CHAPTER 18

The "Revolution" of Ptolemy

Germaine Aujac

At the end of the 2nd century of our era, the *Geographike Hyphegesis* (more commonly called *Geography*) composed by Ptolemy in Alexandria, appeared as the final and decisive step in the development of the science called Geography by Eratosthenes, some five centuries earlier. Collecting the latest improvements in the knowledge of the inhabited world, it aimed not only at inscribing them on a map, but also at offering anyone the means of drawing a map of the world or maps of any country of his choice. In his major astronomical work, the *Almagest*, examining the whole cosmos, earth and sky, Ptolemy had clearly anticipated what would be the main target of his *Geography*. These treatises were the last important ones and the only entirely surviving ones in the field of astronomy and geography (meaning cartography). The handling of these subjects by Ptolemy was so "revolutionary" that their influence lasted for many centuries and was perceptible thereafter to any scholar keen on the study of sky and earth.

1 Ptolemy, an Outstanding Scholar

Claudius Ptolemy's life (ca. 100–180) is largely unknown, except for the references to his observations made in Alexandria between 125 and 141. After its conquest by Octavian (the future emperor Augustus) in 30 BC, Egypt had become a Roman Province, but Alexandria remained an active commercial place and an exceptional centre of Greek learning, enjoying the benevolence of the Antonines Emperors. Ptolemy chose the beginning of the reign of Antoninus Pius (138) as the epoch of his star catalogue.

During the reign of Hadrian (117–138), another Alexandrian, Dionysius[1] wrote a *Periegesis* in 1187 hexameters. This poem, relying mostly on Eratosthenes or Strabo, and translated into Latin by Avienus (4th cent.) and Priscianus (early 6th cent.), was a great success for many centuries, conveying to a lot of students the traditional knowledge of the Ancients about the inhabited world.

1 Jacob 1990.

© KONINKLIJKE BRILL NV, LEIDEN, 2016 | DOI 10.1163/9789004284715_019

Ptolemy, his contemporary, only concerned about recent discoveries or new prospects, never mentioned such an outdated handbook.

Ptolemy's first great work, *Mathematike Syntaxis*, later named *Almagest* under Arabic influence,[2] was composed not earlier than 150. In the foreword of this book, he claimed the superiority of Mathematical Science, the only one "offering to its devotees a sound and unquestionable knowledge" (*Alm*. 1.1). He considered Mathematics, a science built on geometry and arithmetic, as the only one being able to give reliable results. So, in his description of the cosmos, he did not leave any room for doubt or wavering. He demonstrated that the celestial sphere revolved daily around one of its diameters (the axis of rotation), the centre of this sphere being occupied by a motionless terrestrial globe. As the spherical geometry required (*Spherics* was the first name given to Astronomy), he specified: "the earth is approximately a point compared to the radius of the sphere of the so-called fixed stars" (*Alm*. 1.6). But the terrestrial globe was a reality; so it had regularly been thought of as a small replica of the celestial sphere.[3]

In order to facilitate the study of the presumed rules controlling the movements of the cosmos, Ptolemy provided many geometrically established table (*Alm*. 1.9), explaining at once the method to calculate them. "Our aim is not only to make up tables to be used by people knowing nothing about the subject, but, through appropriate geometrical demonstrations, to give everybody the means of easy check" (*Alm*. 1.10). Ptolemy the mathematician was also an excellent teacher, ready to give anyone the necessary data.

Convenience was indeed one of his main concerns. Dealing with extremely intricate problems, he always looked for an easier and more convenient way of reaching the expected answer. So he extensively used the Greek adjective *procheiros* (or a word derived from it), often translated by "handy". In particular, wishing to provide mere amateurs with an easier tool than the bulky *Almagest*, he published a revised version of the tables included in it as a separate work, entitled *Procheiroi Kanones*, or *Handy Tables*, whose format was more convenient for practical use than the corresponding sections of the *Almagest*. This propensity to combine or alternate major scholarly researches and vulgarising proceedings was a typical feature of Ptolemy's genius.

Whatever subject he would deal with, Ptolemy wished to be as exhaustive and up to date as possible, but also easily understandable, so that every piece

2 Pedersen 2011; Toomer 1984. Most of the quotations from the *Almagest* are inspired by Toomer's translation.

3 Strab. 2.5.5: "Beneath each of the celestial circles falls the corresponding terrestrial circle which bears the same name on the earth as in the sky".

of his work should become "a possession for all time[4]" as Thucydides had wished for his *History*. In astronomy as in geography (meaning cartography), he aimed (and generally succeeded) at being the matchless standard for future generations.

2 A Survey of the Earth in the Almagest

The earth played a permanent role in the first books of the *Almagest*. Dealing with the terrestrial as well as the celestial sphere, Ptolemy considered the inhabited world as included in one quarter of the globe,[5] a northern one, bounded by the equator and a meridian. In order to give a survey of the main features of this quarter, he made up a catalogue of the terrestrial parallels from the equator to the Northern Pole, reporting for each one its main characteristics (length of the longest daylight, distance in degrees to the equator, ratio of the gnomon to the equinoctial and solstitial noon shadows). These parallels were separated by a fraction of equinoctial hour[6] in the length of the longest daytime, which meant that they were not equidistant.[7] The first 26 parallels were distant from one another by a quarter of an hour, the following 7 ones by half an hour, the last one being the parallel where the longest daytime lasted 24 hours, 66° 8' 40" north of the equator;[8] further on, 6 parallels were registered, distant by a whole month, the last one being the place, 90° from the equator, where the pole was at the zenith (*Alm.* 2.6).

Starting from the equator, Ptolemy alluded to the widespread hypothesis, supported among others by Eratosthenes, Posidonius and Polybius, of a rather temperate (and maybe inhabitable) equatorial zone. "It is said that the regions beneath[9] the equator could be inhabited, since the climate must be quite temperate ... But what these inhabited places are, we have no reliable grounds to

4 Thuc. 1.22: "It (this *History*) has been composed not as a prize essay to be heard for the moment, but as a possession for all time".

