Introduction

Ptolemy's *Geography* is a treatise on cartography, the only book on that subject to have survived from classical antiquity. Like Ptolemy's writings on astronomy and optics, the *Geography* is a highly original work, and it had a profound influence on the subsequent development of geographical science. From the Middle Ages until well after the Renaissance, scholars found three things in Ptolemy that no other ancient writer supplied: a topography of Europe, Africa, and Asia that was more detailed and extensive than any other; a clear and succinct discussion of the roles of astronomy and other forms of data-gathering in geographical investigations; and a well thought out plan for the construction of maps.

Ptolemy himself would not have claimed that the *Geography* was original in all these aspects. He tells us that the places and their arrangement in his map were mostly taken over from an earlier cartographer, Marinos of Tyre. Again, Ptolemy comprehended fully the superior value of astronomical observations over reported itineraries for determining geographical locations, but in this he was, on his own admission, anticipated by other geographers, notably Hipparchus three centuries earlier.[1] Even so, he was too far ahead of his time in maintaining this principle to be able to follow it in practice, because he possessed reliable astronomical data for only a handful of places.

But in the technique of map-making Ptolemy claims to break new ground. He introduced the practice of writing down coordinates of latitude and longitude for every feature drawn on a world map, so that someone else possessing only the text of the *Geography* could reproduce Ptolemy's map at any time, in whole or in part, and at any scale. He was apparently also the first to devise sophisticated map projections with a view to giving the visual impression of the earth's curvature while at the same time preserving to a limited extent the relative distances between various localities.

At the very outset of the *Geography*, Ptolemy describes his subject as "an imitation through drawing of the entire known part of the world together with the things that are, broadly speaking, connected with it," and the work's Greek

[1]The geographer Strabo (1.1.12, Loeb 1:23–25) also ascribes to Hipparchus the opinion that the relative positions of widely separated places must be determined by astronomical observation.

title, *Geōgraphikē hyphēgēsis*, can be rendered as "Guide to Drawing a World Map." The core of the *Geography* consists of three parts necessary for Ptolemy's purpose: instructions for drawing a world map on a globe and on a plane surface using two new map projections (Book 1.22–24), a catalogue of localities to be marked on the map with their coordinates in latitude and longitude (2.1–7.4), and a caption or descriptive label (*hypographē*) to be inscribed on the map (7.5). As a supplement Ptolemy adds instructions for making a picture of a globe with a suitable caption (7.6–7), and describes a way of partitioning the known world into twenty-six regional maps, with a detailed caption for each (Book 8). The introductory chapters (1.1–21) set out fundamental principles for obtaining the data on which the world map is to be based, and necessary conditions for a good map projection; Ptolemy devotes much space here to criticism of his predecessor, Marinos.

For most modern readers, the parts of greatest interest will be those treating the theoretical questions and the relationship of Ptolemy's work to that of his predecessors. The enormous catalogue of localities and their coordinates is chiefly of concern to specialists in the geography of various parts of the ancient world, for whom an edited Greek text is indispensable. Accordingly, our translation omits the geographical catalogue and the captions for the regional maps, although we have provided a specimen of each.

The plan of the *Geography* is, for such a long work, very simple; yet certain of its features have turned out to be pitfalls. First, there is Ptolemy's characteristically parenthetic style of writing. His thoughts are continually being suspended partway through by qualifications and digressions, and completed only much later, which tends to give rise not only to long, elaborately nested sentences, but also to paragraphs of reasoning that sometimes extend over several chapter divisions.[2] The reader who is not prepared for Ptolemy's fondness for suspension and resumption of argument may be led to suspect that the text has been subjected to extensive interpolations, or even that Ptolemy did not know his own mind.[3]

Another serious difficulty is presented by the chapters in Books 7 and 8 that are entitled *hypographē*, a word that has usually been interpreted as "description" (of a map). If they are read in the same way as the other narrative parts of the *Geography*, that is, as Ptolemy speaking to the reader, then it is not easy to see the reason for their presence in the text. Historians have been taxed to explain why these chapters repeat material presented elsewhere in the *Ge-*

[2] It is not clear to what extent Ptolemy was himself responsible for the traditional division of the *Geography*'s text into chapters. Toomer (1984, 5) has raised doubts about whether the chapter divisions of the *Almagest* are Ptolemy's; and some of the chapter titles in the *Geography* break the text in awkward places or inadequately describe the contents.

[3] Polaschek (1959) is particularly given to hypotheses of this kind.

ography, and why the *hypographai* for the twenty-six regional maps express the locations of cities according to a system of coordinates different from the longitudes and latitudes of the catalogue in Books 2–7.[4] These apparent redundancies and inconsistencies, together with variations in the order and contents of the *Geography* as it is presented in the medieval manuscripts, have given rise to theories of the work's origin that deny its integrity—for example, hypothesizing that Ptolemy wrote Book 8 long before the rest of the *Geography*, or even that the various parts of the work were originally separate compositions by perhaps several authors, united only in the Middle Ages under Ptolemy's name.[5] The scribes who furnished some of the medieval manuscripts of the *Geography* with maps comprehended the function of the *hypographai*, however: they rightly used them as captions to be "written below" (*hypographein*) the maps. In these chapters Ptolemy is not addressing the cartographer; rather the cartographer is addressing the public. The *hypographai* should be understood as if within quotation marks, as part of the map-making kit.

A third obstacle is the degree to which different manuscripts diverge in the versions that they present of parts of the *Geography*, which is one reason why no satisfactory edition of the whole text of the work has been achieved in modern times. There can be no doubt that the *Geography* was badly served by its manuscript tradition; the most conscientious scribe was certain to introduce numerous errors in copying its interminable lists of numbers and place names, and some copyists did not resist the temptation to "emend" the text. The instability of the textual tradition chiefly affects the geographical catalogue and the captions for the regional maps.

Our translation attempts to redirect the reader's focus away from the topographical details of the map, as represented in the catalogue and the regional captions, to where we believe it belongs, which is on Ptolemy's exposition of the theory and method of cartography. We accepted as a working hypothesis that the *Geography* as it has come down to us is a coherent, intelligent, and logically organized treatise that forms an integral part of Ptolemy's scientific oeuvre and belongs to an identifiable stage in the development of his thought. The experience of interpreting and annotating the work has only confirmed our belief that this is the appropriate way to approach it.

What Ptolemy Expected His Reader to Know

In addition to the circumstances that we have already described that have tended to obscure Ptolemy's purpose in writing the *Geography*, the book presents diffi-

[4]On the regional *hypographai* in Book 8 see, for example, Berger 1903, 643–644; and on 7.7 (the *hypographē* to the picture of the ringed globe), Neugebauer 1959, 29.

[5]For the first theory, see Schnabel 1930; for the second, Bagrow 1943.

culties for the modern reader that would not have been felt by readers of his own time. Sites to which he refers, which would have been instantly recognized by his contemporaries as thriving emporia and capitals of great kingdoms, are to most of us only names in a long list of places we have, at best, only read of as archaeological sites. Or, if they are known to the modern world, they often come to us cloaked in unrecognizable names, such as "Lake Maiōtis" for the Sea of Azov or "Taprobanē" for Sri Lanka. We have tried to lessen this last difficulty by providing the modern equivalents of places mentioned (when they can be identified) in the Geographical Index (Appendix H).

But Ptolemy writes against the background not only of a world that has vanished but also of a set of assumptions about the cosmos and its mathematical description, some of which are as foreign to the modern reader as are most of the localities he mentions. Accordingly, this section reviews the most important of Ptolemy's cosmographical presuppositions and their meanings, drawing where possible on Ptolemy's own treatment of these topics in his earlier astronomical treatise, the *Almagest*. We also discuss here the units of distance measurement and ways of describing directions that occur in the *Geography*.

The Terrestrial and Celestial Spheres

Ptolemy assumes that the reader understands and accepts the two-sphere model of the cosmos, that is, the geometrical conception of the heavens as an immense sphere that rotates daily around an axis through its center, with this center occupied by a second sphere, that of the earth (Fig. 1). The stars are thought of as fixed to the surface of the outer sphere, which is so vast that, as Ptolemy says in the *Almagest* (1.6, Toomer 43), "the earth has, so far as the senses can per-

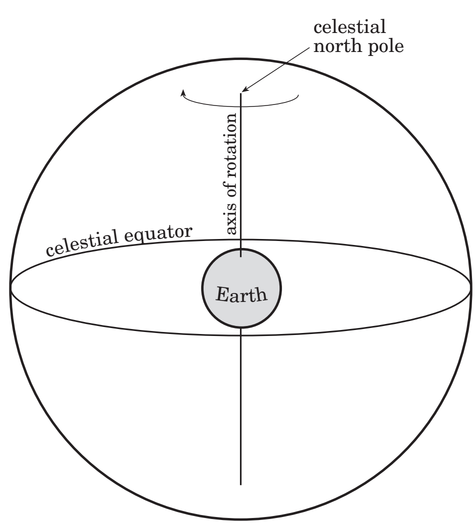

Fig. 1. The two-sphere model

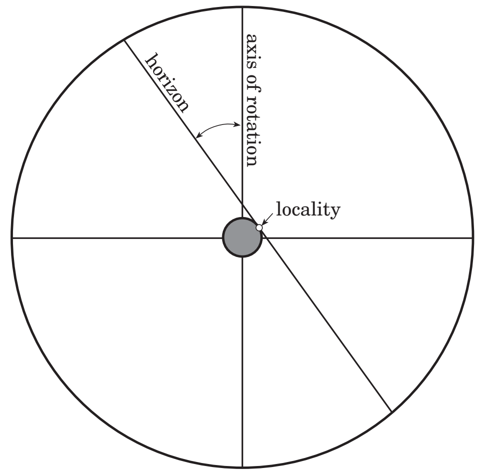

FIG. 2. Celestial sphere and local horizon of a terrestrial observer

ceive, the relation of a point to the distance to the sphere of the so-called fixed stars." The intersections of the axis of rotation with the sphere of the fixed stars define the north and south celestial poles, and, with respect to these directions, the daily rotation of the heavens is in a direction from east to west (i.e., clockwise if we imagine ourselves viewing the celestial sphere from outside and above its north pole). As a result of this daily rotation, the stars fixed to the surface of the celestial sphere trace out parallel circles, all centered on the poles, and the largest of these parallel circles is the *equator*, which is defined by the plane through the center of the cosmos and perpendicular to the axis.

The Horizon

Since the earth is a sphere, each locality on its surface admits a tangent plane, known as its horizon plane. However, Ptolemy reminds his readers in the *Almagest* (1.6, Toomer 43) that one of the reasons for regarding the earth as being so small relative to the cosmos is that the horizon plane seems to divide the celestial sphere into two exactly equal parts and could, therefore, be taken as passing through the center of the earth. The horizon, then, is another great circle of the cosmos, but it must not be thought of as rotating, for the earth did not rotate in the Ptolemaic cosmos. Rather, for a particular locality, the horizon is imagined as being fixed and therefore as making a fixed angle of inclination with the axis of rotation of the celestial sphere (Fig. 2).

Parallels and Latitude

This angle of inclination, known to Ptolemy as the *latitude* of a locality, varies with the location of the observer and determines which stars are capable of being seen. An observer at the north or south poles, whose latitude is 90°, would

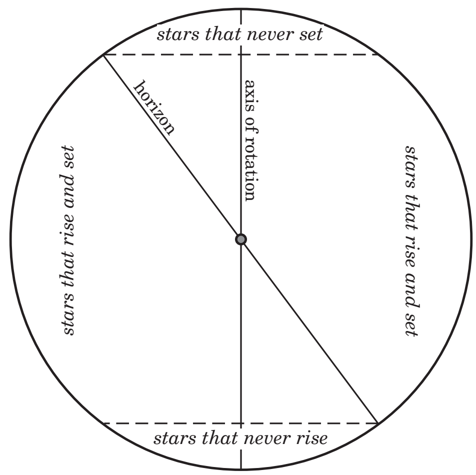

FIG. 3. Classes of stars on the celestial sphere

find that the equator coincides with the horizon and that stars north of the equator are always visible at night, and those south of the equator are always invisible. When the inclination is 0° (i.e., the horizon plane is parallel to the axis of the cosmos), the observer is on the earth's equator, both celestial poles are on the horizon, and all stars rise and set—each spending as much time above the horizon as below.

Ptolemy assumes, however, that his reader is at an intermediate latitude of the northern hemisphere, and for such a person the stars fall into three groups: stars that never set but are always above the horizon; stars that rise and set, and therefore are sometimes visible and at other times invisible, and stars that never rise and therefore are always invisible (Fig. 3). Separating these three groups of stars on the celestial sphere are two parallel circles of equal size. The one, to the viewer's north, separates the stars that never set from those that set and rise and is known as *the greatest of the always visible circles*. The other, to the viewer's south, separates the stars that never rise from those that set and rise and is known as *the greatest of the always invisible circles*. The two points where these circles touch the horizon mark due north and south for the observer, and the intersections of the equator with the horizon mark the points due east and west of the observer. Thus for the ancient geographers, geographical directions were in the first instance defined astronomically.

As one proceeds northward from the equator, the circle of ever-visible stars grows until, at the north pole, it coincides with the horizon. Simultaneously, the circle of always invisible stars also increases. Consequently, it can be demonstrated that locality A is north of locality B if some star in the northern hemisphere is always visible at A but rises and sets at B, or if some star that cannot be seen at A rises and sets at B.

These are just two astronomical criteria among many that may be used to judge how far north of the equator a locality is.[6] Because all these phenomena remain unaltered if one travels due east or west on the earth's surface, they define a *parallel* of latitude, that is, a circle on the terrestrial sphere parallel to the equator. The concept of identifying the phenomena characteristic of all localities having the same latitude, i.e., lying along the same parallel, had been known to geographical writers since the fourth century B.C.,[7] and Ptolemy specifically refers to it at several places in the *Geography* (1.2, 1.7, and 1.9). In *Almagest* 2.1 (Toomer 75–76) he lists as being among the more important phenomena characteristic for a latitude:

1. the elevation of the north or south celestial pole above the horizon;
2. whether, at any time during the year, the sun passes directly overhead;
3. the ratios of an upright stick (*gnōmōn*) to its shadow on the longest and shortest days of the year, as well as on the equinoxes; and
4. the amount by which the longest day of the year exceeds the equinoctial day, or equivalently, the ratio of the longest day of the year to the shortest, or simply the length of the longest day, measured in uniform time units.

In *Almagest* 2.6 (Toomer 82–90) Ptolemy adds two further phenomena to this list:

5. whether shadows in a given locality can point both north and south at different times of the year; and
6. which stars are always visible, which stars rise and set, and which stars can be directly overhead.

Phenomena (2) and (5) determine the latitude only within certain bounds. However, given any one of (1), (3), (4), and (6), we can determine the latitude and all the other phenomena, so that it is sufficient to specify any one of these three for a given locality. Ptolemy's basic datum is often the length of daylight; hence his principal parallels are chosen at constant increments of longest day. The latitudes corresponding to the regular sequence of increments in daylight are not equally spaced, but become more crowded the further we get from the equator. For this reason Ptolemy uses quarter-hour increments until he reaches the parallel for which the longest day is 15½ hours, and increments of half an hour thereafter until he reaches the parallel that he believes marks the northern limit of the known world, where the longest day is twenty hours. Some of

[6]Analogous rules apply to places south of the equator (none are invoked in the *Geography*).

[7]The traveler Pytheas of Massalia (c. 330 B.C.) reported polar elevations and lengths of longest day for several of the places in northwestern Europe that he claimed to have visited; see Dicks 1960, 180, 185–187.

Ptolemy's principal parallels, including those that mark the southern and northern limits of the part of the world covered by his map, are shown in Figure 4.

