Eratosthenes’ Contribution to Ptolemy’s Map of the World

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ABSTRACT: This article attempts to shed some light on the origins of Ptolemy’s map of the world, which remains a mystery. The premise is that Ptolemy and other ancient geographers largely drew on the same or a similar pool of sources and common beliefs. Similarities between them can, therefore, give us a key to understanding the prehistory of Ptolemy’s map. Comparison of distances on his map with those given by other sources leads to the conclusion that a large area of the map, approximately from the Bosporus to the Indus, reproduced Eratosthenes’ geographical system, with linear distances converted to angular degrees according to Eratosthenes’ own scale. It is argued that this area represents a remnant of an earlier version of Ptolemy’s map. Analysis of latitude and longitude reveals notable differences between Ptolemy’s map and Eratosthenes’ ideas concerning the latitude of Babylon and the Alexandrian prime meridian, and the impact this seems to have had on the shape of neighbouring regions is noted.

KEYWORDS: Ptolemy, Ptolemy’s map, Ptolemy’s Geography, Eratosthenes, Hipparchus, circumference of the earth, units of measurement, Alexandrian meridian, cartometric methods, structural deformation, ancient cartography, ancient geography.

Ptolemy’s treatise Γεωγραφικὴ ὑφήγεσις (Geographical Guide), more commonly known as the Geography (composed around AD 150), is considered the most important of all ancient geographical sources but one of the least explored. Ptolemy’s work is undoubtedly the culmination of ancient geography. It by far surpasses all other (extant and lost) ancient geographical treatises in the amount of information, cartographical precision and methodological sophistication.[1] In a nutshell, the whole history of ancient geography can be regarded as the prehistory of Ptolemy’s work.

Equally radical is the difference between Ptolemy’s work and other ancient geographical treatises both in form and in content. Ptolemy’s Geography can be recognized as the first GIS, in the sense that it presents all information in a ‘digitized’ form—in terms of angular coordinates (latitude and longitude in degrees).[2] This explains why all the extant medieval copies of Ptolemy’s maps are largely secondary to the text. Accordingly, the term ‘Ptolemy’s map’ refers, in this article, to a digital map reconstructed from his text.[3] By using different GIS software, the reconstruction can be represented in a variety of ways; for example, as clusters of coordinate points (Fig. 1).

The gap between Ptolemy and his predecessors was so great that it seems hardly possible that the Geography could have appeared *ex nihilo*. It is more reasonable to suppose that there is a missing link between Ptolemy and his predecessors and that an intermediate stage in the evolution of geography between them has been largely lost sight of in the surviving material. All Ptolemy’s works were designed as handbooks for specialists, and in this respect the Geography is in line with the rest of his oeuvre: the Almagest was for astronomers, the Tetrabiblos for astrologers, the Optics for those

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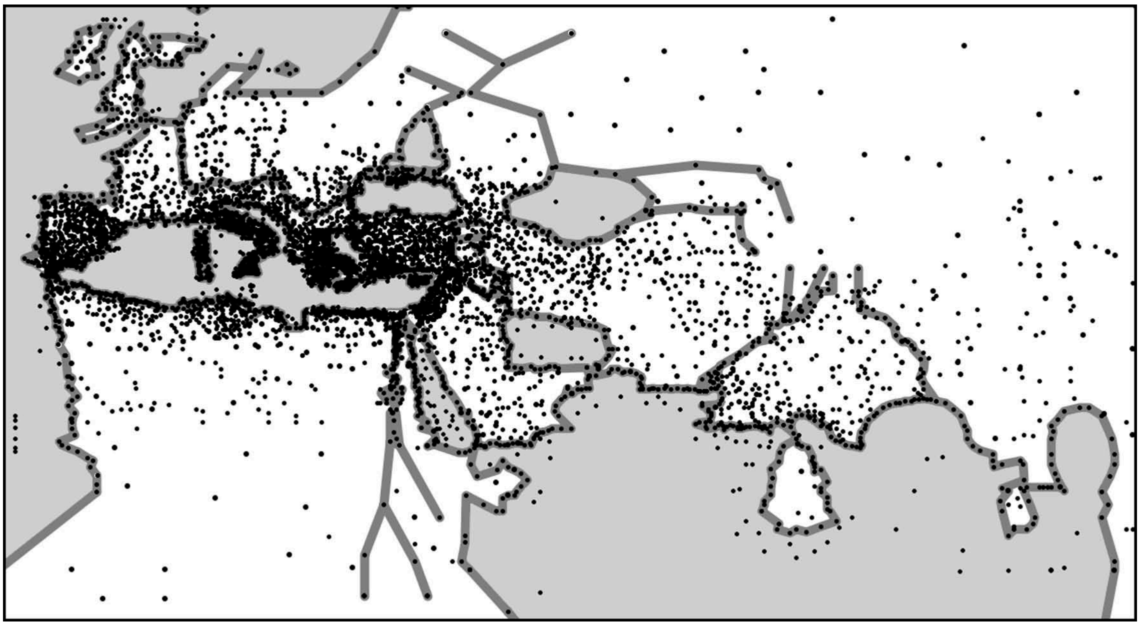

Fig. 1. Claudius Ptolemy's map of the world (*c.* AD 150), showing the distribution of the coordinates in the Ω recension of the Geography when plotted using a Geographical Information Systems program with coasts and the largest rivers outlined. The coordinate points clearly gravitate towards the Mediterranean 'core' of the ancient world. (Author's drawing.)

studying the theory of light and vision.[4] Each treatise brought together the achievements in its field, but at the same time it overshadowed the earlier works to the extent that modern historians have tended to regard the Ptolemaic corpus as their key source. My argument is that Ptolemy's Geography is important not only in itself, but also as a basis for reconstructing earlier stages in the history of ancient cartography.

Ptolemy's Geography remains a *terra incognita* for researchers, not least because, of all the ancient geographical sources we have, his work is the most opaque. He designed the Geography as a practical guide for composing a world map. Accordingly, Book I alone is devoted to theoretical issues, aims and methods, while the seven subsequent books consist of lists of toponyms with coordinates but without references to sources. Equally, little is known about how Ptolemy determined coordinates in such number and with such precision.[5] It is not surprising, thus, that the majority of publications on Ptolemy's Geography have been devoted either to a rather superficial survey of the most general questions, namely those that Ptolemy himself discusses in Book I, or to specific issues concerning separate localities.[6]

Ptolemy's Geography was almost inaccessible to systematic investigation before a modern critical edition was published in 2006, since when studies of Ptolemy's Geography have experienced something of a boom.[7] Most of the recent studies, however, share a feature in common in that they all analyse Ptolemy's map through direct comparison with modern maps.[8] This approach is obviously valid, but it has a major flaw: it tends to lose sight of the complex nature of Ptolemy's map, which is not merely a distorted reflection of reality, but the result of a long process of compilation from different sources and multi-step editing.

Out of the immense literature on Ptolemy's Geography, studies that have attempted to deal seriously with these issues can be counted on one hand, some of which can be singled out as of fundamental importance. One is Paul Schnabel's article of 1930, in which he made the first attempt to distinguish successive stages in the evolution of Ptolemy's geographical ideas, showing, among other things, that the Almagest, Ptolemy's main work in astronomy, represents an earlier stage than the Geography.[9] In the Almagest, Ptolemy held the circumference of the earth to be 252,000 stades, a value almost universally accepted in antiquity after it had been proposed by Eratosthenes in the third century BC.[10] In the Geography, one of his later works, Ptolemy accepted another value, 180,000 stades, which had been little-known before him.[11] Of equal significance are the undeservedly forgotten works by Antonin Wurm who found that within Ptolemy's map as described in the Geography is a remnant of an earlier version based on Eratosthenes' value for the earth's circumference, not Ptolemy's.[12]

My aim in this article is to advance along the path pioneered by Schnabel and Wurm by employing a simple yet largely neglected approach, namely, a comparison of Ptolemy's map of the world with information from other ancient sources. My investigations have involved two steps. Initially, I searched for correspondences between the distances measured on Ptolemy's map and those given by Eratosthenes and other geographers on the assumption that the latter constitute the geometrical framework underlying Ptolemy's map. I then considered the two major differences between Ptolemy's and Eratosthenes' data—in the latitude of Babylon and in the prime meridian of Alexandria—and traced the impact that these inconsistencies may have had on the shape of neighbouring regions on Ptolemy's map. I argue that the displacement of Babylon and the points traditionally connected with the prime meridian from their initial Eratosthenic positions produced a 'chain reaction' of deformations that affected a large part of the map. Finally, a comparison of Ptolemy's map with Eratosthenes' data, together with an examination of the geometrical structure of Ptolemy's map, makes it possible to reconstruct a plausible model of these deformations.

