by any individual. In consequence Ptolemy is at the mercy of whatever empirical data he can lay hands on, and it is overwhelmingly of the distance-measurement variety. He therefore proposes a "plan B," to establish a scattered network of locations on the basis of the "more indisputable of the reports" (again that word *adistaktoteron*!), relative to which the other places are to be situated as best they may. Significantly, Ptolemy phrases this proposal without explicitly equating "more indisputable" with "astronomical," so that he lays the way open for a relative prioritization even among the available distance-measurement reports.

Ptolemy and Marinus

We are now at the point of learning where Ptolemy intends to find the specific data for his map; and the answer is surprising, indeed almost without parallel in Greek scientific literature. It turns out that, in spite of the foregoing review of the possible methods of data gathering, Ptolemy has no intention of conducting a new broad survey of the available reports of distances, directions, and astronomical phenomena. Instead he is prepared to acquiesce in the work of a predecessor, Marinus, but not before subjecting him to a round of criticism that might seem more suitable for a polemic than for an acknowledgment of indebtedness. Polemic, to be sure, is a common enough element in the writings of Greek intellectuals. But Ptolemy is elsewhere a most unaggressive author, brief and sparing in his barbs against contemporaries and predecessors, whom he rarely names. In the *Almagest* he does single out Hipparchus for quite a few errors, but he is careful always to speak of him as an intellectual equal whose very lapses are the symptoms of a burning love of truth.

With Marinus the case is different. Ptolemy starts off with tepid compliments: Marinus has the accidental virtue of being the most recent gatherer of cartographic data, and he was diligent. Then for page after page Ptolemy goes after Marinus's mistakes and misjudgments. He seems to be saying, "See what riches Marinus has accumulated; but see how incompetent he was to organize, sift, and exploit them!" Ruthlessly, Ptolemy dispossesses Marinus of the authority over his own data, so that by the end he has established himself as its new and better master.

The first part of the attack goes after Marinus's grasp of astronomy, with perhaps an oblique retrospective justification of an earlier misstep of Ptolemy's own. In the *Almagest* Ptolemy had written that the regions at the earth's equator might well be habitable, but that anything people said about them was guesswork because up to now no one from his part of the world had traveled so far south. Marinus, however, maintained correctly that the "known world," that is, the regions reached by people from the Greco-Roman world, extended well south of the equator, and

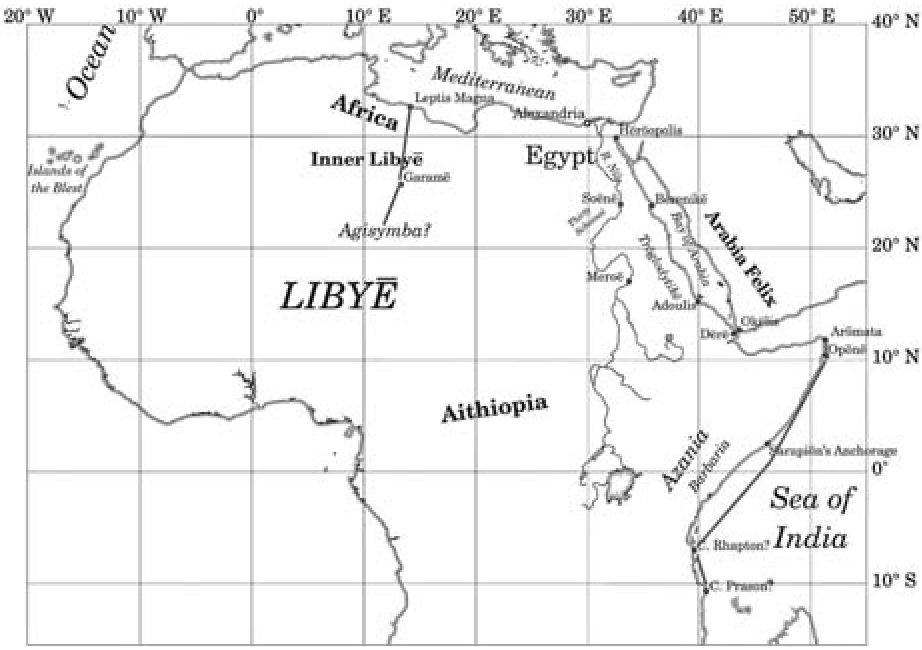


FIGURE 4.3 Conjectural routes of the journeys providing the basis for Marinus's estimate of the southern extent of the known world. He seems to have ultimately settled on the southern tropic (approximately 24 degrees south) for the latitude reached by both routes, whereas Ptolemy argued for about sixteen degrees south. In fact, while Greco-Roman traders regularly reached points well south of the equator along the east coast of Africa in Ptolemy's day, the Romans who were said to have traveled overland to an otherwise unknown place called Agisymba probably did not get far beyond the *northern* tropic. Drawing by the author.

part of his argument consisted of observed astronomical phenomena. Ptolemy's review of these is devastating: Marinus turns out not to have known the difference between a predicted phenomenon and an observed phenomenon, and even when he is talking about real observations, he fails to see that they are all compatible with places of observation north of the equator. Marinus is left stripped of credibility with respect to handling the highest order of cartographical data.