Ptolemy's highlighting of a sequence of unequally spaced parallels defined by the maximum length of day instead of parallels at uniform intervals of, say, 5° seems awkward from a modern perspective, but reflects the traditional practice of Greek geography. Earlier writers often made use of a division of the Greco-Roman world into latitudinal strips, or *klimata* (sing. *klima*), such that within each *klima* the maximum length of day was supposed not to vary significantly. (*Klima* means "inclination," signifying the angle between the axis of the celestial sphere and the plane of the horizon.) The lists of *klimata* that are found in various classical authors vary in the range of latitudes that they cover, although the number of *klimata* was by convention seven, counted from south to north. Ptolemy generally eschews the *klimata* in his own astronomical and geographical writings, but they figured in the work of his predecessor Marinos.

Meridians and Longitude

Intervals of time are also fundamental in the division from east to west. If we imagine a plane containing the north-south axis and passing through a locality on the earth's surface, this plane will intersect the terrestrial sphere in a great circle called a *meridian*. All places on the same meridian will observe the sun's

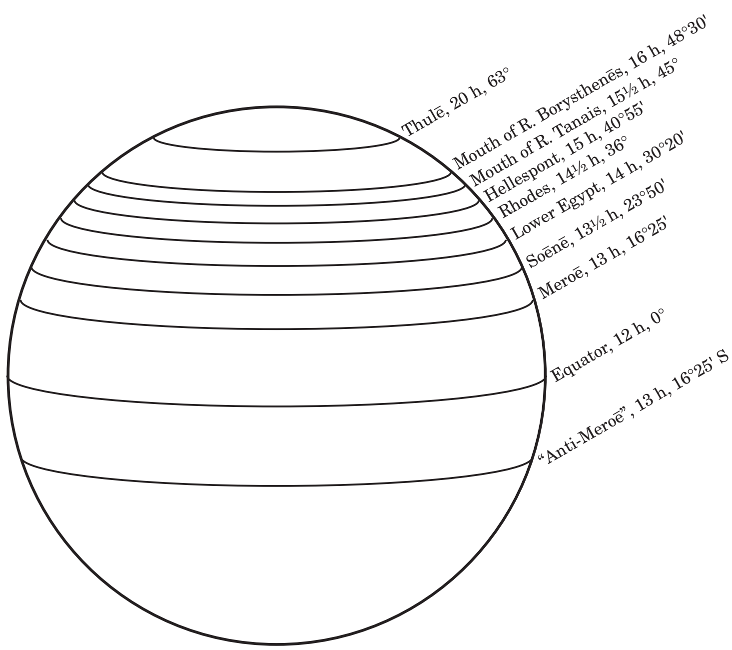

FIG. 4. The principal parallels defined by greatest length of daylight

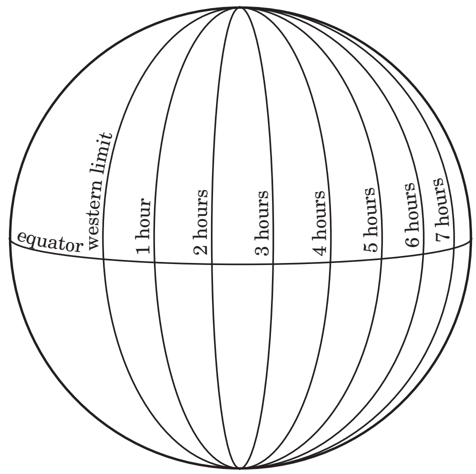

FIG. 5. The principal meridians defined by difference in local time

noon crossing of the meridian plane at the same time. Whereas latitude is readily defined by taking the arc of any meridian cut off between a special parallel, the equator, and a given parallel, there is no natural counterpart of the equator among the meridians from which the *longitude*, or angle to the other meridians, should be measured. By convention Ptolemy chooses to count longitudes eastward from the meridian at the western limit of the world known to him, and he writes (1.23) that "it is appropriate to draw the meridians at intervals of a third of an equinoctial hour," that is, at intervals of 5°." Thus it is fundamentally a net of time, not of degrees, that Ptolemy casts over the earth (Fig. 5).

The Ecliptic

An important great circle on the celestial sphere, and rotating with it, is the *ecliptic*, which Ptolemy refers to either as "the zodiacal circle" or as "the circle through the middle of the signs [of the zodiac]." The sun traverses this circle annually at an average rate of just under a degree each day, from west to east relative to the stars—that is, opposite to the daily rotation of the celestial sphere.

Since the ecliptic is the central circle of the belt of signs making up the zodiac, it inherits that belt's division into signs—the familiar Aries, Taurus, Gemini, etc., shown in Figure 6. The annual eastward progress of the sun is counterclockwise in the diagram. The signs are each 30° in length, and so coincide only approximately with the constellations for which they are named.

Since the ecliptic is a great circle like the equator, it intersects the equator in two diametrically opposite points: the beginning of Aries, where the sun is at the spring equinox, and the beginning of Libra, where the sun is at the autumnal equinox. The ecliptic is tilted at an angle of about 24° with respect to the celestial equator, and so there is a most northerly point on the ecliptic, located at the beginning of the zodiacal sign of Cancer, and a most southerly point, at the beginning of the sign of Capricorn. The circles on the celestial sphere that are parallel to the equator and that pass through these two points are known, respectively, as the Tropic of Cancer (or Summer Tropic) and the Tropic of Capricorn (or Winter Tropic). As the sun travels annually around the ecliptic, it moves alternately north and south of the equator, with the two tropic circles as the limits of this motion (Fig. 7).

The center of the earth is the center of the cosmos; hence it may be used to define "down" in the cosmos as toward the center of the earth and "up" as away from the center. With this understood, one can imagine for the equator and tropic circles on the celestial sphere a corresponding circle directly below it on the earth, and we shall follow the Greeks in using the same names for the terrestrial circles as for their celestial counterparts. The terrestrial tropics are limiting circles for one of the varieties of astronomical phenomena used to determine latitude: only for observers in the belt between them does the sun pass directly overhead in the course of the year.

Another pair of circles closer to the terrestrial poles have a corresponding limiting role for a different latitudinal phenomenon. For observers at these circles, the length of the longest day of the year just reaches its greatest possible value, twenty-four hours, so that between these circles and the poles there will be some days of the year when the sun never sets. The limiting circle surrounding the north pole is the *arctic* circle, and its southern counterpart is the *antarctic* circle. Each is as far from its pole as the tropics are from the equator.

Climatic Zones

Although the various circles on the celestial sphere are primarily of astronomical significance, some ancient geographers used the corresponding circles on

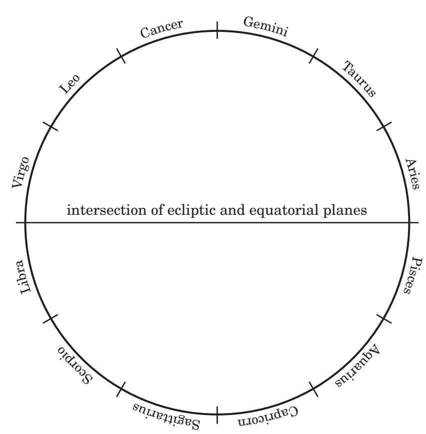

FIG. 6. The ecliptic and zodiacal signs

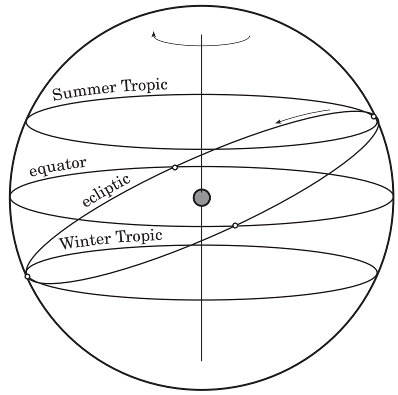

FIG. 7. The ecliptic and tropic circles

the earth's surface to divide the earth into zones with geographical, and even climatic, significance. Thus, according to Aristotle (*Meteorology* 2.5, 362a32, Loeb 179–181), there were two "frigid" zones (one north of the arctic circle and one south of the antarctic circle), two "temperate" zones (between the frigid zones and the two tropics), and a torrid zone (located between the tropics). It appears from 1.7 that Marinos set the limits of the torrid zone at a bit more than 12° north and south of the equator—as did Posidonius before him.[8] Ptolemy occasionally makes use of the principle that climate (including the range of plant and animal life and the appearance of the human inhabitants) is dependent on latitude to deduce that localities sharing the same climate must be at approximately the same distance from the equator.

Ptolemy also uses an even simpler division of the earth's surface, based on shadows rather than *klimata*. At localities between the two tropics the noon sun would be, according to the time of the year, sometimes to the north and sometimes to the south of the zenith, so that the corresponding shadows of a vertical rod (*gnōmōn*) would, during the course of the year, point north on one day and south on another. (Thus the regions are referred to as *amphiskian*, for the Greek word signifying that the shadows point in both directions, north and south, during the course of a year.) For persons exactly on the tropic circles, the noon shadows would point always north or always south, with the exception of one day of the year on which there is no noon shadow. At localities between the tropics and the arctic or antarctic circles, noon shadows will always point north or always point south. Such localities are known as *heteroskian*. Finally, at localities between the poles and the arctic or antarctic circles, there will be a part of the year during which the *gnōmōn*'s shadow makes a complete circuit around it. These localities, called *periskian*, play no role in the *Geography*.[9]

[8]Strabo (2.2.1–2.3.1, Loeb 1:361–371) has a very interesting discussion of geographical zones.
[9]See the discussion in *Almagest* 2.6 (Toomer 89–90) and Strabo 2.5.43 (Loeb 1:517–521).

Degrees

Ptolemy makes use of the *degree* as a unit for measuring arcs along meridian circles and parallels of latitude. This unit, which had its origin in the Babylonian practice of dividing both the day and the zodiac into 360 equal parts, was already being applied by the Greeks to circles on the celestial and terrestrial spheres in Hipparchus' time. Ptolemy, however, seems to have been the first geographer to establish a uniform coordinate system in degrees for specifying precise positions on the earth's surface. This system was devised on analogy with a convention astronomers had long been using to specify positions of stars and planets on the celestial sphere by two numbers: a *latitude* ("breadth") above or below the ecliptic, and a *longitude* ("length") measured along the ecliptic from a conventional zero point. For geographical purposes the equator replaces the ecliptic, and Ptolemy measures latitude north or south from the equator to a locality along a meridian circle, and longitude along the equator between that meridian and the meridian passing through the westernmost place on his map (the Islands of the Blest). Compared to the divisions of the globe based on celestial phenomena, the coordinates of latitude and longitude had the practical advantage for the cartographer of precision and uniformity of units. Nevertheless Ptolemy preferred that the finished map and its captions should express everything in terms of hour divisions and the other fundamental, astronomically defined circles.

Units of Distance

Measured linear distances from place to place were expressed in several different kinds of unit in the various sources on which Marinos and Ptolemy drew. The most important of these units was the *stade*, the standard unit of terrestrial distance in classical geography, which was probably understood by Ptolemy and his predecessors as a distance amounting to approximately 185 meters.[10] Stades could be converted into degrees according to the assumed equivalence of 500 stades to one degree measured along the equator or along a meridian. Distances from Roman sources, for example those pertaining to the Roman roads, would be expressed in the Roman mile (approximately 1.48 kilometers), which was usually treated as interchangeable with eight stades. In Egypt distances could be stated in the *schoinos*, which Ptolemy takes to be thirty stades. For the roads of the Parthian Empire the old Persian *parasang* was used; this was near enough in length to the *schoinos* so that in Ptolemy's sources the Egyptian name is substituted, and the same ratio is applied to convert to stades.

[10]There has been much disagreement concerning whether there was a single standard stade employed by all the geographical writers, and how large it was. We agree with Dicks (1960, 42–46), Engels (1985), and Pothecary (1995, 50–51) that they all used—or at least believed that they were using—the so-called Attic stade.

Directions

Ptolemy alludes to two ways of describing directions of travel, one based on the points of the horizon where the sun rises and sets, the other based on conventional names of the winds that blow from various directions. On the vernal and autumnal equinox, the sun is seen to rise due east of an observer, and to set due west. Hence these directions are sometimes called the directions of equinoctial sunrise and sunset. During the half of the year when the sun is north of the equator, which includes the summer for the northern hemisphere, the points of sunrise and sunset on the horizon are north of due east and west, reaching an extreme limit on the summer solstice; and similarly the rising and setting points are furthest south of due east and west on the winter solstice. Ptolemy refers to these directions as the directions of the sun's summer or winter rising or setting. In fact, they are not the same for observers at different latitudes: at the equator they are approximately 24° from due east and west, but the angles become larger as one moves further away either north or south. Ptolemy treats them, however, as being 30° from the east-west line regardless of the latitude; this is approximately correct for the latitude of Rhodes, which was traditionally thought of as the central east-west axis of the known world.

Additionally, Ptolemy and his sources use a scheme of twelve winds to specify directions. Four of these are equivalent to the cardinal directions, north, south, east, and west. The remainder are treated as equally spaced at 30° intervals between the cardinal directions, so that for Ptolemy the system based on the sun's rising and setting points is largely interchangeable with the system based on winds. The whole scheme is illustrated in Figure 8 (wind names in parentheses do not occur in the *Geography*). Note that the arrowheads indicate the direction of travel *toward* the designated wind, which is of course opposite to the direction from which the wind is supposed to blow.

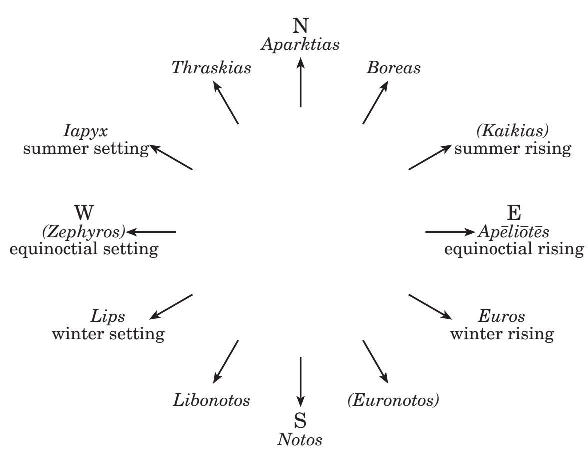

Fig. 8. Indications of direction by winds, sunrise, and sunset

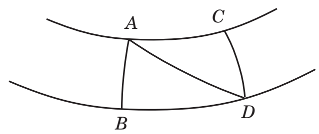

FIG. 9. Conversion of terrestrial distances to longitude and latitude

Conversion of Distance Measurements to Degrees

Ptolemy often has to translate a given interval between two localities, expressed as a number of units of distance in a particular direction, into the number of degrees of longitude between the meridians through the two localities and the number of degrees of latitude between their parallels. His procedure sometimes involves several stages.

a. If a locality A is s stades due north of another locality B, or vice versa, they lie along the same meridian (Fig. 9). Since a meridian is a great circle, Ptolemy uses the assumed equivalence of one degree with 500 stades along a terrestrial great circle. The difference in degrees between their latitudes is $s/500$.

b. If locality A is s stades due west of locality C, or vice versa, they lie along the same parallel (Fig. 9). Since a parallel is not a great circle (unless it happens to be the equator), Ptolemy has to find the number of stades corresponding to 1° along the parallel, which is in the same ratio to 500 as the circumference of the parallel is to the circumference of the equator. Suppose that the latitude of A and C is ϕ degrees. The circumference of the parallel at latitude ϕ is $\cos\phi$ times the circumference of the equator.[11] Hence the difference in degrees between the longitudes of A and C is $s/(500\cos\phi)$.

c. If A is s stades from D in some intermediate direction (Fig. 9), we must analyze the interval between them into north-south and east-west components, AC and CD respectively. In doing this, Ptolemy neglects for the moment the sphericity of the earth; that is, he regards the spherical triangle ACD as so small relative to the earth that it may be treated as a plane triangle with a right angle at C. Let the horizon angle between AD and the parallel through A (i.e., angle CAD) be θ. Then the east-west component of the interval in stades is $s(\cos\theta)$, and the north-south component is $s(\sin\theta)$. Each component is separately converted to intervals in degrees as described above.