Converting Distance Measurements to Degrees

Although Ptolemy presented all his information in terms of angular coordinates, only the latitudes of a few major cities on his map could have been determined astronomically (for example, Alexandria, Rhodes, Athens, Rome, Massalia).[13] Without doubt, Ptolemy drew heavily on earlier geographers who described space mostly in terms of distances on the ground measured in customary units (Greek stades, Roman miles).[14] It is reasonable to assume, therefore, that, with few exceptions, Ptolemy's coordinates were derived from such distances converted to angular units for the map.[15] A comparison of distances measured on Ptolemy's map with those available in other written sources can, therefore, facilitate our understanding of the internal structure and genesis of his map of the world. However, before analysing the data, we need to take account of at least three important points about how Ptolemy and/or his predecessors processed distance measurements and translated them into coordinates.[16]

When calculating longitudes of places at the same latitude, the ancient geographers normally measured the distance between them not along the great circle, as modern geodesists do, but along the parallel. Ptolemy, for instance, simply divided the distance on the ground by the length of a degree of longitude at the given latitude.[17] One may assume that he hardly bothered too much about being highly accurate and that he did not calculate the length of a degree for each individual latitude. Most probably, he used the respective values for the nearest *klimata*, the main latitudes determining the layout of his map.[18] The system of these latitudes was, in essence, the principle tool available to pre-Ptolemaic geographers to construct a mathematical basis of a map. In this respect Ptolemy's dependence on earlier tradition can be traced most clearly.

In ancient geography, *klimata* was the technical term for selected latitudes defined by the length of the longest daylight and spaced at half-hour intervals, such as 13½ hours at the latitude of Syene (23° 51′), 14 hours at Lower Egypt (30⅓°) and 14½ hours at Rhodes (36°). Correspondingly, the length of a degree of longitude was taken by Ptolemy to be 400 stades at the latitude of Rhodes (that is, 500 stades × cos 36°); at the latitude of Alexandria it must have been about 430 stades; and so on. The detailed system of *klimata* had constituted the basis of the world map of Marinus, which served Ptolemy as his model and main source of his map. In turn, many elements of Marinus' system went back to the table of *klimata* composed by the most famous astronomer before Ptolemy, Hipparchus of Nicaea, as a part of his geographical treatise 'Against the Geography of Eratosthenes' (compiled *c*.135–126 BC).[19] In this way, the seven major *klimata* used by Ptolemy and Marinus can be linked back to Eratosthenes (Fig. 2).[20]

Small differences in latitude could be easily ignored. When a difference was significant, Ptolemy could calculate the coordinates by applying either Menelaus' theorem for a spherical surface or Pythagoras' theorem for a plane.[21] In the interest of simplicity Menelaus' theorem can be replaced by the modern formula:

$$\cos S_{AB} = \cos \Delta\lambda_{AB} \times \sin(90^\circ - \varphi_A) \times \sin(90^\circ - \varphi_B) + \cos(90^\circ - \varphi_A) \times \cos(90^\circ - \varphi_B), \quad (1)$$

where S_{AB} is the distance between points A and B expressed in degrees, $\Delta\lambda_{AB}$ is the longitudinal interval between them, and φ_A and φ_B are their latitudes.

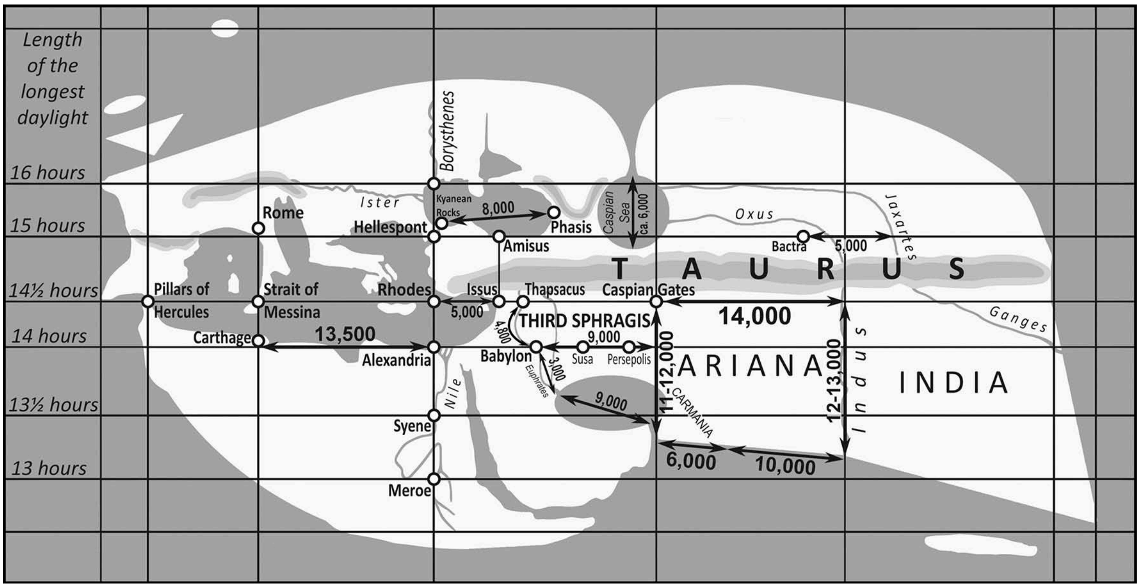

Fig. 2. The world according to Eratosthenes, based on the prime meridian of Alexandria, with the grid of the main parallels and meridians and distances in stades. The numbers on the left indicate the length of the longest day traditionally associated with the main parallels by ancient geographers. Reconstructed by the author based on the map available online at https://commons.wikimedia.org/wiki/File:Eratosthenes_world_map_(German_text).png.

It also needs to be borne in mind that Ptolemy and his predecessors had a tendency to round numbers. Eratosthenes, for example, often rounded distances to the nearest thousand.[22] It meant that he could give the same distance in both precise and rounded variants. Similarly, Ptolemy rounded coordinates[23] and the values of a degree of longitude at different latitudes.[24] What is more, the precision of Ptolemy's coordinates correlates clearly with their density on his map. Where they are most sparse, usually on the periphery, the coordinates have the highest percentage of values in whole degrees, but for places closer to the Mediterranean, the fractions of a degree become increasingly smaller and more frequent. Figuratively speaking, in short, Ptolemy's map had 'low resolution': it could reproduce general outlines of large objects, but was inaccurate in details. For this reason, when comparing Ptolemy's map with the distances given by other sources, it makes sense to use only those applying to relatively long intervals.

Finally, various distances reported by ancient sources cannot in principle be harmonized completely. For instance, Eratosthenes was aware how unreliable all the data at his disposal were and did not try to make his map mathematically impeccable, treating some distances as if they were not on a sphere but on a plane.[25] Consequently, when choosing some distances as a basis for his map, Ptolemy must have inevitably neglected others.