Nor does Marinus fare much better at Ptolemy's hands with respect to his use of data of the distance-measurement variety. Continuing his review of Marinus's argument seeking to establish how far south the known world extends, Ptolemy explains how Marinus estimated this distance from a handful of reports of the duration of southward journeys by land across the Sahara and by sea along the east coast of Africa (fig. 4.3). Marinus turns out to have converted these durations into distances naively, just multiplying the reported numbers of days by rule-of-thumb estimates for an optimum rate of travel; hence he obtained the absurd result that the travelers concerned had apparently reached a latitude as far south of the equator as the southern Ukraine and the English Midlands lie north of it. Ptolemy's criticism is not that this result is unacceptable (Marinus himself admitted as much), but that Marinus had no rationale for his subsequent decision to reject his calculated distance and simply situate the southern limit at the Tropic of Capricorn.

Ptolemy has no difficulty in demonstrating that a careful reading of the travelers' reports will turn up reasons for doubting the wisdom of treating their routes as steady and rapid southward journeys. Are the reports worthless, then? No, he believes, because they include a kind of information that Marinus did not exploit, namely what the travelers found at their destination: people with very dark skin color, and elephants, and gatherings of rhinoceros. We can estimate, therefore, that they had reached a latitude no further south of the equator than we find such people and animals north of the equator. In reasoning thus, Ptolemy shows that his prioritization of the levels of attainable knowledge permits some flexibility. Marinus's method fell within the category of the mathematics of mundane objects, whereas Ptolemy's belongs to the category of physics, since it presumes some degree of regularity in the qualitative, physical effects arising from one's situation relative to the sky and the sun. He stresses that inferences drawn from such environmental considerations are inexact and unreliable, but they are preferable to a *bad* inference from mathematical considerations. However, the moment someone comes back from these places with a measurement of a gnomon's shadow length on an equinox or some other astronomical observation yielding latitude, we can forget about the rhinoceros.

The outcome of a long examination of Marinus's efforts to estimate how far the known world extends eastwards is a similar impression that he relied upon inappropriately naive assumptions that travelers by land and sea made long journeys in a straight line eastwards at a rapid, steady pace (fig. 4.4). In this instance, however, Ptolemy cannot offer an alternative physical criterion to replace the distances and times in Marinus's reports, so instead he still works from his data, but subjects the numbers to systematic corrections that are supposed to compensate for the presumed indirectness and variable speed of the journeys. In this section Ptolemy also invokes analogy as a means of filling gaps in the quantitative information of the reports, although this is clearly a method of last resort.

Ptolemy's theme now shifts back from wrong and right methods of research to wrong and right methods of representing data. One aspect of this topic is the question, what should the map look like, and how should it be laid out? It is the question with which Ptolemy began his book, and it was only partially answered there to the effect that the map should be a schematic, geometrical drawing having an appropriate size and level of detail. But before resuming this topic, he raises a prior question, how *texts* should present the data obtained by digesting and analyzing the reports and observations that constitute our empirical evidence. Here Ptolemy assumes a stance that was not necessarily shared by his predecessors in the cartographic literature from Eratosthenes to Marinus, namely that a cartographic text ought to provide in and of itself all the information that one needs to draw a

