11 · The Culmination of Greek Cartography in Ptolemy

O. A. W. Dilke
With Additional Material Supplied by the Editors

By the time of Marinus of Tyre (fl. A.D. 100) and Claudius Ptolemy (ca. A.D. 90–168), Greek and Roman influences in cartography had been fused to a considerable extent into one tradition. There is a case, accordingly, for treating them as a history of one already unified stream of thought and practice. Here, however, though we accept that such a unity exists, the discussion is focused on the cartographic contributions of Marinus and Ptolemy, both writing in Greek within the institutions of Roman society. Both men owed much to Roman sources of information and to the extension of geographical knowledge under the growing empire: yet equally, in the case of Ptolemy especially, they represent a culmination as well as a final synthesis of the scientific tradition in Greek cartography that has been traced through a succession of writers in the previous three chapters.

The remarkable influence of Ptolemy on the development of European, Arabic, and ultimately world cartography can hardly be denied.[1] Through both the *Mathematical Syntaxis* (a treatise on mathematics and astronomy in thirteen books, hereafter called the *Almagest*)[2] and the *Geography* (in eight books), it can be said that Ptolemy tended to dominate both astronomy and geography—and hence their cartographic manifestations—for over fourteen centuries. It is true that during the period from the second century A.D. to the early fifteenth century Ptolemy's geographical writings exerted relatively little influence on Western cartography, though they were known to Arab astronomers and geographers.[3] The *Almagest*, although translated into Latin by Gerard of Cremona in the twelfth century, appears to have had little direct influence on the development of cartography. With translation of the text of the *Geography* into Latin in the early fifteenth century, however, the influence of Ptolemy was to structure European cartography directly for over a century. In the history of the transmission of cartographic ideas it is indeed his work, straddling the European Middle Ages, that provides the strongest link in the chain between the knowledge of mapping in the ancient and early modern worlds.

Notwithstanding his immense importance in the study of the history of cartography, Ptolemy remains in many respects a complicated figure to assess. Many questions about his work remain unanswered. Little is known about Ptolemy the man, and neither his birthplace nor his dates have been positively established.[4] Moreover, in relation to the cartographic component in his writings, we must remember that no manuscript earlier than the twelfth century A.D. has come down to us, and there is no adequate modern translation and critical edition of the *Geography*.[5] Perhaps most serious of all for the student of mapping, however, is the whole debate about the true authorship and provenance of the general and regional maps that accompany the several versions of the Byzantine manuscripts (pp. 268–74 below). Al-

1. Some existing authorities tend to eulogize Ptolemy excessively by viewing his work out of context of the sources available to him. See, for example, Lloyd A. Brown, *The Story of Maps* (Boston: Little, Brown, 1949; reprinted New York: Dover, 1979), chap. 3, esp. 79–80. Others criticize his "egregious errors": see R. R. Newton, *The Crime of Claudius Ptolemy* (Baltimore: Johns Hopkins University Press, 1977); cf. note 31 below.

2. Ptolemy, *Ptolemy's Almagest*, trans. G. J. Toomer (London: Duckworth, 1984); Toomer translates the Greek title as "mathematical systematic treatise." The Arabic title given as al-mjsty (consonantal skeleton only) comes from a Greek form, μεγίστη, "the greatest [treatise]" see Toomer *Almagest*, 2. All translations from the *Almagest* appearing in this text are taken from Toomer's edition.

3. See volume 2 of the present *History*.

4. G. J. Toomer, "Ptolemy," in *Dictionary of Scientific Biography*, 16 vols., ed. Charles Coulston Gillispie (New York: Charles Scribner's Sons, 1970–80), 11:186–206, esp. 186–87.

5. Editions of Ptolemy's *Geography* include: *Claudii Ptolemaei Geographia*, 3 vols., ed. C. F. A. Nobbe (Leipzig: C. Tauchnitz, 1843–45), reprinted in one volume with an introduction by Aubrey Diller (Hildesheim: Georg Olms, 1966); *Claudii Ptolemaei Geographia*, 2 vols. and tabulae, ed. Karl Müller (Paris: Firmin-Didot, 1883–1901); *Claudii Ptolemaei Geographiae Codex Urbinas Graecus 82*, 2 vols. in 4, ed. Joseph Fischer, Codices e Vaticanis Selecti quam Simillime Expressi, vol. 19 (Leiden: E. J. Brill; Leipzig: O. Harrassowitz, 1932); and *Geography of Claudius Ptolemy*, trans. Edward Luther Stevenson (New York: New York Public Library, 1932). Because of the complexity and often technical nature of the *Geography*, editions vary substantially in coverage and quality and therefore no single edition was selected for use in the *History*. The Nobbe and Müller editions were consulted for making translations; Stevenson, the only complete English edition, is in many respects inadequate and was not used. Unless otherwise indicated, the translator for all quotations from the *Geography* is James Lowe, Ph.D. candidate (1985) at the University of Wisconsin-Madison. When appropriate or necessary, specific editions are cited in the footnote.

though Bagrow, Crone, and other authors claim it cannot be established whether maps were drawn in connection with the *Geography* in the second century A.D., a rereading of the early Greek version may demonstrate that such maps existed.[6] There is as yet no general agreement on this question, and it illustrates how the whole subject of Ptolemy's place in cartographic development—over the long period of his influence—must be handled with caution. Here we try to bypass the wide swaths of speculation in the earlier literature and to concentrate on reconstructing Ptolemy's work directly from the textual evidence. In particular, we will examine Ptolemy's review of the mapping of Marinus of Tyre, the instructions Ptolemy provides for drawing celestial globes and terrestrial maps, and the likely content of his own maps (if they existed) as inferred from the evidence of the coordinate tables and the maps in the Greek manuscripts of the thirteenth and fourteenth centuries.

Updating the World Map: Ptolemy's Criticism of Marinus of Tyre

As the Roman world continued to expand its territorial influence during the first century A.D., and as previous gains were consolidated into the administration of the empire, there could have been some pressure on scholars and administrators to update those maps that were used by the bureaucracy or displayed in public places. The flow of new geographical knowledge can be traced to both military and commercial enterprises. The fleet of Gnaeus Iulius Agricola (A.D. 40–93) had sailed around the British Isles, and it was claimed that the island of Thule had been seen in the distance;[7] it was in fact Mainland, the largest of the Shetland Isles. The campaigns against Germany or Dacia, and the Roman explorations into central Africa or to the sources of the Nile in Ethiopia, had likewise made areas familiar that had previously been considered far outside the inhabited world. Or yet again, by the age of Ptolemy, Chinese merchants were exporting silk to Rome and to other parts of Europe, either by land through Asia, or by sea through the Indian Ocean and the Persian Gulf or the Red Sea.[8] The potential sources for the mapmaker were thus greatly enriched. In the Roman world, just as much as in the Age of Great Discoveries, in a society that was already familiar with maps (see chap. 12 below), this new information in turn created incentives for revising maps to accord with the new knowledge of reality.

It is in this general context of an expanding world that we can place the specific attempts of Marinus of Tyre to modify existing maps from new discoveries. Little is known about Marinus, but the busy Phoenician port from which he originated, maintaining extensive commercial contacts across the known world, suggests some of the channels by which new knowledge may have reached him.[9] Ptolemy devoted a great deal of space in the *Geography* to a thorough criticism of Marinus's work, describing him as the "latest," in the sense of the most recent, "of the contemporary geographers"[10] and later drawing extensively on his materials in compiling his own *Geography*. The importance of Marinus in the process of updating the world map, although he was not the first to attempt this task, lay in his critical approach to existing maps, even those he had compiled himself, which he revised as new information became available. As Ptolemy suggested in book 1 of the *Geography*, much of Marinus's working life was devoted to this task: "He obviously included many accounts in addition to those already known before his time. He also considered worthy of correction those accounts which both he (the first time) and others had carelessly trusted; this we can see from his editions (of which there are many) of the correction of the map."[11] This passage should not be read to imply that Ptolemy was uncritical of Marinus, and subsequent chapters are devoted to correcting, or to making more intelligible, the text that confronted him. Yet if Marinus was sometimes obscure, Ptolemy revealed himself to be a true cartographer, almost in the modern definition of that word, by focusing primarily on the techniques by which maps were compiled rather than solely on their geographical content. As a result, there emerges from Ptolemy's critique of Marinus a clear perception of three major cartographic problems confronting the mapmaker of that age.

The first of these problems, in a long lineage of Greek work, concerned the size and position of the inhabited world. For these calculations Marinus had adopted, largely uncritically, 180,000 stades as the value for the circumference of the earth. He simply said that "one

6. See below, pp. 189–90; 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; Leo Bagrow, *History of Cartography*, rev. and enl. R. A. Skelton, trans. D. L. Paisey (Cambridge: Harvard University Press; London: C. A. Watts, 1964), 34–37.

7. Tacitus *Agricola* 10; see *The Agricola [and] The Germania*, trans. Harold Mattingly, rev. S. A. Handford (Baltimore: Penguin Books, 1970).

8. John Ferguson, "China and Rome," in *Aufstieg und Niedergang der römischen Welt*, ed. Hildegard Temporini and Wolfgang Haase (Berlin: Walter de Gruyter, 1972–), 2.9.2 (1978): 581–603; Manfred G. Raschke, "New Studies in Roman Commerce with the East," in *Aufstieg und Niedergang* (above), 2.9.2 (1978): 604–1361, and map appendix following.

9. No other Greek writer apart from Ptolemy mentions Marinus of Tyre, nor does any Latin writer; for an Arabic reference see volume 2 of the present *History*.

10. Ptolemy *Geography* 1.6.1 (note 5).

11. Ptolemy *Geography* 1.6.1 (note 5).

part [i.e., degree] contains just about 500 stades,"[12] thus making his measurement the same as the smaller of those estimates ascribed to Posidonius.

According to Marinus, the north-south width of the inhabited world extended from the parallel through Thule, at 63°N, to the parallel through the country of the Ethiopians, named Agisymba, and the promontory of Prasum.[13] This southerly parallel, which Marinus said was below the winter tropic, is in fact the southern tropic, at 24°S. As for the island of Thule, which Pytheas and Eratosthenes located at 66°N, on the polar circle, Marinus did not explain (or at least Ptolemy does not tell us) why he moved it to 63°N. Marinus therefore attributed 87° or 43,500 stades to the latitudinal breadth of the known world. He estimated its length at fifteen hours of longitude[14] between two meridians, that is, 225° or 90,000 stades along the Rhodian parallel, 36°N, on which he had assumed one degree of longitude was about 400 stades.

So the inhabited world according to Marinus occupied well over a quarter of the terrestrial globe. His map also differed greatly from earlier maps in two respects. First, it was drawn on both hemispheres, even though most of it lay in the Northern Hemisphere. Second, the extent of the ocean between the extreme east and west edges of the inhabited world was considerably reduced: it was depicted as 135° longitude or 54,000 stades along the Rhodian parallel, as compared with 225° longitude or 90,000 stades from Spain to China by land.

It is true that Marinus or his source made some astronomical observations, quoted by Ptolemy in *Geography* 1.7.4 and following sections; but Ptolemy dismisses these as inconclusive. Marinus's method was simply to employ the various records of travelers and merchants, by converting into stades the number of days necessary to go by land or sea from one place to another. When the number of stades seemed excessive to him, he arbitrarily reduced it to suit his conceptions. However, Marinus was the first geographer to extend the known world significantly by including in his map the eastern part of Asia, "from the Stone Tower to Sera, the capital of the Seres, a journey of seven months."[15] Likewise, he integrated the part of Africa lying south of the Garamantes (a people living in the Sahara) into the world view, writing about Agisymba, far toward the south and beyond the equator.

A second cartographic problem in which Ptolemy shared an interest with Marinus—and indeed may have built on the foundations he had provided—was that of map projections. Apparently Marinus never completed the final revision of his map of the world, for, as Ptolemy puts it, "he himself says, even in the last edition he has not come to the point of revision in which he corrects the *climata* and the hours."[16] Yet even if this exercise in mathematical geography did not reach its final cartographic expression, Marinus had nevertheless made a careful study of the problem of representing a portion of the globe on a plane. Like Eratosthenes and Strabo, he adopted a rectangular projection in which the parallels and meridians were all drawn as straight parallel lines, the meridians being perpendicular to the parallels. But unlike Eratosthenes, who had selected only a few parallels and a few meridians at irregular distances, Marinus seems to have used a complete network of parallels and meridians at regular distances from one another (fig. 11.1). In this system all the parallels are the same length: Marinus gave them the length of the parallel through Rhodes. According to Ptolemy, "he kept only the parallel passing through Rhodes proportional to the meridian according to the approximate 4:5 ratio. . . . he had no concern for any of the others with respect to their proportionality or spherical shape."[17] As a result, the distances on the equator fell short by one-fifth of their correct measurement, and the distances on the parallel through Thule were increased by four-fifths.[18] Indeed, Ptolemy stated, "Marinus devoted considerable attention to this and generally found fault with all the systems of the plane-maps; nevertheless he used a system of representation especially unsuitable for keeping distances proportional."[19] Its overall effect was to make Marinus's

12. Ptolemy *Geography* 1.7.1 (note 5, Müller edition).

13. As has been previously mentioned, Agisymba refers to central Africa and Cape Prasum is somewhere near Zanzibar, south of Rhapta (possibly Cape Delgado).

14. One hour is fifteen degrees of longitude; but one degree of longitude is equal to 500 stades on the equator (if the circumference of the earth is taken as 180,000 stades) and only 400 stades on the Rhodian parallel.

15. Ptolemy *Geography* 1.11.3 (Müller edition), 1.11.4 (Nobbe edition) (note 5). Sera is the capital of the silk country, China. There is some discrepancy, even within Ptolemy, as to the exact location of the Stone Tower; see J. Oliver Thomson, *History of Ancient Geography* (Cambridge: Cambridge University Press, 1948; reprinted New York: Biblo and Tannen, 1965), 307–9.

16. Ptolemy *Geography* 1.17.1 (note 5, Müller edition).

17. Ptolemy *Geography* 1.20 (note 5). Müller, in his edition, correctly explains ἐπιτέταρτος here as 4:5. The literal sense (cf. ἐπίτριτος, ἐπίπεμπτος) is "a quarter in addition," which could mean 1¼:1 or, as here, 1:1¼. *A Greek-English Lexicon*, 2 vols., comp. Henry George Liddell and Robert Scott, rev. and augmented Henry Stuart Jones (Oxford: Clarendon Press, 1940), translates the adjective wrongly as "ratio of 4:3." (However the Supplement to these volumes, published in 1968, amends the statement to read "ratio of 5:4"; p. 61.) E. L. Stevenson, drawing on a Renaissance Latin translation, brings in a nonexistent character Epitecartus. What Ptolemy means is that Marinus treated the whole world, for the sake of simplification, as if it were like the area around Rhodes, where a degree of longitude was taken as 400 stades, of latitude as 500.