In these conditions it is difficult to expect exact correspondences between Ptolemy's map and the distances used by other geographers. Nevertheless, such correspondences are numerous, as I show below. For example, Ptolemy himself explains (1.12.11) that the main proportions of the Mediterranean on his map were determined by a series of distances along the parallel of Rhodes as given by Marinus of Tyre (*c.* 70–130 AD), his immediate predecessor and the main source of his information, and converted to degrees using the rate of 500 stades to one degree of the great circle.[26] Marinus' distances, in turn, are close to a similar series reported earlier by Artemidorus of Ephesus in his treatise entitled Geographic Description (*c.*104–100 BC) and by Strabo in his Geography (*c.* AD 23).[27]

The 'Eratosthenic Part' of Ptolemy's Map

In this section, it is argued that a large part of Ptolemy's map—between Babylon or even the Bosporus in the west and the Indus in the east—represents, with high accuracy, the main parameters of Eratosthenes' geographical system according to Eratosthenes' scale (700 stades to one degree), not Ptolemy's (500 stades to one degree). This observation, unconventional as it may be, is not entirely new. Similar observations have already been made by a number of researchers independently of one another.[28] A working hypothesis proposed by Wurm is that this part of Ptolemy's map came from the early version that was initially based on Eratosthenes' value for the circumference of the earth.

Eratosthenes, the most famous of the ancient geographers, was the author of the first map known to have been expressed in rigorous geometrical terms and keyed to a grid of latitudes and longitudes (see Fig. 2). His magisterial work is the Geography, dating from the third quarter of the third century BC.[29] In this work, Eratosthenes divides the known world into a number of the so-called *sphragides* or 'seals', large regions shaped as quadrangles bounded by parallels and meridians. Strabo, our sole source on this subject, describes only four *sphragides* in the southern half of Asia.[30] To the north, all four were bounded by the Taurus range that Eratosthenes said ran along the parallel of Rhodes. Laterally, each *sphragis* was delimited by a meridian: one passed along the Indus and separated India from Ariana, defining the first and the second *sphragides*; another passed through the Caspian Gates (Sirdar Pass), separating Ariana from the third *sphragis*. The western boundary of the third *sphragis* ran along the Euphrates and was tied to the meridian of Thapsacus in the north and to that of Babylon in the south.

Even at first sight, the outlines of the second and the third of Eratosthenes' *sphragides* are discernible on Ptolemy's map (Fig. 3). More importantly, the main dimensions of Eratosthenes' Ariana (its length along the parallel of Rhodes and the breadth along the meridian) and the length of his third *sphragis*, as measured from Babylon to the eastern border, either coincide exactly or agree closely (to within 100–500 stades) with the corresponding distances on Ptolemy's map (Appendix 1).

However, two major differences between Ptolemy's and Eratosthenes' maps stand out. First, in Ptolemy, the Indus no longer forms the boundary between India and Ariana, but flows instead within India. Its direction is not from north to south, but northeast to southwest, with its lower reaches cutting off part of Ariana (see Fig. 3). The effect of this alignment is to locate the Indus delta much further west on Ptolemy's map than it should be according to Eratosthenes. Second, the shape of Ptolemy's Mesopotamia also differs significantly

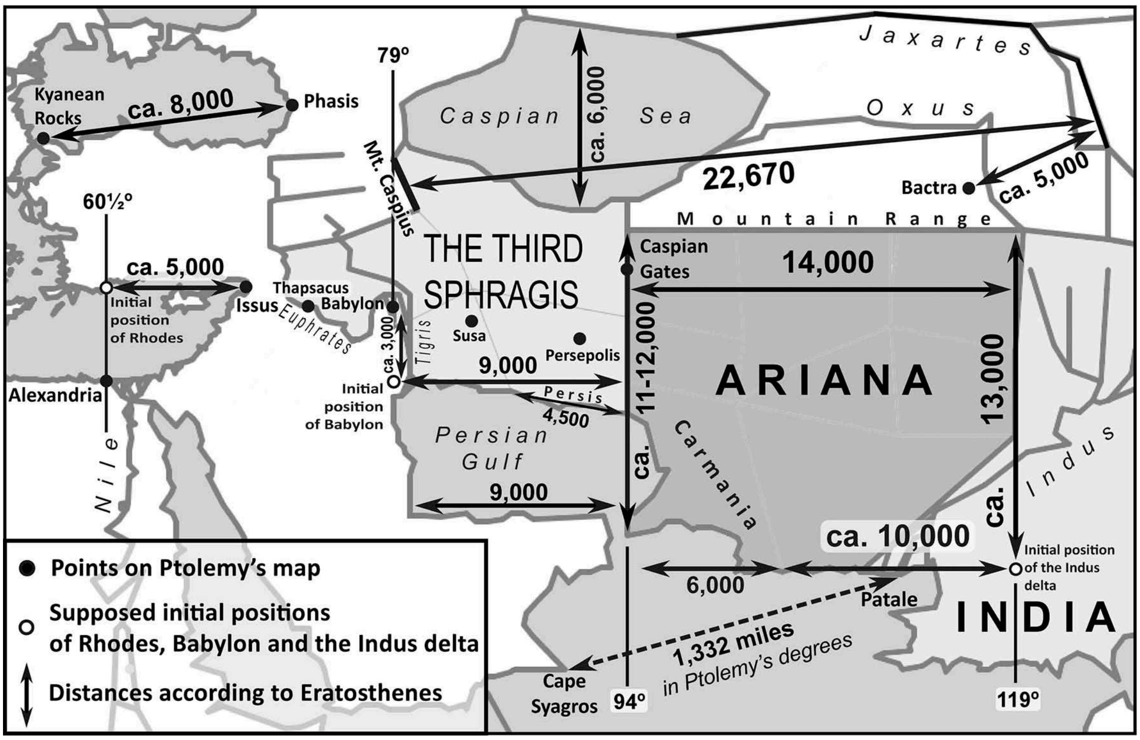

Fig. 3. The Middle East on Ptolemy's map of the world, showing the outlines of the *sphragides* as described by Eratosthenes, with distances in stades matching those given by Eratosthenes and converted to degrees according to Eratosthenes' scale (1° = 700 stades). The location of the Indus delta seems to have been determined by the distance from Cape Syagros as recorded by Pliny the Elder and converted to degrees using Ptolemy's own scale (1° = 500 stades). Map outlines are based on the coordinates in the Ω recension of Ptolemy's Geography. (Author's drawing.)

from Eratosthenes', which affects the configuration of all surrounding areas. As will be shown below, this discrepancy can be accounted for by assuming that Ptolemy has shifted Babylon by approximately 4° to the north from Eratosthenes' original location at about the latitude of Alexandria.

These differences mean that the other dimensions of the Eratosthenic *sphragides* on Ptolemy's map do not agree with Eratosthenes' distances (the length of the coast of Ariana and the length of the western side of the third *sphragis* along the Euphrates). One way of explaining this is to accept that in the earlier version of Ptolemy's map the Indus delta was located at the meridian running along the boundary between India and Ariana (119°) and Babylon was approximately at the latitude of Alexandria (31°). Such an adjustment would allow the length of the coast of Ariana (in other words, the southern side of the second *sphragis*) and the length of the western side of the third *sphragis* along the Euphrates to coincide closely with Eratosthenes' distances (see below and Appendix 1).

It has been pointed out above that the Indus delta is too far to the west on Ptolemy's map. This can now be explained by referring to a passage in Pliny the Elder's Natural History (6.101) where it is said that the safest route to India 'is to start from Cape Syagros [Ras Fartak] in Arabia with a west wind (the native name for which in those parts is Hippalus) and make for Patale [the Indus delta], the distance being reckoned as 1,332 miles [10,656 stades]'.[31] If we draw a line representing 10,656 stades on Ptolemy's map from Cape Syagros (at 90° long., 14° lat.) towards India, its eastern tip will point exactly to the middle of the Indus delta (namely, at 111.4° long., 20° lat.; see Fig. 3). Hence we may suppose that the westward displacement on Ptolemy's map of the Indus delta from its original Eratosthenic longitude of 119° came from sailors' reports similar to that recorded by Pliny.[32]

Asia Minor can also be added to the 'Eratosthenic part' of Ptolemy's map. Two distances are relevant here: the length of the northern side of Asia Minor, from the Kyanean Rocks (near the Bosporus) to the mouth of the Phasis (Rioni in Georgia); and the length of the southern side, from Rhodes to Issus (for details, see Appendix 1). The northern boundary as stated by Eratosthenes coincides within 100 stades with the corresponding straight distance on Ptolemy's map.[33] For the southern edge, in order to make a correct comparison, we need to bear in mind that Eratosthenes had placed Rhodes on the meridian of Alexandria, whereas Ptolemy put it 1° 50′ further west. As will be seen, there are good reasons to suggest that, in the early version of the map, Rhodes would also have been situated on the meridian of Alexandria, thus, measured from this hypothetical point, Ptolemy's distance to Issus matches Eratosthenes to within 40 stades.[34]

Other, less important, coincidences between distances given by Eratosthenes and Strabo and those measured on Ptolemy's map, are listed in Appendix 1 (see also Fig. 3). In conclusion, it is important to emphasize that all the correspondences noted above are exact, closely interconnected, apply to the same region, and refer to the key parameters of Eratosthenes' geography. Taken together, they exclude the possibility of accidental similarity.