[11]Ptolemy would not have employed the modern trigonometrical functions *sin* and *cos*, but rather the "chord" function, which is the length of a chord subtended by a given angle in a circle of radius 60. A table of chords as a function of angles is presented in *Almagest* 1.11. What we call cos θ, Ptolemy would have calculated as chord $(180° - 2\theta)/120$.

d. We have assumed that we know the direct-line distance between *A* and *B*. Ptolemy recognizes, however, that distances estimated by travelers generally are longer than the most direct route. One reason for this was that the route taken was not always straight; for example, mariners would follow the outlines of bays rather than sail straight across. Moreover, distances expressed in stades were sometimes calculated from the time taken in making the journey by multiplying by an assumed ideal rate of travel, but this would lead to an exaggerated figure if there had been delays on the route. Ptolemy allows for these tendencies in a very arbitrary way, typically by reducing a reported stade distance by one-third. Thus Ptolemy's analysis of a reported interval from one place to another can often involve steps (d), (c), and (a) and (b), in that order.

The Place of the Geography *in Ptolemy's Work*

Ptolemy (or, to give his full name, Klaudios Ptolemaios) was born about A.D. 100 and began his scientific career in the mid-120s, working in or near Alexandria in Egypt. He probably lived into the last quarter of the century.[12] Ptolemy's incitement to determine numerical coordinates for geographical locations throughout the known world may have come from the astronomical researches with which his scientific career began, and for which he is now best known.

We can see this origin in the *Almagest*, Ptolemy's great treatise on the mathematical theory of the motions of the heavenly bodies, which is generally regarded as his earliest major writing.[13] The *Almagest* is concerned with the apparent motions of the sun, moon, planets, and fixed stars, how to account for them quantitatively by means of models involving combinations of circular motions, and how to compute the instantaneous positions of the heavenly bodies and other celestial phenomena using tables based on these models. Geographical considerations arise in various ways in the execution of Ptolemy's project, most obviously in the fundamental problem of converting the recorded times of astronomical observations made in different places to Alexandria mean time. The same astronomical event will be observed in two places of different longitude at different intervals of time since the preceding local noons, and this difference is proportional to the difference in longitude between the two places. Moreover, ancient observers did not measure the times of observations in constant *equinoctial* hours after noon or midnight. Instead they divided the two intervals between sunrise and sunset and between sunset and sunrise into twelve equal *seasonal* hours, and described observations as having occurred at such-

[12]For a survey of Ptolemy's life and works, see Toomer 1975.

[13]The *Almagest* was finished later than A.D. 147 (Hamilton et al. 1987); in it Ptolemy cites astronomical observations that he made from A.D. 127 on.

and-such an hour of day or of night. To convert a reported time in seasonal hours to the number of equinoctial hours since local noon, one had to know the length of the seasonal hour in equinoctial hours, which is a function of both the sun's position on the ecliptic (i.e., the time of year) and the observer's latitude.

If Ptolemy had worked only on the basis of his own observations, he would still have needed to know the latitude of his locality, Alexandria. Since, however, he also used older observations made in a few other places, he needed values not only for the latitudes of these sites, but also for the differences between their longitudes and the longitude of Alexandria. Similarly, anyone else not living at Alexandria who wished to use Ptolemy's tables would have had to know his own latitude and relative longitude in order to convert his local time in seasonal hours to the uniform time of the tables, and vice versa.

In the *Almagest*, Ptolemy's treatment of matters related to the observer's geographical position is almost wholly theoretical. The relationship between longitude and time is a simple proportionality, and requires no special discussion.[14] For the more complex problems connected with latitude, Ptolemy designates a series of special parallels on the earth, computing for each parallel relevant astronomical data, including the tables of *oblique ascensions*, which are the basis for converting seasonal to equinoctial hours.[15] The complete list of parallels starts with the equator, and proceeds north at intervals such that the duration of daylight at the summer solstice increases by quarter-hours from 12 equinoctial hours at the equator to 18 equinoctial hours at 58° N, and then by larger time-intervals (because the parallels get closer together) to 24 equinoctial hours at the arctic circle (66°8'40" N). For the purposes of his tables, Ptolemy cuts this list down first to eleven parallels at intervals of half-hours of increase in longest daylight from the equator to 54°1' N (17 equinoctial hours), and later to just seven parallels (cf. Fig. 4) at half-hour intervals from 16°27' N (13 hours) to 48°32' N (16 hours).[16]

For most of these parallels, Ptolemy indicates a geographical location through which the parallel passes. In some instances this location is a city; for example, the parallel for 13½ hours is through the city Soēnē (modern Aswān). Other parallels are said to pass through less precise geographical features, or even

[14]Ptolemy states the rule (fifteen degrees of longitude correspond to one equinoctial hour) briefly in *Almagest* 2.13 (Toomer 130) and again at 6.4 (Toomer 282).

[15]*Almagest* 2.6–13. The oblique ascension associated with a given point on the ecliptic is the arc of the celestial equator that rises at the horizon of a given locality simultaneously with the arc of the ecliptic between the vernal equinoctial point, Aries 0°, and the given point. The interval in equinoctial hours between sunrise and sunset is proportional to the arc of the equator that rises above the horizon during that time, i.e., the difference between the oblique ascension of the point of the ecliptic diametrically opposite to the sun and the oblique ascension of the sun's position.

[16]In giving special prominence to these seven parallels, Ptolemy was following in an established tradition; see p. 10.

broadly defined districts; for example, that for 14 hours passes through Lower Egypt (the Nile delta). Apart from these latitudes, the only explicitly stated geographical data in the *Almagest* occur in the context of analyzing specific observations. Thus, Ptolemy gives Alexandria's latitude (30°58'), as well as latitudes and time differences from Alexandria for Babylon, Rhodes, and Rome.

The scarcity of geographical data in the *Almagest* is deliberate. At the end of the section in which he computes and tabulates the astronomical phenomena for his series of parallels, Ptolemy writes (*Almagest* 2.13, Toomer 122–130):

> What is still missing in the preliminaries is to determine the positions of the noteworthy cities in each province in longitude and latitude for the sake of computing the phenomena in those cities. But since the setting out of this information is pertinent to a separate, cartographical project, we will present it by itself following the researches of those who have most fully worked out this subject, recording the number of degrees that each city is distant from the equator along the meridian described through it, and how many degrees this meridian is east or west of the meridian described through Alexandria along the equator, because it was for that meridian that we established the times corresponding to the positions [of the heavenly bodies]. For the present, however, we take the [geographical] locations for granted.

The project of compiling a catalogue of important cities and their coordinates, which Ptolemy had not finished (and perhaps had not even begun) when he wrote this, was the germ from which the *Geography* grew. On the way, however, Ptolemy's scope broadened from the establishment of coordinates for a few hundred cities to a far more comprehensive codification of thousands of elements (towns, borders, natural features) of the entire known world; and his primary purpose shifted from compiling a table ancillary to his astronomical tables to laying down new and better foundations for drawing maps of the world.

Ptolemy did not, however, lose sight of his earlier plan. Among the roughly 8,000 localities in the huge catalogue of *Geography* Books 2–7, several hundred cities and towns were marked as being of particular importance;[17] and in the captions of the twenty-six regional maps (Book 8) Ptolemy listed these "Important Cities" with their positions translated into time units: the time difference from the meridian of Alexandria in equinoctial hours, and the length in equinoctial hours of the longest daylight. And when Ptolemy published a revision of the tables of the *Almagest* as a separate work, entitled the *Handy Tables*, he included in it a "Table of Important Cities," which presents substantially the same cities that he picked out in the *Geography*, with their longitudes and lati-

[17]The important cities originally seem to have been indicated by a special symbol in the margin, a notation that survives vestigially in at least one manuscript.

tudes in degrees extracted from the main catalogue of Books 2–7 and listed more or less in the order of Book 8.[18] Aside from this table, which is more an abridgment than a revision, the *Geography* appears to represent Ptolemy's final word on geographical questions.

Ptolemy's Evolving Conception of the World

When Ptolemy wrote the *Almagest*, he accepted a geographical picture of the known, inhabited world (the so-called *oikoumenē*) that was not radically changed from that of Eratosthenes (third century B.C.) and Hipparchus (c. 140 B.C.). He accepted as a matter of course that the earth was spherical; *Almagest* 1.4 presents arguments on this point, but by Ptolemy's time scarcely any educated person would have seriously questioned it.

There is some reason to believe that at this stage Ptolemy accepted the estimate going back to Eratosthenes that the earth's circumference is approximately 250,000 stades, which was usually expressed by the equation of one degree of the earth's equator with 700 stades.[19] If, as we believe, one stade was approximately 185 meters, then Eratosthenes' measurement (which was based on heavily rounded data) was about 15 percent too large.

The whole of the *oikoumenē* fits inside one quarter of this sphere, bounded on the south by the equator and on the east and west by a single meridian circle (*Almagest* 2.1, Toomer 75). Ptolemy was willing to believe (*Almagest* 2.6, Toomer 83) that the regions along the equator had a habitable climate, less torrid perhaps than districts closer to the Tropic of Cancer because the sun was close to the zenith for a briefer part of the year; but it was his opinion that no one from the Greco-Roman world had ever been as far south as the equator, and that one could not trust tales purporting to describe what was found there. The southernmost locality to which Ptolemy refers is the island Taprobanē (Sri Lanka), which he situates on the parallel 4¼° north of the equator. No place is mentioned on the east coast of Africa further south than the Bay of Avalitēs (north of the Horn of Africa), and no place on the Nile further south than Meroē (between the junctions of the Blue Nile and the Atbara with the White Nile). At the

[18]The order in which the cities are listed in all three contexts (*Handy Tables*, *Geography* 2–7, and *Geography* 8) is determined first by Ptolemy's division of the world into the twenty-six maps, and subordinately by the logical order in which the features of each province are supposed to be drawn on the map. This fact establishes that the *Geography* must have taken its present form (if it had not actually attained its final state) before the *Handy Tables* were published.

[19]The evidence is that Ptolemy assumes smaller time differences between the meridians of Rome, Alexandria, and Babylon in the *Almagest* than in the *Geography*, roughly in the proportion that would result if the same stade distance had been converted to degrees of longitude using respectively 700 stades and 500 stades to the degree (Schnabel 1930, 219). On Eratosthenes' measurement of the size of the earth, see, e.g., Dicks 1971, 390–391.

northern extremity of the *oikoumenē*, Ptolemy states that the parallel 64½° north of the equator passes through "lands of the unknown Skythians," presumably in the Baltic regions. Parallels from 63° southward to 55° are associated in turn with the island of Thulē, the Hebrides, Ireland, and places in northern and central England. The inclusion of the British Isles and the mouth of the Rhine in Ptolemy's list of parallels is the only prominent reflection in the *Almagest* of geographical knowledge acquired since the beginning of the Roman Empire in the late first century B.C.

Between the *Almagest* and the *Geography*, Ptolemy wrote an important astrological treatise known as the *Tetrabiblos*, in which there is a chapter (2.3, Loeb 129–161) setting out his version of the traditional topic of astrological geography, correlating the supposed characteristics of various peoples with the influences of the zodiacal signs and the planets. Again Ptolemy situates the *oikoumenē* inside a half of the northern hemisphere, and he further partitions this into four quarters divided by a parallel passing through the Mediterranean and along a range of mountains extending eastward through Asia, and by a meridian passing through the Sea of Azov, the Black Sea, the Aegean, and the Red Sea. If this meridian was intended to bisect the *oikoumenē* longitudinally, then it may be inferred that the world known to Ptolemy did not yet extend eastward much beyond the Ganges, although the countries listed include Sērikē, the "Silk country" that represents the Chinese terminus of the Silk Road. In the southerly direction, Ptolemy now knows of Azania, a stretch of the East African coast south of the Horn that he was to situate just south of the equator in the *Geography*. Unfortunately, the seventy-two countries named in the *Tetrabiblos* are arranged in schematic groupings that correspond to their geographical locations only in a loose way, so that we cannot reconstruct an underlying "map."

The *oikoumenē* portrayed in the *Geography* is more extensive than it is presented, not merely in Ptolemy's earlier writings, but in any other classical text before or after Ptolemy, except for those few authors who adapted Ptolemy's work. By this stage Ptolemy was convinced by investigations that are otherwise unknown to us (and of which he gives no details) that the earth was a smaller globe than Eratosthenes had thought, so that only 500 stades corresponded to one degree of the equator, and the earth's circumference amounted to 180,000 stades.[20] Hence in contrast to Eratosthenes' estimate, Ptolemy's is about 18 percent too small.[21] His *oikoumenē* still fitted within the 180° of longitude

[20]Ptolemy also uses this smaller value for the size of the earth without comment in the *Planetary Hypotheses*, an astronomical work written after the *Handy Tables*; see Goldstein 1967, 11.

[21]It is often stated in modern discussions that Ptolemy took his figure of 180,000 stades for the circumference from a lost geographical work of Posidonius (first century B.C.). Ptolemy does not say so, and the only ancient source that appears to ascribe the number to Posidonius (Strabo 2.2.2, Loeb 1:361–365) contains a serious numerical inconsistency at just this point (Taisbak 1974). The

bounded by a single meridian circle, but only just; and it now stretched from the old northern limit at 63° to a southern limit more than 16° south of the equator. One of the more remarkable features of the map he draws inside this frame is that most of the edge consists of land, not ocean: Ptolemy was one of the few ancient geographers willing to admit that the theoretically habitable land mass of the world extended indefinitely beyond the limits of knowledge of his time.[22]

Ptolemy's *oikoumenē* is divided into three great continents, Europe, Libyē (our Africa), and Asia. To an eye accustomed to modern maps of the world, Ptolemy's Europe is the most instantly recognizable continent. The outline of the European mainland is complete as far north as the east coast of the Baltic. Distortions of direction and scale are obvious in the more remote parts toward the north and west, as in the outlines and relative positions of the British Isles; and even in the Mediterranean there is a surprising error of orientation in the shape of Italy. The accuracy of the Mediterranean and Red Sea coasts of Ptolemy's Libyē falls off somewhat as the Horn of Africa is rounded, but it is the Atlantic coast, with its straight north-south orientation terminated by a bend toward unknown lands to the southwest, that renders this continent strangely unfamiliar. Asia exhibits greater and greater distortions as one progresses further east, the most obvious faults being the north-south compression of the Indian subcontinent so that its western coast is made to run parallel to the equator, and the exaggerated size of the island of Taprobanē (Sri Lanka). At the eastern edge, where the lands represent central China and Southeast Asia, it is virtually impossible to identify any of the features on Ptolemy's map with real counterparts. At his eastern limit Ptolemy draws the coast of Asia as turning south and then west, eventually to join the east coast of Africa, thereby making the Indian Ocean a vast enclosed sea unconnected with the Atlantic Ocean.[23]

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assertion (no less common) that Eratosthenes' measurement was remarkably accurate and Ptolemy's grossly in error results from supposing that the geographers' stade was much smaller than the Attic stade.

[22]Compare Strabo, writing a century and a half before Ptolemy, who maintains (1.1.8 and 2.5.5, Loeb 1:17–19 and 431–433) that the known *oikoumenē* is entirely, or almost entirely, surrounded by sea; and similarly, in the mid-first century A.D., Pliny the Elder (2.166–170, Loeb 1:301–305).