18. Ptolemy *Geography* 1.20.7 (note 5); see also Armando Cortesão, *History of Portuguese Cartography*, 2 vols. (Coimbra: Junta de Investigações do Ultramar-Lisboa, 1969–71), 1:98 n. 52.

19. Ptolemy *Geography* 1.20.3 (note 5).

maps of the inhabited world misleading "and, in many cases, they [the editors following Marinus] go far astray from the general consensus because of the inconvenient and disjointed nature of the directions, as any experienced person can see."[20]

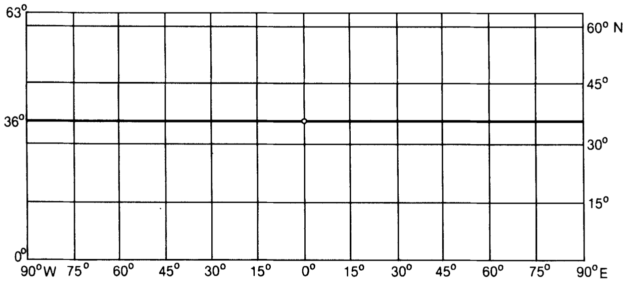

FIG. 11.1. MARINUS'S PROJECTION RECONSTRUCTED FROM PTOLEMY'S DESCRIPTION. Marinus appears to have used a complete network of parallels and meridians in which all the parallels were the same length as that of Rhodes, thereby introducing considerable deformation.
After Otto Neugebauer, *A History of Ancient Mathematical Astronomy* (New York: Springer-Verlag, 1975), fig. 68.

A third and final problem in Marinus's maps related to errors accumulated in the compilation of geographical detail from written commentaries. Ptolemy had discovered that, as a result of uncritical copying, some of the commentaries could not be satisfactorily collated with the content of the maps. He explained that "the constant transfer [of data] from earlier to later models brings about gradual change that usually culminates in a vast discrepancy" and added that many of those working with Marinus's map did not use the latest edition.[21] It seems that mapmakers in Ptolemy's day—and not only Marinus in this respect—usually worked in isolation, incorporating at random the modifications required in their maps as a result of the growth of geographical knowledge.

A combination of such inaccuracies led Ptolemy to reject Marinus's work as a cartographer. As already noted, he believed the information in many of Marinus's maps was neither coherent nor practical. For example, in one work Marinus might correct the latitudes only, in another the longitudes; but the places taken into account were not the same in both works, so that it was difficult to find a place with both sets of coordinates correctly rendered. Consequently Ptolemy—although he evidently made extensive use of Marinus's material—regarded the drawing of a map according to Marinus's commentaries as a hopeless undertaking.

Ptolemy's Instructions for Mapmaking

Ptolemy's most crucial legacy to the long-term development of cartography is the instructions he codified as to how maps of various types should be drawn. These instructions are scattered in various texts, but if brought together they may be said to constitute a technical manual of some sophistication for would-be mapmakers. Moreover, in association with such theoretical guidance, Ptolemy also compiled at length the empirical substance for the content of such maps. As is well known, these survive in the form of coordinate lists of both celestial and terrestrial positions, so that if Ptolemy stopped short of drawing maps or having them drawn for him, which now appears unlikely,[22] he at least left sufficient materials for their construction by others. Indeed, his work was so unambiguously cartographic in its intention that the absence of graphic records would do nothing to diminish its interest for the history of cartography. To make a simple analogy to modern cartographic data bases, we might say that Ptolemy transmitted his cartographic knowledge in digital rather than graphic form, leaving his successors to recreate the images he so clearly envisaged as the end product of the mapping process.

While it is generally believed that Ptolemy was born in Upper Egypt and subsequently lived in Alexandria, he is known to us mainly through his various writings surviving first in a number of Byzantine recensions.[23] The traditional literature of the history of cartography—with its emphasis on geographical maps—has tended to overlook the fact that Ptolemy was a polymath, ranging over topics as diverse as astronomy, mathematics, physics, optics, harmonics, chronology, and geography. As Cortesão has pointed out, however, quite a few of these works contain material relevant to his interests in mapmaking. For example, Ptolemy's *Analemma* deals with the theory of the gnomon and orthographic projection; *Planisphaerium* examines stereographic projection; and *Tetrabiblos*, the large treatise on astrology, also has references to geography.[24] It is, however, through the *Almagest* and through the *Geography*, which in certain manuscripts of the Byzantine recensions contain world or regional maps or both, that his influence on cartographic development was largely transmitted.

So interrelated are the concepts and facts in these last two works that in the history of cartography they have to be considered together. In the *Almagest* Ptolemy taught how to draw a celestial globe; in the *Geography*, how to draw the map of the inhabited world on a globe (said to be simple and similar to the mapping of the celestial sphere) or on a plane surface. In both works he

20. Ptolemy *Geography* 1.18.3 (note 5).
21. Ptolemy *Geography* 1.18.3 (Müller edition), 1.18.2–3 (Nobbe edition) (note 5).
22. See below, pp. 189–90.
23. See below, pp. 268–72.
24. Cortesão, *History of Portuguese Cartography*, 1:92–93 (note 18), and Toomer, "Ptolemy" (note 4).

presented a complete series of coordinates. Since these constitute the only sets of coordinates to survive from classical antiquity, they can justly be said, despite certain imperfections, to mark a critical datum line in the development of celestial and terrestrial cartography.

THE CELESTIAL GLOBE IN THE *ALMAGEST*

Ptolemy, who made astronomical observations in Alexandria between A.D. 127 and 141, was in the first instance an astronomer. His major purpose was to gather as much information as possible and to organize it into an exhaustive synthesis that could be used as an essential tool by every student in this field. So he started by composing a treatise in which he studied all the problems concerning the motion of the celestial bodies, and the relation between the motionless earth and the moving sphere of the sky.

A systematic star catalog, following certain technical rules, is required to make a celestial map or globe.[25] Ptolemy's catalog was derived from that of Hipparchus, and like Hipparchus, according to Toomer, Ptolemy describes the stars "as if they were drawn on the *inside* of a globe, as seen by an observer at the centre of that globe, and facing towards him."[26] All the known stars in the heavens were grouped into constellations: twenty-one constellations lay north of the zodiac, twelve on the zodiac, and fifteen south of it; so forty-eight constellations containing 1,022 stars were listed in the whole catalog. For each star, Ptolemy indicated the longitude and latitude in relation to the ecliptic rather than the equator, so that the positions of the stars would not change owing to the precession of the equinoxes: the latitudes do not vary, and one need only add the values of the precession for any time to find the longitudes.

In a few cases Ptolemy had to amend the naming of the positions of the stars within the constellations to make them relate more closely to the outlines of human figures or animals usually sketched to represent them:

> Futhermore, the descriptions which we have applied to the individual stars as parts of the constellation are not in every case the same as those of our predecessors (just as their descriptions differ from their predecessors'): in many cases our descriptions are different because they seemed to be more natural and to give a better proportioned outline to the figures described. Thus, for instance, those stars which Hipparchus places "on the shoulders of Virgo" we describe as "on her sides" since their distance from the stars in her head appears greater than their distance from the stars in her hands, and that situation fits [a location] "on her side," but is totally inappropriate to [a location] "on her shoulders."[27]

The names Ptolemy gave to the stars were thus slightly different from the forms found in Hipparchus. But as Ptolemy explained: "One has a ready means of identifying those stars which are described differently [by others]; this can be done immediately simply by comparing the recorded positions."[28] Their relative positions were, in fact, to remain unaltered on his celestial globe, and it is only the names that were subject to variation.

Having listed all the stars that he wanted to take into account, Ptolemy explained in great detail how to make a solid sphere as an image of the sky. It was advisable to select a dark globe, its color symbolizing the night sky and allowing the stars to be seen clearly. Two points, diametrically opposed, would indicate the poles of the ecliptic. Two great circles would then be drawn, one of them passing through these poles, the other, perpendicular to it, representing the zodiac (one of the points of intersection is selected as the starting point for graduating the ecliptic into 360 degrees).

Nor did Ptolemy neglect to provide practical, mechanical instructions for the globe maker.[29] It would be convenient, he suggested, to attach two semicircles to the globe (Rings A and B in fig. 11.2). so that the relationship between equatorial coordinates and ecliptic coordinates could be demonstrated.

When the exact place of the star has been located, Ptolemy continued, it should be marked by a yellow point or, for some stars, the colors noted in the star catalog, of a size appropriate to the brightness or the magnitude of the star. As for the figures of the constellations, they should be dimly sketched schematically, hardly visible against the dark background of the sphere, so that they do not conceal the stars.[30]

Thus Ptolemy's celestial globe differed greatly from those described by Eudoxus or Aratus or carried by the Farnese Atlas. In those earlier periods, astronomers preferred to group stars into constellations so as to be able to name and identify them, hence the emphasis on the outlines of the constellations. By Ptolemy's day, however, the identification of stars had become less dependent on the constellations, for they could be located—

25. Ptolemy *Almagest* 7.5–8.1 (note 2), contains the tabular layout of the constellations.
26. Toomer, *Ptolemy's Almagest*, introduction, p. 15 (note 2).
27. Ptolemy *Almagest* 7.4 (note 2).
28. Ptolemy *Almagest* 7.4 (note 2).
29. For a full account of the instruments Ptolemy describes, see D. R. Dicks, "Ancient Astronomical Instruments," *Journal of the British Astronomical Association* 64 (1954): 77–85.
30. Ptolemy *Almagest* 8.3 (note 2). For a detailed technical interpretation of some of the Greek at this point, see the translation and notes in Toomer, *Ptolemy's Almagest*, 404 n. 179 and 405 nn. 180, 181 (note 2).

on the sphere as in the catalog—by giving the coordinate positions of each individual star.[31]

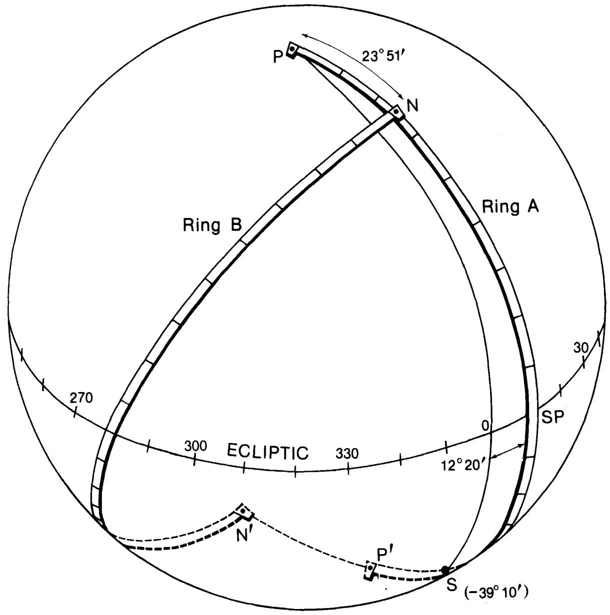

FIG. 11.2. PTOLEMY'S INSTRUCTIONS FOR CONSTRUCTING A STAR GLOBE. The *Almagest* contains explicit instructions for constructing a celestial globe from ecliptic coordinates. Ring A, on the axis PP′, is fixed at the solstitial point, 12°20′E of the meridian of Sirius, which represents its position at that time (first year of the principate of Antonius Pius, A.D. 137). This fixes the axis of the sidereal coordinate system with Sirius as the reference star. Equatorial coordinates could be mechanically converted from the ecliptic coordinates with the help of ring B, which rotates freely around the axis NN′, which is 23°51′ distant from the axis PP′ to allow for the obliquity of the ecliptic.
After Otto Neugebauer, *A History of Ancient Mathematical Astronomy* (New York: Springer-Verlag, 1975), fig. 79.

THE *CLIMATA* IN THE *ALMAGEST*

In book 2 of the *Almagest*, Ptolemy turned to a standard problem in mathematical geography: establishing the position of the inhabited world on the terrestrial globe, and its relation to the celestial sphere, together with the distribution of the *climata*. First of all, he asserted that "our part of the inhabited world is approximately bounded by one of the two northern quarters."[32] Then he decided to compute systematically the celestial phenomena relating to several parallels of the northern hemisphere, noting for each one data such as the height of the pole above the horizon, the ratios of gnomon to shadow on solstitial and equinoctial days, and the length of the longest day. All these values were obtained by calculation (not by observation), as Ptolemy explained in later chapters.

Ptolemy's tables were almost certainly inspired by the table of *climata*[33] drawn up by Hipparchus, in which similar information could have been found. But whereas Hipparchus dealt with parallels spaced at one degree (or 700 stades) apart, Ptolemy used in his calculations a difference of one-quarter of an hour (or sometimes half an hour or even an hour) in the length of the longest day from one parallel to the next. This implies that the parallels employed may not have been equidistant, and hence Ptolemy was obliged to increase the difference of time for the northern parallels.

Curiously enough, Ptolemy mentioned the traditional hypothesis of a probable inhabited world along the terrestrial equator, on the grounds that these latitudes enjoy a milder climate than the areas near the tropics. Yet at the same time he accepted that "what these inhabited regions are we have no reliable grounds for saying. For up to now they are unexplored by men from our part of the inhabited world, and what people say about them must be considered guesswork rather than report. In any case, such, in sum, are the characteristics of the parallel beneath the equator."[34] From the equator to the polar circle, Ptolemy listed thirty-three parallels: the equator is first, followed by the parallel with a 12¼-hour longest day, at 4¼°N, which was assigned to Taprobane (Sri Lanka); the last in the series, with a 24-hour longest day, at approximately 66⅙°N, was not related to a known country. The last parallel to relate to the known inhabited world was the 21-hour parallel, at 64½°N, in the location of unknown Scythian tribes; it was next to the parallel through Thule (day of 20 hours, at 63°N). Beyond the 24-hour parallel, Ptolemy referred to the parallels representing the longest day of one to six months at monthly intervals, the last, of course, being under the pole. It may be noted that the countries or towns related to each parallel were either the traditional ones, for the central part of the map, or, for the southern or northern parts, places that are difficult to identify. In any case, such places were used only for reference in relation to the *climata*.

31. Various scholars, and lately Newton, *Crime of Claudius Ptolemy* (note 1), have accused Ptolemy of not having made the observations he claims to have made and of having falsified records obtained by his predecessors in order to bolster his own theories. But in introducing his star catalog, Ptolemy does not conceal his debt to his predecessors, or at any rate to Hipparchus, even if he claims to have verified their observations; no doubt he used celestial globes, quite usual in his time, to choose coherent sets of coordinates. His originality consists in having preferred ecliptic coordinates to equatorial ones and in having provided complete sets of coordinates so that anyone should be able to draw constellations on a globe.