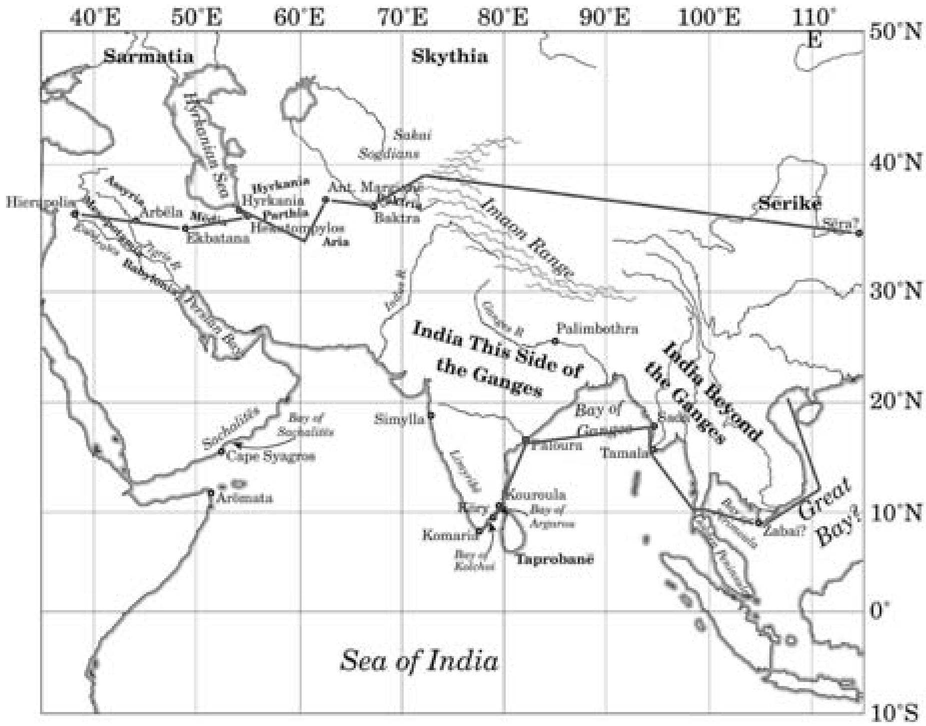


FIGURE 4.4 Marinus's and Ptolemy's discussions of the eastward extent of the known world were based on reports of trade routes across central Asia (the "Silk Road") and the Indian Ocean coasts. Ptolemy reduced Marinus's greatly exaggerated estimate of the longitudinal interval covered by these routes, but not by nearly enough. Drawing by the author.

world map. So far as we can tell, these earlier authors, including Marinus, did not try to cite in their texts every individual feature and locality that was to be marked on a map; still less did they mean to provide an exact location for every place. Rather, the texts dealt with certain geographical issues, the resolution of which would establish a partial framework for marking places on the map; but within that framework many places might be incorporated in the map directly from the source material. Thus Marinus wrote sections, or possibly entire books, on special topics such as determining localities that lie along certain lines of latitude. If this was how he worked, then it might not seem quite fair for Ptolemy to fault him for failing to provide a comprehensive body of data that he had never even intended to provide.

However, Ptolemy softens up Marinus's defenses by means of a rapid-fire barrage of mistakes and inconsistencies that he has detected here and there in his writings. The point is clear: even on his own terms, Marinus cannot avoid getting into tangles of conflicting information, because his text is not structured in the best possible way.

Ptolemy's idea of the best possible presentation of the data for the map is radically different from any earlier geographical text. The idea for it almost certainly came out of his astronomical work. In his *Almagest* (bks. 7 and 8), he produced a catalog of about a thousand stars, grouped by constellation and with numbers to indicate their brightness and their position in the sky. The position numbers are angles measured in degrees, the first number showing what point of the zodiac circle is directly north or south of the star, and the second number showing how far north or south the star is from the zodiac circle. In other words, this is a system of coordinates. Ptolemy's name for the position along the zodiac circle is *mēkos*, which means "length," but by way of Latin we get the technical term "longitude." His name for the position north or south of the zodiac circle is *platos*, "breadth," or "latitude." These are of course the same terms that were used in geography to designate a locality's position along the equator and north or south of it.

One reason for having this catalog of stars is to help with analyzing astronomical observations, for example sightings of planets near bright stars which might be used to establish theories of planetary motion. But Ptolemy also has in mind that one might wish to construct a globe representing the stars and their constellations. Since he intends the globe to be as exact an image as possible of the visible heavens, there is no question of simply daubing pictures of the constellations freehand on its surface. One sets up graduated rings, a fixed one along the zodiac circle and a swinging one at right angles to the first ring, and one uses these to mark each star at the position indicated by the numbers of degrees in the catalog.