The final example of Ptolemy's use of the 'Eratosthenic scale' concerns the longitudinal distance between Alexandria and Babylon that was given as 12½° in the Almagest and as 17½° in the Geography. Schnabel explains the discrepancy by assuming that both figures derived from the same distance converted from stades to degrees according to different rates: 1° = 700 stades and 1° = 500 stades, respectively.[35] If we convert the distance between Alexandria (60½° long., 31° lat.) and Babylon (79°, 35°) as stated in the Geography into Eratosthenes' degrees, the longitudinal interval between them amounts to 12.77°, which is close to the 12½° given in the Almagest and, interestingly, to Eratosthenes' own distance (Fig. 4).[36] Thus, Ptolemy's interval of 12½° longitude at latitude 31°, where 1° longitude equals 600 stades (in Eratosthenes' degrees), works out at 7,500 stades.[37] According to Eratosthenes, the distance between Alexandria and Babylon is just over 7,400 stades.[38]

From all these observations, it is reasonable to conclude that early versions of Ptolemy's map and/or its sources must also have been based on Eratosthenes' value for the circumference of the earth. One is tempted to assume, therefore, that the 'Eratosthenic area' of Ptolemy's map was a remnant of this early version.

The Latitude of Babylon

Ptolemy changed his estimate of the longitude of Babylon with respect to Alexandria from 12½° in the Almagest to 18½° in the Geography. Here I argue that he also changed the latitude of Babylon from the approximately 31° used in the supposed source for the 'Eratosthenic area' of his map to the 35° adopted in the Geography and, probably, in the Almagest.[39]

The latitude of 35° derives from the ratio of 3:2 between the lengths of day and night at the solstice that was traditionally used in Babylonian astronomy. Before Ptolemy, Babylon was placed at this latitude in the system of astrological *klimata* and, probably, in Hipparchus' table of *klimata*.[40] Eratosthenes, however, is thought to have placed Babylon at about the latitude of Alexandria (see Fig. 2).[41] Three points suggest that in the sources underlying Ptolemy's map of the Middle East Babylon had also been situated at about the latitude of Alexandria.

The first point relates to the strange configuration of the Euphrates on Ptolemy's map, where the river is shown with a large loop that does not exist in reality.[42] At latitude 33⅓°, the river abruptly bends to the north and then, at latitude 35⅔°, turns back to follow a southward course (see Fig. 4). No other source mentions anything like this. Although Eratosthenes emphasized that the Euphrates did not follow a straight line but 'after flowing from the mountains to the south turns toward the east and then back to the south', this does not imply any northward bend.[43] However, Ptolemy's configuration of the Euphrates becomes explicable, as soon as it is assumed that the river turned to the north following the northward displacement of Babylon.

The second point concerns similar hints of deformation on Ptolemy's map of the Middle East. Here four straight lines can be identified, inclining at roughly the same angle (see Fig. 4).[44] The first line connects Babylon (79° long., 35° lat.), Susa (84°, 34¼°) and Persepolis (90¼°, 33⅓°).[45] The second line is formed by the chain of the Parachoathras mountains that forms the boundary between Persis and Carmania in the south and Media and Parthia in the north (it connects three points: 84° long., 36° lat.; 94°, 34½°; 102½°, 33°). The third runs along the northern coast of the Persian Gulf roughly from Teredon, at the mouth of the Tigris (80° long., 31° 10′ lat.), to the mouth of the Bagradas (94°, 29¼°). The fourth line is the boundary between Carmania and Gedrosia in the south and Carmania Deserta and Drangiana in the north (it connects three points: 94° long., 31° lat.; 101°, 29° 50′; 111½°, 28°).

As was shown above, this area on Ptolemy's map was based on Eratosthenes' data. It is remarkable in this connection that Eratosthenes explicitly mentioned the first and the second of the four lines. The only difference is that Eratosthenes oriented them along parallels: the line Babylon–Susa–Persepolis along that of Alexandria,[46] and the Parachoathras, as a part of the Taurus range, along that of Rhodes (see Fig. 2).[47] It is reasonable, accordingly, to suggest that in the early version of Ptolemy's map all four lines belonged to the same data set and that they were also oriented along parallels. Their later inclination can be explained by the shift of Babylon by approximately 4° to the north.

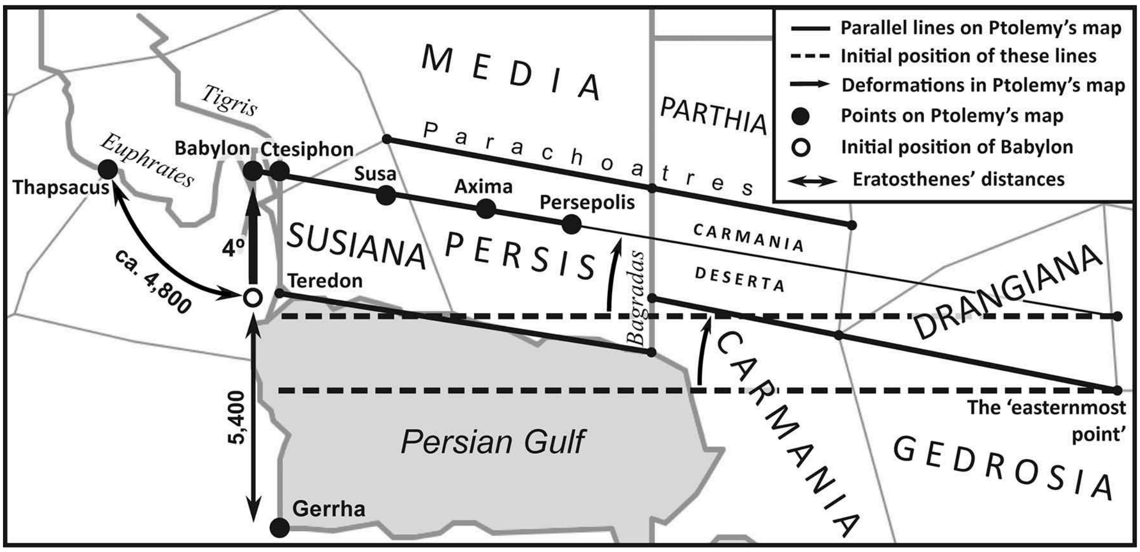

Fig. 4. Possible deformations in the structure of Ptolemy's map of the world as a result of his northward shift of Babylon. The empty circle indicates where Babylon must have been located in the hypothetical early version of the map, when the distances from it to Thapsacus and to Gerrha (marked by the double-headed arrows) match Eratosthenes' figures when these were converted to degrees using Eratosthenes' scale. The tilted lines are presumed to have been initially aligned with parallels. The upper dotted line indicates the initial position of the parallel passing through Babylon, Susa and Persepolis. (Author's drawing.)