5 This was the traditional teaching. See Strab. 2.5.6.

6 The Greeks used for everyday life the temporary hour, which varied according to the season. The scientists used the equinoctial hour, the same as ours. The length of the longest daytime was the usual reference to the latitude of a place.

7 A few centuries earlier, Hipparchus had examined the astronomical characteristics of the parallels distant from one another by one degree of latitude, from equator to the North Pole.

8 Geographers used generally the round number 24° for the distance between equator and tropic, or between polar circle and pole, but astronomers knew a more accurate value.

9 For the Greeks, the main circles of the sphere were first of all celestial, the terrestrial ones being the mere projection of them on the terrestrial globe.

say. For up to now, they are unexplored by men from our part of the inhabited world, and what people say about them must be considered guesswork rather than report" (*Alm.* 2.6). On this parallel (our terrestrial equator), day and night are always equal in length. As regards the parallels where the longest day exceeds 24 hours, Ptolemy was fully aware of their characteristics. The theory demonstrated that, where the Northern Pole is distant from the equator by 90 degrees, there was only one day and one night of six months each; the main celestial circles, equator, horizon, ever-visible and ever-invisible circles[10] coincided, as the geometry of the sphere had taught long ago.[11]

Further on, making up the table of the rising-times of the zodiacal signs according to the latitudes, Ptolemy reduced his investigations to eleven parallels, from 0° to 54° (*Alm.* 2.8); then, making up a « table of zenith distances and ecliptic angles » according to the latitudes, he considered only the seven main parallels, of Meroe (13h, at 16°, 27'N), Syene (13h 1/2, at 23° 51'N, modern Aswan), Lower Egypt (14h, at 30° 22'N), Rhodes (14h 1/2, at 36°N), Hellespont (15h, at 40° 56'N), Middle of the Pontus (15h 1/2, at 45° 1'N, our Black Sea), Borysthenes (16h, at 48° 32'N, modern Dniepr) (*Alm.* 2.12). This selection of seven main parallels, the seven "*klimata*[12]", had been in constant use in Antiquity, establishing a kind of frame for the latitudes of the inhabited world.

At the end of this "table of zenith distances …", Ptolemy added a note clearly showing that, later on, he intended to more or less fulfil for the earth (or rather for the inhabited world) what he had done for the sky. "Now the only remaining topic … is to determine the coordinates in latitude and longitude of the noteworthy cities in each province, using the computations about the phenomena[13] in each of these cities. As the setting out of this matter belongs to a specific field, geography, we shall present it by itself in a special treatise; taking into account the researches of those who have most fully worked out this subject, we shall record for each of the cities its distance in degrees from the equator, measured along its own meridian, and its distance in degrees, along the equator, of that meridian, to the east or west, from the meridian through

10 As the celestial sphere could be almost entirely observed except for the area round the South Pole, it was rather easy to situate the position of the main circles, equator, tropics, ever-visible and ever-invisible circles; their projection on the earth defined the main terrestrial circles. Whence the usual wording: people living « beneath » such or such parallel.

11 The mathematician Theodosius of Bithynia (ca. 150–70 BC), author of *Spherica*, had also composed a *Peri oikeseon*, or astronomical tables for the main terrestrial parallels.

12 See Honigmann 1929. A *klima* was the stretch of earth, between two parallels, in which the length of the longest daylight had roughly the same number of half-hours.

13 The *phainomena* ("what is observed") were the astronomical data peculiar to each city.

Alexandria, because it was for that meridian that we established the hour-intervals corresponding to the positions of the cities.” (*Alm.* 2.12).

Of course, the *Almagest* had the sky as its main concern; but the handling of the sky foreshadowed the handling of the earth in the *Geography*. Dealing with the starry sky, Ptolemy made up a huge list of more than a thousand stars, gathered into constellations, twenty for the northern hemisphere, six for the northern zodiacal signs (*Alm.* 7.5), six for the southern zodiacal signs, fifteen for the southern hemisphere (*Alm.* 8.1). For each star, he wrote down its longitude and its ecliptic latitude: as the precession of the equinoxes, discovered by Hipparchus and confirmed by him, was doomed to make the equatorial scheme (used by Hipparchus) rapidly obsolete, he chose to rely on the ecliptic one so that his star catalogue could enjoy an everlasting life.

In a following chapter, Ptolemy, as efficient as usual, gave the rules to observe when drawing the constellations on a solid globe so that they could be easily recognised by anyone: “The shapes of the individual constellations should be as sketchy as possible, a single line encompassing all the stars included in one constellation; its colour should not be too vivid against the general background of the globe. It is essential not to lose the advantages of the distinctions introduced between the stars; a variety of colours would destroy the resemblance of the image to the original. It will be easier, when directly observing the sky, to remember the combined positions of the stars, since we will be accustomed to the unadorned appearance of the stars in their representation on the globe too” (*Alm.* 8.3).

Although the major part of the *Almagest* was dedicated to the planetary motions, Ptolemy had already elaborated the method to be used when he was to deal separately with the terrestrial globe, its inhabited part and its representation on a globe or on a plane map. Moreover, the *Almagest* had already displayed a lot of geographical notions.

3 Ptolemy’s *Geography*

Towards the end of his life, Ptolemy carried out the project hinted at in the *Almagest*, “to determine the positions of the noteworthy cities in each province, in longitude and latitude” (*Alm.* 2.12). In this special treatise,[14] he would confine himself to the terrestrial part of the cosmos, and more particularly to the inhabited world and its representation on a globe or on flat map. The

14 For an edition and translation of this treatise, see Stückelberger, and Graßhoff 2006.

Geographike Hyphegesis,[15] in eight books, fulfilled this program. In the first book, Ptolemy discussed the amount of knowledge handed down by his predecessors, specially by the last one, Marinus of Tyre (fl. 120 AD) and defined his own ideas about the size of the inhabited world and the best ways of drawing maps. The following ones, second to seventh, were devoted to an exhaustive catalogue of all the cities or features to be inscribed on the map, with their coordinates. The last book is a kind of summary, detailing 26 regional maps to be drawn after that of the world.