32. Ptolemy *Almagest* 2.1 (note 2).

33. Ernst Honigmann, *Die sieben Klimata und die* πόλεις ἐπίσημοι (Heidelberg: Winter, 1929).

34. Ptolemy *Almagest* 2.6 (note 2).

In other chapters of book 2, Ptolemy selected only a few *climata* to draw up tables of astronomical phenomena according to latitude. In book 2, chapter 8, eleven *climata* are enumerated, from the equator (12-hour) to the Tanais (Don) River (17-hour), with a regular increase of half an hour in the length of the longest day. Later in book 2, chapter 12, he reduced to seven the number of selected *climata*, and these indeed reappear frequently in the *mappaemundi* of the later Middle Ages:

—the 13-hour parallel, through Meroë
—the 13½-hour parallel, through Syene
—the 14-hour parallel, through Lower Egypt
—the 14½-hour parallel, through Rhodes
—the 15-hour parallel, through the Hellespont
—the 15½-hour parallel, through the central part of the Black Sea
—the 16-hour parallel, through the river Borysthenes.

In the commentary on the last (astronomical) table, cited above from the *Almagest*, Ptolemy announced his project of composing a *Geographike hyphegesis* (Manual of geography), now usually known as the *Geography*:

> Now that the treatment of the angles [between ecliptic and principal circles] has been methodically discussed, the only remaining topic in the foundations [of the rest of the treatise] is to determine the coordinates in latitude and longitude of the cities in each province which deserve note, in order to calculate the [astronomical] phenomena for those cities. However, the discussion of this subject belongs to a separate, geographical treatise, so we shall expose it to view by itself [in such a treatise], in which we shall use the accounts of those who have elaborated this field to the extent which is possible. We shall [there] list for each of the cities its distance in degrees of that meridian from the meridian through Alexandria, to the east or west, measured along the equator (for that [Alexandria] is the meridian for which we establish the times of the positions [of the heavenly bodies]).[35]

Ptolemy was to wait some twenty years before executing his project.

THE *GEOGRAPHY*

As with the *Almagest*, there is no doubt that the *Geography* was deliberately planned as a manual for mapmakers. In its opening paragraph Ptolemy explains its scope by defining "geography" as "a graphic representation of the whole known part of the world, along with the things occurring in it."[36] Later he explains the difference between geography and chorography thus: "The aim of chorography is a consideration of the parts, as would be the case for someone depicting [i.e., painting or drawing] just the ear or eye; but the aim of geography is a consideration of the whole, as it is for those (to use the same analogy) who depict the entire head."[37]

In drawing up his catalog of stars, Ptolemy had simply gathered all the available information and arranged it into a systematic table of coordinates enabling anyone to make a celestial globe. In like manner in his *Geography*, he collected information from his predecessors, especially from the most immediate, Marinus of Tyre,[38] and arranged it within a systematic table of coordinates. Thus, Ptolemy believed, it would be easy for anyone to draw a map of the inhabited world, or regional maps with the main towns and characteristic features of the countries.

In outlining his aim to provide mapmakers with an appropriate tool in handy form, Ptolemy seems to have been fully aware of deficiencies in some of his information. This is shown in his declaration: "But as for [the degrees of latitude and longitude of] places not visited in this manner, it is advisable, because of the scarcity and uncertainty of the accounts, to base the reckoning more completely upon the proximity of reliably known positions or configurations, so that none of the things inserted to fill up the whole world may have an undefined place."[39] It is clear that Ptolemy believed it was preferable for mapmakers to locate as many places as possible in the known world, even where the authority for this location was shaky, perhaps recognizing intuitively that only thus would such maps eventually be challenged and become more complete.

The contents of the *Geography* are as follows:

Book 1 Introduction, including map projections and criticism of Marinus.
Book 2 Ireland, Britain, the Iberian Peninsula, Gaul, Germany, the upper Danube provinces, Dalmatia.
Book 3 Italy and adjacent islands, Sarmatia in Europe, the lower Danube provinces, Greece and adjacent areas.
Book 4 North Africa (west-east), Egypt, interior Libya (Africa), Ethiopia.
Book 5 Asia Minor, Armenia, Cyprus, Syria, Palestine, Arabia Petraea, Mesopotamia, Arabia Deserta, Babylonia.
Book 6 The former Persian empire apart from areas already covered (west-east); the Sacae and Scythia bordering on that empire.
Book 7 India, the Sinae, Taprobane, and adjacent areas. Summary of world map. Description of armillary sphere including the map of the inhabited earth. Summary of regional sections.
Book 8 Brief survey of the twenty-six regional maps.

35. Ptolemy *Almagest* 2.13 (note 2).
36. Ptolemy *Geography* 1.1.1 (note 5, Müller edition).
37. Ptolemy *Geography* 1.1.2 (note 5).
38. Ptolemy *Geography* 1.6–7 (note 5).
39. Ptolemy *Geography* 2.1.2 (note 5).

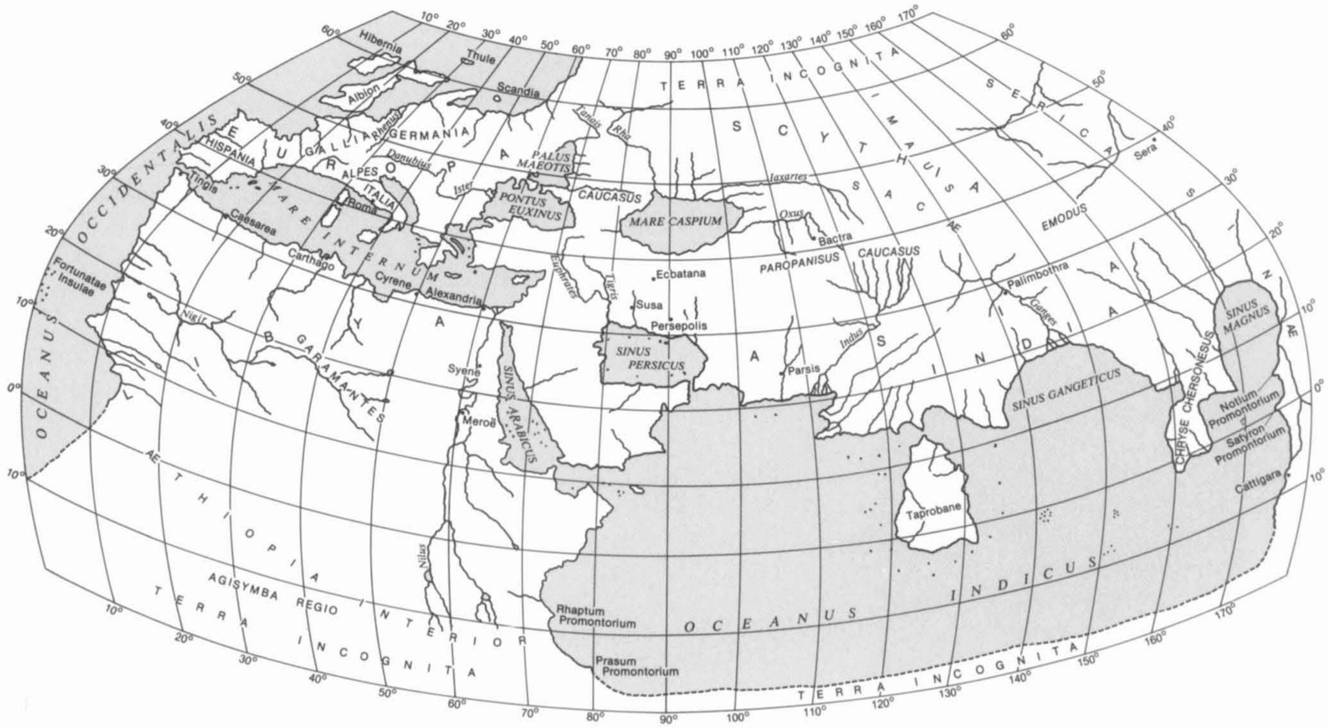

FIG. 11.3. A RECONSTRUCTION OF THE WORLD OF CLAUDIUS PTOLEMY. After Edward Herbert Bunbury, *A History of Ancient Geography among the Greeks and Romans from the Earliest Ages till the Fall of the Roman Empire*, 2d ed., 2 vols. (1883; republished with a new introduction by W. H. Stahl, New York: Dover, 1959), map facing p. 578.

In the case of this survey of the regional maps in book 8, standard information is given for each map. In turn, Ptolemy indicates the proportion of one degree on the central parallel of the map in question to one degree of meridian; he describes roughly the outlines of the map; and then he locates the main towns by a pair of coordinates. But he expresses latitude in terms of length of the longest day and longitude in number of hours east or west of the Alexandrian meridian.[40]

SIZE AND DIMENSIONS OF THE INHABITED WORLD IN THE *GEOGRAPHY*

Ptolemy criticized Marinus for having extended the inhabited world too far. Accepting the Thule parallel (63°N) as the northern limit, he rejected the southern tropic (24°S) as the southern limit and located the region of Agisymba and the promontory of Prasum, the farthest known countries, on the parallel opposite the one through Meroë (which one may call Anti-Meroë), at 16° 25′S or about 8,200 stades south of the equator (fig. 11.3). Thus the whole latitudinal extent of the inhabited world was reduced to 79°25′ or nearly 40,000 stades (Ptolemy used the value he had borrowed from Marinus of 180,000 stades for the circumference of the earth).

Similarly, the length of the inhabited world was reduced from Marinus's fifteen-hour longitude to twelve hours or 180°, from the Fortunate Isles (the Canaries) in the extreme west to Sera and Cattigara in the extreme east.[41] Ptolemy claimed to have accomplished this reduction by examining and comparing land and sea journeys, but it is likely that he relied more on guesswork than on sound calculation. So he fixed the length of the inhabited world at 72,000 stades, calculated along the 36°N parallel passing through Rhodes, on which one degree of longitude was reckoned to be 400 stades.[42] For the distance between the Fortunate Isles and the Euphrates, Ptolemy indicated 72° or 28,800 stades;[43] from the Euphrates to Sera or Cattigara, 105°15′ or 42,100 stades via the Stone Tower.[44]

40. In the *Almagest* 2.13 a prime meridian of Alexandria is proposed, but when Ptolemy came to write the *Geography*, the extreme westerly meridian of the Fortunate Isles was preferred—at least in books 2–7—to allow all longitudes to be expressed as east of this line. A remnant of the earlier system is found in the *Geography*, book 8. See Toomer, *Ptolemy's Almagest*, 130, n. 109 (note 2).

41. Ptolemy *Geography* 1.11 (note 5). Cattigara, south of Sera, may be somewhere near the modern city of Hanoi, although other theories have been advanced; see pp. 198–99 below.

42. Ptolemy *Geography* 1.11.1, 1.12.10 (note 5).

43. Ptolemy *Geography* 1.12 (note 5).

44. Ptolemy *Geography* 1.12.9 (note 5).

By such calculations in his *Geography*, Ptolemy thus accepted that the inhabited world extended south of the equator in latitude; in longitude, as proposed by Posidonius, it now constituted one-half of the Northern Hemisphere.[45] On the whole, in spite of his criticism of Marinus's map, Ptolemy adopted most of the information transmitted by him, modifying the sections necessary to fit his own concept of the size of the inhabited world: "But were we to find nothing lacking from his last arrangement, it would have been sufficient for us to construct a map of the inhabited world just from these commentaries, and waste no time on anything else."[46]

MAP PROJECTIONS

Since it was usual to draw the map of the inhabited world on a plane surface, Ptolemy examined different types of map projection and their ability to maintain the characteristics of a sphere. With hindsight it may be said that this was perhaps his most vital contribution to the long-term development of the mathematical basis of mapmaking. Ptolemy, revealing a clear conceptual insight into the fundamental problem of map projections, writing of globes and of flat maps respectively, says:

> Each of these conceptual systems would have its advantages. The first system, which locates the map on a sphere, obviously preserves the likeness of the world's shape and obviates the need for any manipulation of it; on the other hand, it hardly provides the size necessary for containing most of the things that must be set in place, nor can it let the entire map be seen from one vantage point: instead, one must move either one's own eyes or the sphere in order to view the rest.
>
> The second system, representation on a flat surface, avoids the aforementioned shortcomings altogether. But it lacks some sort of method for preserving the likeness of the spherical shape whereby it might make the distances recorded on its flat surface as proportional as possible to the true distances.[47]

The *Geography* contains a detailed exposition of four systems of map projection: (1) a projection with straight and perpendicular parallels and meridians, like that of Marinus; (2) a projection with straight converging meridians and curved parallels; (3) a projection with curved converging meridians and curved parallels; and (4) a special projection of the globe as viewed from a distance.[48] This whole subject has generated a substantial literature since the nineteenth century, much of it mathematically confusing, with an emphasis on the modification of the Ptolemaic map projections during the European Renaissance.[49] Ptolemy's explanations certainly need to be handled with caution, and there is the danger, as Keuning argues, of defining his methods too literally in terms more appropriate to the formality of modern projections.[50]

Marinus's Projection

Marinus had selected for his world map what could be defined (in modern terms) as a rectangular projection, represented in a graticule by straight parallel meridians and straight parallels orthogonal to the meridians, forming a grid of rectangles. The scale along the parallel of Rhodes (36°N) and along all meridians was assumed to be constant. Marinus had also assumed the length of the parallel of Rhodes—the central parallel of the inhabited world—to be approximately four-fifths the length of the equator (and thus also of any meridian great circle); Ptolemy modified this slightly by expressing the proportion of the length of a degree of longitude on the central parallel to a degree of latitude on the meridian as being 93:115, which very closely approximates cos 36° = 0.809.

This method of projection was to be used for some versions of the regional or provincial maps that were attached to the later texts of the *Geography*. But Ptolemy rejected the system for the world map on the grounds that the various parallels appear in its construction to be of the same length, causing severe deformation away from the central parallel. He calculated the proportion of the length of the parallel of Thule to the length of the equator, for example, as 52:115 (cos 63° = 0.454), yet it is represented by a line of the same length as the equator on the Marinus projection.[51]

Ptolemy's First Projection

To overcome this disadvantage, Ptolemy devised a system of projection, usually called his first projection, in which the meridians were to be drawn as straight lines from a theoretical point (not the North Pole) and the parallels as arcs of a circle with the same point as center. This, in fact, was the projection usually employed for

45. Strabo *Geography* 2.3.6; see *The Geography of Strabo*, 8 vols., trans. Horace Leonard Jones, Loeb Classical Library (Cambridge: Harvard University Press; London: William Heinemann, 1917–32). Also see Strabo, *Géographie*, ed. François Lasserre, Germaine Aujac, et al. (Paris: Belles Lettres, 1966–).

46. Ptolemy *Geography* 1.6.2 (note 5).

47. Ptolemy *Geography* 1.20.1–2 (note 5).

48. In identifying these four systems we follow Otto Neugebauer, *A History of Ancient Mathematical Astronomy* (New York: Springer-Verlag, 1975), 879–959. See also Cortesão, *History of Portuguese Cartography*, 1:97–109 (note 18), who gives a full summary with extensive quotations of Ptolemy's ideas from the *Geography*.