[23]Claims that mariners from Egypt or Spain had succeeded in circumnavigating the southern part of Africa were typically met with disbelief in antiquity (Herodotus 4.42, Loeb 2:239–241 and Strabo 2.3.4, Loeb 1:377–385). Hipparchus (cf. Strabo 1.1.8–9, Loeb 1:17–19) and Polybius (3.38, Loeb 2:89) had previously considered it possible that the Atlantic and Indian Oceans did not join south of Africa. Ptolemy does not actually provide coordinates for the coast of the unknown land linking Africa and Asia, but he refers to it verbally in 7.3, 7.5, 7.7, and 8.1.

Marinos and Other Sources

For all his disagreement with his predecessor concerning points of method and detail, Ptolemy ungrudgingly acknowledges that the collection of geographical data presented in the *Geography* is substantially the work of Marinos of Tyre. As he tells us in 1.4–6, the cartographer's task is not to gather and digest afresh all the information that is to go into his map, but to take as his starting point the most recent comprehensive and competent work of the same kind, correcting and augmenting it using his critical skills and the most up-to-date specialized sources; and in Ptolemy's time it was Marinos' map and geographical writings that best represented the current state of knowledge.

It is from the *Geography* alone that we know of Marinos' existence and can reconstruct some aspects of his work.[24] Most of what Ptolemy has to say about him is by way of exposing his faults; but then Ptolemy expected that his reader would be able to consult Marinos' works and judge them for himself. Ptolemy's treatment of Marinos is not altogether unlike his treatment of Hipparchus in the *Almagest*: the mistakes of both his predecessors seemed deserving of careful exposition precisely because of the stature of their overall achievement. After all his criticisms, Ptolemy professes that his intention is "to preserve [Marinos'] opinions [as expressed] through the whole of his compilation, except for those things that need some correction" (1.19).

Although Marinos is first introduced to the reader as "the latest [author] in our time to have undertaken this subject" (1.6), the manner of Ptolemy's references to him strongly suggest that he was dead when Ptolemy undertook the *Geography*, and that some time had elapsed since his "final publication" (1.17): enough, at least, so that Ptolemy could write of discrepancies between Marinos' work and "the reports of our time." Ptolemy includes in his map features, presumably taken over from Marinos, that reflect the state of the Roman Empire about the first decade of the second century A.D., whereas there are extremely few features that came into existence after about A.D. 110.[25] Moreover, the latest explorations of the interior and east coast of Africa on which Marinos based his

[24]The tenth-century Arabic historian al-Masʿūdī claimed to have seen a "book of *Geōgraphia* of Marinos," which contained maps (*Kitāb al-Tanbīh wa'l-ishrāf*, ed. de Goeje, p. 33; trans. Carra de Vaux, p. 53), but this is likely to have been a reconstruction from Ptolemy's text rather than an original work of Marinos. Elsewhere in the same book al-Masʿūdī asserts that Marinos lived in the reign of the emperor Nero, i.e., A.D. 54–68 (ed. de Goeje, p. 127, trans. Carra de Vaux, p. 178). It is hard to imagine the source for this date, which is probably about half a century too early. Wieber (1995) surveys these and other Arabic references to Marinos, concluding that all Arabic knowledge of Marinos' works derived from Ptolemy.

[25]Honigmann (1930, 1767–1768) pointed out the presence in the *Geography* of place names reflecting Trajan's Dacian campaigns (which ended in A.D. 107), but none from the Parthian campaigns that began in 114. Desanges (1964, 40–41) established a similar terminal date of 110 for Ptolemy's description of north Africa.

estimates of the southern extension of that continent appear to have taken place in the second half of the first century.[26] We will therefore not be far off the mark if we situate Marinos' activity in the years about A.D. 100.

That Marinos produced an actual map of the *oikoumenē* seems clear from Ptolemy's criticism of his choice of projection in 1.20, and besides, it is difficult to imagine how Ptolemy could have constructed his own map without having access to the map of Marinos. For the most part, however, Ptolemy directs his attention to the series of writings that Marinos published on various aspects of the map. Ptolemy's references tend to be vaguer than we might wish, because he presumed that Marinos' writings would be accessible to his readers. In 1.6 he writes of Marinos' many "publications (*ekdoseis*) of the revision of the geographical map," which might mean either a number of reeditions of a major cartographical treatise or a series of bulletins setting out corrections to an initial version of the treatise or of the map itself. The next sentence seems to support the first of these interpretations, since it mentions Marinos' final "composition" (*syntaxis*) as a possible, though unsatisfactory, basis for drawing the map of the world.[27] Again in 1.17 Ptolemy attributes some of Marinos' inconsistencies to the abundance of information in his "compositions" and their being "split up" (*kechorismenon*). By this last word Ptolemy means that Marinos' "composition" was divided into sections devoted to single kinds of geographical data or relationships rather than proceeding region by region through the *oikoumenē*. We can identify some of these sections from the survey of Marinos' inconsistent statements in 1.15–16.

One part dealt with the identification of localities that were "oppositely situated" (*antikeimena*), a technical term that Ptolemy defines in 1.4 as being "on a single meridian." He adds that these places had been so identified by the observation that the sail from one to another was effected by the north or south wind; and in fact, all the instances cited from Marinos are of localities on the coasts of the Mediterranean and its islands.

In another part, which Ptolemy calls "the division of the *klimata* and of the hour-intervals," Marinos located places within latitudinal belts called *klimata* or within longitudinal sectors called *hour-intervals*. An hour-interval was the part of the globe bounded by two meridians separated by 15° of longitude, so that local noon (when the sun crosses the observer's meridian) would take place

[26]Desanges (1978, 197–213) gives plausible arguments for dating the expedition of Julius Maternus to Agisymba to about A.D. 90, and that of Septimius Flaccus a few years earlier. The voyage of Dioskoros, which extended knowledge of the African coast beyond Rhapta to Cape Prason, was known to Marinos but not to the author of the *Periplus of the Erythraean Sea*, who wrote about the middle of the first century (see p. 27 n. 32 below). The *Periplus* is also much vaguer than Marinos concerning the south coast of Asia beyond the Ganges.

[27]It is worth recalling that the original title of Ptolemy's *Almagest*, a comprehensive treatise in thirteen books, is "Mathematical *Syntaxis*."

one equinoctial hour earlier at the eastern edge of the hour-interval than at its western edge. The "description of the parallels" (1.15) seems to have been a treatment of circles of latitude separate from the section on the *klimata*. Presumably this part contained lists of localities that were supposed to lie exactly on, or slightly to the north or south of, certain significant parallels.

A section that Ptolemy calls "the definition of the boundaries" (1.16) apparently took up in turn each of the major regions and provinces, and described its outline in relation to the other regions and bodies of water that neighbored it to the north, east, south, and west. This is a structural device that Ptolemy imitated in the catalogue of the *Geography*, but it does not seem that Marinos provided the precise quantitative descriptions of each coast and boundary comparable to Ptolemy's lists of coordinates. Even so, the "provinces and satrapies" into which Ptolemy divided the known world for the purposes of his geographical catalogue are likely to correspond in large part to Marinos' regions.

Ptolemy's chapters on the latitudinal and longitudinal extent of the *oikoumenē* give us fascinating glimpses of the varied informants on whom he and Marinos drew for the more remote parts of the world: merchants, mariners, and soldiers. We know far less about the sources for the more accessible regions, such as the provinces of the Roman Empire itself, precisely because Ptolemy is willing to take over these parts from Marinos on trust. In this respect Ptolemy is following the practice of earlier geographers in thinking of the world map as a traditional rather than a personal production. One had to justify any innovations one was imposing on the inherited picture; but there was no need to cite evidence for whatever was left unaltered. Ptolemy's allusion to Marinos' "many publications of the revision of the geographical map" suggests that Marinos, too, thought of himself as a corrector rather than a creator.

Hence, although much effort has been expended in hunting through Ptolemy's catalogue of localities for clues to the sources out of which it was put together, the prehistory of the map is certainly too complex to be reconstructible in its entirety from the evidence at our disposal. We can, however, make plausible guesses about some of the sources that Marinos and Ptolemy would have found useful.

These, of course, would have included older maps, for just as Ptolemy used Marinos' world map as a basis for his revision, Marinos surely also consulted the maps of his predecessors (who, with the exception of Eratosthenes, are unknown to us). In many cases this would not have been a straightforward process of copying or reading off locations, because not all detailed maps would have been constructed according to a strict projection defining each locality's position on the globe. Some of the spatial distortions in Ptolemy's map might have arisen because Marinos was taking information from a map that represented shapes, distances, and directions schematically or qualitatively.

Whether directly or at some remove, the localities eventually inscribed in Marinos' or Ptolemy's map would have originally been recorded in some kind of text. Few if any of these textual resources would have been composed in the first instance with the cartographer in mind, so that information of critical importance for drawing a map was typically left out or very poorly supplied. Among the most helpful would have been the so-called *itineraria* and *periploi*, comprising verbal records of the sequence of and distances between places along roads and coasts, respectively.[28] Examples of both types of text survive from antiquity, although none of the extant documents can be demonstrated to have been among the specific sources for Ptolemy's map.

An *itinerarium* would typically provide lists of localities along a network of roads, with the intervening distances, as in the following excerpt from the *Itinerarium provinciarum Antonini Augusti*, a work compiled in the third century A.D.:[29]

From Treveri to Agrippina, 78 leagues,[30] as follows:	
Beda village	12 leagues
Ausava village	12 leagues
Egorigium village	12 leagues
Marcomagus village	8 leagues
Belgica	8 leagues
Tolbiacum village of the Sopeni	10 leagues
Agrippina city	16 leagues
From Treveri to Argentoratum, 128 miles:	
Baudobrica	18 miles
Salisio	22 miles
Vingium	23 miles
Mogontiacum	12 miles
Bormitomagus	16 miles
Noviomagus	18 miles
Argentoratum	19 miles

Lists like this would have supplied the cartographer with series of place names to be strung out at the appropriate distances; but one would have had to learn the general direction of each route from other sources, while the direction of each single stage would have been a matter of guesswork.

The most detailed *itineraria* available to Marinos and Ptolemy would probably have pertained to the Roman road system, but there were comparable texts

[28] Dilke 1985, 112–144.

[29] Cuntz 1929, 57; see Dilke 1985, 125.

[30] The *league* was a Gallic unit equivalent to 1.5 Roman miles.

also for regions outside the Roman Empire, such as the so-called *Parthian Stations* of Isidoros of Charax (first century A.D.), an *itinerarium* of the roads through the Parthian Empire that constituted part of the overland trade route from the Mediterranean to central Asia.[31] It was apparently only when journeys did not follow well-established roads that writers provided rough indications of directions as well as distances, as was the case with the African expeditions of Septimius Flaccus and Julius Maternus (1.8 and 10), and the trade route through northwestern China from the Stone Tower to Sēra described by Maes Titianus (1.11).

The *periplus* was a handbook, analogous to the *itinerarium*, but listing places and distances of maritime travel. Since sailing routes in antiquity usually followed coasts, seldom crossing open water, most of the surviving *periploi* provide the reader only with distances (usually in stades, sometimes in days of sail), not directions. The cartographer working from a *periplus* would therefore have to draw on other sources as well as his imagination to turn the list of places into a graphical outline, naturally taking advantage of indications of capes and bays to give some verisimilitude to the shape of the coast.

A surviving *periplus* that is of particular interest for Ptolemy's *Geography* is the *Periplus of the Erythraean Sea*, a guide for merchants to the trade routes along the African and south Asian coasts of the Red Sea and Indian Ocean.[32] This anonymous work was written about the middle of the first century A.D., and seems to have been comparable in character to sources of information concerning these regions that were available to Marinos and Ptolemy. Distances are specified in the *Periplus of the Erythraean Sea* sometimes in stades, but also often in "runs" or days of sail, which the cartographer would have to convert to stades using a conventional estimate of the distance sailed in a day (cf. *Geography* 1.9). On the other hand, it does give many indications of directions of sail, albeit rather imprecise ones (only the four cardinal directions are named). A clear sign that Ptolemy used a source resembling the *Periplus of the Erythraean Sea* is his inclusion, contrary to his usual practice, of remarks concerning local products and articles of trade in the part of the geographical catalogue delineating the coasts of the Indian Ocean beyond the Ganges and the island of Taprobanē (7.2–4).[33]

From the narrative writings of travelers and historians one might also have extracted place names and descriptions of physical features, but few precise indications of their geographical location. It is difficult to say how widely Marinos or Ptolemy surveyed this class of literature for data to incorporate in the map.

[31] Edited in Müller 1855–1861, 244–254; translation in Schoff 1914.

[32] Casson 1989. For the date of composition of the work, see his pp. 6–7.

[33] This is evidently what Ptolemy is alluding to in 2.1 where he writes that he may occasionally include "some bit of current knowledge [that] calls for a brief and worthwhile note."

One instance that has often been cited is a village in northern Germany, mentioned by no other classical author, that might have arisen from a misunderstanding of a sentence in the *Annals* of the Roman historian Tacitus.[34]

One can imagine Marinos or Ptolemy turning with relief from such materials to the handful of places for which they believed they had a satisfactory, astronomically determined latitude or longitude. Inaccurate and sparse though the astronomical data were, they provided the cartographer with his most satisfactory control of the broad outlines of the map: a loose framework of determined parallels and meridians between which one had to fit the otherwise hopelessly flexible strings of place names found in the other sources. Considering the indispensable role of this kind of data in the construction of the map, it should not be surprising that Marinos and Ptolemy admitted among them several traditional positions that would not have stood up to the scrutiny of careful observation.

The principle of measuring latitude by observing the sun's noon altitude on an equinox or solstice was already a commonplace in Eratosthenes' time; and Hipparchus evidently knew how to convert a given maximum length of daylight for a locality into its latitude.[35] Nevertheless Ptolemy writes (1.4) that "Hipparchus alone has transmitted… elevations of the north pole for a few cities… and [lists of] the [localities] that are situated on the same parallels." Hence so far as Ptolemy knew, the three centuries that had elapsed since Hipparchus had produced no significant advancement in collecting this kind of data.

Some of Hipparchus' latitudes for specific places can be recovered from Strabo and other sources.[36] For a few cities, such as Athens, Carthage, and Alexandria, Hipparchus had a ratio of a *gnōmōn* to its shadow on the equinox, which is simply tan ϕ where ϕ is the latitude. Others are assumed to be situated on the parallels associated with maximum lengths of daylight increasing by steps of a quarter-hour. When we compare these Hipparchian latitudes with the latitudes

[34]"Siatoutanda" (*Geography* 2.11), perhaps from the phrase, "The rebels having departed to ensure their safety [*ad sua tutanda*]" (Tacitus *Ann.* 4.73, Loeb 4.129). The resemblance (which was first noticed by H. Müller in 1837) may, however, be accidental; see Furneaux 1896, 1:11 n. 7. The *Annals* were not published before A.D. 116, which is after the latest datable contents of Ptolemy's map that can plausibly be ascribed to Marinos (Syme 1958 2:471–473).

[35]Strabo (2.1.18 and 2.5.34–43, Loeb 1:281–285 and 502–521) reports from Hipparchus a series of distances in stades between the parallels corresponding to various maximum lengths of daylight; as shown by Diller (1934), the numbers are in most cases accurate if one calculates assuming 700 stades per degree and assuming a value of 23°40' for the obliquity of the ecliptic (which is an accurate parameter, but not directly attested for Hipparchus). Dicks (1960, 192–194) and Neugebauer (1975a, 2:734 n. 14) criticize Diller's procedure; but Neugebauer's attempt (pp. 304–306) to explain the Hipparchian latitudes as generated by an arithmetical sequence accounts for fewer of the data.