It is difficult to reconstruct the model of this deformation, all the more so because it may not have been mathematically accurate from the beginning. As the simplest working hypothesis, I made the assumption that the northward shift of Babylon displaced the four lines in question in such a way that they remained parallel and retained the initial latitudinal intervals between one another. In such case, the only point of the four lines that would have retained its initial latitude was the easternmost point (see Fig. 4). Assuming that this point marks the intersection between the boundaries of Drangiana, Arachosia and Gedrosia, if the line Babylon–Susa–Persepolis is continued east until it intersects the meridian of this point, then the latitude of this intersection, which is the initial latitude of Babylon, can be determined as approximately 30.19°.[48]

It then follows that, if Babylon is placed approximately at the latitude of Alexandria, Ptolemy's map would match Eratosthenes' distances as expressed in the 700-stade degrees.[49] According to Eratosthenes, the distance from Thapsacus to Babylon was 4,800 stades along the Euphrates; from Babylon due south to the mouth of the Tigris and Euphrates there were 3,000 stades; and thence 2,400 stades along the coast of Arabia to the port of Gerrha.[50]

The latitude of Babylon can be found by converting those distances to Eratosthenes' degrees and measuring from the relevant points on Ptolemy's map. Three calculations are involved. If the latitude of Gerrha is 23.33° and the distance between Gerrha and Babylon is 5,400 stades or 7.71°, the latitude of Babylon works out at 31.04°. If Thapsacus's coordinates of 73.5° long. and 35.083° lat. are used, the longitude of Babylon is at 79°, and the distance between them is 4,800 stades or 6.86° in a straight line, the latitude of Babylon, calculated trigonometrically, is 30.02°. Finally, if account is also taken of the fact that, according to Eratosthenes, the latter distance was not a straight line, but contained two bends, Babylon should be placed further north.

From this, it may be concluded that, on the early version or in a source of Ptolemy's map, Babylon is likely to have been located somewhere between 30° and 31° latitude.[51]

Eratosthenes' Prime Meridian

Ptolemy's map bears signs of similar deformations in Asia Minor, the Balkan region and Italy, which were probably all connected with the displacement of a straight line running through Alexandria, Rhodes, and Byzantium. This line was evidently a part of the prime meridian of Eratosthenes' map.

Eratosthenes placed Alexandria, Rhodes, the Hellespont, and the mouth of the Borysthenes on the central meridian of his map (see Fig. 2).[52] This Alexandrian axis, or its separate segments, was accepted by Hipparchus, Posidonius, Strabo and even by Ptolemy in the Almagest.[53] In the Geography, the axis has been broken and all the points previously connected with it are at different longitudes.[54] Nevertheless, one can easily see that on Ptolemy's map, Alexandria (60½° long., 31° lat.), Rhodes (58⅔°, 36°), and Byzantium (56°, 43° 5′) all fall on a straight line that is inclined so that Byzantium is located 4½° west of Alexandria (Fig. 5).[55]

A displacement of the Alexandria–Rhodes–Byzantium axis from its initial meridional position on an early map would inevitably have affected the surrounding regions. And indeed, a comparison of Ptolemy's map with the evidence of other sources and in relation to the internal structure of the map reveals signs of similar displacements in at least three other regions.

Asia Minor

Three pieces of evidence indicate that the whole northern coast of Asia Minor, together with Byzantium, was shifted westward by 4½° (see Fig. 5). In the Almagest, Ptolemy refers to astronomical observations in Bithynia made by a certain Agrippa (AD 92) that fell 5° east of the Alexandrian meridian, but in the Geography, the easternmost point of Bithynia has a longitude of 61°, only ½ degree east of Alexandria.[56] This means that the meridian running 5° east of Alexandria could have crossed the territory of Bithynia only if it were placed 4½° at least further east.[57] In addition, Eratosthenes and Strabo located Amisus (Samsun) on the same meridian as Issus (see Fig. 5).[58] On Ptolemy's map, however, Amisus is 4½° west of Issus.

As was shown earlier, two distances on Ptolemy's map—those between the initial position of Rhodes (at the meridian of Alexandria) and Issus and between the Kyanean Rocks and the mouth of the Phasis—closely coincide with the figures given by Eratosthenes when converted to stades using Eratosthenes' rate (see Figs. 2 and 3). We may thus take it for granted that these distances belonged to the basic framework that underlies Ptolemy's map, an assumption with two implications, namely that the longitude of Issus was not affected by the displacement of the Alexandria–Byzantium axis and that, in the early version of Ptolemy's map, if Byzantium was on the meridian of Alexandria, then the Phasis must have

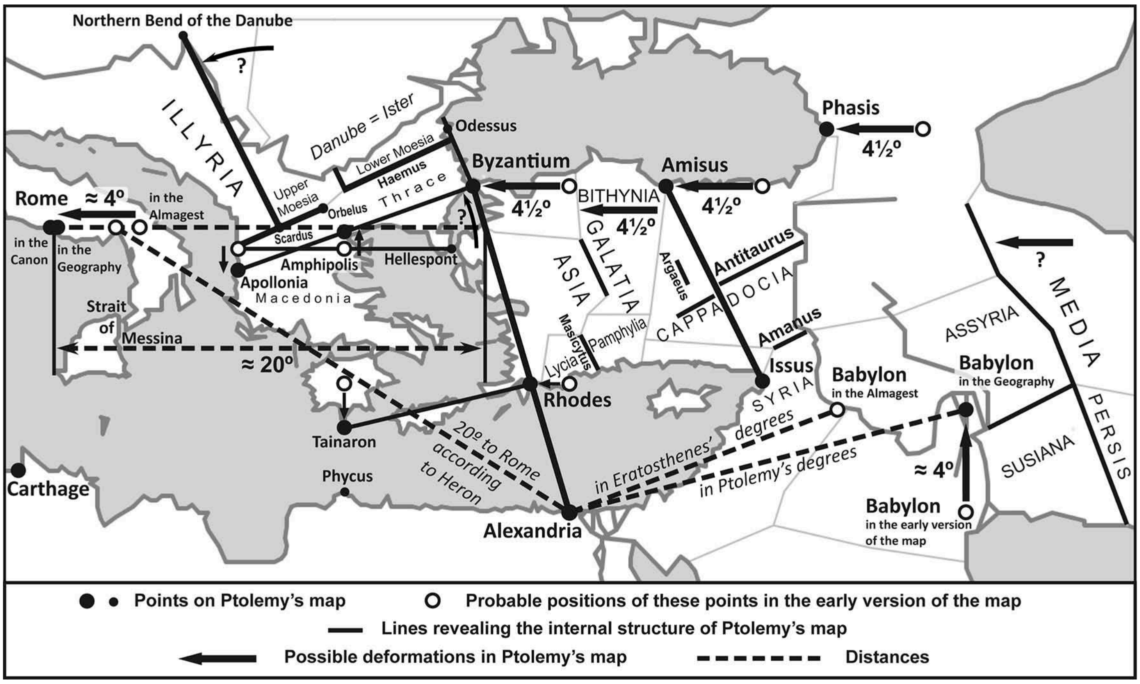

Fig. 5. Possible deformations in the structure of Ptolemy's map of the world resulting from the westward tilting of Eratosthenes' prime meridian passing through Alexandria, Rhodes and Byzantium. The northern coast of Asia Minor is presumed to have been displaced westward by 4½°, pulling more eastern areas and pushing the Balkans and Rome further west. The Balkan region has undergone a slight counterclockwise turn (marked by the two curved arrows). Note that for Babylon three different positions are indicated (according to the Geography, the Almagest, and the hypothetical early version of the map) and four positions are indicated for Rome (according to the Geography, the Canon of noteworthy cities, the Almagest, and the Dioptra of Heron of Alexandria). (Author's drawing.)

been situated 4½° further east than it is in the final version. In other words, the whole of the northern coast of Asia Minor moved westward in the process of revision of Ptolemy's map by 4½° relative to the southern coast.[59]

Finally, Ptolemy's map of Asia Minor contains a set of lines inclined approximately at the same angle as the line Amisus–Issus (see Fig. 5). This set includes the border between the provinces Asia and Galatia (connecting the points 61° long., 41¼° lat. and 62¼°, 39¼°); the Masicytus mountains separating Lycia and Pamphylia (connecting the points 61° long., 37° 50′ lat. and 61° 50′, 36½°); the Argaeus mountains in Cappadocia (connecting the points 65½° long., 40½° lat. and 66°, 39⅔°); and the entire length of the western coast from, approximately, the Hellespont to Rhodes (this line is less easily discerned owing to the irregularity of the coastline). Another three lines are almost exactly perpendicular to those listed above: the Antitaurus mountains in Cappadocia; the Amanus mountains between Cappadocia and Syria; the boundary between Assyria and Susiana. It is very likely that the inclination of all these lines resulted from the shift of the north coast to the west. Initially, these lines probably followed the meridians.