49. These projections will be dealt with fully in the present *History*, volume 3.

50. See Johannes Keuning, "The History of Geographical Map Projections until 1600," *Imago Mundi* 12 (1955): 1–24, who writes (p. 9), "The Ptolemaic projections appear very like conical projections, though they are not. In antiquity there was no question of projecting on a cone or on a cylinder."

51. Ptolemy *Geography* 1.20 (note 5).

constructing the map of the inhabited world associated with the later manuscripts. Its advantage over Marinus's projection was not only that it maintained constant scale along the central parallel (Rhodes) and the meridians (as had Marinus's) but that the proportion of the length of the parallel of Thule to the length of the equator was also correct. This scale could not, of course, be the same as along the parallel of Rhodes, but since this represented the traditional central parallel, and so many distances were known along it, Ptolemy scaled the whole map to it:

> Since it is impossible for all of the parallels to keep the proportion that there is in a sphere, it will be quite sufficient to observe this proportion in the parallel circle running through Thule and the equinoctial, in order that the sides of our map that represent latitude may be proportionate to the true and natural sides of the earth.
>
> The parallel passing through Rhodes must be inserted because on this parallel very many proofs of distances have been registered, and inserted in right relation to the circumference of the greatest circle, following in this Marinus, who gave the ratio for the equal circumferences of the equator (and the meridians) to the parallel of Rhodes as 5:4. By thus doing, we shall ensure that the longitude of our earth, which is the better known, will be in right proportion to the latitude.[52]

The frame of the map—following the traditional proportions of the inhabited world—would have to be rectangular in shape, the center of the circles representing the parallels lying outside this framework for the map (fig. 11.4). Within it would have to be drawn thirty-six plus one meridians one-third of an hour of longitude (5°) apart. For the section of the map south of the equator he advised drawing one parallel only in addition to the parallel of Anti-Meroë (see above, p. 184): the parallel passing through Rhapta promontory and Cattigara, at a half-hour distance from the equator, which would be the same length as the parallel opposite at 8°25′N (see table below).

To mark the localities that were to be placed on the map, Ptolemy continued, the mapmaker should take a narrow ruler, equal in length to the radius of the circle used to draw the equator. He should attach it to the point taken as the center of the curved parallels, so that it could be made to coincide with any given meridian. Then, using the graduations in latitude inscribed on the ruler and the graduations in longitude inscribed on the equator, he should quite easily be able to mark the towns or geographical features in their true places.[53] We can see from these details that even in the event Ptolemy may not have illustrated his projections either in an actual map or in the form of a diagram of the meridians and

Parallel	Length of Longest Day	Degrees
	North of Equator	
1	12 hr 15 min	4°15′N
2	12 hr 30 min	8°25′N
3	12 hr 45 min	12°30′N
4 Meroë	13 hr	16°25′N
5	13 hr 15 min	20°15′N
6 Syene	13 hr 30 min	23°50′N
7	13 hr 45 min	27°10′N
8	14 hr	30°20′N
9	14 hr 15 min	33°20′N
10 Rhodes	14 hr 30 min	36°N
11	14 hr 45 min	38°35′N
12	15 hr	40°55′N
13	15 hr 15 min	43°05′N
14	15 hr 30 min	45°N
15	16 hr	48°30′N
16	16 hr 30 min	51°30′N
17	17 hr	54°N
18	17 hr 30 min	56°10′N
19	18 hr	58°N
20	18 hr 30 min	61°N
21 Thule	19 hr	63°N
	South of Equator	
Rhapta	12 hr 30 min	8°25′S
Anti-Meroë	13 hr	16°25′S

parallels, his instructions for future mapmakers were nonetheless quite explicit. At the same time, it is hard to imagine how such precise instructions could have been compiled without resorting to graphic experiments.

Ptolemy's Second Projection

Despite its improvements over Marinus's projection, Ptolemy's simple first projection was not without its drawbacks. First, the north and south portions of the meridians form acute angles at the equator; second, the proportions of the parallels between Thule and the equator are not the same as on the sphere. So Ptolemy proposed a further projection—often known as his second projection—to alleviate these problems.[54] It was to be

52. Ptolemy *Geography* 1.21.2 (note 5), translated by O. A. W. Dilke. The translation in Stevenson, *Geography of Claudius Ptolemy* (note 5), following Latin versions, gives a completely incorrect rendering. For another example of Stevenson's unacceptable translation, see note 103 below.

53. Ptolemy *Geography* 1.24.7 (note 5).

54. Ptolemy *Geography* 1.24.9–20 (note 5). Marie Armand Pascal d'Avezac-Macaya, in his pioneer study, *Coup d'oeil historique sur la projection des cartes de géographie* (Paris: E. Martinet, 1863), gave it the name "homeotheric projection"; it may also be regarded as the ancestor of the Bonne projection. D'Avezac-Macaya's study was originally published as "Coup d'oeil historique sur la projection des cartes de géographie," *Bulletin de la Société de Géographie*, 5th ser., 5 (1863): 257–361, 438–85.

constructed with curved parallels and meridians (fig. 11.5). According to Ptolemy, its aim was to give the lines representing the meridians the appearance they have on the sphere when viewed by an observer looking directly at the center of the map.[55]

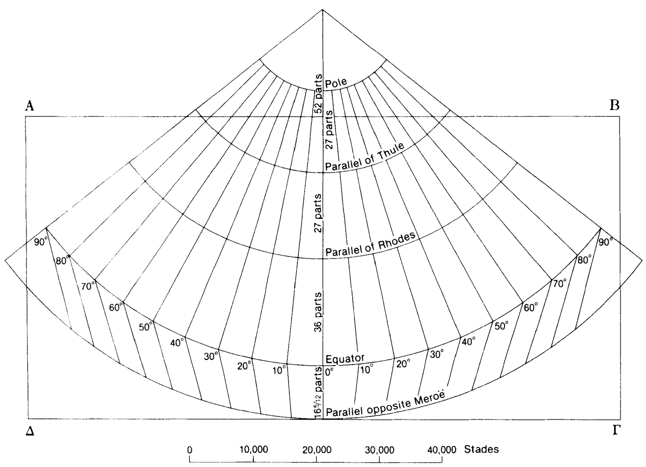

FIG. 11.4. PTOLEMY'S FIRST PROJECTION. The frame of the inhabited world (ΑΒΓΔ) is shown superimposed upon a conic graticule with straight converging meridians and parallels as arcs of circles. Although Ptolemy explained that it was easier to construct and use than his second projection (see fig. 11.5), it did not reflect the spherical shape of the earth as effectively, and only two parallels (as well as all the meridians) maintained their true lengths.
After Erich Polaschek, "Ptolemaios als Geograph," in *Paulys Realencyclopädie der classischen Altertumswissenschaft*, ed. August Pauly, Georg Wissowa, et al. (Stuttgart: J. B. Metzler, 1894–), suppl. 10 (1965): 680–833, fig. 4.

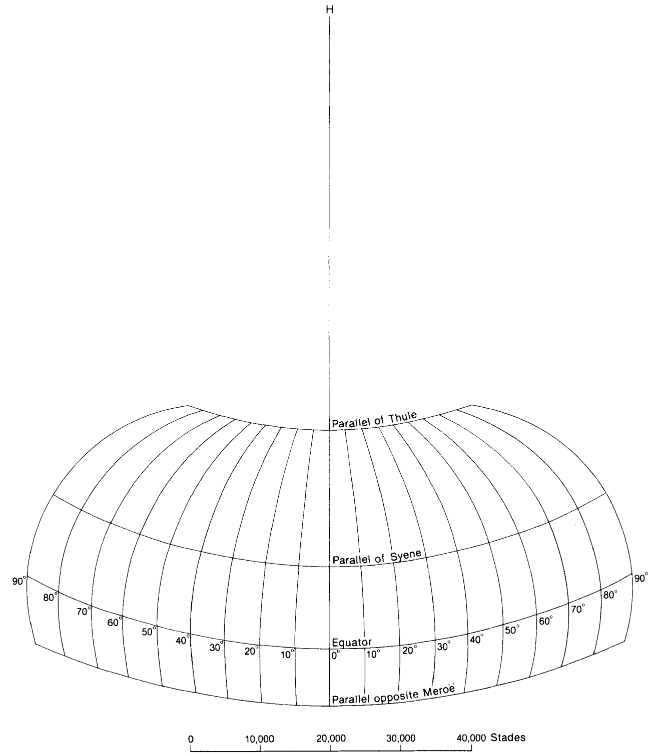

FIG. 11.5. PTOLEMY'S SECOND PROJECTION. Constructed with curved meridians and parallels, this was designed to alleviate some of the problems associated with Ptolemy's first projection (see fig. 11.4). It was especially popular with later editors of the *Geography* in the Renaissance.
After Erich Polaschek, "Ptolemaios als Geograph," in *Paulys Realencyclopädie der classischen Altertumswissenschaft*, ed. August Pauly, Georg Wissowa, et al. (Stuttgart: J. B. Metzler, 1894–), suppl. 10 (1965): 680–833, fig. 5.

The central parallel of the map was designed to run through Syene, at 23°50′ north of the equator. Syene was approximately midway between the parallels of Thule (63°N) and Anti-Meroë (16°25′S). From a center outside the rectangular panel on which the map was to be drawn (H in fig. 11.5), Ptolemy advised that it would be convenient to plot the arcs of the circles representing the main parallels: Thule, Syene, and Anti-Meroë.[56] Second, the thirty-six meridians would be drawn as circular arcs, eighteen on each side of the straight central meridian at five-degree intervals (every one-third hour). Circular meridians were possible, since only three parallels were chosen along which to preserve the true proportions of distances. It was left to later commentators to discover that if the arcs were not circular, all of the parallels in such a projection—not just three—could be drawn preserving their true lengths. Apparently the first person to employ this procedure was Henricus Martellus Germanus on his manuscript world map of about 1490, now at Yale University. In 1514 Johannes Werner, along with his new translation of book 1 of the *Geography*, added a theoretical discussion of Ptolemy's second projection.[57]

Ptolemy's exposition of his second projection ends on a remarkably pragmatic note. Although he believed it offered a better theoretical solution, the task of drawing the map was rendered more difficult. The curved meridians in particular meant that the geographical details could no longer be plotted, as with the first projection, by the straightforward use of a ruler. Ptolemy thus re-

55. Ptolemy *Geography* 1.24.9 (note 5).

56. The parallels would thus be drawn in approximately the following proportions: 5 the equator, 2.25 the Thule parallel, 4.35 the Syene parallel, and 4.4 the Anti-Meroë parallel.

57. Ptolemy, *Geographia*, ed. and trans. Johannes Werner (Nuremburg, 1514). See also the discussion by Neugebauer, *History of Ancient Mathematical Astronomy*, 885–88 (note 48), who does not, however, mention the Martellus map.

tained both methods "for the sake of those who will have recourse to the handier method because of indolence."[58] The recognition that mapmakers sometimes preferred the easier road was prophetic: most of the early scholars attempting to draw a world map from Ptolemy's instructions seem to have preferred the first projection.

Ptolemy's Third Projection

Ptolemy's so-called third projection arises out of his description of the armillary sphere.[59] He mentions that several of his predecessors had attempted to give this demonstration, but inconclusively. It does not seem to have been used in practical map drawing, nor does it appear (unlike the first and second projections) to have influenced the subsequent development of that subject. As Ptolemy describes it: "It is reasonable to add here how the hemisphere in which the inhabited world lies could be represented on a plane surface, with the hemisphere itself being surrounded by an armillary sphere."[60] The aim was to give a plane representation corresponding in some measure to the visual impression of the terrestrial globe in such a way that all the inhabited world could be seen unencumbered by the rings of the armillary sphere. The drawing of its construction in book 7 of later manuscripts of the *Geography* does not entirely clarify the complex exposition in the text.[61] Yet Ptolemy visualized the eye of the viewer situated outside the rings of the imaginary armillary sphere at such a distance that the ring representing the celestial summer tropic would just clear the parallel of Thule on the globe, and the ring representing the celestial equator would just clear the most southerly parallel of the inhabited world (Anti-Meroë). The position of the viewer is thus represented in figure 11.6 by the intersection of the extension of the lines YF and TB. The viewing axis is on a horizontal plane passing through Syene. Figure 11.7 illustrates the concept from the observer's position. In both these diagrams we can see that, in order that the ring on the armillary sphere representing the ecliptic should not obscure the inhabited part of the world, the southern part of the ecliptic should be adjusted on the viewer's side. In his example, in order that all these conditions be met, Ptolemy assumed that the radius of the solid globe was 90 parts, that the ratio of the radius of the armillary sphere to that of the globe must be 4:3, and

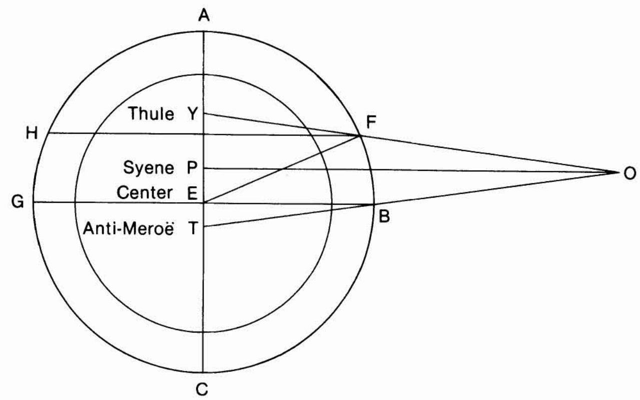

FIG. 11.6. PTOLEMY'S THIRD PROJECTION. This diagram shows the position of the viewer (O) in relation to the position of the globe (center E) within the surrounding armillary ring (ABCG). It thus demonstrates how the inhabited world between the parallels of Thule (Y) and Anti-Meroë (T) can be seen through the armillary rings representing the equator (BG) and the summer tropic (FH). Whereas the armillary sphere itself is seen in perspective, the *oikoumene* is not. Instead, latitudes are preserved along the central meridian. This explains why the line EF does not coincide with PO at the earth's surface, as might otherwise be expected.
After Otto Neugebauer, *A History of Ancient Mathematical Astronomy* (New York: Springer-Verlag, 1975), fig. 78.