[36]The table in Dicks 1960 (p. 193) lists these localities, but one must consult the original texts elsewhere in his volume to find how Hipparchus expressed their latitudes.

that Ptolemy assigns to the same places, we find that Ptolemy has often preserved Hipparchus' values, but not always.

Especially toward the northern and southern extremities of the map, when Hipparchus situated places on the parallels associated with particular maximum lengths of daylight, Ptolemy keeps them there. Meroē and Ptolemais Thērōn in Aithiopia south of Egypt are right on the parallel for which the longest day is 13 hours; Berenikē and Soēnē in Egypt are on the parallel for 13½ hours (which is also the Summer Tropic circle); Tyre in Phoenicia is on the parallel for 14¼ hours; Rhodes is on the parallel for 14½ hours; Byzantion in Thrace and Massalia in Gallia Narbonensia are on the parallel for 15¼ hours; and the mouths of the Borysthenēs are on the parallel for 16 hours. Among these latitudes, those for Ptolemais, Byzantion, and the mouths of the Borysthenēs are significantly in error, by as much as 2½°.[37] Another false latitude derived from a traditional value for the longest day is Ptolemy's placement of Babylon 35° north of the equator, which is 2½° too far north and corresponds to the assumption made by the ancient Babylonian astronomers that the ratio of longest to shortest day at Babylon is 3:2. In this instance, however, Ptolemy seems not to be following Hipparchus, who had situated Babylon at very nearly its correct latitude, 32°30'.[38]

One city for which Ptolemy retained a Hipparchian latitude derived from an equinoctial *gnōmōn* shadow is Alexandria at 31° (more precisely, 30°58', as we know from the *Almagest*). This is remarkably close to the truth, considering that it is obtained from a shadow ratio in small round numbers, 5:3. Still, it is surprising that Ptolemy did not detect from his own observations at Alexandria that the accurate latitude was about a quarter of a degree further north (31°13').

The only astronomical method available in antiquity of determining the interval in longitude between two places was to establish the difference in equinoctial hours between noon at the places in question by observing the local times of a lunar eclipse at both places. Ptolemy complains (1.4) that only a small number of records existed of eclipses seen at different places, and mentions a particular one "seen at Arbēla at the fifth hour and at Carthage at the second hour." This was the famous eclipse that took place on the evening of September 20, 331 B.C., eleven days before the battle of Gaugamela (near Arbēla, in Assyria) in which Alexander defeated Darius III of Persia. The association of the eclipse with this momentous event likely explains why sightings of it in different places lived in memory. The three-hour difference in the observed times for Arbēla and Carthage would amount to approximately 45° difference in longitude; and Ptolemy turns out to have actually assigned the two cities longitudes 45°10' apart.

[37]Ptolemy's erroneous latitude for Byzantion (later Constantinople) continued to be used there until the eleventh century, when better geographical data from Arabic sources became available.

[38]Dicks 1960, 134.

Ptolemy does not say that this was the *only* simultaneously observed eclipse available to him, although that may well have been the case.[39] But the example is revealing in ways that he could not have known. For observers at Arbēla the eclipse actually began about 1½ hours after sunset, was total from about 2⅔ hours to about 3¾ hours after sunset, and ended a little before 5 hours after sunset; at Carthage the times would have been about 2¼ hours earlier, so that observers there would have seen the moon already almost totally eclipsed when it rose, with totality beginning in the middle of the first hour of night and ending about the middle of the second hour. Thus Ptolemy's report is barely acceptable for Carthage if mid-eclipse is meant and "at the second hour" means the beginning of that hour, but in serious error for Arbēla whether it refers to the middle or the beginning of the eclipse. Remarkably, a second report exists of simultaneous observations of this same eclipse, but for a different pair of localities and with different times. According to the Roman writer Pliny the Elder (d. A.D. 79), the moon was eclipsed at the second hour of night at Arbēla, and at moonrise (i.e., sunset) at Syracuse.[40] Pliny's version accurately describes the times of the eclipse's beginning. [41]

Clearly the reports of eclipses could be inaccurate and inconsistent, especially when they derived from unscientific observation. But even if a report specified the correct hour and it was clear what stage of the eclipse was meant, a longitudinal difference deduced from the difference between times reported only by the hour within which the event took place would have been subject to errors of 15°, which makes the procedure practically worthless except as a control on the intervals between very widely separated places. Ptolemy's 45° longitudinal interval between Carthage and Arbēla is grossly in excess of the correct figure, which is close to 34°, but when expressed in terms of terrestrial units of distance the error almost vanishes, because his equivalent for one degree in stades is only about 82 percent of what it should be. Thus incorrect observational data combined with a defective estimate of the size of the earth led Ptolemy to a result that happened to be concordant with the basically accurate east-west intervals between places in the Mediterranean and the Near East that he took over from Marinos, which were probably obtained from the stade distances in *periploi* (1.12).

[39]Heron *Dioptra* 35 (Teubner ed., 3:302–307) demonstrates a method of determining the great-circle distance between two cities using a lunar eclipse that he says was observed at Alexandria and Rome, with a two-hour difference. Neugebauer (1938–1939) identified this as the eclipse of March 13, A.D. 62. Ptolemy's longitudes for Rome and Alexandria are 23°50' apart, rather than the 30° that would result from taking this eclipse report seriously.

[40]Pliny 2.180 (Loeb 1:313).

[41]Ginzel 1899, 184–185. The eclipse was also recorded in a contemporary Babylonian "Diary" tablet, but the times are unfortunately broken off; see Sachs and Hunger 1988–, 1:176–179.

Ptolemy's Map Projections and Coordinate Lists

In introducing the principles of map-making, in *Geography* 1.20, Ptolemy refers to the two kinds of map, spherical and plane, and points out that although maps on spheres keep the earth's spherical shape and consequently preserve perfectly the relative proportions of intervals on the earth, they are usually too small to show all the things one wants to map, and they cannot be surveyed by the eye in a single glance. Plane maps, on the other hand, although they fulfill the two last demands, require "some method" to satisfy the first two.

Plane maps do not have to represent the spatial relationships between places in a definite, quantitative way. We know that world maps in classical antiquity could be highly schematic, like the circular map that appears in a group of medieval Greek astronomical manuscripts, in which, for example, Egypt and the upper Nile are portrayed as an oblique rectangle straddling a horizontal chord representing the Tropic of Cancer.[42] Herodotus (4.36, Loeb 2:235) and Aristotle (*Meteor.* 2.5 362b12, Loeb 181–183) both describe the world maps (*periodoi*) of their time as circular, with a ring-shaped Ocean entirely surrounding the land-mass of the *oikoumenē*; though the fact that both authors describe the plan of these maps as laughable shows that they had a conception that a map should somehow portray the regions of the world with roughly correct relative positions and sizes. The *Tabula Peutingeriana* ("Peutinger Table"), a medieval Latin map of the Roman Empire and its environs that is an indirect copy of a lost fourth century map, illustrates still another possibility: the map is a rectangular strip, nearly 7 meters wide but only 34 centimeters high, so that north-south distances are greatly compressed relative to east-west distances, and all outlines are accordingly distorted.[43] The lost source-map was designed primarily to exhibit the network of roads with their distances, for which there was no need to preserve much semblance to the shapes on the globe, and the map's dimensions were likely dictated by the original medium, possibly a papyrus roll.[44]

On the other hand, any world map that displayed localities in relation to a "graticule" (grid of principal parallels and meridians) would be practically forced to conform to a *projection*, that is, a mathematically definable rule for establishing a unique point on the planar surface corresponding to each point determined by a given parallel and meridian on the globe. And there is considerable evidence, especially in Strabo, that the "revision" of the traditional map of the world that Eratosthenes (c. 285–194 B.C.) presented in the third book of his

[42]Neugebauer 1975b (with illustration).

[43]A color reproduction of a section of the *Tabula Peutingeriana* is shown in *History of Cartography*, vol. 1, plate 5; for the whole, see Miller 1916 or Bosio 1983.

[44]Dilke 1985, 113–120.

Geography extensively employed geometrical constructions in relation to a grid of parallels and meridians.[45]

We may presume, therefore, that the history of map projections began not later than Eratosthenes in the third century B.C. Ptolemy tells us that Marinos criticized "absolutely all" previous methods of making plane maps, which implies that there had in fact been considerable experimentation with making such maps prior to his time. We know almost nothing about what these methods were, with the exception of the geographer Strabo's verbal description of a graticule suitable for the world map (early first century A.D.). Although frustratingly lacking in technical detail, the passage is worth quoting as the only surviving discussion of the topic before Ptolemy:[46]

> But [a world map] requires a large globe, so that the aforesaid segment of it [containing the *oikoumenē*], being such a small fraction of it, will be sufficient to hold the suitable parts of the *oikoumenē* with clarity and give an appropriate display to the spectators. Now if one can fashion [a globe] this large, it is better to do it in this way; and let it have a diameter not less than ten feet. But if one cannot make [a globe] of this size or not much smaller, one ought to draw [the map] on a planar surface of at least seven feet. For it will make little difference if instead of the circles, i.e., the parallels and meridians with which we show the *klimata* and directions and other variations and placements of the parts of the earth relative to each other and to the heavens, we draw straight lines, with parallel lines for the parallels, and perpendicular lines for the [meridians] perpendicular to them. [This is permissible] because the intellect is able easily to transfer the shape and size seen by the sight on a planar surface to the [imagined] curved and spherical [surface]. The same will apply to oblique circles [on the globe] and straight lines [corresponding to them on the map]. And though it is true that the meridians everywhere, since they are all described through the pole, all converge to one point on the globe, nevertheless it will not matter if on the planar surface one makes the straight lines for the meridians bend together only a little. For even this is not necessary in many situations when the lines [representing the meridians and parallels on the globe] are transferred to the planar surface and drawn as straight lines, nor is the convergence [of the meridians] as conspicuous as the curvature [of the globe].

Strabo evidently has in mind two ways of drawing the lines representing the circles of latitude and longitude. In the first, parallels of latitude are represented by horizontal straight lines, and meridians by vertical straight lines, so

[45] Strabo 2.1 (Loeb 1:253–361).

[46] Strabo 2.5.10 (Loeb 1:449–451).

that every parallel intersects every meridian exactly at right angles and the meridians, being represented by parallel lines, do not converge at all toward the north. In the second, the parallels of latitude are again drawn as horizontal lines, but the meridians converge a little at the north end of the map. This might mean that the meridians are drawn as straight lines inclined slightly from the vertical as if to meet at a point somewhere above the north end of the map, in which case they cannot all be perpendicular to the parallels. But Strabo may merely have in mind a slight inward curvature of the meridians only at the very top of the map, as if to suggest schematically their ultimate convergence while keeping them otherwise perpendicular to the equator and parallel to each other.[47]

Strabo appraises these representations only from the point of view of their adequacy in giving the general visual impression of the *oikoumenē* as it would be seen on a globe, and so he says nothing about what metrical properties of the map on the globe, such as distance, area, or direction, are preserved in either planar projection. At least in the version of the map with the meridians drawn throughout as parallels, one would presumably have kept the horizontal intervals between meridians on the map in correct proportion to the longitudinal intervals between the actual meridians, and likewise the vertical intervals between parallels on the map proportional to the latitudinal intervals between the actual parallels. Strabo's first grid would therefore have resulted, in modern terminology, in an *equirectangular cylindrical* projection, in which distances measured along all meridians would be portrayed in correct ratio to distances measured along, at most one parallel north of the equator, or along the equator itself. If he intended the meridians in the second version of the grid to be convergent straight lines, the projection would have resembled the so-called *Donis* or *trapezoidal* projection invented by Nicolaus Germanus in the 1460s, in which the meridians are drawn as straight lines converging so that distances measured along the top and bottom parallels are in correct ratio to each other, and only the central meridian and central parallel are at right angles and in correct proportionality of distances to each other.[48]

Whatever the variety of projections Marinos had to choose from, he had, according to Ptolemy, adopted just that mapping which was least successful in preserving proportionality of distances. In Marinos' map graticule (Fig. 10), the parallels of latitude are represented by a set of parallel straight lines and the meridians by another set of parallel straight lines at right angles to them, as in Strabo's projection. But Marinos also specified how distances along the paral-

[47]This is definitely what Strabo has in mind when he applies the same vocabulary to the courses of the Rhine and the Pyrenees in 4.5.1 (Loeb 2.253).

[48]"Donis" is a misreading of *donnus* or *dominus*, prefixed as an honorific to Nicolaus' name, apparently because he was a Benedictine.

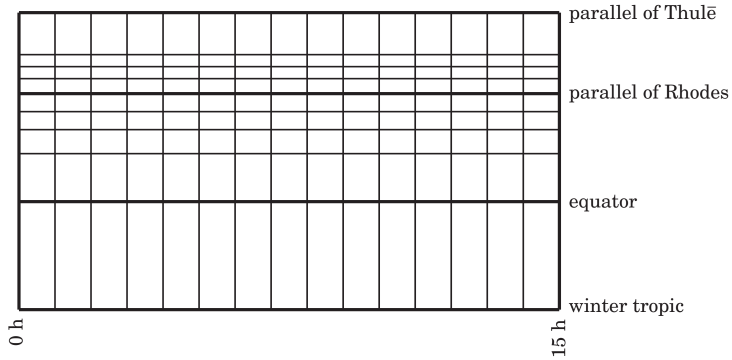

FIG. 10. Graticule of Marinos' projection

lels and meridians were to be represented in the projection. The ratio of the spacing of the lines separated by a given number of degrees of latitude relative to that of the lines separated by the same number of degrees of longitude was chosen to be 5:4, so that the ratio of a segment representing a degree in the east-west direction anywhere on the map to a segment representing a degree in the north-south direction is what it is on the globe at the latitude of Rhodes. As Ptolemy points out in 1.20, this means that the east-west spacing of places situated north or south of the parallel of Rhodes is progressively contracted the further south of Rhodes they are and progressively expanded the further north they are. The distortion would have been more pronounced in Marinos' map than in the map envisioned by Strabo, because Marinos' *oikoumenē* reaches significantly closer to the north pole than Strabo's does, and also extends to the equator and beyond, whereas Strabo assumed that the *oikoumenē* came to an end well north of the equator.

Ptolemy concedes this much to Marinos' choice of mapping, that if one imagines one's eye placed so that "the line of sight [is] directed at the middle of the northern quadrant of the sphere, in which most of the *oikoumenē* is mapped," and if the sphere is then revolved around its axis, each meridian in turn does appear as a straight line "when its plane falls through the apex of the sight." Hence, as a composite of a series of views of the sphere, the use of straight lines for meridians can be justified. But he also observes that to such an eye looking at the sphere, "the parallels… clearly give an appearance of circular segments bulging to the south," and a given pair of meridians "always cut off similar but unequal arcs on the parallels of different sizes, and always greater [arcs] on those nearer the equator."[49] Marinos' choice of projection lacks these properties.

[49]Not all of these statements are to be taken as a literal description of what is in fact seen, since in reality the parallels are seen as elliptical segments, not circular, and the portions of the arcs of different parallels between two meridians are not similar.

Ptolemy's First Map

After some further discussion, Ptolemy introduces the layout for his first map, in which he follows each statement about the geometry of the configuration with remarks about its effect (1.21):

> *First geometric criterion:* "It would be well to keep the lines representing the meridians straight, but [to have] those that represent the parallels as circular segments described about one and the same center, from which (imagined as the north pole) one will have to draw the meridian lines."
>
> *Its effect:* "Above all, the semblance of the spherical surface will be retained… with the meridians still remaining untilted with respect to the parallels [i.e., perpendicular to them] and still intersecting at that common pole."

> *Second geometric criterion:* "Since it is impossible to preserve for all the parallels their proportionality on the sphere, it would be adequate to keep this [proportionality] for the parallel through Thulē and the equator."
>
> *Its effect:* "The sides that enclose our [*oikoumenē*'s] latitudinal dimension [i.e., the bounding circular arcs representing the parallels of Thulē and the equator] will be in proper proportion to their true magnitudes."