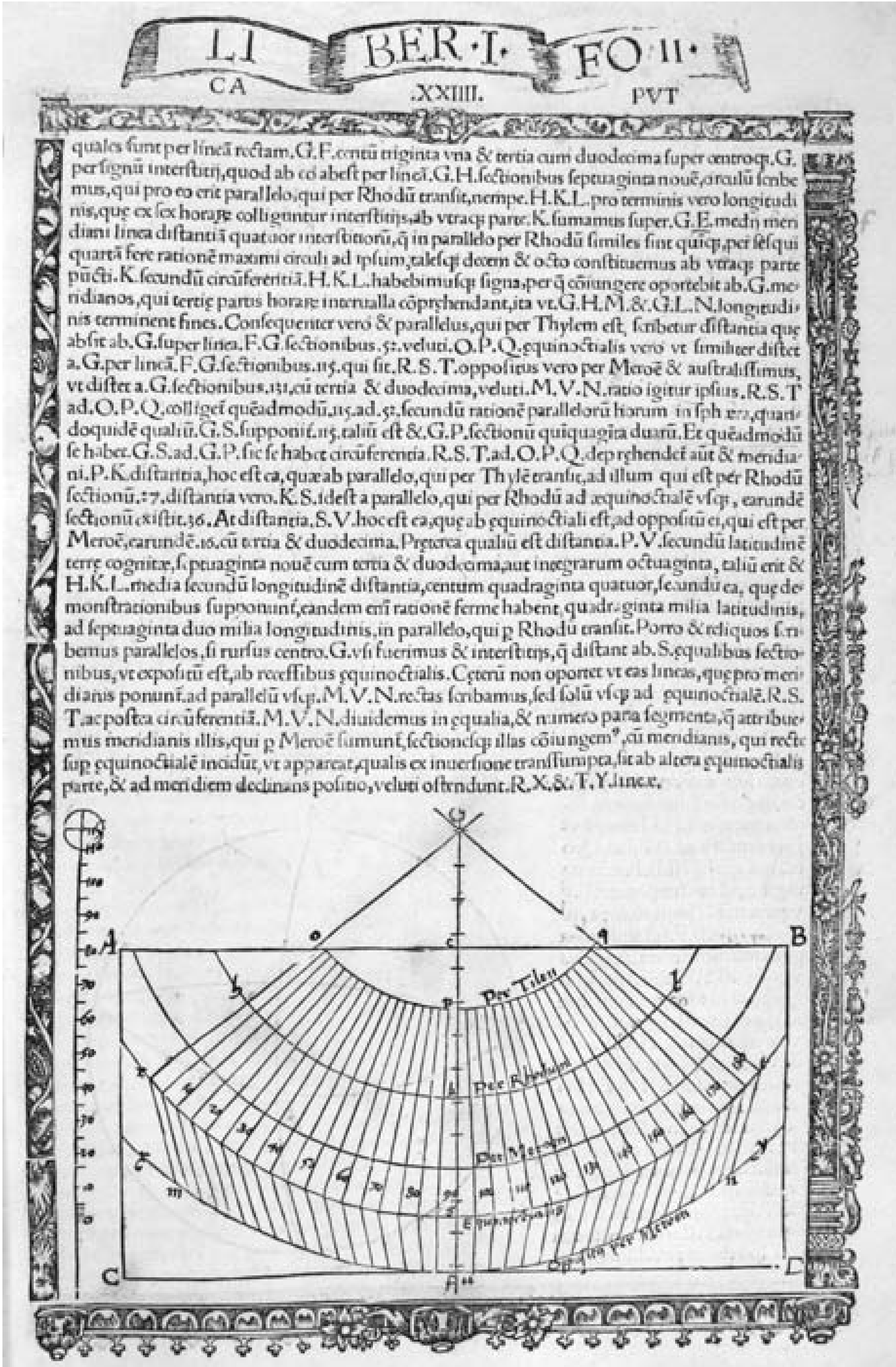
It was obvious how this approach could be transferred to the context of terrestrial cartography. Instead of stars, one is now plotting localities: cities, promontories and bays, points along rivers, and mountains. Of course a map does not consist only of isolated points, but for extensive features such as coastlines, rivers, and mountain ranges one can record numbers representing the positions of a few points distributed along the feature's length, and the mapmaker will understand that it is necessary to join them up with a continuous line. But now at last we see why it was so important for Ptolemy to assert at the outset that the map is a geometrical artifact, not an object of art.

Ptolemy's catalog of localities in the *Geography* is an enormous document, accounting for about three-quarters of the bulk of the treatise, with about eight thousand places. Each place is assigned its two numbers of degrees, a longitude measured eastwards from the western edge of the map, and a latitude measured north or south of the equator. Each number is expressed to a precision of a twelfth of a degree, which would be equivalent to about 8 km or less. Readers who skip straight to the catalog without reading Ptolemy's introduction might suppose that he is claiming great accuracy for all these positions, as if they were all measured carefully with first-rate astronomical instruments.

But that is not the reason for Ptolemy's precision. What he does not say outright, although it becomes obvious as soon as one tries to imagine how he must have proceeded, is that he had to draw a map first, and only then did he compile the catalog by reading off each position from the map. His original map would have been based on the information scattered throughout Marinus's writings, possibly on actual maps drawn by Marinus or other geographers, as well as on a certain amount of new geographical information that he had managed to obtain himself, mostly concerning south Asia and east Africa. The twelfth-of-a-degree precision of the catalog was necessary not because Ptolemy believed that the map was really this accurate, but because he wanted the numbers to represent with sufficient faithfulness all the little wiggles in the coasts and rivers and the relative positions of cities in the denser regions.

Ptolemy's invention of the geographical catalog obviously represents a huge advance in the reproducibility of maps. But there was also a huge cost. He has effectively renounced the obligation to provide verbal justifications for the map's details. The arguments in his introduction are there only to make his general methodological points, to distance himself from Marinus, and to establish the extreme limits of the map. The user of the *Geography* has to accept everything inside these limits on faith, or look back to Marinus's books in search of the underlying evidence and reasoning. To the extent that Ptolemy's *Geography* served as a model for later cartographic works, it tended to suppress the dialectical, argumentative aspect that had been so prominent in the earlier Greek tradition. The book became nothing more nor less than an encoding of the map.