It would be reasonable to expect that the displacement of the north coast of Asia Minor would have affected areas to the east. Indeed, the western boundary of Media and Persis is inclined by approximately the same angle as the axis Alexandria–Byzantium (see Fig. 5). But no traces of such a deformation are found east of Ptolemy's meridian of 94°: all boundaries there more or less follow the meridians.

The Balkans

Any westward shift of Byzantium had to have affected the Balkan region. It seems, however, that here the deformation was more complex than in Asia Minor. In addition to a westward shift of part of the Balkans, the whole region was also turned counterclockwise, with the result that its western side—the Illyrian (Adriatic) coast—was displaced to the south and its eastern (Black Sea coast) side to the north.

Ptolemy's map of the Balkan Peninsula exhibits a set of lines that are inclined approximately at the same angle as the similar set of lines in Asia Minor (see Fig. 5). This set includes the west coast of the Black Sea running approximately along a line between Byzantium and Odessus, the river Cebrus separating Upper and Lower Moesia, the border between Upper Moesia and Illyria and a line running along the Danube as far as its northern bend.[60] Another two lines are almost exactly perpendicular to those listed above: the Haemus mountains between Lower Moesia and Thrace; the northern boundary of Macedonia passing through the Scardus and Orbelus mountains. It would be reasonable to suggest that this set of lines would have come about in similar fashion to those in Asia Minor and, thus, that the former were also initially aligned with parallels and meridians. The supposition is confirmed by Strabo's account of the shape of Macedonia, which reads:

> [it] is a sort of parallelogram ... [which] is bounded, first, on the west, by the coastline of the Adrias; secondly, on the east, by the meridian line which is parallel to this coastline ... ; thirdly, on the north, by the imaginary straight line which runs through the Bertiscus Mountain, the Scardus, the Orbelus, the Rhodope, and the Haemus; for these mountains, beginning at the Adrias, extend on a straight line as far as the Euxine'; '[the aforementioned] Thracian mountains are parallel to the Ister [Danube], thus completing what is almost a straight line that reaches from the Adrias as far as the Pontus.[61]

In view of all this, it is tempting to assume that, on Ptolemy's map, Strabo's parallelogram was turned counterclockwise, a hypothesis for which support can be found. To start with, there are indications that in the early version of Ptolemy's map the west coast of the Balkans lay about ¾°–1⅔° further north than in the final version (see Fig. 5). For instance, in his table of *klimata* Hipparchus placed Apollonia at the latitude of the Hellespont (40° 55′ approximately equal to 41° in Ptolemy), while Ptolemy sited it at the latitude 40° 10′.[62] Marinus placed Cape Tainaron at the latitude of Rhodes (36°), while Ptolemy shifted it to 34⅓°.[63] Finally, it is striking that on Ptolemy's map the extreme points of Crete lie almost exactly on the line joining Cape Tainaron and Rhodes that, we may assume, initially passed along the parallel of Rhodes.[64]

There is also a hint that in the early version of the map the eastern part of the Balkans could have been further south than it is on the map we have, for both Hipparchus and Marinus placed Amphipolis on the Hellespont parallel, while Ptolemy has it at latitude 41½° (see Fig. 5).[65] It is difficult to imagine, however, that Ptolemy could have placed the eastern coast of Thrace further south, because its position on his map was firmly linked to the latitude of Byzantium (43° 5′) as determined by Hipparchus.[66] Consequently, the model of deformation for the Balkan region suggested below can be no more than tentative.

To arrive at a model, we need to bear in mind that Eratosthenes tied the north coast of Asia Minor (Amisus in particular) not to the parallel of Byzantium, but to that of the Hellespont (see Fig. 2).[67] He could therefore have placed Thrace at the same latitude. That he did is partly confirmed by the fact that according to Eratosthenes the parallel of the Hellespont passed through the Propontis (Sea of Marmara) whereas on Ptolemy's map the Propontis is north of this parallel.[68] Now, on Ptolemy's map, Apollonia, Amphipolis and Byzantium fall on precisely the same straight line (see Fig. 5). Furthermore, this line intersects both the Hellespont parallel (at 47° 47′ long., 40° 55′ lat.) and the line running through the northern bend of the Danube and the mountains of Scardus (at *c.*47° 35′, 40° 50′) at roughly the same place.

The force of this observation is to suggest that here lay the point of rotation for the whole Balkan region. If the region is rotated clockwise around this intersection until Apollonia is on the Hellespont parallel, Amphipolis and Byzantium are also moved to the same parallel and the line between Scardus and the northern bend in the Danube is pointing almost due north. If valid, the reconstruction is a further record of the adjustment of essentially Eratosthenic views to Hipparchus' net of latitudes embedded in Ptolemy's map of the world.

Italy

In the Almagest, Rome was placed 20° west of Alexandria.[69] In the Canon of noteworthy cities (a part of the Handy Tables) and in the Geography, the longitudinal interval between them increased to 24°10′ and 23° 50′, respectively.[70] But the interval between Rome (36⅓° long. in the Canon and 36⅔° in the Geography) and the point of intersection of its parallel (41⅔°) with the axis Alexandria–Byzantium works out at 20.19° or 19.86°, respectively (see Fig. 5).[71] In view of the extent to which Ptolemy usually rounded geographical coordinates, this is an acceptably close approximation to 20°.[72] Hence, we may infer that in the Geography the longitude of Rome was set in the same way as in the Almagest—as 20° west from the axis Alexandria–Byzantium—and that its westward shift was connected with the displacement of this axis.

From this it follows that initially Rome must have been placed on Ptolemy's map near the meridian of 40° running along the west coast of southern Italy, then near the Strait of Messina, and through the eastern extremity of Sicily (see Fig. 5). This conclusion is indirectly confirmed by the fact that this position for Rome agrees with the views of Eratosthenes, who placed Rome, the Strait of Messina and Carthage on the same meridian (F 65; compare Fig. 2).[73]

It also follows that Ptolemy's longitude of Rome with respect to Alexandria, unlike that of Babylon, was not recalculated from the 700-stade degrees in the Almagest to the 500-stade degrees in the Geography. Additional confirmation of this conclusion comes from the Dioptra of Heron of Alexandria (first century AD), a famous mathematician and engineer, who stated that the distance between Alexandria and Rome along the great circle is 14,000 stades or 20° according to Eratosthenes.[74] Heron's value is surprisingly close to Ptolemy's for the distance between Alexandria and Rome when this is calculated by formula (1): 21.85° in the Geography and 19.24° in the Almagest (provided that the latitude of Rome is the same as in the Geography; see Fig. 5). Had Ptolemy recalculated the distance of 14,000 stades to the 500-stade degrees, he would have placed Rome about 8½° further west.

The findings presented in this paper lead to the conclusion that part of Ptolemy's map of the world represents Eratosthenes' data translated from stades to degrees according to Eratosthenes' scale (1° = 700 stades). It is tempting to assume that this part is a remnant of an earlier version of Ptolmey's map that was based entirely on Eratosthenes' scale. If so, that early version must have looked considerably different from the image we are accustomed to seeing on Ptolemy's map today. On it, all distances, including for instance, the length of the Mediterranean, would have been 1.4 times shorter in angular terms when measured in Eratosthenes' 700-stade degrees as opposed to being expressed in Ptolemy's 500-stade degrees.

However, the situation is not the simple matter of a blanket conversion. Within Ptolemy's map, different scales prove to be sometimes closely intertwined. For example, the longitude of Rome reckoned in Eratosthenes' degrees is embedded within the area of the map where the distances are normally expressed in 500-stade degrees. The distance from Cape Syagros, in Arabia, to the Indus delta, on the contrary, is expressed in the 500-stade degrees although it is immediately adjacent to the 'Eratosthenic part' of the map.[75] The shift from one scale to another was inconsistent, entailing radical and (for us) unexpected alterations in the layout of the map. These observations open promising new perspectives for further studies in the history of ancient geography.