3.1 *To Account for Recent Discoveries*

In the *Almagest*, and later on in his famous astrological treatise, the so-called *Tetrabiblos* (in four books), Ptolemy had adopted the usual concept of an inhabited world included in one of the northern quarters of the terrestrial globe. But a recent geographer, Marinus of Tyre, doing his best to mend the existing maps of the known world, had considerably extended its limits by taking into account various recent narratives about military or commercial expeditions to southern Africa[16] or eastern Asia.

Septimius Flaccus, *legatus pro praetore* in Numidia, had (probably after 76 AD) led his army from Libya southwards; three months later, he had reached Ethiopia. Then (ca. 83–92), Julius Maternus, looking for rhinoceroses and their ivory, left Leptis Magna and went south with the king of the Garamantes[17] for four months; he mentioned a strange African place named Agisymba, far south of the equator. So Marinus took the winter tropic (24°S) as the southern limit of the known world. As he took the parallel of Thule (63°N) as its northern limit, the inhabited world according to him was 87° wide.

In Asia, the silk trade had been flourishing thanks to the peaceful relations between Parthia and the Roman Empire (63–113). Towards the end of the 1st century, a Macedonian trader, Maes Titianos, had sent his servants to the silk-producing land, held by the Seres;[18] they travelled for twelve months through central Asia, reached a stopping-place called the Stone Tower, then went on to Sera, the capital of the country. Marinus—and Ptolemy after him[19]—related

15 Berggren, and Jones 2000, 4, proposed a more meaningful translation for the Greek title: "Guide to Drawing a World Map". The quotations of the theoretical chapters of the *Geography* are mostly inspired by their translation.

16 See Desanges 1978, 197–200. Agisymba, reached by Maternus, was probably not so far south as Marinus and Ptolemy believed.

17 The capital Garama is located at longitude 43° and latitude 21° 30'N in *Geog*. 4. 6.30.

18 Mollat, et Desanges 1988, 118.

19 Ptol., *Geog*. 1.11.

this unusual expedition. Relying on this report, Marinus fixed the length of the inhabited world, from the Blessed Islands (*sc.* Canaries) to Sera, to fifteen hour-intervals or 225 degrees. So, in latitude as in longitude, the traditional idea of an inhabited world entirely included in one of the northern quarter of the terrestrial globe, allowing the chance of three other unknown worlds[20] in the three remaining quarters, definitively burst to pieces.

Did Marinus, who had so vividly criticized his predecessors and made so many revisions of the ancient maps, succeed in drawing a duly corrected map? In fact, he probably tried, as Ptolemy blamed him for having selected the worst method of drawing plane maps (*Geog*. 1.20). But he probably was so keen at pointing out the supposed errors made by previous mapmakers that he had no time to finish the job. Anyway Ptolemy reproved Marinus for lacking coherence in his display of coordinates: "the parallels are drawn through some places and the meridians through others, so that many localities lack one or the other position" (*Geog*. 1.18). Moreover in his localisations, Marinus was not steady; he often varied from one revision to the next one. So, wishing to correct these shortcomings, Ptolemy proclaimed that he would provide for each registered place both coordinates, longitude and latitude, and offer a better method for drawing plane maps, easier to read, and more suggestive of reality.

First of all, Ptolemy corrected many distances handed down by Marinus, in Asia or Africa. He censured him for having too easily converted sailing or marching days into stadia, without taking into account the curves of the roads or the variability of the winds. So, at the end of numberless calculations, Ptolemy drastically reduced Marinus' data. He limited the length of the *oikoumene* at twelve hour-intervals, or 180°. He chose as southern limit of the inhabited world the parallel in the southern hemisphere opposite to the one through Meroe in the northern one, so 16°1/2S. Therefore the whole width of the inhabited world, from this southern limit to the Thule parallel (63°N), would amount to roughly 80°. This new size of the inhabited world, in particular the 180° in length, was much more convenient than the Marinus' one for drawing the whole *oikoumene* on a plane map; many intricate criticisms of Marinus' distances probably aimed at reaching such handy results.

Determined to preserve Marinus' corrections when he judged them legitimate, but intending as well to introduce his own improvements, Ptolemy

20 Crates of Mallus (fl. ca. 170 BC), the first Head of the Library in Pergamum, had built a huge terrestrial globe with four inhabited worlds, in each quarter of the globe, separated by two oceanic belts, one along the equator, the other along a meridian (See Strab. 1.2.24 and 2.5.10). The only known world was "ours", as it was called.

provided a catalogue of provinces and satrapies[21] both exhaustive and handy. "We have taken care that our account should be convenient. Hence we have written down for each province the details of its boundaries, its position in longitude and latitude, the relative situation of the more important peoples in it, and the accurate location of the more noteworthy features, cities, rivers, bays, mountains, and generally all that ought to appear in a map of the *oikoumene*. So we have written down the number of degrees (of such as the great circle contains 360) counted in longitude, along the equator, between the meridian drawn through the required place and the meridian that marks off the western limit of the *oikoumene*, and the number of degrees counted in latitude, along the meridian of the place, between the parallel drawn through the said place and the equator" (*Geog*. 1.19). Actually, Ptolemy filled books second to seventh with huge lists of provinces and satrapies; he accurately located their noteworthy cities or features through pairs of coordinates, using as prime meridian the one through the Blessed Islands.

But what was the estimated size of the terrestrial globe? Eratosthenes,[22] who had been the Head of the Library in Alexandria five centuries earlier, had estimated the terrestrial circumference at roughly 252,000 stadia, thanks to a geometrical method. Hipparchus had adopted this estimation "which does not differ much from the truth",[23] so that one degree of meridian or of equator would be 700 stadia long. Strabo, Geminus,[24] later geographers relied on this value of the terrestrial circumference.