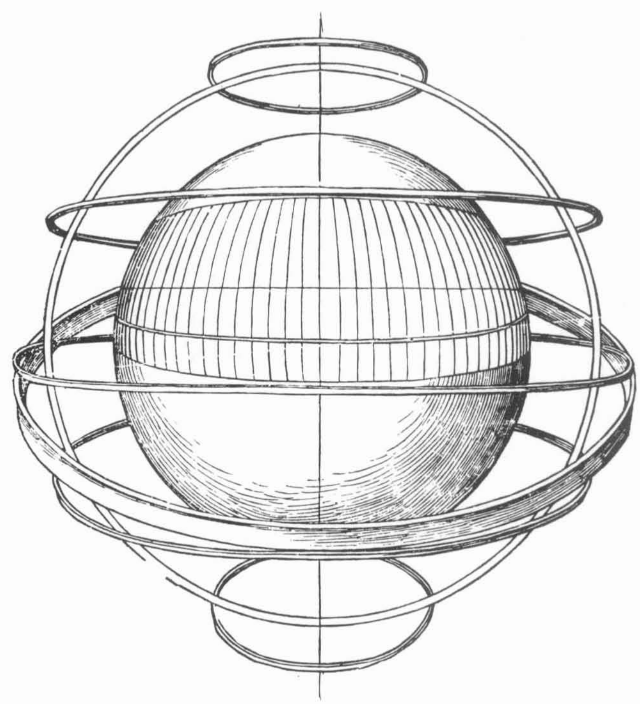

FIG. 11.7. PTOLEMY'S THIRD PROJECTION AS SEEN BY THE OBSERVER. The armillary rings (including the ecliptic) are positioned so as not to impede the full view of the inhabited world.
After Ptolemy, *Geographicae enarrationis libri octo* (Vienne: Gaspar Trechsel, 1541).

58. Ptolemy *Geography* 1.24.22 (Müller edition), 1.24.29 (Nobbe edition) (note 5).

59. Ptolemy *Geography* 7.6.1 (note 5).

60. Ptolemy *Geography* 7.6.1 (note 5, Nobbe edition). Otto Neugebauer, "Ptolemy's *Geography*, Book VII, Chapters 6 and 7," *Isis* 50 (1959): 22–29 gives the best translation and commentary.

61. Ptolemy *Geography* 7.6 and 7.7 (note 5).

that the eye must be placed on the axis described above. The result, once these details had been resolved, would be a projection for the inhabited world in which the parallel and the meridian of Syene were straight lines and all the other parallels and meridians curved, with their concave side toward the central parallel and meridian.[62]

In conclusion, we may emphasize the great significance of Ptolemy's study of map projections for the further development of cartography. Even if he or his contemporaries did not construct maps according to these principles, which is unlikely, and although his instructions lay dormant for centuries, it was largely through the *Geography* that the Greek contribution to the scientific construction of maps was transmitted first to Arab and Byzantine mapmakers and then to the cartographic workshops of Renaissance Europe. Edgerton suggests that book 7, sections 6 and 7, of the *Geography* may also have had an influence on the development of perspective theory in the Renaissance.[63] The best testimony to Ptolemy's instructions is that they were widely followed. All the regional maps in the Greek codices and early Latin translations were drawn on the rectangular projection employed by Marinus and described by Ptolemy. It proved convenient for this purpose, and it was accurate enough so long as the proportion of one degree longitude on the central parallel of the map to one degree of latitude on the meridian was observed (e.g., for Italy 3:4, or for Britain 11:20). Yet one consequence of its adoption was that a map of the whole world could not be obtained by fitting together the regional maps, and the mapmakers were forced to turn to Ptolemy's other projections to represent the inhabited world as a whole. As already noted, they seem to have preferred Ptolemy's first projection. It was used for the world maps in most of the early codices and in the most of the first printed editions of the *Geography*. Ptolemy's second projection was more rarely used[64]—as, for example, in Codex Seragliensis 57, Sultan's Library, Istanbul, of the late thirteenth century—but the history of its dissemination and modification in the Renaissance again points to the long-term, albeit much delayed, importance of his ideas.

Through his discussion of the size and location of the inhabited world, as well as through his projections, Ptolemy also codified for posterity an image of its outlines and general arrangement. Ptolemy's map, as reconstructed or seen in the later manuscripts, depicts the inhabited world as no longer an island in the ocean (see fig. 15.5). It was limited eastward by an unknown land occupying the territory of the East Asian peoples; southward by an equally unknown land surrounding the Indian Sea and the part of Ethiopia south of Libya called Agisymba; westward by an unknown land circling the Ethiopian Gulf in Libya and by the Western Ocean surrounding the western parts of Libya and Europe; and northward by the contiguous ocean, surrounding the British Isles and the northern parts of Europe, and by the unknown land stretching along northern Asia, Sarmatia, Scythia, and the silk land.[65] Inside the inhabited world there were two enclosed seas, the Caspian[66] (or Hyrcanian) and the Indian (with its various gulfs, the Arabian, Persian, Gangetic), and one sea open to the ocean, the Mediterranean.

PTOLEMY AS A MAPMAKER: THE TABLES OF COORDINATES

A final aspect of Ptolemy's instructions for mapmaking concerns the relationship between the tables of coordinates in the *Geography*—which clearly form the raw material for compiling geographical maps—and the geographical maps that first appear in the Byzantine manuscripts of the *Geography*. This may be regarded as a major enigma of Ptolemaic scholarship. It has long been debated whether Ptolemy himself or a contemporary drew maps for the *Geography*, whether they were added after his time under the Roman Empire, or whether those we have go back only to Byzantine times.[67] To Joseph Fischer, for example, that the Biblioteca Apostolica Vaticana's Codex Urbinas Graecus 82 (late thirteenth century) has maps corresponding very closely to the text is an argument that it must depend on a cartographic archetype of the Roman Empire.[68] But if we take as a parallel the maps in the *Corpus Agrimensorum*, we find that the further removed they are from the original the more corrupt they become. Hence Leo Bagrow doubts whether any extant Ptolemaic maps go back to an archetype earlier than about the twelfth century.[69]

The lack of a careful critical edition of the *Geography* is clearly an impediment to our understanding of this

62. Neugebauer, *History of Ancient Mathematical Astronomy*, 883, 889 (note 48); idem, "Ptolemy's *Geography*," 25–29 (note 60); Cortesão, *History of Portuguese Cartography*, 1:106 (note 18).

63. Samuel Y. Edgerton, "Florentine Interest in Ptolemaic Cartography as Background for Renaissance Painting, Architecture, and the Discovery of America," *Journal of the Society of Architectural Historians* 33 (1974): 275–92. See also Neugebauer, *History of Ancient Mathematical Astronomy*, 890 (note 48).

64. Neugebauer, *History of Ancient Mathematical Astronomy*, 885 (note 48).

65. Ptolemy *Geography* 7.5.2 (note 5).

66. For the Caspian as an enclosed sea in Ptolemy, see p. 198.

67. For a list of the authors on either side of the debate, see Erich Polaschek, "Ptolemy's *Geography* in a New Light," *Imago Mundi* 14 (1959): 17–37.

68. Fischer, *Urbinas Graecus 82* (note 5).

69. See Leo Bagrow, "The Origin of Ptolemy's Geographia," *Geografiska Annaler* 27 (1945): 318–87.

question. Whereas in books 1 and 2 Ptolemy speaks of mapping only in the future tense, in 8.2.1 he says "we have had maps drawn up," ἐποιησάμεθα, specifying the twenty-six regional maps as given below. He mentions in this connection not degrees of latitude and longitude, but lengths of daylight and distances from Alexandria. If the passage is genuine, which seems likely, and if this use of the future tense in books 1 and 2 can be taken literally, this suggests, as Polaschek thought, that Ptolemy revised the earlier part of his work but not the later part; that he decided to be content with those regional maps he had already commissioned and to leave to others the compilation of any based on the more exact system of his coordinates, working from degrees and minutes. This is certainly true of book 1 and of book 2, section 1 of the *Geography*. Book 8 was probably composed at a different time from these. The concluding sentence, "These things being settled beforehand we can now attend to that which remains," may indeed apply to the future drawing of maps, but this does not rule out the possibility that some maps or the projections for them had previously been completed. Neither does it tell us whether Ptolemy or others finished the task in his lifetime. In any case, even if there were any, no maps have survived that can positively be ascribed to Ptolemy's period. Marcianus (fourth/fifth century A.D.) may, in bringing the eastern section of the map of the inhabited world up to date, have appended a map of it based on Ptolemy's coordinates. Similarly, Agathodaimon of Alexandria, the technician who drew a map of the world from the *Geography* discussed more fully below (pp. 271–72), may not have drawn any of the regional maps. But unfortunately the information about Agathodaimon does not settle the disputed question of whether Ptolemy's text was in his lifetime accompanied by maps; though to us the preposition ἐκ, "from," in the context that he drew maps *from* Ptolemy's *Geography*,[70] suggests that it was not. There is thus no positive proof that any of the extant maps attached to the later Greek recensions of the *Geography* were copied from maps circulating during the time of the Roman Empire. All features, including such refinements as cartographic signs for tribal areas, may have been reconstructed by Byzantine scholars (p. 268 below) from the text of the *Geography*.

In any event, all that can be said with certainty is that Ptolemy provided raw material for future mapmakers to work. In relation to the content of the geographical maps—as opposed to their mathematical construction—the most important part of the *Geography* was that containing the tables of coordinates (books 2–7). For each country a certain number of towns or places were selected, the positions of which were precisely, if not always accurately, defined by latitude and longitude. Ptolemy began with the western parts of the inhabited world, Europe first, then Africa, and last Asia. The coordinates were expressed in degrees of longitude east of the meridian drawn through the Fortunate Isles (the prime meridian) and in degrees of latitude north or south of the equator (Ptolemy puts the longitude first, since he expected the mapmaker to draw the map from left to right). He planned twenty-six regional maps: ten for Europe, four for Africa, and twelve for Asia. But the tables of coordinates were meant to be used for both regional and world maps.[71]

Cartographic Insights from Ptolemy's Topography: The Coordinates and the Regional Maps

It is not the aim of the present *History* to reconstruct the content of particular maps.[72] In the case of Ptolemy's *Geography* it would be entirely inappropriate to attempt to summarize the massive literature that has sought to reconstruct, often fancifully, his topography for different parts of the known world.[73] Yet though this subject has been of primary concern to classical historians, it also can be harnessed—through the selective assessment of the topography in the coordinates and in the maps—to throw light on broader cartographic questions. A knowledge of the pattern of mapping in the Byzantine manuscripts, for example, may at least enable us to visualize the sort of maps Ptolemy may have had in front of him (such as those of Marinus) even if we do not accept that he drew such maps himself. Moreover, a comparative examination of coordinates and maps may reveal how individual mapmakers might have worked from Ptolemy's instructions and raw materials (or indeed suggest what a modern scholar could achieve by a rigorous re-

70. Not "of," as given by Bagrow, "Origin," 350 (note 69).

71. It is obvious that in establishing these sets of coordinates Ptolemy either relied on previous sources or, more probably, read them off from a map of the inhabited world graduated with latitude and longitude. The coordinates he gives are coherent on the whole and allow anyone to draw a map; but they are largely inaccurate and suggest that he did not verify either his own observations or those made by others. For instance, he stated that the southern coast of Sardinia was at 36°N, probably relying on Dicaearchus's estimates, and did not correct the latitude of Byzantium, erroneously fixed at 43°N by Hipparchus. In this respect Ptolemy's *Geography* may perhaps be regarded as a useful tool for *mechanikoi* (draftsmen) in drawing maps to unspecified accuracy rather than a fully scientific treatise.

72. See Preface, pp. xv–xxi, esp. p. xix, of the present *History*.

73. See each year's issue of *L'Année Philologique: Bibliographie Critique et Analytique de l'Antiquité Gréco-Latine* (1928–), pt. 1, "Auteurs et Textes," s.v. "Ptolemaeus"; William Harris Stahl, *Ptolemy's Geography: A Select Bibliography* (New York: New York Public Library, 1953).

construction along these lines).[74] In any case, only through painstaking topographical research does it become possible to identify Ptolemy's sources, to assess their reliability, to weigh up his skill in reconciling their often conflicting evidence, and not least to be able to decipher the cartographic image of the known world held by the Greek and Roman map users of Ptolemy's day and later that of the scholars of the Byzantine Empire.

This section will therefore illustrate, by means of brief regional examples, the potential of such topographical research. It will be approached first from the evidence of the coordinates and second, from that of the maps in the Greek manuscripts. While both sources are closely interrelated, albeit in ways that depend on our view of their respective origins, they can nevertheless sometimes throw a different light on cartographic questions.

PTOLEMY'S TOPOGRAPHY IN THE COORDINATES AND MAPS: GENERAL CONSIDERATIONS

There are three sources for Ptolemy's gazetteer: the Κανὼν ἐπισήμων πόλεων (*Canon of Significant Places*);[75] books 2–7 of the *Geography*; and book 8 of the *Geography*. Of these only the second gives all the names; the first and third give only a selection of places regarded by Ptolemy as significant for one reason or another. In addition, there are some criticisms of Marinus of Tyre in book 1 of the *Geography* that have a topographical bearing. For topographical details the maps in the Latin text can be mostly ignored, since they are based on extant Greek ones.

In books 2–7 the manuscripts all have coordinates (except that a few lack them toward the end). A fair proportion also have maps. Where coordinate tables and maps disagree in their toponymic detail, the former are usually more reliable, particularly if they are the same in a number of authoritative manuscripts. There are exceptions, however, and in a few cases the names on the maps in the Codex Urbinas Graecus 82 are more correct than the texts, which may mean that the scribe also had another manuscript at hand. For example, whereas on the map of Thrace Byzantium is so called, as it is in Ptolemy's text, on the general map of Europe the name "Konstantinupolis" is found. Here, as elsewhere, the explanation may be that the name was not copied from any ancient manuscript but was inserted by or for Maximus Planudes when maps were being prepared from the text of Ptolemy.

In interpreting the place-names in either the tables of coordinates or the maps, it is also helpful to bear in mind Ptolemy's emphasis in compiling the *Geography* as well as his range as a linguist. He was more interested in establishing latitude and longitude than in place-names; and he does not seem to have known Latin well. In some cases we cannot be sure that a mistake originated with him, though one may well imagine that he wrote Alpha Bucens for Alba Fucens (Italy), alpha being more familiar than Latin *alba*, "white"; Fucens may have meant "connected with materials for dyeing," but Bucens is meaningless.[76] The most glaring mistake in Latinity concerns a place in Germany that he calls Siatutanda. Tacitus has the phrase, referring to a German tribe, *ad sua tutanda*, "to protect their possessions."[77] Ptolemy has corrupted the last two words of this to Siatutanda and incorporated it into the German section as a place-name.[78]

A further element in reconstructing Ptolemy's topography and its underlying compilation process is that in some cases he may have employed signs rather than toponyms to locate geographical features. This may be regarded as a step in the eventual codification of the cartographic signs employed on maps, which was to become much more general in the Renaissance;[79] in particular, in Codex Urbinas Graecus 82 and the Ptolemaic manuscripts in the Biblioteca Medicea Laurenziana, Florence (see table 15.1), small signs were used to denote tribal territories or subdivisions of provinces.[80] Some of these are astronomical signs; others appear to be invented specially for the purpose. In Ireland, Germany, and the Danube provinces there are none, since there the system is inapplicable; in Aquitania and Gallia Lugdunensis, where we would expect signs, there are none. In Britain, Spain, and the other Gallic provinces the signs do not agree in the two manuscripts, whereas in Italy they nearly all do. Codex Urbinas Graecus 82 has signs in Liburnia and Dalmatia; the Laurenziana's Plut. 28.49 has not.