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APPENDIX. Eratosthenes' distances corresponding to those on Ptolemy's map when 1° = 700 stades.[76]

Distances on Ptolemy's map are computed in three different ways: (1) the distance between two points on the same meridian is equal to the angular difference between their latitudes converted to stades at the rate of 1° = 700 stades; (2) the distance between two points on the same parallel is equal to the angular difference between their longitudes multiplied by the length in stades of a degree of longitude at the nearest *klima* (660 stades at 20° lat., 640 stades at 23° 51′, 600 stades at 31°, 560 stades at 36°); (3) the distance between two points with different longitudes and latitudes is calculated trigonometrically using formula (1), given in the text.

Distance	In stades	Source	Corresponding distance on Ptolemy's map	
			coordinates in degrees	in stades
Main dimensions of the second *sphragis* (Ariana) measured along the meridian or a parallel of latitude (stated in parenthesis)				
Length from the Caspian Gates to the Indus[77]	14,000	F 37, 78	between 119° and 94° long. (at 36°, the latitude of Rhodes)	25° = 14,000
Breadth from the Taurus along the Indus to its mouth	12,000–13,000	F 78; cf. 12,000, according to Patroclus (Strabo 2.1.7 C70), or 13,000, as 'usually said': F 69; see also F 72.	between 39° and 20° lat. (along the meridian)	19° = 13,300
Length of the southern coast of Ariana from the mouth of the Indus to the eastern boundary of Carmania + the coast of Carmania up to the mouth of the Persian Gulf	10,000[78] and 6,000[79]	F 78 F 72	between 119° and 104° long. and between 104° and 94° long. (at 20°, the latitude of Napata)	15° = 9,900 and 10° = 6,600
Breadth from 'certain promontories' in the Erythrean Sea (the Indian Ocean) to the Caspian Gates	8,000–9,000 and 3,000[80]	F 83	between 34½° and 22° 10′ lat. and between 39° and 34½° lat. (along the meridian)	12⅓° = 8,633 and 4½° = 3,150
Main dimensions of the third sphragis				
Length from Babylon to the eastern boundary of Persis[81]	9,000	F 27; or more precisely, 9,200 in F 83, 84	between 94° and 79° long. (at 31°, the latitude of Alexandria; see Eratosthenes F 60)	15° = 9,000
Distance from the mouth of the Tigris and Euphrates to Babylon	3,000 or 3,300	F 83, 84; Arrian, *Indica* 2.41.8 (see note 50)	between 35° and 31° or 30¼° lat. (along the meridian)	4° = 2,800 or 4¾° = 3,325
Distances measured along the meridian or a parallel of latitude (stated in parenthesis)				
Length of the Persian Gulf from its mouth to the opposite coast[82]	9,000	F 9	between 93° or 94° and 79° or 80° long. (at 23° 51′, the latitude of Syene)	14° = 8,960
Breadth of the Caspian Sea (along the meridian)	6,000	Strabo 2.1.17 C74	between 48° 50′ and 40° lat. (along the meridian)	8° 50′ = 6,183
Babylon – Susa	3,400	F 85	between 84° and 79° long. (at 31°)	5° = 3,000
Susa – Persepolis	4,200	F 86	between 91° and 84° long. (at 31°)	7° = 4,200
Persepolis – Carmania	1,600	F 86	between 94° and 81° long. (at 31°)	3° = 1,800
Coast of Susiana and Persis	4,300 or 4,400	F 86; cf. Arrian, *Indica* 38.1 (see note 50)	between 94° and 86½° (at 31°)	7½° = 4,500
Distances measured between two points at different latitudes				
Northern side of Asia Minor from the Kyanean Rocks to the mouth of the Phasis[83]	8,000	F 52	between 56½° long., 45° lat. and 72½° long., 43° lat.	8,100
Southern side of Asia Minor from Rhodes to Issus	5,000	F 13; cf. F 52	between 69½° and 60½° long. (at 31°, the latitude of Alexandria)	9° = 5,040
Mt. Caspius – Jaxartes	22,670	F 108	between 79° long., 42½° lat. and 123°, 47°, or between 80½°, 40° and 125°, 43°	21,806 – 23,151
Bactra – Jaxartes	5,000	F 108	between 116° long., 41° lat. (Bactra) and a certain point at the upper course of the Jaxartes	5,000

NOTES AND REFERENCES

1. Ptolemy lists 6,345 coordinate points with precision to 5 minutes and 1,404 place-names without coordinates: Alfred Stückelberger, 'Masse und Messungen', in *Klaudios Ptolemaios: Handbuch der Geographie. Ergänzungsband mit einer Edition des Kanons bedeutender Städte*, ed. A. Stückelberger and F. Mittenhuber (Basel, Schwabe, 2009), 241. Ptolemy also employed methods of spherical trigonometry and cartographical projections.

2. Leif Isaksen, 'Lines, damned lines and statistics: unearthing structure in Ptolemy's *Geographia*', *e-Perimetron* 6:4 (2011): 260; idem, 'Ptolemy's Geography and the birth of GIS' (2012): http://www.dh2012.uni-hamburg.de/conference/programme/abstracts/ptolemys-geography-and-the-birth-of-gis (accessed 25 Feb. 2017).

3. The text of the Geography has been transmitted in two recensions commonly denoted as Ξ and Ω. While both descend from antiquity, no extant manuscript is older than the late 13th century. The Ξ recension is considered to be earlier and more authentic, but it is represented by a sole manuscript, Vaticanus Graecus 191 (*c.*1295). Unfortunately, it omits all coordinates for the eastern half of the map (that is, for Asia, except Asia Minor and Asiatic Sarmatia), which is central to my analysis, and I have been obliged to rely on the Ω recension. For a detailed discussion of the manuscripts, see Paul Schnabel, *Text und Karten des Ptolemäus* (Leipzig, K.F. Koehlers, 1938); Renate Burri, 'Übersicht über die griechischen Handschriften der ptolemäischen Geographie', in Stückelberger and Mittenhuber, *Ergänzungsband* (see note 1), 10–25; idem, *Die 'Geographie' des Ptolemaios im Spiegel der griechischen Handschriften* (Berlin, De Gruyter, 2013).

4. For the chronology of Ptolemy's works, see Paul Schnabel, 'Die Entstehungsgeschichte des kartographischen Erdbildes des Klaudios Ptolemaios', *Sitzungs-Berichte der Preussischen Akademie der Wissenschaften*, Philologisch-historische Klasse 14 (1930): 214–50; Otto Neugebauer, *A History of Ancient Mathematical Astronomy*, pt. 1–3 (Berlin, Springer, 1975), 835, 934, 939; and Burri, *Die 'Geographie' des Ptolemaios* (see note 3), 30–3, 45–48.

5. The coordinates mentioned in Ptolemy's Book I do not always agree with those for the same places in the other books of the Geography. See Antonin Wurm, *Marinus of Tyre (Some Aspects of His Work)* (Chotěboř, B. Stýblo, 1931), https://drive.google.com/open?id=0ByHnqj0cHCZMU3pQOWJtcDgzVFk (accessed 25 Feb. 2017), 35 n.41; Erich Polaschek, 'Ptolemy's Geography in a new light', *Imago Mundi* 14 (1959): 33 n.46; idem, 'Klaudios Ptolemaios: Das geographische Werk', in *Paulys Real-Encyclopädie der classischen Alterthumswissenschaft*, Suppl.-Bd. 10 (Stuttgart, J.B. Metzler, 1965), 696, 699; Elisabeth Rinner, *Zur Genese der Ortskoordinaten Kleinasiens in der Geographie des Klaudios Ptolemaios* (Bern, Tilman Sauer, 2013), 116, 122–24.