However, Posidonius (ca. 135–50) who had spent the best part of his life in Rhodes, had tried an astronomical (but unfortunately unfit) method to measure the terrestrial circumference[25] and proposed two possible values for it, either 240,000 stadia, or only 180,000 stadia, "the measurement which makes the earth smallest in circumference" (Strab. 2.2.2).

Curiously enough, Marinus, and later on Ptolemy, without trying to make their own investigation, adopted the value 180,000 stadia for the circumference of the earth, asserting (wrongly) that it was the most commonly used.[26] Thus one degree of meridian was 500 stadia long, a very convenient number for further calculations. However, while one degree of meridian would be

21 Ptolemy refers to the administrative divisions of the Roman and Parthian Empires.

22 Aujac 2001, 41–64.

23 Strab. 1.4.1.

24 Geminus of Rhodes (ca. 50 BC) wrote a handbook of astronomy and mathematical geography entitled *Introduction to the Phenomena*. See Aujac 1975, or Evans, and Berggren 2006.

25 See Cleomedes, *Kuklike theoria meteoron* 1.10.2 (Bowen, and Todd 2004).

26 Ptol., *Geog*. 1.7.1; 1.11.2; 7.5.12.

always 500 stadia worth, the degree on the parallels varied in length, growing steadily shorter from the equator to the pole, in which place it was reduced to a point. It had long been known that the parallel through Rhodes (36°N) was in length four fifth of the equator; if one degree on the equator was worth 500 stadia, one degree on the parallel through Rhodes was only worth 400 stadia, a round number very easy to use in reckonings.

This choice for a smaller size of the earth had strange consequences. As Ptolemy generally used the distances in stadia[27] proposed by his predecessors, he enlarged all these data by one third. So, the Mediterranean was much longer according to Ptolemy than in reality, and it was the same for the distance Blessed Islands—Sera. While Eratosthenes had estimated the distance Cadiz—India through the Atlantic Ocean to be 2/3 of the Rhodes parallel, Ptolemy's maps reduced this distance to less than one half of this parallel, and Marinus to only 135°.

3.2 *Mapping the Inhabited World on a Globe or on a Plane Chart*

The catalogue that Ptolemy would provide was meant to be a very convenient tool to draw a map. Of course, the likeness to the real *oikoumene* would be best if the map was drawn on a globe. Two centuries earlier, Crates of Mallus had built a globe whose surface was occupied by four symmetrical worlds, one known and inhabited, the three others existing only by guess.

On a terrestrial globe, the map of the inhabited world, whose size could be either the one proposed by Marinus, or the one drastically reduced by Ptolemy, would still occupy more than one northern quarter of the globe,[28] but much less than, on the celestial sphere, the visible part of the sky described in the *Almagest*.

At first Ptolemy explained how to draw a world map on a globe. He advised to draw meridians "at intervals of a third of an equinoctial hour" (*Geog*. 1.23). As the inhabited world has been fixed by Ptolemy to twelve hour-intervals in longitude, 36 meridians should be drawn, at 5° distance from one another. As for the parallels, Ptolemy pointed out 21 of them north of the equator, at a distance of 1/4, 1/2, 1 hour in the length of the longest daylight, from the 4° 1/4 parallel ("as approximately established by geometrical demonstrations") to the one through Thule, put by Marinus and Ptolemy at 63°N; two parallels had to be added south of the equator, with a difference of half-hour each. The first one was through Cape Rhapton (near the modern Dar es Salaam) and Kattigara

27 If one degree on the meridian was 700 stadia long, the *stadion* used by the scientists would be roughly 158 m.; if it was only 500 stadia, the *stadion* would be roughly 222 m.

28 As Ptolemy's Asia was not limited by the Ocean, the continent extended eastwards.

(near Hanoi), at 8° 5/12S. The other one is the southern limit, “as far south of the equator as the parallel through Meroe is north of it” (*Geog*. 1.23). In this brief list of the parallels to be drawn on the globe, the only geographical places quoted are Meroe, Syene (on the summer tropic), Rhodes, and Thule; all of them are north of the equator; none is quoted south of it.

A globe, on which a relatively small space was needed for the drawing of the map, would be both unwieldy and difficult to read. So Ptolemy chose to deal mostly with the mapping on a flat surface. He criticized Marinus for having used the orthogonal scheme, with meridians and parallels drawn as straight lines and at right angles, each parallel being equal to the one through Rhodes; he judged this procedure unable to take into account proportionality or spherical appearance.[29] This kind of orthogonal scheme was probably the one also used by Eratosthenes and supported by Strabo, who justified this choice: “Our mind can easily transfer to a circular and spherical surface the figure observed by the eye on a plane surface” (Strab. 2.5.10). Of course, it was rather legitimate to use this method for an inhabited world mostly stretching along the Mediterranean. But the maps intended by Marinus or Ptolemy were much larger. So it became compulsory to provide new types of flat maps, more likely to preserve both proportionality and spherical appearance.

First of all, Ptolemy reckoned the relations between the main parallels to be used in the mapping of the world. It was well known that the parallel through Rhodes was the four-fifth of the equator, but Ptolemy added: “On the globe, if the great circle is 5, the parallel through Thule amounts to nearly 2 1/4, the one through Syene to 4 7/12, the one through Meroe to 4 5/6” (*Geog*. 1.24.17). These were the four parallels used to draw the world map; the one through Thule (63°N) was taken as the northern limit of the *oikoumene*, the one through Rhodes (36°N) was the central parallel on Eratosthenes’ map, the one through Syene (modern Aswan, beneath the summer tropic, 24°N) was the central parallel on Ptolemy’ map, the one through Meroe (16° 5/12) had so far been considered as the southern limit of the known world, this limit being conveyed by Ptolemy to its opposite in the southern hemisphere.