Both Marinus and Ptolemy assumed that the actual layout of the map had to be established through a grid of lines representing meridians of longitude and parallels of latitude, in the first instance because all geographical locations, however they were originally deduced, must ultimately be referred to the spherical earth with its equator and poles. One possibility was that the map could be drawn, like Ptolemy's star map, on the surface of a large globe; but of course it was more often expected that a map should be drawn on a large flat surface. The fact that Marinus used a simple rectangular grid of meridians and parallels (in modern terminology, a "cylindrical projection") suggests that he saw the framework primarily as an organizing device giving structure to the map. Ptolemy has other concerns foremost in mind. His first desideratum is that distances as represented on the map should be approximately proportionate to distances on the actual earth, regardless of where they lie or in what orientation. The second, and actually more important, concern is that the map as a whole should impart to the spectator the truth about our place in the cosmos by *looking* like part of a globe. Hence he offers us two choices for a grid for the map, in which some or all of the parallels and meridians are represented by circular arcs to impart the curved appearance that they would have for a spectator looking at a globe, and in which the spacing of the meridians is broadest at the equator and narrows towards either pole (figs. 4.5 and 4.6). The second grid, in particular, would be quite challenging to draw, especially on a large scale, but it undoubtedly achieves Ptolemy's aim of looking like a spherical surface by means of a kind of qualitative perspective (figs. 4.7 and 4.8 and plate 4).



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quales sunt per lineā rectam.G.F.centū triginta vna & tertia cum duodecima super centroq;.G. per signū interstitij,quod ab eo abest per lineā.G.H.sectionibus septuaginta nouē,circulū scribemus,qui pro eo erit parallelo,qui per Rhodū transit,nempe.H.K.L.pro terminis vero longitudinis,quę ex sex horarę colliguntur interstitijs,ab vtraq; parte.K.sumamus super.G.E.medij meridiani linea distantiā quatuor interstitiorū,q̄ in parallelo per Rhodū similes sint quisq;,per sesquiquartā fere rationē maximi circuli ad ipsum,talesq; decem & octo constituemus ab vtraq; parte pūcti.K.secundū circūferentiā.H.K.L.habebimusq; signa,per q̄ cōiungere oportebit ab.G.meridianos,qui tertię partis horarę interualla cōprehendant,ita vt.G.H.M.&.G.L.N.longitudinis terminent fines.Consequenter verò & parallelus,qui per Thylem est,scribetur distantia quę absit ab.G.super linea.F.G.sectionibus.52.veluti.O.P.Q.equinoctialis vero vt similiter distet a.G.per lineā.F.G.sectionibus.115.qui sit.R.S.T.oppositus vero per Meroē & australissimus, vt distet a.G.sectionibus.131.cū tertia & duodecima,veluti.M.V.N.ratio igitur ipsius.R.S.T ad.O.P.Q.colligetur quēadmodū.115.ad.52.secundū rationē parallelorū horum in sphęra,quandoquidē qualiū.G.S.supponitur.115.taliū est &.G.P.sectionū quinquaginta duarū.Et quēadmodū se habet.G.S.ad.G.P.sic se habet circūferentia.R.S.T.ad.O.P.Q.deprehendetur aūt & meridiani.P.K.distantia,hoc est ea,quæ ab parallelo,qui per Thylē transit,ad illum qui est per Rhodū sectionū.27.distantia vero.K.S.idest a parallelo,qui per Rhodū ad æquinoctialē vsq;, earundē sectionū existit.36.At distantia.S.V.hoc est ea,quę ab equinoctiali est,ad oppositū ei,qui est per Meroē,earundē.16.cū tertia & duodecima.Preterea qualiū est distantia.P.V.secundū latitudinē terrę cognitæ,septuaginta nouē cum tertia & duodecima,aut integrarum octuaginta, taliū erit & H.K.L.media secundū longitudinē distantia,centum quadraginta quatuor,secundū ea, quę demonstrationibus supponuntur,eandem enī rationē ferme habent,quadraginta milia latitudinis, ad septuaginta duo milia longitudinis,in parallelo,qui p Rhodū transit.Porro & reliquos scribemus parallelos,si rursus centro.G.vsi fuerimus & interstitijs,q̄ distant ab.S.equalibus sectionibus,vt expositū est,ab recessibus equinoctialis.Cęterū non oportet vt eas lineas,quę pro meridianis ponuntur,ad parallelū vsq;.M.V.N.rectas scribamus,sed solū vsq; ad equinoctialē.R.S.T.ac postea circūferentiā.M.V.N.diuidemus in equalia,& numero paria segmenta,q̄ attribuemus meridianis illis,qui p Meroē sumuntur,sectionesq; illas cōiungemus,cū meridianis, qui recte sup equinoctialē incidūt,vt appareat,qualis ex inuersione transsumpta,fit ab altera equinoctialis parte,& ad meridiem declinans positio,veluti ostendunt.R.X.&.T.Y.lineæ.

FIGURE 4.5 Grid for Ptolemy's first method of drawing a planar map of the known world, from Claudius Ptolemy, *Geographia*, translated by Willibald Pirckheimer, with annotations by Regiomontanus, edited by Johann Huttich, maps by Laurent Fries (Strasbourg: Johannes Grüninger, 1525). The Newberry Library, Gift of Edward E. Ayer. Reproduced with permission.