> *Third geometric criterion:* "Divide [the parallel] that is to be drawn through Rhodes… in proportion to the meridian, that is in the approximate ratio of similar arcs of 5:4."
>
> *Its effect:* "The more familiar longitudinal dimension of the *oikoumenē* is in proper proportion to the latitudinal dimension."

The map that he produces has the following features:

1. The parallel bounding the *oikoumenē* on the north (the parallel through Thulē) is correctly represented relative to the size of the equator, i.e., the relative sizes of semicircles of the greatest and smallest parallels are correctly portrayed.
2. The longitudinal extent of the *oikoumenē* along the parallel of Rhodes relative to its latitudinal extent along the central meridian is faithfully represented on the map.
3. Each unit of distance along the straight lines representing the meridians between the parallels through anti-Meroē and Thulē faithfully rep-

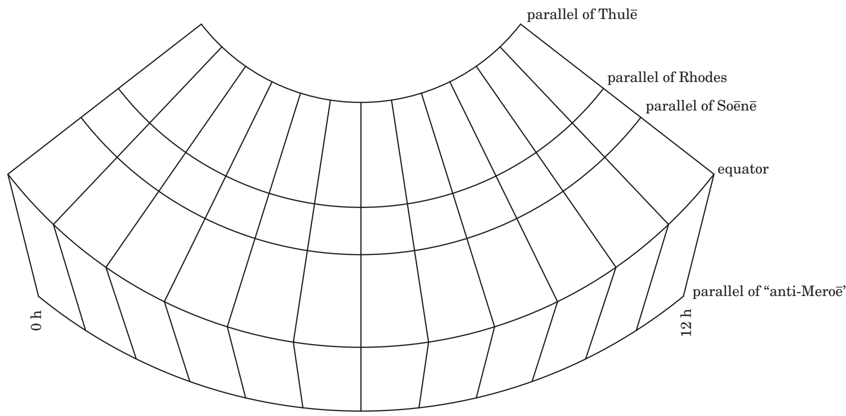

FIG. 11. Graticule of Ptolemy's first projection

> resents one degree of arc on the corresponding meridians on the globe. This is sometimes phrased as "distances are preserved on all radii."[50]

In modern nomenclature, this is a version of the *simple conical* projection (conical projections in general are those in which parallels are represented by concentric circles, and meridians by straight lines intersecting at a single point). This projection has the property that east-west distances are portrayed in correct proportionality to north-south distances only along the selected parallel through Rhodes, and are progressively exaggerated the further north or south one goes from this parallel. In Ptolemy's view, the distortion becomes intolerable for parallels south of the equator, because from this point on the actual parallels on the globe diminish in circumference, while the arcs representing them on the map continue to increase in length.

To compensate for this unwanted effect, Ptolemy introduces an ad hoc modification of his graticule. The arc representing the southernmost parallel to be included in the map is shortened to make it equal in arc length to the arc standing for the parallel that is the same distance north of the equator, and east-west distances along the two parallels are therefore in correct proportion to each other (though not to the meridians). The graticule is completed by drawing the parts of the meridians between the equator and the southernmost parallel as straight lines joining equal longitudes on the corresponding arcs (Fig. 11). The part of the map south of the equator is thus in a *pseudoconical* projection. This adjustment introduces a practical difficulty for anyone drawing the map, since one can no longer use a swinging ruler pegged to the common inter-

[50] E.g., Neugebauer 1975a, 2:881. Note that if this proportionality of distances is continued beyond the upper limit of Ptolemy's map, the north pole will be represented not by point *H*, where the meridians all converge, but by an arc with radius 7 units from *H*.

section of the meridians to locate points south of the equator. It also compromises the mathematical consistency of the projection, but to castigate this as a fault is to impute to Ptolemy a concept of map projection that was not his own.[51]

Ptolemy's Second Map

In contrast to the first map, where the eye is thought of as passing over each meridian in turn, in the second map the eye and the globe remain fixed relative to each other. Ptolemy attempts to produce the impression of the meridians and parallels as they would be seen when the axis of the visual cone joins the eye to the center of the sphere and passes through the intersection of the central meridian and the central parallel of the *oikoumenē*,[52] the eye being sufficiently far away from the globe so that for all practical purposes it sees a hemisphere. Such an eye will perceive two semicircles of great circles as straight lines. One of these is the visible half of the central meridian, and the other is a great circle passing through the two poles of the central meridian and the city of Soēnē (chosen because it lies exactly on the Summer Tropic circle). On the other hand, the same eye will view (1) the other meridian circles as a series of arcs equally balanced on either side of the central meridian, like right and left parentheses but increasingly curved the farther they are from the central meridian, and (2) the visible portions of the parallel circles as a series of concentric circular arcs.

Ptolemy also wishes to do this in such a way that (1) the lengths of the arcs of the parallel circles represented have the correct ratio to each other, not just for the equator and the parallel through Thulē, as in his first map, but also "as very nearly as possible for the other" parallels, and that (2) his map preserves the ratio "of the total latitudinal dimension to the total longitudinal dimension… not only for the parallel drawn through Rhodes…, but [at least] roughly for absolutely all [the parallels]" (1.24).

To accomplish this, Ptolemy imagines the viewing eye as seeing the visible hemisphere as a circle, bisected by two perpendicular diameters, whose length he arbitrarily sets at 180 units (representing linearly the 180° of the semicircle in the direction of the eye). In terms of these units he establishes where the equator crosses the central meridian at $23\frac{5}{6}$ units below the center (because the eye is supposed to be above Soēnē, which is at latitude $23\frac{5}{6}°$ north), and then where the center of the circle representing the equator will be. Since this will also be the center of the other parallel circles, he is now able to draw the circles on which the following parallels lie: that of "anti-Meroē" (marking the southern limit of the *oikoumenē*), that of Soēnē, and that of Thulē (at the north-

[51]Berggren 1991, 134–138.

[52]His central meridian cuts through the Persian Gulf, passes slightly to the west of Persepolis, and then heads northward through the Caspian Sea and Skythia. The central parallel of latitude is the parallel of Soēnē, in Lower Egypt.

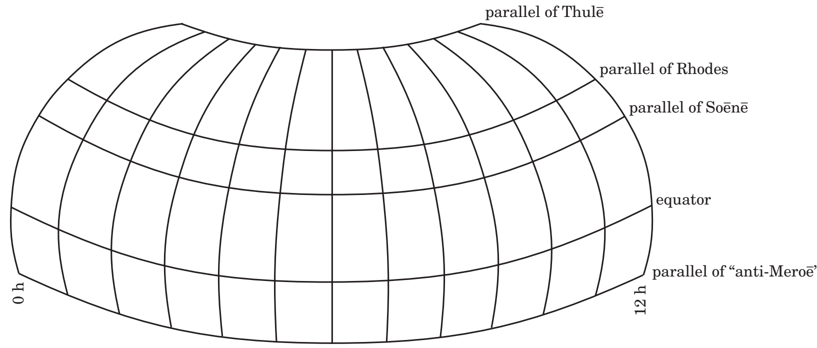

FIG. 12. Graticule of Ptolemy's second projection

ern limit). Taking arcs of five degrees to be equal to their chords, Ptolemy now marks off on each of these three parallels lengths corresponding to intervals of five degrees, and then joins triples of corresponding points with circular arcs to represent the meridians.

Figure 12 shows the resulting graticule. This is again a pseudoconical projection, since the parallels are drawn as concentric circular arcs, but the meridians are drawn as curves rather than as converging straight lines. Since a circular arc can be drawn through any three noncollinear points but not through any four, Ptolemy cannot keep distances measured along more than three of the parallels in exact proportionality with distances along the central meridian; and distances along the other meridians are distorted as a consequence of their curvature. If Ptolemy had made all the parallels proportionate in length to their actual lengths on the globe, and allowed the meridians to be drawn freely as the curves joining corresponding points on all parallels, he would have obtained the *Bonne* projection, which incidentally has the property of preserving areas of arbitrary regions on the globe.[53] Ptolemy, of course, would not have known this, and there is no suggestion that he, or any other ancient writer, had thought of preservation of areas as a desideratum in a map projection.

The Map in the Picture of the Ringed Globe

In 7.6, Ptolemy sets out a long geometrical construction of an image of the terrestrial globe surrounded by rings representing the principal circles of the celestial sphere. The construction consists of two distinct parts: determining points

[53]Printed editions of the *Geography* of the late fifteenth century gave either Ptolemy's first projection (e.g., the Rome edition of 1490, reproduced in Nordenskiöld 1889, plate I) or the second (e.g., the Ulm edition of 1482). Bernardus Sylvanus (1511) and Johannes Werner (1514) were the first to generalize Ptolemy's second projection along the lines described above; see Neugebauer 1975a, 2:885–888.

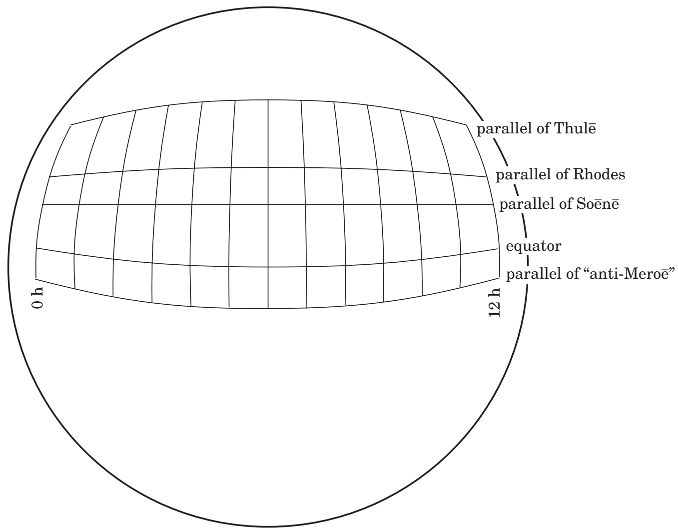

FIG. 13. Graticule of the projection in Ptolemy's picture of the ringed globe

through which the curves representing the various rings are to be drawn, and establishing a graticule for the map of the *oikoumenē* that is supposed to be visible between the rings. Ptolemy treats the two problems quite differently. The rings are drawn according to true linear perspective; that is, one imagines linear rays radiating from a point in space (representing the eye) through several points on each ring and onto a vertical plane, and the rings are drawn on that plane as ellipses passing through the projected points. This is in fact the unique example of a construction according to linear perspective surviving from antiquity. Ptolemy carries out the projection by treating the drawing plane first as the vertical plane containing the eye and the center of the globe, and thereafter as the plane of projection, which is at right angles to the former plane, so that the final drawing is made on the same plane as the geometrical construction of the perspective projection. This device, which eliminates the need for transferring measurements from one diagram to another, is reminiscent of the *analemma* constructions of sundial theory.[54]

Ptolemy's method for constructing the parallels of latitude portrayed on the terrestrial globe makes use of projected rays from the point representing the eye in a manner that superficially resembles the linear perspective used for the rings, but in fact the procedure has nothing to do with linear optics, and merely serves to generate a series of circular arcs that have their concavities facing a straight central parallel, thus qualitatively imitating the appearance of the actual parallel circles seen from an eyepoint in the plane of the chosen central parallel. The resulting projection (Fig. 13) resembles Ptolemy's second projec-

[54]Neugebauer 1975a, 2:839–856.

tion in using circular arcs to represent all meridians except the central one, which is a straight line, and in treating distances along this central meridian as proportional to the true distances on the globe; but the parallels are now laid out according to a plan analogous to that of the meridians instead of being drawn as concentric circular arcs. Again as in the second projection, proportionalities of distances are preserved along three parallels, along the top, bottom, and center of the map.

One may think of this third projection as a modification of Marinos' cylindrical projection, such that only one central meridian and one central parallel are drawn as straight lines in correct proportionality of distances, while the remaining parallels and meridians are drawn as circular arcs with curvature increasing as one goes further from the center of the map, to imitate the perspective appearance of the globe.

The Regional Maps

Having dismissed Marinos' cylindrical projection as unsuitable for a map of the entire *oikoumenē*, Ptolemy reintroduces it for the twenty-six regional maps into which he partitions the *oikoumenē* in Book 8. Each region is to be drawn in a graticule employing orthogonal straight lines for all meridians and parallels, and such that distances are represented in correct proportion along all meridians and along the central parallel for the region in question. The ratio of the lengths of one degree along the central parallel and along the meridians is stated in the caption to each regional map. Ptolemy left it to the cartographer, however, to find out just which meridians and parallels bound each region by finding the maximum and minimum longitudes and latitudes in the lists of coordinates. Someone after Ptolemy extracted these numbers, and listed them in a supplementary chapter that appears at the end of some manuscripts of the *Geography* (8.30 in Nobbe's edition).

The Coordinate Lists

Once the cartographer has constructed an appropriate graticule for the map of the world or one of the twenty-eight regions, the next task is to draw the map using the coordinate lists that make up the bulk of the *Geography* (Books 2.2–7.4). For this purpose, Ptolemy divided the *oikoumenē* into about eighty districts, which are grouped broadly into three continents (Europe, Libyē, and Asia), and within each continent are ordered loosely from west to east and from north to south. The chapters into which this part of the *Geography* is divided correspond to these districts.[55]

[55]It is not always obvious whether Ptolemy considers certain groupings of districts to belong together or not, so that the chapter divisions and the total number of districts are not definitely fixed.

Ptolemy refers to the districts in 2.1 as "provinces" and "satrapies," which would seem to identify them with the administrative divisions of the Roman and Parthian Empires, respectively. It does appear that Ptolemy (or Marinos) intended the districts contained by the Roman Empire to follow at least approximately the official borders of the provinces. On the other hand, Ptolemy's partition of Asia beyond the Roman frontier reflects the division of the Persian Empire into satrapies that was in effect in the time of Alexander the Great, and that had become part of the traditional apparatus of Greek geography. Ptolemy's map in fact makes little attempt to represent political geography, so that one cannot even tell from his map which districts belonged to the Roman Empire.

The map is composed of three kinds of object: one-dimensional (curvilinear) objects such as coastlines, the longer rivers, and some mountain ranges, which are to be drawn by connecting two or more points; pointlike objects such as cities, small islands, mountains, and the mouths of minor rivers; and peoples inhabiting small districts, who are located only in terms of the cities inside each district. Surprisingly, given that *itineraria* probably provided Marinos and Ptolemy with a good part of their geographical data, roads do not appear on the map. Each chapter begins with the definition of the outline of the province or satrapy, consisting of coastlines and borders (which sometimes coincide with rivers or mountain ranges). Borders that have already been described in a preceding chapter for the adjacent province are not repeated, and one generally has to refer back to the earlier chapter to find the last point from which drawing is to be continued. Cities and other features that lie on coasts are listed as part of the definition of the coastline. The coordinates defining the course of longer rivers are usually inserted as a digression at the point when the drawing of the coast has reached the river's mouth; for example, in 2.7 Ptolemy interrupts the description of the coast of Gallia Aquitanica when he has come to the mouth of the Garuna in order to insert the coordinates of two inland points that determine its course. The bends of some of the more complex rivers, such as the Nile, can only be drawn by inference after one has inscribed all the cities that are stated to be on one side or the other, a rare violation of Ptolemy's usual practice of giving specific longitudes and latitudes for all the cartographically significant points. Since the coordinates are specified only to the twelfth part of a degree, the resolution of the map is incapable of displaying distances smaller than that, so that, for example, the sizes and placements of offshore islands are not to scale.