This first type of mapping the whole inhabited world on a flat surface could be called the plain conic projection.[30] A rectangle whose length was twice the width was bisected by a median perpendicular to its basis; the top of this median, far outside the rectangle, would figure the Northern Pole. From this fictitious pole as a centre, one should draw four circles (or rather arcs of

29 See *Geog*. 1.20.

30 These so called projections are only geometrical procedures to obtain a convenient scheme. They are not to be mistaken for modern types of projection.

them), figuring the parallels through Thule, Rhodes, the equator and Anti-Meroe. Moreover, from the same fictitious pole, one should draw six straight lines (figuring the meridians) on each side of the median, distant from one another by 4 units on the parallel through Rhodes. So, if the fictitious pole[31] is 131 units 5/12 distant from the basis of the rectangle, the parallel through Rhodes (36°N) should be drawn with a radius of 79 units, the one through Thule (63°N) with a radius of 52 units, the equator with a radius of 115 units and the one through Anti-Meroe (16° 30'S) with a radius of 131. As the real Anti-Meroe parallel was shorter than the equator, one had to break the meridians at the equator in order to reduce this parallel to its true value. Except for this small area south of the equator, it would be rather easy to locate the points figuring cities or other landmarks on the map: one could use a revolving ruler, pegged at the fictitious Northern Pole and duly graduated.

This plain conic projection, convenient as it was, had a major drawback: the breaking of the meridians at the equator. So Ptolemy planned another type of conic projection which would make this plane map more evocative of what was seen on a globe: the meridians would be rounded off, except the central one, and the parallels slightly flattened, the fictitious pole being distant from the equator by 181 units 5/6,[32] reduced to 180 units as more convenient. The three parallels to be proportioned in length to the real ones would be those through Thule (63°N), Syene (24°N, the central one) and Anti-Meroe (16° 1/2S). This kind of map, more similar to what was seen on a globe, would be more difficult to work out: the ruler could no longer be used, so that the various features to inscribe on the map would have to be located more or less at a guess. Therefore Ptolemy did not try to blot out the plain conic method, which obviously would be favoured by lazy people, always "quite ready to stick to the handiest procedure" (*Geog*. 1.24.22). Among the mapmakers working during the Renaissance, some of them used the plain conic projection, while others favoured the modified one.

As for the regional maps, which could have different sizes according to the number of features to be inscribed on them, "it will not be very inaccurate if we draw straight lines instead of circles, and if moreover the meridians are not converging but parallel to one another" (*Geog*. 1.24.22). So, for the regional maps, Ptolemy advised to use the orthogonal scheme, as more appropriate to

31 Ptolemy does not explain here his choice of this number. In fact, he adds 25 to the sum of 90 (the distance in degrees from the equator to the Northern Pole) and 16 5/12 (the distance in degrees from the equator to Anti-Meroe); so the radius for the Rhodes parallel, at 54° from the real North Pole, will be 79 (= 25+54) in length; and so on.

32 Ptolemy obtains this result through a geometrical demonstration (*Geog*. 1.24.10–13).

relatively small areas. A few Renaissance mapmakers chose to use a trapezoidal scheme, forgetting Ptolemy's relevant advice,

A third method for sketching the inhabited world was proposed by Ptolemy near the end of his *Geography*. For a long time, the earth had been known through the sky and the terrestrial globe considered as a replica of the celestial sphere. So Ptolemy, probably wishing to emphasize this dependence, resolved to figure the inhabited world inside a celestial sphere, reduced to a network of rings,[33] as it was in an armillary sphere. But as the map of the inhabited world had to be entirely visible and easily readable, Ptolemy carefully reckoned the adequate size of both spheres, and the correct position of the celestial circles so that the sketch of the *oikoumene* should not be partly hidden by the celestial rings. Some drawings made during the Renaissance according to Ptolemy's instructions give a rather clear idea of what he had in mind.

3.3 *The Lists of Places to be Inscribed on World or Regional Maps*

Books second to seventh of the *Geography* were filled with the catalogue of the noteworthy cities or features likely to appear on a world map. Each quoted place was precisely located by both coordinates, expressed in degrees, the latitude north or south of the equator, the longitude east of the meridian through the Blessed Islands (our Canaries) regarded as the prime meridian. In his previous project, as stated in the *Almagest*, Ptolemy had already wished to use degrees for the coordinates, but then he considered as prime meridian the one through Alexandria, so the longitudes would have to be registered as east or west of this meridian. To use the meridian through the Blessed Islands as prime meridian was more convenient.

Were these coordinates, expressed so precisely in degrees and fractions of degrees, as accurate as they appear? It is highly dubious. While Ptolemy, at work in Alexandria, could observe almost all the stars written down in the *Almagest*, it is obvious that he could not have checked by himself the localisation of so many terrestrial places registered in the *Geography*. But being well aware that, to draw a map, every feature to inscribe on it had to be exactly characterised by both coordinates, he never failed to indicate latitude and longitude for each place, so that anybody, even a layman, would be able, thanks to this catalogue, to draw fresh maps instead of copying old ones with the risk of making them more and more erroneous.

33 See Ptol., *Geog*. 7.6.1–15 and *Geog*. 7.7.1–4. Solid spheres, on which the constellations were drawn, and ringed (or armillary) spheres including a small terrestrial globe inside the main circles of the celestial sphere, were instruments commonly used in Greco-roman schools (see Gem. 16.10).

However, fearing a possible misinterpretation of his work, Ptolemy had duly warned his readers. "The numbers of degrees in longitude and latitude of well-trodden places could be considered as quite close to the truth because rather consistent accounts have been continuously passed down; but for the places that have not been so well explored, owing to the sparseness and uncertainty of the information, the coordinates should be considered as roughly estimated according to their proximity to more trustworthy positions or drawings. Our only purpose was that none of the places to be included in the whole *oikoumene* would lack a defined position" (*Geog*. 2.1.2). So, as Ptolemy himself had clearly notified, it would be vain to rely on apparently so accurate but really so approximate coordinates for every quoted place, except for the very well-known ones.