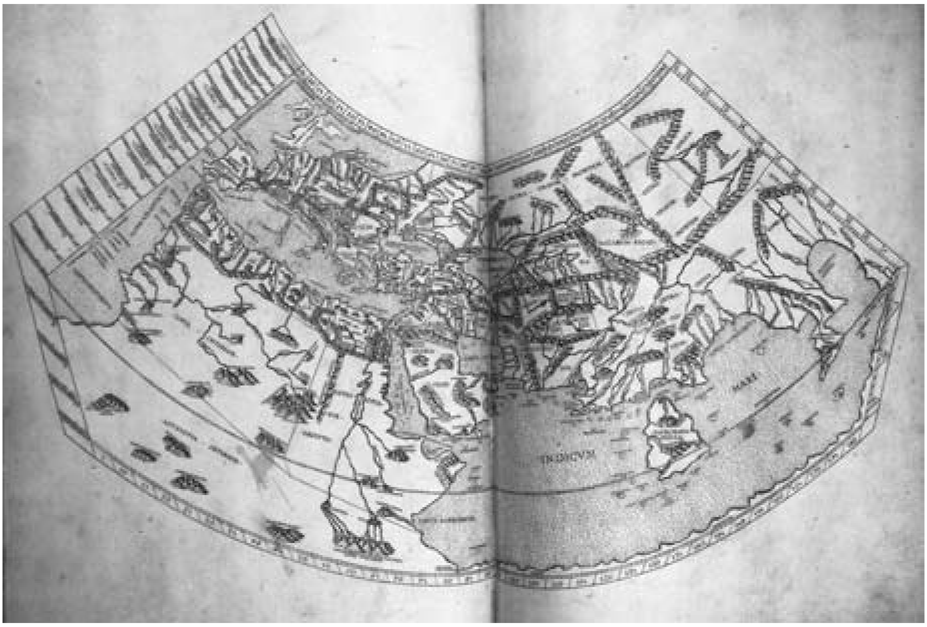
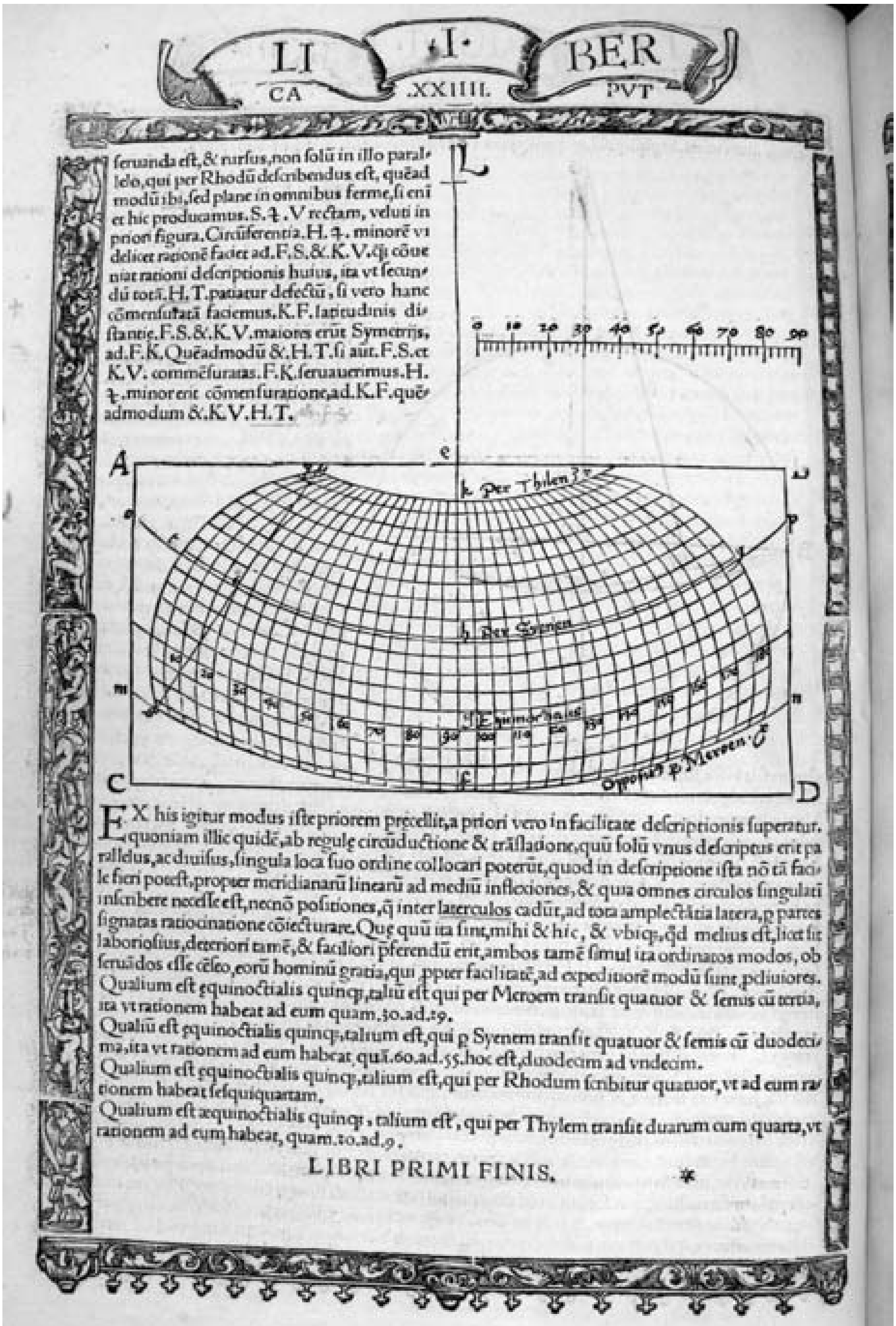