The Manuscripts of the Geography

Some understanding of the textual history of the *Geography* is indispensable for anyone who intends to study—or translate—the book from the available editions. We shall therefore give a brief outline of the ancestry of those manuscripts that are believed to be the most important for restoring Ptolemy's text.[56]

Our knowledge of the text of the *Geography* depends, for all practical purposes, on more than fifty Greek manuscripts, none older than the end of the thirteenth century. The genealogy of these manuscripts, though still not completely sorted out, is much better understood now than it was a century ago, when Nobbe and Müller published the last editions of the text to include the parts translated here.[57]

All manuscripts of the *Geography* seem to descend from a common ancestor later than Ptolemy. It is necessary to assume such an archetype (as opposed to two or more independent lines of descent from Ptolemy's autographs) in order to explain the errors common to all branches of the tradition, which are too numerous and often too serious to be the author's own.[58] Some variants between the manuscript families that are attributable to misreading the archetype indicate that it was written in capitals, which means that it was copied out earlier than the tenth century; it may in fact have dated back to late antiquity.[59]

The text of the *Geography* as it appeared in the archetype was already flawed, not only by accidents of copying, but also, apparently, by deliberate attempts to correct or improve Ptolemy's geographical data. One such instance, relating to part of the south coast of Italy, can be proved because some of Ptolemy's original coordinates have been handed down in the "Table of Noteworthy Cities" in his *Handy Tables*. Elsewhere Ptolemy's text may have been altered in ways that are more difficult to detect now.

The archetype also contained, perhaps at its end, some texts that did not originally belong to Ptolemy's work. The most important of these was a list of provinces classed according to Ptolemy's twenty-six regional maps, but with deviations from Ptolemy's provinces.[60] Among the other supplements are two

[56]Schnabel (1938, 5–33) describes forty-six Greek manuscripts containing all or part of the *Geography* (summarized on pp. 120–121 in a table and a rather tangled *stemma*). This list is not complete (see the addendum, p. 128, and Diller 1940b). A more up-to-date selective list is Diller 1966. We follow Diller's notations for the manuscripts, which are largely consistent with the conventions of Cuntz, Müller, and other previous editors of the *Geography*.

[57]The most significant contributions to the sorting out of the *Geography*'s manuscript tradition are Cuntz 1923 (esp. 1–37); Schnabel 1938; and Diller 1936, 1939, 1940a, 1940b, 1941, 1943, and 1966. Schnabel's monograph is still the most comprehensive treatment of the problem, but he unfortunately omitted much of the detailed argumentation behind his conclusions, some of which has since been shown to be incorrect. Fischer 1932a, although primarily concerned with the maps in the manuscripts, contains much that impinges on the history of the text.

[58]Examples are given by Cuntz (1923, 15). For some common errors in the description of Gaul, see pp. 126–127 (southern end of border between Gallia Aquitanica and Narbonensia; source of Sequana; Cemmena Mountains).

[59]Diller 1939, 229.

[60]Diller 1939, 93–95.

passages intended to be added to the captions for Ptolemy's world map and his picture of the globe (these may be by Ptolemy but are more probably spurious)[61], a small table that has to do with the motion of the sun north and south of the ecliptic,[62] a short poem in hexameters intended to be inscribed on a world map, and a note by a certain Agathos Daimon or Agathodaimon, engineer (*mēchanikos*) of Alexandria, announcing that he "sketched" (*hypetypōsa*) a map of the whole *oikoumenē* on the basis of the eight books of Ptolemy's *Geography*.[63]

Through most of the Middle Ages, Ptolemy's *Geography* was a rare and little-read text, a situation paralleled in the history of other ancient scientific and technical works.[64] The fortunes of the *Geography* changed abruptly around the year 1300, when several copies of the work—the earliest that survive—were made. From this time forth, manuscripts of the *Geography* proliferated.

The explanation of the *Geography*'s renewed popularity is likely to be found in the claim of the Byzantine scholar Maximos Planudes (c. 1255–1305) that he had "discovered through many toils the *geōgraphia* of Ptolemy, which had disappeared for many years."[65] We shall return in the following section to the question of what Planudes actually claims to have done, in particular whether he means that he rediscovered the text of the *Geography*, with or without maps, or that he reconstructed the maps from the text. But whatever the nature of Planudes' activity, there is a probable case for connecting it with a family of manuscripts of the *Geography* that date from about 1300.[66] These manuscripts were all copied, directly or indirectly, from a single lost copy. Three of the most important are beautiful large-format parchment codices containing maps. The cost of materials and workmanship must have been enormous, suggesting that these were presentation copies for very wealthy (or imperial) patrons.

The manuscripts of this family present a distinct recension of the text of the *Geography* characterized by extensive corrections of perceived errors in the text. Other alterations seem to be connected with the drawing of the maps, or to result from comparison with other authors. Such emendations are obviously a scholar's work.[67] We will refer to this version below as the "Byzantine revision."

These are the most important manuscripts of this group:

U = *Urbinas gr.* 82 (Vatican), a large parchment codex, c. A.D. 1300. The world map (employing Ptolemy's first projection in 1.24) follows the end of

[61]See p. 108 n. 1 for the former passage.

[62]Schnabel 1938, 64–67. The table is relevant to the problem of determining when the sun is directly overhead in tropical localities; see Neugebauer 1975a 2:936.

[63]Schnabel 1938, 92–94.

[64]See pp. 50–51.

[65]Kugéas 1909, 115–118.

[66]Diller 1940a. See also Diller 1936, 236–238; and Wilson 1981.

[67]For comparable examples in Planudes' studies of classical texts, see Wilson 1983, 232–236.

Book 7, while the twenty-six regional maps alternate with their respective captions in Book 8. A facsimile of this manuscript has been published.[68]

K = *Seragliensis gr*. 57 (Istanbul), a large parchment codex in the same format as **U**, c. A.D. 1300.

F = *Fabricianus gr*. 23 (Copenhagen), a single parchment sheet containing maps and text from Book 8, c. A.D. 1300. The manuscript to which this originally belonged was very like **K**.

N = *Bodl.* 3376, formerly *Selden.* 41 (Oxford), a paper manuscript containing the text of the *Geography* without maps, c. A.D. 1300.

R = *Marc. gr.* 516 (Venice), **V** = *Vat. gr.* 177 (Vatican), **W** = *Vat. gr.* 178, **C** = *Par. suppl. gr.* 119 (Paris). These fourteenth-century paper manuscripts are copies of a lost sister manuscript to **UKFN**. **R** contains a somewhat defective set of regional maps; **VWC** have none.

As has already been mentioned, the text of the *Geography* in this family shows clear signs of having undergone deliberate changes, which become apparent through comparison with other manuscripts to be described below. The redactor has here and there attempted to correct or smooth over difficulties in the sense and harshnesses in the language, often detecting real corruptions in the received text, but sometimes, one suspects, correcting Ptolemy himself. The spelling of many place names and some of the coordinates have been altered, evidently to resolve inconsistencies that became apparent in drawing maps. The captions of the regional maps in Book 8 have undergone fairly extensive revision.

We turn now to manuscripts that are partly or entirely free of the Byzantine revision:

X = *Vat. gr.* 191 (Vatican), a paper codex containing a large corpus of mathematical and scientific writings, copied by numerous hands and assembled about 1296.[69] The text of the *Geography* was originally copied by three hands, and some missing pages in the beginning have been replaced by a fourth; there are no maps. For some unknown reason the second and third scribes omitted all the numerical coordinates in the geographical catalogue from Book 5.13 on. In spite of this serious defect, **X** is a manuscript of the greatest importance for the text of the *Geography*, because it is the only copy that is uninfluenced by the Byzantine revision.

[68]Fischer 1932b.

[69]For the date and composition of the manuscript, see Turyn 1964, 89–97.

Z = *Pal. gr.* 314 (Vatican), a paper manuscript copied in about 1470. The text of this manuscript appears to derive from a text originally like that of **X** but extensively corrected against a manuscript related to **RVWC**.

T = *Burney* 111 (London), a fourteenth-century parchment manuscript with maps, apparently descended from a copy of a manuscript in which the Byzantine recension had been collated throughout against a manuscript of the unrevised text.

The Maps in the Manuscripts

We have argued that, taken as a whole, the *Geography* is a unified composition that may be ascribed with confidence to its traditional author, Ptolemy. The same cannot be said, however, of the maps that accompany the work in many manuscripts. These are of two types: world maps, showing the whole of Ptolemy's *oikoumenē*, and regional maps. Practically all manuscripts containing maps have the world map, laid out according to Ptolemy's first map projection (except for **K**, which employs the second projection); but they fall into two different classes according to the number of regional maps they contain.

One of these classes, the manuscripts of so-called A version, contain twenty-six regional maps. These correspond closely to the maps to which Ptolemy refers in Book 8 in the following words: "We have made ten maps of Europe, four maps of Libyē, and twelve maps of the whole of Asia" (8.2). In these manuscripts the regional maps appear in Book 8 alternating with the relevant captions in Ptolemy's text. The manuscripts of the so-called B version contain sixty-four maps that portray smaller regions of the *oikoumenē* than Ptolemy's twenty-six regions; these are scattered at appropriate places in the catalogue of localities in Books 2–7.[70] In the Greek copies of both versions, the regional maps follow the cylindrical projection prescribed by Ptolemy, so that east-west distances along the central latitude of the map are in correct ratio to north-south distances, and the frame of each map is rectangular. Some later Latin copies adopt Nicolaus Germanus' refinement in which the meridians are drawn as converging straight lines in a trapezoidal frame, so that east-west distances at the top and bottom of the map are in true proportion to north-south distances.

The maps in most manuscripts of the A version are direct or indirect copies of those in **U**; this is obvious from the way that they reproduce trivial features such as the fictitious wiggles and bumps along the coast of unknown land to the south of the Indian Ocean on the world map, which are not derived from Ptolemy's coordinates. It also seems likely that the B version maps were produced from

[70]A few manuscripts of the B version also include four maps portraying the continents of Europe, Libya, and northern and southern Asia.

those of the A version for the convenience of those wanting to fit the *Geography* in manuscripts with smaller page dimensions, which necessitated more maps representing smaller areas. But were the maps in **U** and its sister manuscripts **K** and **F** themselves copies made by eye from maps in a lost manuscript, descending from an unbroken lineage beginning in antiquity, even from Ptolemy himself? Or were they reconstructed by Planudes or some other scholar about A.D. 1300 from the coordinates in the text, following Ptolemy's instructions? These questions have been the subject of much controversy in the past century. Without entering into a detailed discussion of the often complex arguments that have been presented on both sides, we can review some of the considerations that have led us to believe that, whatever the answers to the above questions may be, the maps that are present in the extant medieval copies are not an integral part of Ptolemy's work.

Although some scholars have gone so far as to doubt whether Ptolemy actually drew, or had drawn for him, the maps that he describes in the *Geography*, it seems hard to imagine how he could not have done so.[71] First of all, he could scarcely have compiled his lists of coordinates directly from Marinos' world map, because the places in Marinos' map had not only to be adjusted in accordance with Ptolemy's systematic reduction of the eastward and southward extensions of the *oikoumenē*, but also had to take account of the corrections and additions that existed in verbal form in Marinos' last publications and the reports of Ptolemy's own informants. As Ptolemy insists in 1.17, the way to detect and eliminate inconsistencies such as those he detects in Marinos' writings is to draw a map.

If we concede, as we surely must, that there were intermediate maps and sketches preceding the compilation of Ptolemy's geographical catalogue, it does not have to follow that Ptolemy incorporated actual maps in the manuscript of the *Geography* that he published. The first question in our minds must be whether it is plausible that Ptolemy would have presented such a comprehensive and well-thought-out plan of how to draw maps of the *oikoumenē* without actually trying it out. Certainly Ptolemy's description of the actual mechanics of map-making has the ring of something written by one who had actually made maps from coordinate lists. Statements such as the one (1.22) advising anyone preparing a map on a globe to make sure that the semicircular ruler swinging about the poles is "narrow in order not to obstruct many localities; and [to] let one of its edges pass precisely through the points [representing] the poles, so that we can use it to draw the meridians," or the remark (2.1) that he has arranged his catalogue of localities with a view to "convenience in the drawing of the map in every respect, namely progressing toward the right, with the hand

[71] Berger (1903, 640–641) and Bagrow (1946), among others, have denied that Ptolemy drew maps. See also Dilke 1985, 207 n. 28, for references to other advocates on either side of the question.

proceeding from the things that have already been inscribed to those that have not yet [been inscribed]," suggest that there is solid experience in map-making behind the presentation.[72]

But the maps may not have accompanied the text of the *Geography*, or even have been propagated in manuscript form at all. One mode of presenting a map of the world in antiquity—perhaps the most important one—was its erection in a public place. The most famous example of such a display was the map placed on the wall of a portico in Rome at the beginning of the first century A.D. by the emperor Augustus' friend Agrippa; and a similar map of the *oikoumenē* was apparently put up about A.D. 300 in a portico at Augustodunum (modern Autun in France).[73]

Now, if Ptolemy intended that his world map should be constructible directly from the catalogue of coordinates in the *Geography*, with all the localities visible and labeled, then he must have had a rather large map in mind, certainly no smaller than a meter in height and two in breadth.[74] In Ptolemy's time books such as the *Geography* were in the form of rolls of papyrus, which were commonly in the neighborhood of 30 centimeters, and very rarely as much as 60 centimeters, in height, which is about the height of the leaves in the medieval manuscripts of the A version. Thus a very tall papyrus roll would just have been able to accommodate the twenty-six regional maps of Book 8 in their full detail, but not the world map.[75]

The possibilities and limitations of maps in ancient manuscripts are no longer wholly a matter of conjecture now that a substantial fragment of a papyrus roll dating from approximately the middle of the first century B.C. and containing part of a Greek geographical treatise accompanied by a map has very recently come to knowledge.[76] The text in question is the description of Spain from the *Geography* of Artemidorus (c. 100 B.C.), a work known to Strabo, and the map, which follows (i.e., appears to the right of) the text. The height of the roll was (at least) 32.5 centimeters, which is exceptional for a literary roll of this

[72]Ptolemy's instructions for making the maps in the *Geography* are comparable to those describing the construction of observational instruments and the star globe in the *Almagest* and of experimental apparatus in his *Optics*.

[73]Dilke 1985, 41–54.

[74]Localities are placed on the map as close to each other as one-twelfth of a degree, and the rectangle containing the projection is roughly the equivalent of 90° from top to bottom and twice that in breadth.

[75]Diller (1939, 233 and 237) has shown that the medieval copies of the text of the *Geography* descend from a lost manuscript in which there were only about thirty-five lines to a page, which would have been too small for any of the maps.

[76]Gallazzi and Kramer 1998. The full contents of this remarkable papyrus, which is in a private collection, have not yet been published; our inferences based on the provisional description may in time have to be modified. The manuscript seems not to have been finished, so that the map lacks labels for the localities, and unused parts of the roll were subsequently used for artistic sketches.

period.[77] When complete, the map was more than 93.5 centimeters wide, so that the more or less equal north-south and east-west dimensions of the region must be portrayed with much lateral distortion, as in the *Tabula Peutingeriana*.

We have already mentioned the note by the Alexandrian engineer Agathos Daimon preserved in the manuscripts of the *Geography*, in which he states that he drew the world map according to Ptolemy's text. This note, which probably dates from antiquity (the man's name is unlikely to be Byzantine), could be imagined as the "signature" of a map drawn by Agathos Daimon in an ancestor of our manuscripts, although it does not in fact accompany the world map in those manuscripts that have one. Nothing, however, excludes the possibility that Agathos Daimon left the note as a testimonial to his success in applying Ptolemy's instructions to construct a map somewhere else.