As this catalogue should be used to draw a world map, Ptolemy as usual looked for the most convenient way to facilitate the sketching. "We have chosen an order of presentation which would make the drawing easier; for instance, we shall always progress from left to right, the hand proceeding from what has already been inscribed to what is not yet so. As the northern places are drawn before the southerly ones, and the western before the eastern, upwards means always the North, for the drawer or the observer, and the right-hand side means always the Eastern part of the *oikoumene*, either on the sphere or on the flat map. Therefore we shall first draw Europe which we shall separate from Libya by the Strait of Heracles (Gibraltar), and from Asia by the successive seas between these continents, Lake Maeotis (Sea of Azov), the River Tanaïs (Don) and the meridian further on through an unknown land. Next we would set down Libya, dividing it from Asia first by the seas that extend from the gulf near Cape Prason (possibly Delgado) in Ethiopia to the Arabic Gulf, then by the isthmus which, from the far end of this gulf, towards Heroopolis (near Suez), to our sea (the Mediterranean), separates Egypt from Arabia and Judea; so Egypt will not be split into two parts, as it happens when the Nile is used as the border[34] (anyway it is better, as far as possible, to divide the continents by seas rather than rivers). Last we shall write down Asia" (*Geog*. 2.1.4–5). The catalogue was organised according to these requirements. Going through the three known continents, Ptolemy first dealt with Europe (2.2–3) and Libya (our Africa, 4), the western continents, then Asia (5–7.4),[35] the

34 Strabo (1.4.7) had fully discussed the question of the boundary-lines between the continents; when describing Egypt, he chose the River Nile to divide Asia from Libya.

35 Geographers had different ways of touring the *oikoumene*. Eratosthenes, whose work is lost, had probably started from Far East. Strabo had successively described Europe, Asia, then Libya. Pomponius Mela (*fl.* ca. 40 AD), in his *De Chorographia*, toured the

eastern one. So he began the geographical catalogue with the Britannic Islands, first Ierne (Ireland), then Albion (England), and so on.

More than eighty provinces or satrapies were thus taken into account. For each one, Ptolemy wrote down first the main features of the sides limiting the area described, then the important cities or special spots included in it. Each quoted place was precisely located through its pair of coordinates, as he had promised.

To this exhaustive survey of the *oikoumene*, Ptolemy added a summary account of general data, in order to make the mapping of the inhabited world easier. So he described its boundaries: unknown lands to the east and the south, ocean and unknown lands to the west and the north. Further on, dealing with the three continents, he introduced a new link between Asia and Libya, namely "the unknown land that surrounds the Sea of India" (*Geog*. 7.5.5). Then he indicated in stadia the length of the main half-parallels[36] to inscribe in the maps: 90,000 for the equator, 86,330 for the southern parallel (Anti-Meroe), 40,000 for the northern limit (Thule), 72,000 for the parallel through Rhodes, 82,336 for the one through Syene (Aswan, the summer tropic).

In the last book (8) of his *Geography*, Ptolemy explained how to divide the map of the *oikoumene* into regional maps so that the data should be located on them in an appropriate scale, which would improve their legibility. Accordingly he made up a new catalogue, heavily reduced, to be used in the drawing of regional maps. Forgetting the eighty odd provinces or satrapies described in the previous catalogue, he selected 26 areas to suit the regional maps: 10 for Europe, 4 for Libya, 12 for Asia; these 26 maps were due to fill the whole inhabited world. For each one, he indicated first the ratio between the length of one degree on the central parallel of this map (which varied with the latitude) and the invariable length of one degree on the meridian. Then he detailed the boundaries of the area mapped. When he reached the list of cities or features to inscribe on the map, he selected a different way of mentioning their coordinates. Neglecting the degrees, he pointed out the latitude through the length of the longest daylight (as he had done previously in *Alm*. 2.6 and in *Geog*. 1.23), and the longitude through distances expressed in equinoctial hours either to the east or to the west of the meridian through Alexandria (as he had planned in *Alm*. 2.12 and in *Geog*. 1.23). He would gladly have added the fixed stars

Mediterranean Basin counter-clockwise, from Libya to Asia and Europe. Pliny the Elder (ca. 24–79) had examined the inhabited world (*NH* 2–6), first clockwise for the northern half, then counter-clockwise for the southern half. Later on, Dionysius from Alexandria (ca. 125), in his *Periegesis* in hexameters, described Libya, Europe, Islands, then Asia.

36 Since the length of the inhabited world had been limited to 180°.

getting across the zenith for each quoted place[37] (as Hipparchus had done) if they had remained for ever at the same distance from the celestial equator, but he had learned from Hipparchus and verified by himself that their distance to the equator varied along with the centuries; it would not have been pertinent for him to include so variable data in a work meant to last for ever.

4 Ptolemy's Posterity

Ptolemy had wished for his whole work an everlasting life and a vivid usefulness to future generations. By and large, this wish was rather fulfilled.

4.1 *The Settling of Irremovable Frames*

The *Mathematike Syntaxis*, translated into Arabic in the 9th century, was so valued by the oriental scholars that they called it "The Greatest" (*megiste* in Greek), turned into *Almagest*. The faith in a geocentric cosmos held on for many centuries, till Galilei and Copernicus removed the earth from its central place. But it is obvious that, at least, the geocentric hypothesis had allowed the Greco-roman scholars to get a thorough theoretical knowledge of the whole terrestrial globe.

The star catalogue became the sound basis for any subsequent research. The names of the stars (very often through translation into Arabic) and the figures of the constellations are on the whole still in use; the moderns had only to coin other names and figures for the part of the sky, around the Southern Pole, which had remained invisible to people neighbouring the Mediterranean.

As for the *Geography*, it had been such a new accomplishment, and such an exhaustive one, that it looked for a long time practically intangible. Unlike so many Marinus' treatises, which had left most of the localisations unsettled, Ptolemy's catalogue was apparently so accurate and comprehensive, including so many cities and landmarks with their coordinates, that rapidly it seemed out of question to try any emendation or improvement. The figure of the inhabited world drawn by Ptolemy, in spite of its mistakes, remained unchangeable for centuries.