74. This type of experimental approach is seldom considered by historians of cartography: it could, however, throw much light on the problems of the Byzantine mapmakers confronted by Ptolemy's manuscripts without maps.

75. Honigmann, *Sieben Klimata* (note 33); Erich Polaschek, "Ptolemaios als Geograph," in *Paulys Realencyclopädie der classischen Altertumswissenschaft*, ed. August Pauly, Georg Wissowa, et al. (Stuttgart: J. B. Metzler, 1894–), suppl. 10 (1965): cols. 680–833, esp. 681–92.

76. Ptolemy *Geography* 3.1.50 (Müller edition), 3.1.57 (Nobbe edition) (note 5).

77. Tacitus *Annals* 4.73; see *The Annals of Tacitus*, trans. Donald R. Dudley (New York: New American Library, 1966).

78. Ptolemy *Geography* 2.11.27 (note 5). The connection between Ptolemy and Tacitus, although not absolutely certain, is generally agreed upon.

79. See Catherine Delano Smith's discussion of cartographic signs in volume 3 of the present *History*.

80. Ptolemy, *Die Geographie des Ptolemaeus: Galliae, Germania, Raetia, Noricum, Pannoniae, Illyricum, Italia*, ed. Otto Cuntz (Berlin: Weidmann, 1923), 18–19.

TABLE 11.1 Selected Greek Manuscripts of Ptolemy's *Geography*

Repository and Collection Number	Date	Maps
Rome, Biblioteca Apostolica Vaticana, Vat. Gr. 191	12th–13th century	None extant, but see pp. 268–69; coordinates omitted from 5.13.16[a]
Copenhagen, Universitetsbiblioteket, Fragmentum Fabricianum Graecum 23	13th century	Fragmentary; originally world and 26 regional
Rome, Biblioteca Apostolica Vaticana, Urbinas Graecus 82	13th century	World and 26 regional[b]
Istanbul, Sultan's Library, Seragliensis 57	13th century	World and 26 regional (poorly preserved)[c]
Rome, Biblioteca Apostolica Vaticana, Vat. Gr. 177	13th century	No extant maps
Florence, Biblioteca Medicea Laurenziana, Plut. 28.49	14th century	Originally world, 1 Europe, 2 Asia, 1 Africa, 63 regional (65 maps extant; see pp. 270–71)
Paris, Bibliothèque Nationale, Gr. Supp. 119	14th century	No extant maps
Rome, Biblioteca Apostolica Vaticana, Vat. Gr. 178	14th century	No extant maps
London, British Library, Burney Gr. 111	14th–15th century	Maps derived from Florence, Plut. 28.49
Oxford, Bodleian Library, 3376 (46)-Qu. Catal. i (Greek), Cod. Seld. 41	14th century	No extant maps
Rome, Biblioteca Apostolica Vaticana, Pal. Gr. 388	Early 15th century	World and 63 regional
Florence, Biblioteca Medicea Laurenziana, Plut. 28.9 (and related manuscript 28.38)	15th century	No extant maps
Venice, Biblioteca Nazionale Marciana, Gr. 516	15th century	Originally world and 26 regional (world map, 2 maps, and 2 half maps missing)
Rome, Biblioteca Apostolica Vaticana, Pal. Gr. 314	Late 15th century	No extant maps; written by Michael Apostolios in Crete

[a]Alexander Turyn, *Codices Graeci Vaticani saeculis XIII et XIV scripti*, Codices e Vaticanis Selecti quam Simillime Expressi, vol. 28 (Rome: Biblioteca Apostolica Vaticana, 1964).

[b]Ptolemy *Claudii Ptolemaei Geographiae Codex Urbinas Graecus 82*, 2 vols. in 4, ed. Joseph Fischer, Codices e Vaticanis Selecti quam Simillime Expressi, vol. 19 (Leiden: E. J. Brill; Leipzig: O. Harrassowitz, 1932); Aubrey Diller, "The Greek Codices of Palla Strozzi and Guarino Veronese," *Journal of the Warburg and Courtauld Institutes* 24 (1961): 313–21, esp. 316.

[c]Aubrey Diller, "The Oldest Manuscripts of Ptolemaic Maps," *Transactions of the American Philological Association* 71 (1940): 62–67, pls. 1–3.

If all such factors are taken together, the most useful Greek manuscripts for studying topographical details and place-names in Ptolemy are set out in table 11.1.[81]

PTOLEMY'S COORDINATES: THE EXAMPLES OF THE BRITISH ISLES AND ITALY

Ptolemy's coordinates provided data for mapmaking and were probably modified from Marinus's map. Although anyone reconstructing a regional map from them could not, for example, tell where the coastline was intended to go, the basic pattern would always have been roughly the same. A glance at a map drawn to illustrate the *Geography* will show deformation in parts of the British Isles and Italy, among other regions. This deformation, and the misplacing of certain towns, would become apparent at the first attempt to draw the map. The stress below will be laid on the textual side of Ptolemy's regional chapters, by using the British Isles and Italy as examples not only of his compilation methods, but also of the extent to which some manuscripts were corrupted—or even underwent very tentative attempts to correct them—at the hands of their subsequent copyists.[82]

Ptolemy's name for Britain is Aluion, that is, Albion,[83] which by his time was an outmoded Greek name. The Romans always knew it as Britannia, and Ptolemy himself calls it the Prettanic island of Aluion. Since he lists European countries roughly from the west, he starts with

81. The principal sources for the table are: Lauri O. T. Tudeer, "On the Origin of the Maps Attached to Ptolemy's Geography," *Journal of Hellenic Studies* 37 (1917): 62–76; Cuntz, *Ptolemaeus* (note 80); Fischer, *Urbinas Graecus 82* (note 5); Paul Schnabel, *Text und Karten des Ptolemäus*, Quellen und Forschungen zur Geschichte der Geographie und Völkerkunde 2 (Leipzig: K. F. Koehlers Antiquarium, 1938); Bagrow, "Origin" (note 69); Polaschek, "Ptolemaios," cols. 680 ff. (note 75); idem, "Ptolemy's *Geography*" (note 67); Nobbe, *Claudii Ptolemaei Geographia* (note 5).

82. A. L. F. Rivet, "Some Aspects of Ptolemy's Geography of Britain," in *Littérature gréco-romaine et géographie historique: Mélanges offerts à Roger Dion*, ed. Raymond Chevallier, Caesarodunum 9 bis (Paris: A. et J. Picard, 1974), 55–81; A. L. F. Rivet and Colin Smith, *The Place-Names of Roman Britain* (Princeton: Princeton University Press, 1979).

83. Rivet and Smith, *Place-Names*, 247–48 (note 82).

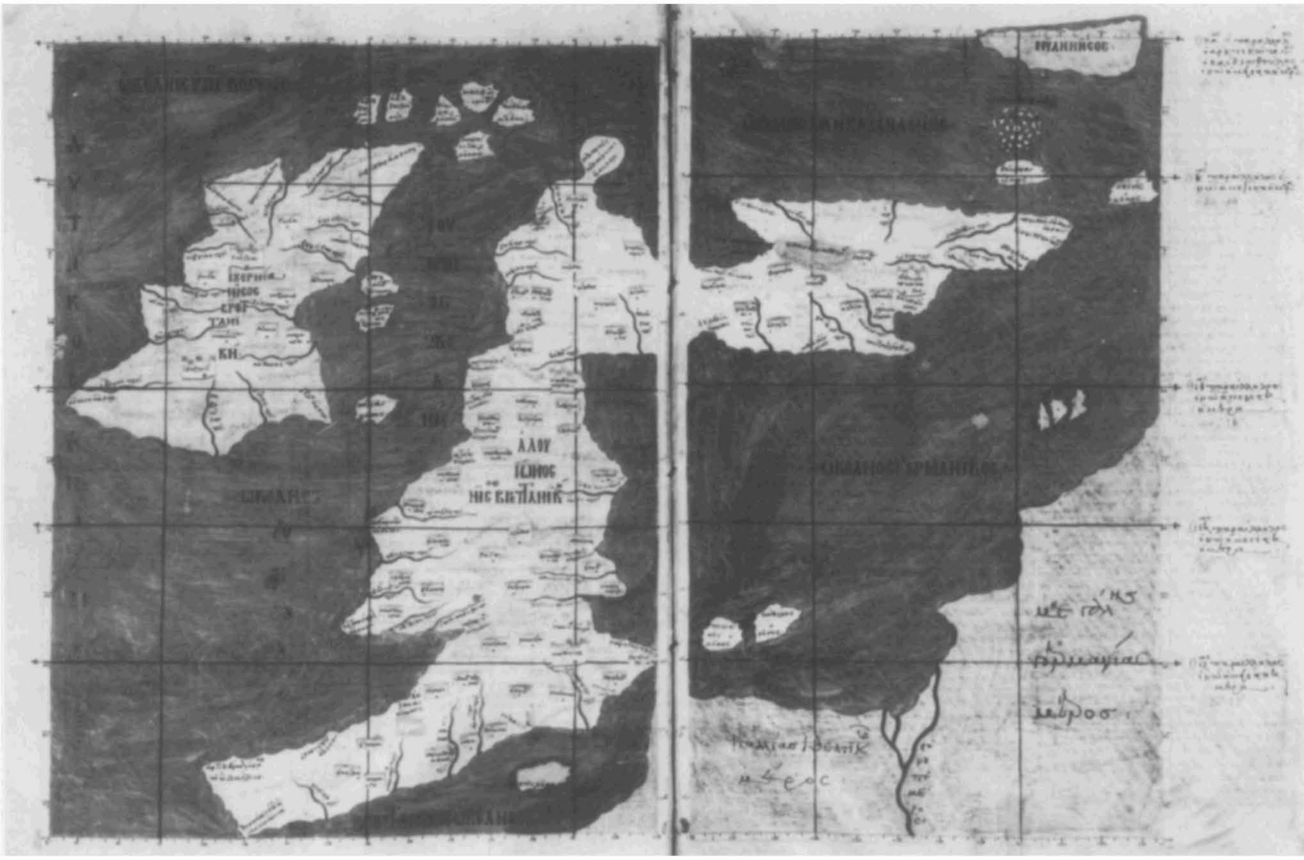

FIG. 11.8. BRITAIN ACCORDING TO PTOLEMY. From a Byzantine manuscript of Ptolemy's *Geography* (late thirteenth century) (see also figs. 11.11 and 15.5). Size of the original: 41.8 × 57.5 cm. Photograph from the Biblioteca Apostolica Vaticana, Rome (Urbinas Graecus 82, fols. 63v–64r).

Ireland (Iuernia). Four oceans surrounding Britain are named the British, for the Channel; the German, for the North Sea; the Irish; and the Duekaledonios,[84] off northern Scotland. The two others mentioned are the Western, off the west coast of Ireland; and the Hyperborean,[85] off the north coast of Ireland (fig. 11.8).

Like the recensions of Ptolemy, so also the Ordnance Survey map[86] and a recent masterly treatment of place-names[87] give only one latitude and one longitude for each natural feature or town. There is, however, some evidence that the variants in place-names found in manuscripts only in certain cases point to corruption, and that in others there has been a deliberate attempt at slight modification. Thus in the distorted promontory of the Novantae (Mull of Galloway) it makes a difference whether we give the latitude of the river Abravannos (identifed as the Water of Luce) as 61°, with most manuscripts, or as 60°15′, with manuscripts of the fifteenth-century Laurenziana group, that manuscript itself here being corrupt (fig. 11.9). This was probably intended as a deliberate correction by one or the other, since for the neighboring Iena estuary (either by the Water of Fleet or the river Cree) the fifteenth-century Laurenziana group also has a slight difference of latitude, 60°20′ instead of 60°30′. Sometimes both latitude and longitude are different; thus Tamare on the river Tamar has, according to Codex Graecus 191 (Biblioteca Apostolica

84. The expected adjective would be Kaledonios: *due* is a prefix of doubtful meaning; Ammianus's Dicalydones may have no connection. Perhaps Duekaledonios is a corruption of Deukalioneios, from Deucalion—son of Minos. He was one of the Argonauts, who according to one tradition sailed around Ireland. He was also at the Calydonian boar hunt, and this Aetolian adjective could have become confused with Caledonian.

85. "Hyperborean" is usually associated with mountains and tribes of northern continental Europe. To Ptolemy it must have meant "beyond northern lands" and can have had no connection with tribes who traded with the Mediterranean, as some scholars have postulated for northern Europe.

86. Ordnance Survey, *Map of Roman Britain*, 4th ed. (Southampton: Ordnance Survey, 1978), 15.

87. Rivet and Smith, *Place-Names* (note 82). See also O. A. W. Dilke, *Greek and Roman Maps* (London: Thames and Hudson, 1985), 190–92.

Vaticana) and the fifteenth-century Laurenziana group, longitude 15°30′ east of the Canaries, latitude 52°40′, whereas according to other manuscripts the figures are 15° and 52°15′, respectively. Obviously this affects the search for what is in this case an unidentified place.[88]

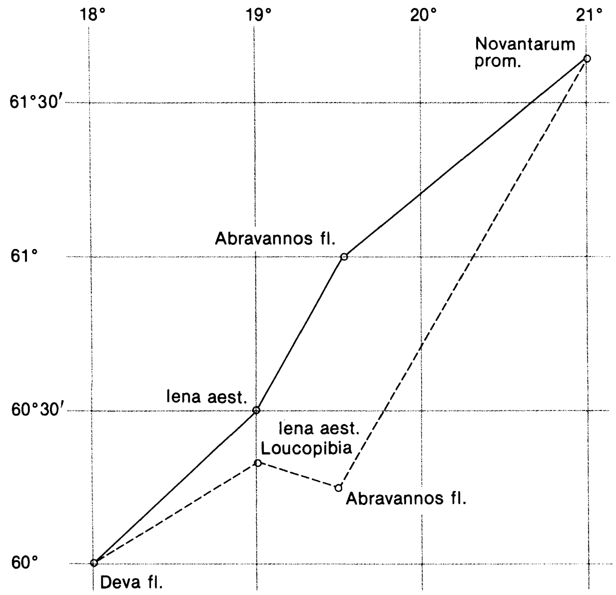

FIG. 11.9. THE MULL OF GALLOWAY IN DIFFERENT VERSIONS OF PTOLEMY. The solid line represents the coastline of Galloway in most manuscripts of the *Geography*, while the dashed line follows the manuscripts of the fifteenth-century Laurenziana recension. Iena aest. (estuary) and Loucopibia are given the same coordinates in some manuscripts. The ratio of meridian to parallel spacing is 11:20.

Ptolemy's two main misunderstandings with respect to the British Isles were the orientation of Scotland and the respective latitudes of Ireland and Great Britain. On the latter point, whereas mainland Britain actually lies between 49°55′ and 58°35′N, Ptolemy made it extend from 51°30′ to 61°40′; Ireland, which lies between 51°30′ and 55°20′, was made by Ptolemy to extend from 57° to 61°30′. This means that it was conceived as running parallel to Scotland to an unjustified distance.