FIGURE 4.6 The world map drawn according to Ptolemy's first method, from Claudius Ptolemy, *Geographia*, edited by Domitius Calderinus, map engraver unknown (Rome: Arnold Buckinck, 1478). The Newberry Library, Gift of Edward E. Ayer. Reproduced with permission.

In spite of all his differences with Marinus, Ptolemy depends heavily on him for the content of the map. We have this by Ptolemy's own admission, and it is consistent with the fact that the geographical information in his catalog best fits a date close to the beginning of the second century, except for those regions around the Indian Ocean about which he tells us he had more recent sources. We should not undervalue Marinus's achievement. His knowledge of the localities of the world was both more detailed and more extensive by far than that of any other Greco-Roman author known to us. Even through the filter of Ptolemy we can tell that he drew upon a huge range of source material, the value of a large part of which would have eluded the comprehension of such an author as Strabo. Ptolemy complains about the inconvenient plan of Marinus's writings, but the fact remains that he succeeded in constructing on their basis a map that creditably represents the physical outlines of most of the world that it covers, including such remote regions as Southeast Asia. Indeed, it still remains usable as a tool for the study of ancient history.

In one important respect Marinus and Ptolemy apparently saw eye to eye. Both disagreed with certain tendencies of cartography in the Roman imperial period, as the austere, unpolitical character of Ptolemy's map demonstrates. Consider what features his catalog records. First, there are physical features: points defining coasts, rivers, and mountains. Second, there are cities, a few of which are designated as "metropolis," although this term does not appear to have a systematic



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seruanda est, & rursus, non solũ in illo paral-lelo, qui per Rhodũ describendus est, quẽad modũ ibi, sed plane in omnibus ferme, si eni et hic producamus. S. ꝗ. V rectam, veluti in priori figura. Circũferentia. H. ꝗ. minorẽ vi delicet rationẽ faciet ad. F.S.&.K.V.ꝗ̃ cõue niat rationi descriptionis huius, ita vt secun-dũ totã. H. T. patiatur defectũ, si vero hanc cõmensuratã faciemus. K.F. latitudinis di-stantie. F.S.&.K.V. maiores erũt Symetrijs, ad. F.K. Quẽadmodũ &. H.T. si aũt. F.S. et K.V. commẽsuratas. F.K. seruauerimus. H. ꝗ. minor erit cõmensuratione, ad. K.F. quẽ-admodum &. K.V.H.T.

EX his igitur modus iste priorem precellit, a priori vero in facilitate descriptionis superatur. quoniam illic quidẽ, ab regulę circũductione & trãslatione, quũ solũ vnus descriptus erit pa-rallelus, ac diuisus, singula loca suo ordine collocari poterũt, quod in descriptione ista nõ tã faci-le fieri potest, propter meridianarũ linearũ ad mediũ inflexiones, & quia omnes circulos singulatĩ inscribere necesse est, necnõ positiones, ꝗ̃ inter laterculos cadũt, ad tota amplectẽtia latera, ꝑ partes signatas ratiocinatione cõiecturare. Quę quũ ita sint, mihi & hic, & vbiq́, q̃d melius est, licet sit laboriosius, deteriori tamẽ, & faciliori ꝑferendũ erit, ambos tamẽ simul ita ordinatos modos, ob seruãdos esse cẽseo, eorũ hominũ gratia, qui ꝓpter facilitatẽ, ad expeditiorẽ modũ sunt ꝓcliuiores.
Qualium est ęquinoctialis quinq́, taliũ est qui per Meroem transit quatuor & semis cũ tertia, ita vt rationem habeat ad eum quam. 30. ad. 29.
Qualiũ est ęquinoctialis quinq́, talium est, qui ꝑ Syenem transit quatuor & semis cũ duodeci-ma, ita vt rationem ad eum habeat, quã. 60. ad. 55. hoc est, duodecim ad vndecim.
Qualium est ęquinoctialis quinq́, talium est, qui per Rhodum scribitur quatuor, vt ad eum ra-tionem habeat sesquiquartam.
Qualium est æquinoctialis quinq́, talium est, qui per Thylem transit duarum cum quarta, vt rationem ad eum habeat, quam. 20. ad. 9.

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FIGURE 4.7 Grid for Ptolemy's second method of drawing a planar map of the known world, from Claudius Ptolemy, *Geographia*, translated by Willibald Pirckheimer, with annotations by Regiomontanus, edited by Johann Huttich, maps by Laurent Fries (Strasbourg: Johannes Grüninger, 1525). The Newberry Library, Gift of Edward E. Ayer. Reproduced with permission.