Manuscript **X** has the following note following the end of Book 8, and written in the same hand as the preceding text: "Here he prescribes twenty-six charts; but in the actual map, twenty-seven. For he divides the tenth chart of Europe into two, putting Macedonia in one, and Epirus, Achaea, the Peloponnese, Crete, and Euboea in the other." These remarks apparently refer to Ptolemy's own maps, or maps that the writer takes to have been Ptolemy's. Again there is no suggestion that they were present in the manuscript in which the note was originally written. **X** contains no maps, and in the manuscripts that have the regional maps, the tenth map of Europe is not subdivided.

Maps based on the *Geography* are likely to have been seen by Pappus (fourth century A.D.) and al-Khwārizmī (eighth century), the authors of geographical works incorporating Ptolemaic data that will be discussed in the following section. In neither case need we presume that the maps accompanied Ptolemy's text. In the tenth century, the Arabic historian al-Mas'ūdī wrote in his *Fields of Gold* (ch. 8) that he had seen a book in Greek entitled *Geographia*, the author of which he refers to simply as "the philosopher," and in this manuscript were detailed descriptions of cities, mountains, seas, islands, and rivers.[78] Al-Mas'ūdī's "philosopher" has generally been taken to be Ptolemy, and since al-Mas'ūdī writes that the mountains and seas in the book were given various colors, it has also been inferred that it contained maps. But the account of what this book contained shows that it was definitely not Ptolemy's *Geography*: the numbers of features are all different, and Ptolemy did not say anything about the heights of mountains or the mines and precious stones in them. In another work al-Mas'ūdī refers to a *Geographia* purporting to be by Marinos that contained maps, which might have been the same book.[79]

[77]Gallazzi and Kramer 1998, 189.

[78]*Murūj al-dhahab wa ma'ādin al-jawhar*, ed. Barbier de Meynard and Pavet de Courteille, 183–185.

[79]See p. 23 note 24.

The more specific argument that the oldest extant Ptolemaic maps are products of the scholarly exertions of Maximos Planudes about A.D. 1300 depends primarily on a poem in hexameter that is entitled in one copy, "Heroic verses by the most wise monk Maximos Planudes on the *Geography* of Ptolemy, which had vanished for many years and then had been discovered by him through many toils."[80] The gist of the poem is as follows:

> What a great wonder, the way that Ptolemy has brought the whole world into view, just like someone making a map showing just a little city. I never saw anything so skillful, colorful, and elegant as this lovely *geōgraphia*. This work lay hidden for countless years and found no one to bring it to light. But the emperor Andronikos exhorted the bishop of Alexandria, who took great troubles that a certain free-spirited friend of the Byzantines should restore a likeness of the picture worthy of a king.

This can be interpreted in two ways. It has been taken as saying that Planudes had come across a manuscript of Ptolemy's *Geography*, which had fallen into oblivion, and that this old manuscript already contained the world map to which the opening lines of the poem clearly refer. But the poem as a whole, with its frequent allusions to the work involved in the rediscovery, is more likely to mean that he had taken great pains to rediscover the art of map-making set out in the treatise, and that the emperor Andronikos II had encouraged the patriarch of Alexandria, Athanasios II (who was in Constantinople at the time), to assume the patronage of the expensive project of reconstructing the map or maps. The word *geōgraphia* would mean not the book, but the map, as Ptolemy uses the word. This interpretation is supported by a second heading preceding Planudes' verses in another manuscript, which states that Planudes drew Ptolemy's map on the basis of Ptolemy's book and uninstructed by anyone else. Although neither poem nor titles mention that there was more than one map involved, it seems more plausible to assume, with Diller, that Planudes thought of the reconstruction of the world map and the twenty-six regional maps as a single exercise of *geōgraphia*, rather than that his exemplar had the regional maps and he restored just the world map.[81]

To sum up our conclusions from this evidence: There is no more reason to imagine that Ptolemy published his *Geography* in a form that incorporated the maps than there is to think that he provided a star globe along with the *Almagest*. The exceptionally large pages of such Byzantine copies as **U** and **K** are the minimum for the regional maps, and they are only able to hold the world map

[80]Stückelberger (1996) presents an edition and German translation of the whole poem with useful commentary, but arrives at conclusions different from those expressed here.

[81]Diller 1940a, 66.

because that map was drawn more or less freehand on the basis of the regional maps rather than directly from Ptolemy's coordinates. The transmission of Ptolemy's text certainly passed through a stage when the manuscripts were too small to contain the maps. Planudes and his assistants therefore probably had no pictorial models, and the success of their enterprise is proof that Ptolemy succeeded in his attempt to encode the map in words and numbers. The copies of the maps in later manuscripts and printed editions of the *Geography* were reproduced from Planudes' reconstructions.

Early Readers and Translators

Ptolemy's *Geography* had other descendants besides the tradition of manuscripts in Greek. Writers starting with Ptolemy himself used the *Geography* for various purposes, extracting and preserving its contents in a new form. Nor was the work's heritage restricted to the Greek-speaking world. The early adaptations of the *Geography* are interesting as a record of the book's prolonged influence.

The earliest and most important adaptation of material from the *Geography* is Ptolemy's own list of important cities in his *Handy Tables*. As mentioned above, the *Handy Tables* is a set of astronomical tables, mostly extracted with modifications from the *Almagest*; it survives in several medieval copies.[82] The "List of Noteworthy Cities," which is found near the beginning of the *Handy Tables*, was certainly an original component of the work, since it is mentioned by Ptolemy in his brief introduction to the tables.[83] Transcriptions of the list have been published from two early (ninth century) copies.[84] The order of the cities, which is the same in the *Handy Tables* and in *Geography* 8, is determined by the plan of the *Geography*, which must therefore be the earlier work.[85]

About A.D. 300, the mathematician Pappus of Alexandria wrote a description of the *oikoumenē* that was based on the *Geography*. This work is known to us only through a medieval Armenian adaptation, although a few details survive through the process of abridgment and translation that are useful for studying the history of Ptolemy's work.[86] A scattering of references, sometimes of textual value, can be found in the late fourth-century Roman historian Ammianus Marcellinus, who used the *Geography* (perhaps through an intermediate adaptation) as a source especially for descriptions of the more distant parts of the

[82]The only edition, unsatisfactory by modern standards, is Halma 1822–1825.

[83]Greek text in Heiberg 1907, 161.

[84]Honigmann 1929, 193–224.

[85]We disagree with Schnabel's opinion (Schnabel 1930, 225–229) that the *Handy Tables* represents an earlier stage of Ptolemy's geographical researches. Schnabel's argues this from differences between the *Handy Tables* list and the *Geography* that are more plausibly to be ascribed to simple copying errors.

[86]Hewsen 1971 and 1992.

world.[87] The text of the *Geography* was also available in Italy in the middle of the sixth century, for it is mentioned by Cassiodorus (*Institutiones* 1.25): "you have the codex of Ptolemy, which sets out all localities so clearly that you would almost conclude that he was an inhabitant of all the regions."[88]

Much more dependent on Ptolemy than these authors, however, is another late writer, Marcianus of Heraclea (before the mid-sixth century),[89] who compiled a small handful of geographical works, very imperfectly preserved, of which the *Periplus of the Outer Sea* is the most important.[90] In this work, Marcianus gives a detailed account of the outline of the Asian part of the Indian Ocean and the European part of the Atlantic, following Ptolemy's account, and giving measurements of the distances between various points in stades, derived mathematically from Ptolemy's coordinates. Bits of the *Geography* are also quoted or adapted by two anonymous ninth-century Byzantine geographical compilations.[91] We next hear of the *Geography* in the *Chiliades* of Johannes Tzetzes (twelfth century), which incorporates a bizarre versification of excerpts from Books 3 and 5.[92] Then there is an interval of more than a century, during which there are no further traces of knowledge of the *Geography*, until we come to the efforts of Maximos Planudes described above.

The contents of the *Geography* were at least partially transmitted through translations and less direct means into the Arabic world as early as the ninth century.[93] However, no actual Arabic translation survives from the medieval period, and in the adaptations that we do possess, data from the *Geography* are mixed up with other sources.[94] Nevertheless, the presence in Arabic astronomical and geographical tables of many coordinates of longitude and latitude derived from the *Geography* has the potential for casting light on the history of the Greek text.[95] An important early Arabic adaptation of material from the *Geography* that has received particular attention is the geographical treatise

[87]Mommsen 1881; Polaschek 1965, cc. 764–772.

[88]There is no need to suppose, with Stückelberger (1996, 205), that Cassiodorus' manuscript contained maps.

[89]Diller 1952, 45.

[90]Edited in Müller (1855–61) v. 1, 515–76.

[91]Diller (1975) 38–41.

[92]*Chiliades* 11.888ff.

[93]According to Ibn al-Nadim in his *Fihrist* (Dodge 1970, 2:640), "Al-Kindi made a bad translation of it and then Thābit [b. Qurra (d. 901)] made an excellent Arabic translation. It is also extant in Syriac." Quite independent of these medieval translations—and with no significant effect on the medieval Islamic tradition of geography—a translation into Arabic was done shortly after the Turkish conquest of Constantinople in 1453, on the order of its conqueror, Sultan Mehmet II, by Georgios Amirutzes and his son. This translation is extant.

[94]For brief discussions of the *Geography*'s Arabic heritage, see Honigmann 1929, 112–122; and Dilke 1985, 155–157.

[95]Kennedy 1987.

Kitāb ṣūrat al-ʻarḍ ("Book of the picture of the world") ascribed to Abū Jaʻfar al-Khwārizmī (usually assumed to be the well-known ninth-century mathematician and astronomer Muḥammad Ibn Mūsā al-Khwārizmī), which describes a world map based ultimately on Ptolemy, but only through intermediaries—perhaps in Syriac—in the form of both text and map.[96]

The Renaissance Latin versions of the *Geography* depend entirely on the Byzantine Greek tradition and have little or no independent value for reconstructing Ptolemy's text. The first translation, by Jacopo d'Angelo, was finished in 1406 and was based on a composite text derived from two manuscripts.[97] This was printed many times from 1475 on, with cumulative revisions based sometimes on Greek manuscripts.[98]

Modern Editions and Translations of the Geography

The Greek text of the *Geography* was first printed in 1533 at Basel, in an edition by Erasmus. This was followed over the next three centuries by several editions or partial editions.[99] The earliest that is still of much use, however, is that of F. W. Wilberg and C.H.F. Grashof, begun in 1838 and terminated prematurely in 1845 with Book 6.[100] This edition gives an apparatus reporting variant readings from several important manuscripts. For Book 6, this is the only critical text with apparatus.

The 1843–1845 edition of C.F.A. Nobbe, although it lacks apparatus and cites only a few manuscript variants (mostly in the spelling of place names) in an appendix, presents the most recent text of the entire *Geography*.[101] It is therefore necessary for the text from 7.5 to the end of the work, and it has useful indexes of place names and terminology.

Another edition was begun in 1883 by C. Müller, with a second (and final) volume published in 1901, after Müller's death, under the supervision of C.T. Fischer.[102] This edition presents the text, with apparatus and notes, only as far as the end of Book 5. Müller used numerous manuscripts, including most of those discussed above (excepting **U** and **K**). An inadequate classification of the manuscripts resulted in a cumbersome apparatus, citing readings from unimportant copies while omitting many important variants in the principal ones. Nevertheless, Müller's remains the best available critical text for Books 1 through 2.6, and 3.2 through 5.

[96]Mžik 1916 and 1926; and Wieber 1974.
[97]Diller 1966, ix–x.
[98]Codazzi 1948–1949.
[99]For a list, see Diller 1966.
[100]Wilberg 1838–1845.
[101]Nobbe 1843–1845.
[102]Müller 1883–1901.

In the 1920s appeared the two intentionally partial editions of Cuntz (2.7–3.1) and Renou (7.1–7.4).[103] Their greatest merit is in providing full citations of the variant readings in the best manuscripts representing the Byzantine recension as well as **Z** and **X**.

The *Geography* has seldom been translated into modern languages. Hans von Mžik's 1938 German translation of Book 1 and the first chapter of Book 2 was intended as the beginning of a complete translation of the work. No more was published, and this first part is not easy to come by. Mžik's rendering of Ptolemy is accurate, and it is accompanied by learned notes. The appendices by Friedrich Hopfner, dealing with technical topics including the map projections, are especially valuable. Germaine Aujac produced in 1993 a French version of parts of the *Geography* almost exactly coextensive with ours as part of a volume that also contains the geographical passages of the *Almagest* and *Tetrabiblos*. She provides a long introduction but comparatively light annotation. Like Mžik, Aujac chooses for the sake of smoothness a less strictly literal style of translation than we have preferred. Her interpretation of the text differs substantially from ours in about a dozen obscure passages.

The only previous English rendering of the *Geography* is that of Edward Luther Stevenson; it was originally published in 1932 in a very small edition, and was reprinted in 1991. Stevenson's translation covers nearly the entire work (omitting the regional map captions of Book 8) and is accompanied by black-and-white photographs of the maps from one of Nicolaus Germanus' manuscripts, the *codex Ebnerianus* of the New York Public Library. These are regrettably its only virtues. Stevenson appears to have based his version primarily, if not exclusively, on the Renaissance Latin texts of the *Geography*, and very frequently misunderstood even them. Diller's comment that "to speak the plain truth, there is not a single paragraph that does not betray some essential and often gross error" is no hyperbole.[104]

Our Translation

Our translation uses as its base text the Greek text of Nobbe, which has the advantage of being complete and fairly accessible; however, we have also regularly consulted the incomplete editions of Wilberg and Müller and photographs of the manuscripts **U**, **K**, **N**, **T**, and **X**. For Books 7 and 8, where we had only Nobbe as a printed text, we established a provisional text on the basis of the manuscripts cited above. Whenever we have chosen a reading of the Greek text significantly different from that of Nobbe, we have reported this in Appendix G, "Textual Notes."

[103]Cuntz 1923; Renou 1925.
[104]Diller 1935, 536.

We have tried to be as faithful to Ptolemy's way of putting things as is consistent with a translation. In particular, this has meant that terms such as *oikoumenē* and *klimata*, the names of winds and units of measurement, and the names of most localities have simply been transliterated. (Where necessary, explanatory notes have been added.) We have not, however, carried this fidelity to the point of reproducing Ptolemy's often exceedingly long sentences, which we have not hesitated to break up.

Square brackets in the translation enclose small additions of our own, intended to make a smoother translation or to clarify ambiguities. Most of these additions are such as would be understood from the grammar by a reader of the Greek text, but some definitely reflect our interpretation of the text.

We have in a few cases translated place names when we judged that it would help the reader, as in the cases of the "Islands of the Blest," the "Caspian Gates," and the "Stone Tower." In a few other cases, we have used modern forms of the names when they diverge little from those in Ptolemy and when the site the modern form refers to is the same as that referred to by the ancient, as, for example, Rhodes, Carthage, or Smyrna. For most places, however, we have retained the ancient names. For those in the western part of Ptolemy's *oikoumenē*, where Ptolemy is transliterating Latin forms into Greek, we have used Latin forms. For the eastern part, we have transliterated the Greek names as Ptolemy gives them. Preserving the Greek spelling often helps the reader to avoid confusing ancient and modern geographical entities that have essentially the same name but refer to different places: for example, we have kept Ptolemy's "Aithiopia" as the name of the southernmost districts of Africa rather than modernizing to "Ethiopia," and "Libyē" as the name for the entire continent of Africa. The possibility of confusion could not be avoided in a few instances, however, such as the name "Africa" itself, by which Ptolemy means the Roman province centered on Carthage. In general, the reader should not take it for granted that names that exist on the modern map refer to the same places in Ptolemy. The Geographical Index (Appendix H) attempts where possible to give modern equivalents for the localities mentioned in the text.

For ancient authors whose works survive and for historical personages likely to be found in reference works, we have used the forms of their names that are standard in modern English scholarship. Other Greek personal names are transliterated.