The "dogleg" appearance of northern Britain is a Ptolemaic feature that becomes most conspicuous with mapping and that persisted into the Renaissance. A number of factors may have contributed to it. First, Ptolemy was clearly convinced that all to the north of 63°N in this region was terra incognita. At that latitude he had to accommodate Thule, which to him was the Shetland Islands. Since he knew that Britain extended in some direction for 4,000 to 4,500 stades, he could not give coordinates that would have made this distance a straight line without infringing his 63° rule. Second, Eratosthenes, or some other Greek author reflected in Diodorus Siculus, had thought of Britain as an obtuse-angled triangle of the type in figure 11.10. Third, the odd feature of the Mull of Galloway as the most northerly point on mainland Scotland requires some explanation. Rivet's is that the island of Epidion (18°30′E of the Canaries, 62°N) and the promontory of Epidion (Mull of Kintyre) were adjacent in Ptolemy's source map, but that Ptolemy, to account for the difficulties mentioned above, gave coordinates rotating northern Britain clockwise by about one-seventh of 360 degrees.[89] Finally, Ptolemy's second projection, when used for world cartography, could have caused much distortion in the areas of the *oikoumene* farthest to the northwest and northeast.

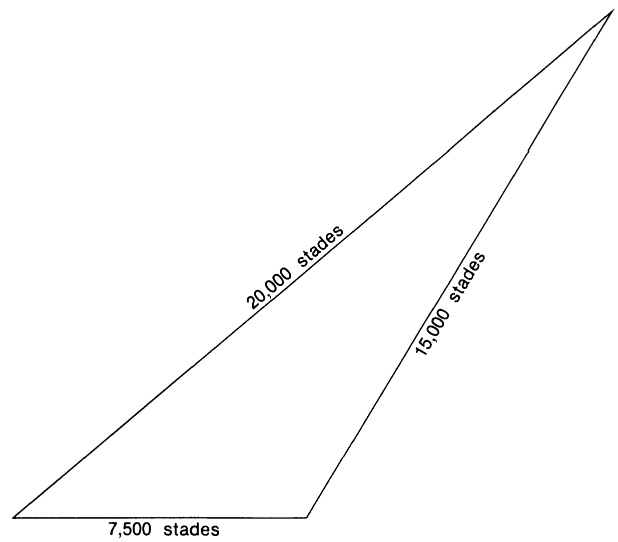

FIG. 11.10. BRITAIN REPRESENTED AS AN OBTUSE-ANGLED TRIANGLE. The belief that Britain was of such a shape, based on measurements recorded in Diodorus Siculus, derived in turn from Pytheas or Eratosthenes, might have influenced Ptolemy's own distinctive version of the island. It appears that Diodorus included the numerous indentations of the west coast, resulting in a longer total westward measurement, thereby accounting for the eastward shift of Scotland.

Some of the mistakes in Ptolemy's Britain—like the many others throughout the *Geography*—must have been present in Marinus's map and not corrected by Ptolemy. Viewed with hindsight, as compared with many nearer provinces that are well portrayed on the whole, it must be admitted to have many defects. Rooted both in his sources and in his compilation decisions, these reflect a variety of components of error, probably

88. Rivet and Smith, *Place-Names*, 464 (note 82), suggest Launceston.

89. A. L. F. Rivet, "Ptolemy's Geography and the Flavian Invasion of Scotland," in *Studien zu den Militärgrenzen Roms, II*, Vorträge des 10. Internationalen Limeskongresses in der Germania Inferior (Cologne: Rheinland-Verlag in Kommission bei Rudolf Habelt, 1977), 45–64.

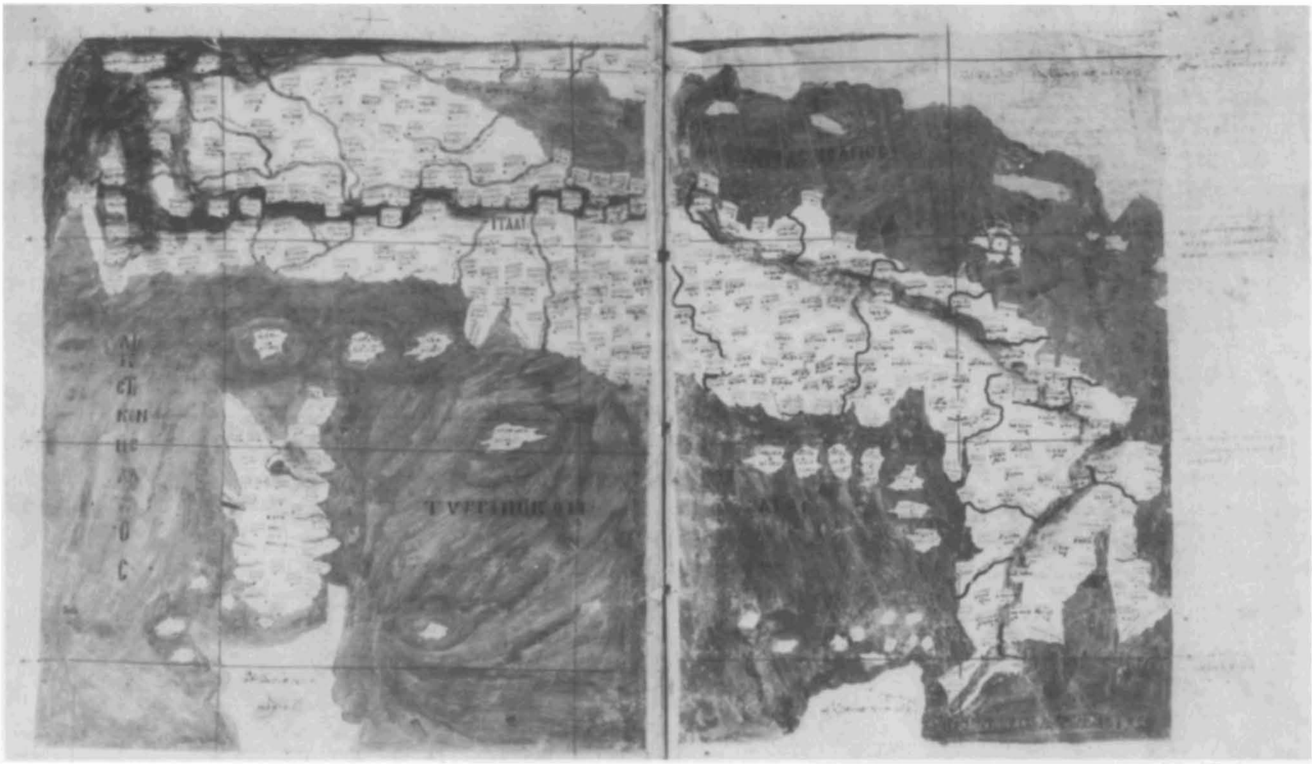

FIG. 11.11. THE PTOLEMAIC MAP OF ITALY.

Size of the original: 41.8 × 57.5 cm. Photograph from the Biblioteca Apostolica Vaticana, Rome (Urbinas Graecus 82, fols. 71v–72r).

including his unwillingness to discard early cartographic attempts such as those of Eratosthenes, insufficient revision of Marinus, and incomplete updating.

Ptolemy's coordinates for Italy[90] are not as good as one might expect for such a well-known area (fig. 11.11). It seems inevitable that anyone attempting to draw a map from them would have problems of orientation over the whole peninsula. Northern and central Italy are bound to be portrayed with a largely west-east rather than northwest-southeast orientation. Although this applies throughout those areas, it can best be illustrated from the Po valley. If we plot the towns along the Via Aemilia (Ptolemy does not give coordinates for roads), we find that many of them lie in a west-east line (fig. 11.12). The result is that the south of Italy appears in too north-south an orientation. This feature applies south of a line Naples–Benevento–Monte Gargano, so that the peninsula, from Ptolemy's coordinates, presents an unwarranted bend. The reason for the Po valley orientation could be that the towns on the Via Aemilia were linked to centuriation schemes, and if Ptolemy looked at centuriation maps he might have concluded that they had north at the top, whereas in fact they tend to follow the orientation of the road (fig. 11.13). For the peninsula in general he may have followed his knowledge of a version of Agrippa's map (pp. 207–9 below), which, being designed to be displayed on a colonnade, may well, since it had north or south at the top, have had more room to spread east-west. Also, he was basing his longitudes on Posidonius's measurements, which gave a greater relative width to each degree than did those of Eratosthenes.

The effect of such decisions on Ptolemy's coordinates—and on the maps drawn from them—is also borne out in a number of other examples. The Gulf of Taranto is more subject than other areas of Italy to three differing recensions of manuscript coordinates;[91] but in all of these it is too long and narrow. The coast from the river Var (now in France) to the river Arno is far too straight; the north coast of the Adriatic has inaccuracies; Lake Larius (Lake Como) is located, as a source of the Po, far from Comum (Como); and several important towns are considerably misplaced. A plotting of "significant places" shows three attempts by different scribes at some

90. O. A. W. Dilke and Margaret S. Dilke, "Italy in Ptolemy's Manual of Geography," in *Imago et mensura mundi: Atti del IX Congresso Internazionale di Storia della Cartografia*, 2 vols., ed. Carla Clivio Marzoli (Rome: Enciclopedia Italiana, 1985), 2:353–60.

91. Polaschek, "Ptolemaios," plan opposite col. 728, with key in cols. 715–16 (note 75).

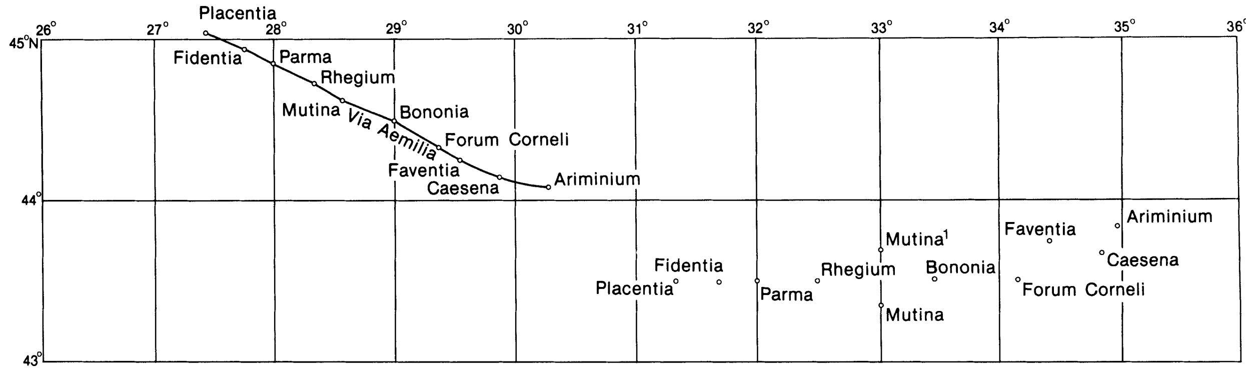

FIG. 11.12. COMPARISON OF PTOLEMAIC AND MODERN COORDINATES OF TOWNS ON THE VIA AEMILIA, NORTHERN ITALY. The shift in orientation may possibly be due to centuriation based upon the Via Aemilia, which was generally oriented perpendicular to the main trend of the road. Ptolemy's coordinates from book 3 of the *Geography* (*right*) assume a west-east trend for the road, perhaps following information derived from such centuriation, in comparison with the modern figures (*left*). The location of Mutina[1] further north is from the Urbinas and Laur. 28.49 manuscripts. The modern equivalents of the towns are, from west to east: Piacenza; Fidenza; Parma; Reggio nell'Emilia; Modena; Bologna; Imola; Faenza; Cesena; Rimini. Longitudes are east of the Canaries.

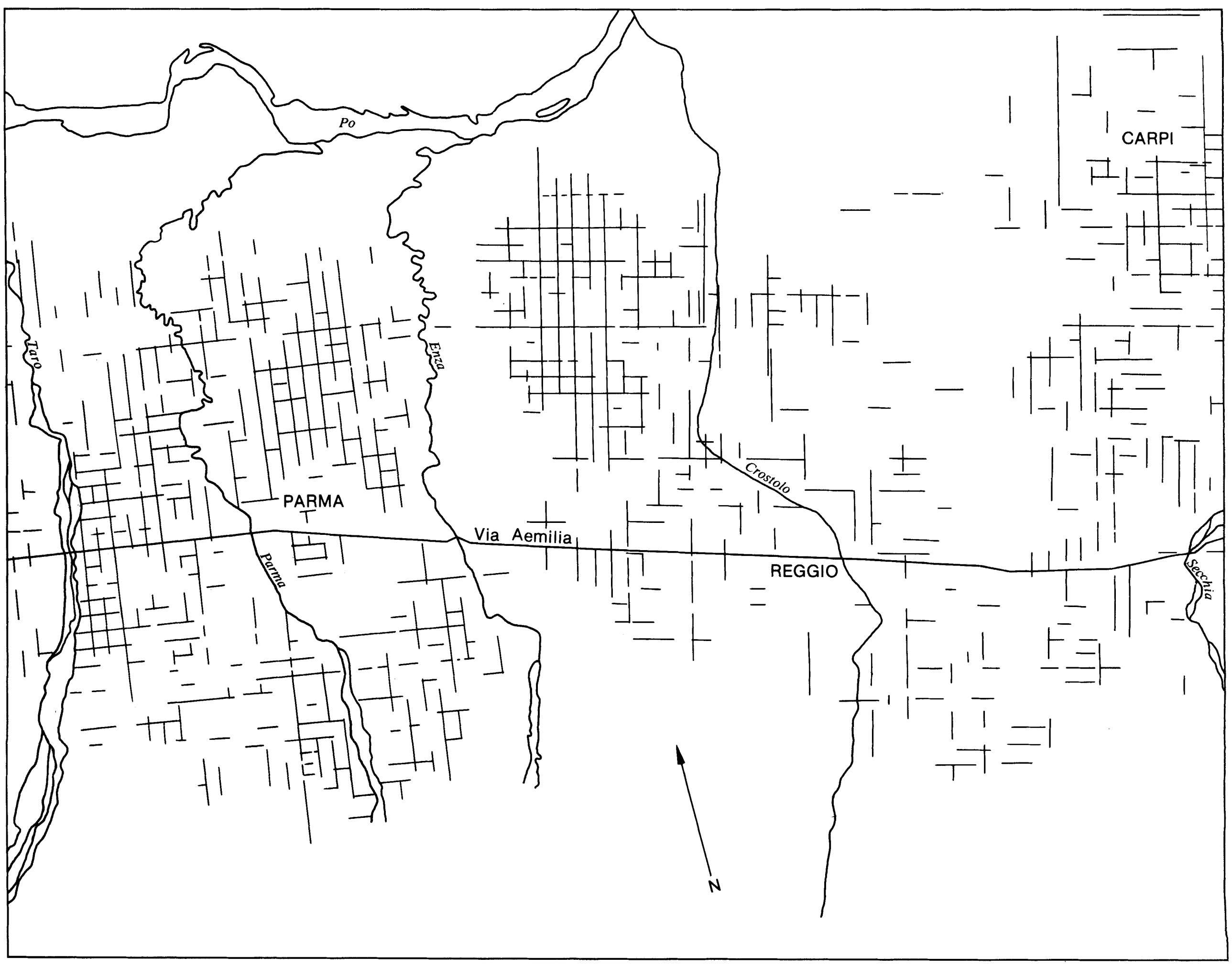

FIG. 11.13. CENTURIATION IN THE PO VALLEY AROUND PARMA AND REGGIO EMILIA. Centuriation of this area, which was oriented approximately perpendicular to the trend of the Via Aemilia, might have misled Ptolemy into making the error shown in figure 11.12.
After R. Chevallier, "Sur les traces des arpenteurs romains," *Caesarodunum*, suppl. 2 (Orléans-Tours, 1967).

coordinate values: in the *Canon of Significant Places*; in book 3, chapter 1; and in book 8. Five pairs of towns in Italy are given coinciding coordinates in all or some manuscripts.[92] The major islands also suffer from inaccuracies: Corsica is given two northern promontories instead of one; Sardinia is placed on the same latitude as Sicily; and the western part of the north coast of Sicily is made to bend to the southwest.