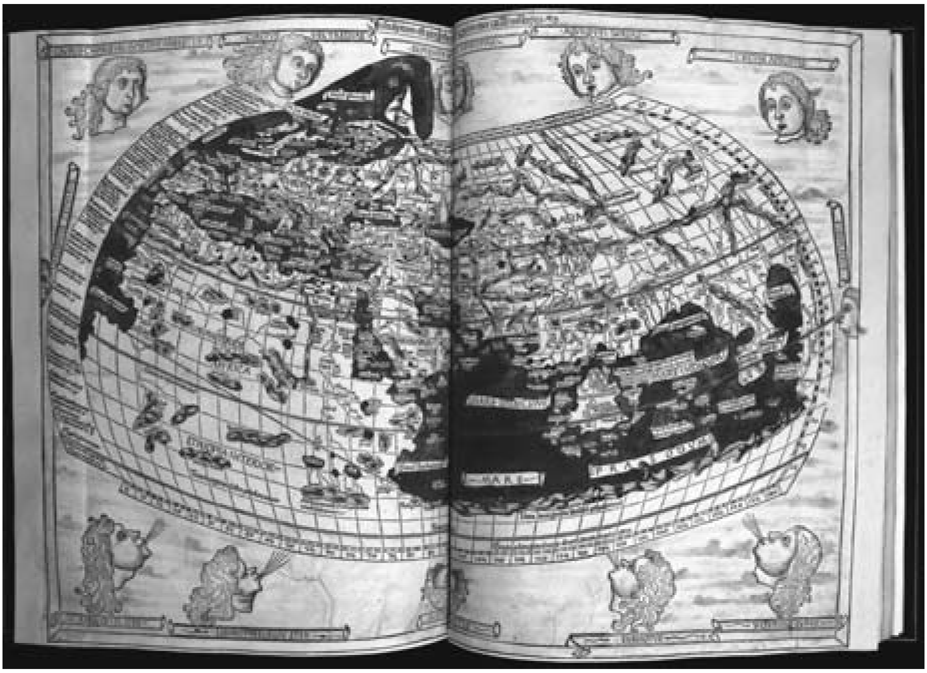

FIGURE 4.8 The world map (incorporating some revisions in northwestern Europe), drawn according to Ptolemy's second method, from Claudius Ptolemy, *Cosmographia*, based on a manuscript edited and with maps by Donnus (Dominus) Nicolaus Germanus (Ulm: Johann Reger, 1486). The Newberry Library, Gift of Edward E. Ayer. Reproduced with permission.

signification. Third, there are the names of native peoples or nations, which are not assigned coordinates in their own right but are roughly situated according to the cities within their districts. Last, there are the boundaries separating what Ptolemy loosely calls "provinces and satrapies": these include provinces of the Roman empire, administrative divisions of the Parthian empire (antiquated by Marinus's time), and an assortment of more far-flung regions. Strikingly, Ptolemy gives not the slightest indication that there exists such an entity as a Roman empire, nor does he tell us which of the "provinces and satrapies" are units of government and which are merely designations of geographical convenience. Notwithstanding the fact that texts detailing road systems must have been among the sources underlying the map, no road is shown. The center of the map is not Rome or Alexandria, but the Persian Gulf.[13]

If there is a rationale behind the choice of what the map does and does not display, it seems to be that peoples and cities are objective realities, effectively part of the physical landscape, whereas other human institutions do not merit a place in what professes to be a picture of the known world. Ptolemy's map is not about power or prestige, but about our place in a cosmos that on the whole has much more important matters to concern itself with than mere human beings.

NOTES

1. The chief weakness of Ptolemy's scheme is its susceptibility to errors arising from miscopying of the text. Such errors affect the maps mostly at the level of fine details.

2. For a general account of his life and work, see Toomer (1975), updated by Jones (2008).

3. The specific works alluded to are, respectively, the *Harmonics*, the *Optics*, and the *Tetrabiblos*.

4. Splendidly translated by Toomer (1984).

5. The broadest study of Ptolemy as a philosopher remains Boll (1894).

6. For English translations of these works, see, respectively, Barker (1989); A. Smith (1996); and Liverpool-Manchester Seminar (1989).

7. The scheme is described in a part of book 1 of Ptolemy's *Planetary Hypotheses* that survives only in Arabic translation; see Goldstein (1967), 6–7.

8. See *On the Kriterion*, sec. 15, and introductory secs. 1–8 of bk. 2 of the *Planetary Hypotheses*. The latter survives only in Arabic translation; for the only available modern-language version (in German), see Nix (1907).

9. For the rejection of Aristotle's fifth-element cosmology, see Falcon (2001).

10. *Harmonics*, bk. 1, chap. 1, gives a lucid statement of this recursive strategy.

11. For the parts of the *Geography* referred to from here on, see Berggren and Jones (2000). The original Greek is now best consulted in Stückelberger and Graßhoff (2006).

12. Geus (2002), 261–63.

13. See further in this connection chaps. 6 and 7 below.