4.2 *A Fruitful Innovation: The Techniques of Map-making*

The best accomplishment in cartographic matter, besides the catalogue of places with a full range of coordinates, was the discussion about the various schemes able to give a tolerable idea of what is spherical when drawn on a

37 Ptol., *Geog*. 8.2.2.

plane surface. Strabo, relying on Eratosthenes, and Hipparchus, had somehow raised this problem,[38] crucial for mapmakers. But Ptolemy, whose researches in this field are the only ones fortunately preserved, explained at length how to proceed.

The Greeks had already sought to produce material pictures of the inhabited world. Herodotus[39] sneered at scholars who drew the *oikoumene* as a circle; but he narrated how Aristagoras from Miletus (ca. 500 BC) used a map carved on a bronze support to show to the leaders of Sparta and Athens the road leading to Babylon. This type of circular world map was in use for a long time. Geminus (ca. 50 BC) complained about this doggedly bad habit of drawing circular world maps: "Those who draw circular maps wander far from the truth, for the length there is equal to the width, which is not the case in nature ... The inhabited part of the earth is a certain segment of sphere having the length the double of the width, so it cannot be bounded by a circle" (Gem. 16.4–5).

Eratosthenes had been the first to try to draw a map to scale, thanks to his measure of the terrestrial circumference. Strabo who, in spite of his criticisms, relies mostly on him, recommended to draw the world map "on a plane board of at least seven feet" (Strab. 2.5.10), for the use of a globe, a better imitation of reality, would be too cumbersome. We gather from Strabo that Eratosthenes' world map was in a kind of orthographic scheme, with the straight lines figuring the parallels equal to the one through Rhodes. Hipparchus, finding fault with this scheme, had probably proposed a kind of conic projection alluded to by Strabo (Strab. 2.5.10). Ptolemy however was surely the first to have detailed all the reckonings necessary to work out the plain conical projection or the modified one. His mapping of the inhabited world was truly revolutionary.

4.3 *The Geography through the Centuries*[40]

Ptolemy's *Geography* had been translated into Arabic as soon as the 9th century, and maps drawn accordingly. The 10th century Arabic historian al-Masudi[41] claimed to have seen, in a *Geography* probably by Ptolemy, brightly coloured maps, with red, yellow or green mountains, variously shaped seas, and even the

38 Strab. 2.5.10: "Although the several meridians drawn through the pole all converge on the sphere toward one point, yet on our plane-surface chart it will not matter to make the straight lines converge slightly, for there is no necessity for this in many cases, nor are the converging straight lines as easily understood as are the curved lines on the sphere".

39 See Hdt. 5.36 and Hdt. 5.49.

40 See Gautier Dalché 2009; Shalev, and Burnett 2011; Talbert, and Unger 2008; Talbert 2012b; Thrower 1999; Broc 1980.

41 See Barbier de Maynard, and Pavet de Courtelle 1861, 183, 204.

course of the River Nile. But in the Occident, the *Geography* seemed to have been more or less forgotten. At least, the learned monk Maximus Planudes (ca. 1255–1305) is said to have discovered in Byzantium a very old and neglected manuscript of the *Geography*, without maps; so he managed to have it copied, and he added maps drawn according to Ptolemy's precepts. The two oldest preserved manuscripts copied at the end of the 13th century, *Urbinas gr*. 82 (actually in the Vatican Library) and *Seragliensis* 57 (in Istanbul), adorned with 26 regional maps after the world one, probably showed the result of his researches and accomplishments.

At the end of the 14th century, the Greek scholar Manuel Chrysoloras, fearing the threatening Ottomans, had brought from Byzantium into Italy a lot of Greek manuscripts, and among them one of the *Geography*. He started to translate it into Latin, then entrusted one of his pupils, the Florentine Jacopo Angelo, with the fulfilment of this task. In 1406, the Latin version of the *Geography* was brought to an end and dedicated[42] to the pope Alexander V. Painters and mapmakers, mainly in Florence, hastened to bustle about, in order to add beautiful maps to the Latin copies of the *Geography* (which Jacopo Angelo had entitled *Cosmography*). They used as well the plain as the modified conic projection for the world map and, for the regional maps, either the orthogonal scheme, favoured by Ptolemy, or a trapezoidal one (the so-called Donis projection)[43] judged more pertinent.

The popularity of mapmaking thanks to Ptolemy induced some artists to propose, after the Ptolemy's maps, modern ones of Spain, Gaul, Italy, Holy Land, etc., with rectified coordinates. Bernard Sylvanus from Eboli, at the end of his Latin edition of the *Geography* (1511), proposed a world map including a part of America newly discovered, in a pseudo-conical equal-area projection similar to the one used later on by R. Bonne (1727–1795). Likewise Gerardus Mercator (1512–1594) had already published the Latin text of Ptolemy's *Geography* and drawn the corresponding maps (1581) when he decided to establish his own collection of maps (1595), using the type of projection named after him: this was an orthographic projection, improved by increasing the distance between the parallels from south to north, so that a straight line joining two points of the map would cut all the meridians with the same angle, a propriety very useful to sailors.

42 In his dedication, Jacopo Angelo greeted Ptolemy as "the most learned of all mathematicians. He meticulously explained the disposition of the earth and everything else, without departing from mathematics" (Shalev, and Burnett 2011, 227).

43 This type of projection had been practised by Nicolaus Germanus about 1460.

In the 15th century, the flourishing of Latin manuscripts and editions of the *Geography* inevitably contributed to increase the desire of enlarging the knowledge of the world. The Genoese Christopher Columbus owned a copy of the 1478 Rome edition, in which he learned that the stretch of Ocean between Iberia and India could be less than 180° according to Ptolemy, or even less than 135° if Marinus was right. It was a strong impulse to sail from Cadiz along the 36° parallel through the Atlantic Ocean; Columbus' journey (1492) had to be interrupted by the presence of islands (Cuba and Haiti) near the new continent, as Strabo[44] had predicted long ago. The discovery of new lands was an indirect consequence of the fame of Ptolemy's mapping of the world.