PTOLEMY'S MAPS: SOME REGIONAL EXAMPLES

The maps included in the Byzantine manuscripts, albeit much delayed in their execution, represent the logical end product of the cartographic processes set in motion by Ptolemy's work. Although it has always been possible to draw regional maps from the coordinates of the text, as the examples of the British Isles and Italy have demonstrated, only with the help of Ptolemy's regional maps does the full cartographic pattern readily appear. These maps can also be subjected to topographical scrutiny; they can be used in assessing the adequacy of Ptolemy's cartographic raw materials (and of his instructions to his successors) and also can enable us to understand the images they may have helped to form in the minds of their contemporary users. The theme of the reliability of the maps will be illustrated from three regions—northern Europe, North Africa and Egypt, and Asia—that supplement the treatment of the British Isles and Italy derived from the coordinates.

First, Ptolemy's knowledge of the areas to the north of continental Europe reflected some of the correct and incorrect concepts of the North current in Greco-Roman literature and earlier cartography.[93] All to the north of $64\frac{1}{2}$°N was terra incognita, and there was a lack of information about much to the south of this. Like other classical writers, Ptolemy had no idea that Norway and Sweden form part of the continent.[94] The north coast of Germany and Poland was for him almost completely straight, just near the fifty-sixth parallel. East of Jutland and in the Baltic north of that coast are one large and a number of small Skandia islands.[95] The central island of the small Skandia islands has a longitude of 41°30′ and a latitude of 58°. The large Skandia island is offshore from the Vistula estuary, having a longitude of 43° to 46° and a latitude of 57°40′ to 58°30′. Ptolemy lists seven tribes that inhabit this island; manuscripts and printed editions do not always include these owing to lack of space. Since there is no reliable topographical distinction among them, his research must have been based on etymological and historical sources, including the record of tribal movements over the centuries.[96] The most recognizable name is Phinnoi, variously located by scholars in Finmark, Lapland, and Finland. A tribe whose name appears in the manuscripts as Daukiones or Dankiones may be the ancestors of the Danes. The Khaideinoi have been equated with the Heinnin, and the Goutai with the Gutar. It must be stressed that the Ptolemaic concept of the area north of Jutland was of ocean only very sparsely dotted with islands. As mentioned, Thule was for Ptolemy the Shetland Islands, not part of Scandinavia; and for any suggestions that Renaissance additions to the Ptolemaic cartography of Scandinavia may rest on a much earlier tradition, there is no evidence whatever.[97]

In the more northerly latitudes Ptolemy's coast of the Baltic correctly takes a bend northward. But at the end of the enumeration of Baltic tribes he lists numerous other tribes in what was evidently intended as a southerly direction. As a result, the Byzantine reconstructions fit them in rather close together on a north-south line,[98]

92. Polaschek, "Ptolemaios," cols. 719–20 (note 75).

93. Cuntz, *Ptolemaeus* (note 80); D. (S. D. F.) Detlefsen, *Die Entdeckung des germanischen Nordens im Altertum*, Quellen und Forschungen zur Alten Geschichte und Geographie 8 (Berlin: Weidmann, 1904); Gudmund Schütte, *Ptolemy's Maps of Northern Europe: A Reconstruction of the Prototypes* (Copenhagen: Royal Danish Geographical Society, 1917); E. Stechow, "Zur Entdeckung der Ostsee durch die Römer," *Forschungen und Fortschritte* 24 (1948): 240–41; Joseph Gusten Algot Svennung, *Scandinavien bei Plinius und Ptolemaios* (Uppsala: Almqvist och Wiksell, 1974); O. A. W. Dilke, "Geographical Perceptions of the North in Pomponius Mela and Ptolemy," in *Exploring the Arctic*, ed. Louis Rey (Fairbanks: University of Alaska Press, Comité Arctique International, and Arctic Institute of North America, 1984), 347–51. For a critical review of Svennung's book see T. Pekkanen in *Gnomon* 49 (1977): 362–66.

94. Svennung, *Scandinavien* (note 93).

95. No name etymologically connected with the Baltic occurs in Ptolemy. For these names in other ancient writers see Joseph Gusten Algot Svennung, *Belt und Baltisch: Ostseeische Namenstudien mit besonderer Rücksicht auf Adam von Bremen* (Uppsala: Lundequistska Bokhandeln, 1953).

96. Schütte, *Ptolemy's Maps* (note 93); Svennung, *Scandinavien* (note 93).

97. Charles H. Hapgood, *Maps of the Ancient Sea Kings: Evidence of Advanced Civilization in the Ice Age*, rev. ed. (New York: E. P. Dutton, 1979), 124–40, reaches what seems to be an absurd conclusion by comparing a fifteenth-century Vatican manuscript, designed to amplify Ptolemy, with the Zeno map of 1380 (according to Hapgood, see point four below): "If the original source of the Ptolemy map came from the end of the ice age, that of the Zeno map may have originated much earlier" (p. 40). However, first of all, there is not, as Hapgood maintains, the slightest evidence that Ptolemy or this "new Ptolemy" even remotely touched upon the cartography of the Arctic or Antarctic. Second, it is not true, as he claims, that "some authorities have considered that they [Ptolemaic maps] were reconstructed from the tables [coordinates of latitude and longitude] . . . in the 15th century" (p. 133). Any such reconstruction must have been much earlier; see p. 268. Third, because certain parts of a Ptolemaic map contain place-names and others do not, they are not necessarily by two different hands. Fourth, the Zeno map is now thought to date not from 1380, as Nicolò Zeno the younger claimed, but from much later.

98. Müller, *Claudii Ptolemaei Geographia*, tabulae, Europae Tab. VIII (note 5).

whereas presumably Ptolemy had planned them to be more spaced out. In general, the tribes of Sarmatia in Europe, largely corresponding to the European regions of the USSR, seem to be unduly increased in number by duplication of names. Some of these pairs are exactly the same, others are similar. An attempt has been made to show how Ptolemy could have used two regional groupings with different orientations.[99] The explanation could be either that one or both sets of tribes were incorrectly placed by his sources or that these sources took insufficient account of tribal movements.

A second example, concerning the Ptolemaic depiction of North Africa and Egypt, takes us into a realm where, theoretically at least, he was much better informed—in part—by firsthand experience. Ptolemy's coastline of North Africa, granted it was based on an inaccurate latitude for much of his native Egypt (see below), is close enough to reality except in the Tunisian section.[100] Here, among other inaccuracies, the coast from Cape Bon to Monastir was made to run roughly east-southeast instead of south, and from Monastir to Gabès there is a similar deformation. This again, like the Po valley as revealed in the coordinates, could have arisen from the fact that the predominant orientation of centuriated land in Tunisia is at about 45° from the cardinal points.[101] Coastal voyages, however, had to avoid the treacherous sandbanks of Syrtis Major (Gulf of Sidra) and Syrtis Minor (Gulf of Gabès) so that they tended to be far straighter than the coastal outline would suggest; and this too may have had an influence on mapping.

Since Ptolemy spent most of his working life in Alexandria, we should expect him to be an expert on the topography of Egypt. Certainly there is much that is reasonably accurate in the more populated parts. But the Mediterranean coastline starts with a minor inaccuracy, the plotting of his native Alexandria at a latitude of 31° instead of 31°20′, and the coast west of this was kept too close to this latitude. The result was that the border between Egypt and Cyrenaica appeared as 31°20′ instead of 32°40′. The upper Nile was less accurately plotted than the lower, and the Gulf of Suez was made too wide.

In the third example, that of Asia, we can detect the same reliance on a patchwork of older and often imperfect sources. Again, this should be construed not as a criticism of Ptolemy, but rather as a reflection of the geographical lore of the Roman period in which he worked. The nearer parts of Asia presented Ptolemy with relatively little problem.[102] The maps err on the shapes of the Persian Gulf and the Caspian Sea. But whereas earlier writers had tended to make the Caspian flow out northward into the Scythian Ocean, Ptolemy insisted that it was landlocked. At this point, however, Stevenson's English translation has Ptolemy say, most improbably, "The Hyrcanian sea, called also the Caspian, is surrounded on all sides by land and has the shape of an island." What he actually meant was "just like the opposite of an island."[103]

Farther east, as the sources became diluted, India was made too small, Taprobane (Sri Lanka) too big. This followed the approach of previous writers, as reflected in the account of the elder Pliny. Some comparison can also be made between Ptolemy's topography and that of Marcianus of Heraclea.[104]

The Ptolemaic outline of Southeast Asian coasts has given rise to considerable discussion. East of the Sinus Gangeticus (Bay of Bengal) the Ptolemaic world maps show the Golden Chersonnese, corresponding roughly to the Malay Peninsula, though on a reduced scale.[105] This is followed to the northeast by what Ptolemy called the Great Gulf, Μέγας Κόλπος (Sinus Magnus). Since this was associated by him with the Chinese, the usual explanation is that it refers to the Gulf of Tonkin. By this explanation Cattigara, the chief town of the area, which is on the coast, would be somewhere in the region of Hanoi. This may represent the farthest point to which sea traders from the West penetrated up to the mid-second century A.D. Marinus's texts evidently contained the itinerary of a Greek called Alexander who had sailed to Cattigara, which he described as being an innumerable number of days from Zabai (perhaps in Kampu-

99. Schütte, *Ptolemy's Maps* (note 93).

100. O. A. W. Dilke, "Mapping of the North African Coast in Classical Antiquity," in *Proceedings of the Second International Congress of Studies on Cultures of the Western Mediterranean* (Paris: Association Internationale d'Etude des Civilisations Méditerranéennes, 1978), 154–60.

101. W. Barthel, "Römische Limitation in der Provinz Africa," *Bonner Jahrbücher* 120 (1911): 39–126; Institut Géographique National, *Atlas des centuriations romaines de Tunisie* (Paris: Institut Géographique National, 1954).

102. F. J. Carmody, *L'Anatolie des géographes classiques: Etude philologique* (Berkeley: Carmody, 1976).

103. Ptolemy *Geography* 7.5.4 (note 5), νήσῳ κατὰ τὸ ἀντικείμενον παραπλησίως, translated by O. A. W. Dilke. Another quite incorrect translation of Stevenson's is at book 1, chap. 20, where, in translating Ptolemy's approval of the latitude of 36° given to Rhodes by Marinus, he makes Ptolemy add: "In this he follows almost exactly the method of Epitecartus." No such person existed, and the Greek text here has an adjective ἐπιτέταρτος, which refers to the proportion 4:5 (see above, p. 179 n.17).

104. For details see Ptolemy, *La Géographie de Ptolémée: L'Inde (VII.1–4)*, ed. Louis Renou (Paris: Champion, 1925); Ptolemy, *Ancient India as Described by Ptolemy*, ed. and trans. John Watson McCrindle (Calcutta: Thacker, Spink, 1885; reprinted Chuckervertty, Chatterjee, 1927).

105. For a masterly interpretation of this question, see Paul Wheatley, *The Golden Khersonese: Studies in the Historical Geography of the Malay Peninsula before A.D. 1500* (Kuala Lumpur: University of Malaya Press, 1961).

chea).[106] But in Ptolemy's concept of the world the sharp turn southward, culminating in unknown land to the south of the Indian Ocean, by no means tallies with the Gulf of Tonkin. For this reason a theory advanced in South America by D. E. Ibarra Grasso, bizarre as it may seem at first, cannot entirely be ruled out.[107] According to him, Ptolemy's Great Gulf is really the Pacific, and Ptolemy's area around Cattigara is actually on the west coast of South America, giving the following equivalents:

Cattigara	=	Trujillo, Peru
Rhabana	=	Tumbes, Peru
Promontory of the Satyrs	=	Aguja Point, Peru

He also maintains that the confusion over distance arose because, whereas Marinus had made the *oikoumene* extend very far east, Ptolemy had decided not to extend it beyond 180° east of the Canaries. One may reply to the theory: first, there is no firm evidence that ancient Europeans reached South America; second, if Ptolemy felt that he had reached the end of the space allotted by himself for the *oikoumene*, he was more likely to distort the orientation, as with Scotland, than to squeeze a vast area, supposedly so represented in Marinus, into a very narrow space; third, the connection with the Chinese should not be ignored; and finally, it is not always safe to argue, as Ibarra Grasso does, from early printed editions of Ptolemy.[108] Admittedly, fifteenth- and sixteenth-century navigators, including Christopher Columbus, used maps that had different interpretations of the Sinus Magnus; but there is no reason to think that ancient navigators or cartographers shared a similar perception of the world.

106. It is very likely that Marcianus influenced the readings of coordinates for the Asiatic part of Ptolemy's *Geography*: see Polaschek, "Ptolemy's *Geography*," 35–37 (note 67), who also equates the explorer Alexander supposedly in Marinus's texts with Alexander Polyhistor, born ca. 105 B.C. at Miletus.

107. Dick Edgar Ibarra Grasso, *La representación de América en mapas romanos de tiempos de Cristo* (Buenos Aires: Ediciones Ibarra Grasso, 1970); Paul Gallez, "Walsperger and His Knowledge of the Patagonian Giants, 1448," *Imago Mundi* 33 (1981): 91–93; Ptolemy *Geography* 1.14.1 (note 5); Hans Treidler, "Ζάβαι," in *Realencyclopädie*, 2d ser., 9 (1967): cols. 2197–220 (note 75); André Berthelot, *L'Asie ancienne centrale et sud-orientale d'après Ptolémée* (Paris: Payot, 1930).

108. Ibarra Grasso, *Representación de América* (note 107).

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