On several world maps of the *Geography*, and particularly on the Ulm edition (1482), the Indian Ocean was enclosed by a strip of land, this "unknown land that surrounds the Sea of India", alluded to by Ptolemy (*Geog*. 7.5.5). Relying on this hint, the Royal Society sent James Cook in search of an Austral continent and its expected profits;[45] several sailings, from 1768 to 1775, were needed to make sure that this continent did not exist; but thanks to this search, many others unknown lands were discovered.

5 Conclusion

Ptolemy was lucky enough or clever enough to get most of his writings preserved. In each one, he tried and succeeded to be not only exhaustive but also up-to-date, presenting a broad account of the scientific knowledge stored during so many centuries of researches, and adding his own experiments and methods of transmission. Working in Alexandria, still a matchless centre of learning, he gathered faithful disciples and, later on, commentators and editors. Ptolemy's various accomplishments were probably accountable for the loss of many noteworthy treatises and clever attempts due to his predecessors. But fortunately enough, Ptolemy was not only a good transmitter, providing a

44 Strab. 1.4.6. Eratosthenes having valued the length of the inhabited world to 78,000 stadia on the parallel through Rhodes (worth 200,000 stadia), could conclude: "If the immensity of the Atlantic Sea did not prevent, we could sail from Iberia to India along one and the same parallel over the remainder of the circle, when has been subtracted the aforesaid distance (*sc*. the length of the inhabited world), which is more than a third of the whole circle". But Strabo objected: "In this temperate zone, there could be two inhabited worlds, or even more, and particularly near the parallel through Rhodes that is drawn across the Atlantic Sea".

45 See Thomas 2003; Richardson 2005.

scientific approach to the knowledge of the cosmos, sky and earth, which has been prevalent in Antiquity, but also a first-rate discoverer of new procedures and useful techniques.

Ptolemy, such an amazing scholar, was able to succeed in all kinds of sharp researches but also to explain most of his proceedings and results in an easy and handy way, so that they should be at the disposal of any amateur. In the *Geography*, his discussion about the best way to represent on a flat surface what is really on a spherical one, his demand of both coordinates for every place to inscribe on a map, provided a sound target to future generations. In the art of mapmaking, as in many other fields, he was a peerless innovator, initiating a kind of revolution accounting for his everlasting fame.

FIGURE 18.1 *Ptolemy, Grec 1401, Fol. 2* (*Courtesy of Bibliothèque Nationale, Paris*).

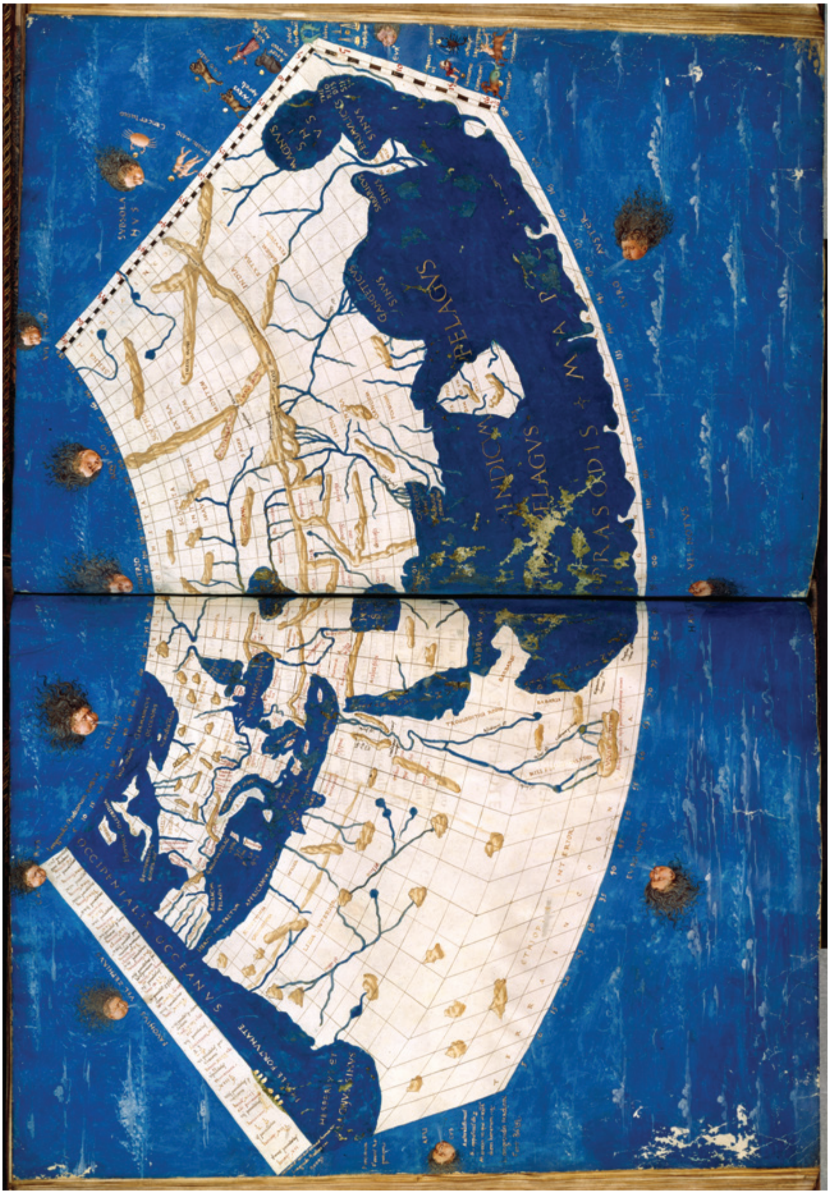

FIGURE 18.2 *Ptolemy, Latin 4801. Fol. 74 (Courtesy of Bibliothèque Nationale, Paris).*

FIGURE 18.3 *Ptolemy, Latin 4801. Fol. 75 (Courtesy of Bibliothèque Nationale, Paris).*

FIGURE 18.4 *Ptolemy, Latin 4801. Fol. 76* (*Courtesy of Bibliothèque Nationale, Paris*).