6. The most important works on Ptolemy's Geography are Josef Fischer, *Claudii Ptolemaei Geographiae Codex Urbinas Graecus 82, Tomus prodromus* (Leiden, E.J. Brill; Leipzig, O. Harrassowitz, 1932), 56–90; Polaschek, 'Klaudios Ptolemaios' (see note 5); John L. Berggren and Alexander Jones, *Ptolemy's* Geography*: An Annotated Translation of the Theoretical Chapters* (Princeton, Princeton University Press, 2000), 3–54; Stückelberger and Mittenhuber, *Ergänzungsband* (see note 1), with further bibliography.

7. The seminal edition is now that of Alfred Stückelberger and Gerd Graßhoff, *Klaudios Ptolemaios: Handbuch der Geographie. Griechisch—Deutsch. Einleitung, Text und Übersetzung*, vols. 1–2 (Basel, Schwabe, 2006). Previous editions by Friedrich Wilhelm Wilberg (1838), Karl Friedrich August Nobbe (1843–1845), and Karl Müller and Curt Theodor Fischer (1883, 1901) are out of date.

8. Robert Darcy and William Flynn, 'Ptolemy's map of Ireland: a modern decoding', *Irish Geography* 41:1 (2008): 49–69; Evangelos Livieratos et al., 'Ptolemy's Geographia in digits', *e-Perimetron* 3:1 (2008): 22–39; Angeliki Tsorlini, 'Higher order systematic effect in Ptolemy's Geographia coordinate description of Iberia', *e-Perimetron* 4:2 (2009): 117–30; Andreas Kleineberg et al., *Germania und die Insel Thule. Die Entschlüsselung von Ptolemaios' 'Atlas der Oikumene'* (Darmstadt, WBG, 2010); Andreas Kleineberg, Christian Marx and Dieter Lelgemann, *Europa in der Geographie des Ptolemaios. Die Entschlüsselung des 'Atlas der Oikumene': Zwischen Orkney, Gibraltar und den Dinariden* (Darmstadt, WBG, 2012); Christian Marx and Andreas Kleineberg, *Die Geographie des Ptolemaios. Geographike Hyphegesis Buch 3: Europa zwischen Newa, Don und Mittelmeer* (Berlin, epubli GmbH, 2012); Rinner, *Zur Genese* (see note 5).

9. Schnabel, 'Entstehungsgeschichte' (see note 4).

10. On Eratosthenes' measurement of the earth, see Christián C. Carman and James Evans, 'The two earths of Eratosthenes', *Isis* 106:1 (2015): 1–16. The two main studies on Eratosthenes' geographical fragments are by Hugo Berger, *Die geographischen Fragmente des Eratosthenes* (Leipzig, 1880); and by Duane W. Roller, *Eratosthenes'* Geography. *Fragments Collected and Translated, with Commentary and Additional Material* (Princeton, Princeton University Press, 2010). References to Eratosthenes are to Fragments (F) as established by Roller.

11. Before Ptolemy this value was used only twice, by Marinus of Tyre, Ptolemy's immediate predecessor in geography, and by the Stoic philosopher Posidonius (*c.*135–51 BC). For a detailed discussion, see Dmitry A. Shcheglov, 'The accuracy of ancient cartography reassessed: the longitude error in Ptolemy's map', *Isis* 107:4 (2016): 692 n.16.

12. As Wurm's works were published in rare editions, they have failed to attract the attention they deserve: Antonin Wurm, *Rozbor Ptolemaiovy osmé mapy Asie* (Chotěboř, B. Stýblo, 1926), https://drive.google.com/open?id=0ByHnqj0cHCZMcWxaUDZvdkEwU2M (accessed 18 Feb. 2017); idem, *Marinus of Tyre* (see note 5); idem, *Mathematické základy mapy Ptolemaiovy* (Chotěboř, B. Stýblo, 1937), https://drive.google.com/open?id=0ByHnqj0cHCZMdmNpdkE2NEJxQTQ (accessed 18 Feb. 2017); idem, *O vzniku a vývoji mapy Ptolemaiovy* (Chotěboř, B. Stýblo, 1940), https://drive.google.com/open?id=0ByHnqj0cHCZMZVdOQ3hDMWJRbnM (accessed 18 Feb. 2017).

13. On the astronomically observed coordinates see, for example, Florian Mittenhuber, 'Falsche Breitenwerte und ihre Folgen', in Stückelberger and Mittenhuber, *Ergänzungsband* (note 1), 245–52. For a list of places whose latitudes featured on ancient portable sundials, see Richard J. A. Talbert, *Roman Portable Sundials: The Empire in Your Hand* (Oxford, Oxford University Press, 2017).

14. The length of the stade is one of the most vexed issues of ancient geography. The overwhelming majority of ancient sources use the ratio of 1 Roman mile to 8 Greek stades. The Roman mile is the most secure of ancient distance units, totalling approximately 1,480 metres, making one 'common' stade equal to *c.*185 metres.

15. A similar opinion is found in Otto Cuntz, *Die Geographie des Ptolemaeus, Galliae Germania Raetia Noricum Pannoniae Illyricum Italia. Handschriften, Text und Untersuchung* (Berlin, Weidmann, 1923), 110; J. Oliver Thomson, *History of Ancient Geography* (Cambridge, Cambridge University Press, 1948), 343; and Gerd Graßhoff, 'Ptolemy and empirical data', in *Astroculture. Figurations of Cosmology in Media and Arts*, ed. S. Neef, H. Sussmann and D. Boschung (München, W. Fink, 2014), 40–42.

16. For further details, see Berggren and Jones, *Ptolemy's* Geography (note 6), 16–17.

17. This was the method Ptolemy used in Book I (chapters 11–13) of his Geography. Others (Dicaearchus, Eratosthenes, Polybius, Artemidorus, Strabo, Marinus) measured the length of the Mediterranean and of the whole oecumene along the parallel of Rhodes; Strabo, 2.1.1–2, C67–68; 2.1.33, C86; 2.5.8, C115; 2.5.14, C118; 2.5.19, C122.

18. On the role of *klimata* (κλίματα; sing. κλίμα) in structuring Ptolemy's map see Wurm, *Marinus of Tyre* (note 5), 20–21, 30; Isaksen, 'Ptolemy's Geography' (note 2).

19. This treatise is known mostly from quotations in Strabo's Geography. The two main studies on Hipparchus' geographical fragments are by Hugo Berger, *Die geographischen Fragmente des Hipparch* (Leipzig, 1869); and by David Dicks, *The Geographical Fragments of Hipparchus* (London, Athlon Press, 1960). In what follows, the fragment numbers of Hipparchus are taken from Dicks's edition. On Hipparchus' *klimata* see Dmitry A. Shcheglov, 'Hipparchus' table of climata and Ptolemy's Geography', *Orbis Terrarum* 9 (2003–2007): 159–92.

20. Ernst Honigmann, *Die sieben Klimata und die πόλεις ἐπίσημοι. Eine Untersuchung zur Geschichte der Geographie und Astrologie im Altertum und Mittelalter* (Heidelberg, C. Winter, 1929); Neugebauer, *A History of Ancient Mathematical Astronomy* (see note 4); Dmitry A. Shcheglov, 'Ptolemy's system of seven climata and Eratosthenes' geography', *Geographia Antiqua* 13 (2004): 21–37. The earliest account of this system is found in the Almagest (2.12–3); see *Claudii Ptolemaei opera quae exstant omnia*, vol. 1: *Syntaxis mathematica*, ed. J. L. Heiberg, pt. 1 (Leipzig, Teubner, 1903), 172–88. The system consists of seven parallels: through Meroe (13 hours of the longest day; 16° 27′), Syene (13½ hours; 23°51′), lower Egypt (14 hours; 30° 22′), Rhodes (14½ hours; 36°), the Hellespont (15 hours; 40° 56′), the middle of the Pontus (15½ hours; 45° 1′), and the mouth of the Borysthenes (16 hours; 48° 32′).

21. Polaschek, 'Ptolemy's *Geography*' (see note 5): 24; idem, 'Klaudios Ptolemaios' (see note 5): 701–2; Berggren and Jones, *Ptolemy's* Geography (see note 6), 16; José María Gómez Fraile, 'Sobre la antigua cartografía y sus métodos. Los fundamentos numéricos de la Hispania de Claudio Ptolomeo', *Iberia* 8 (2005): 47–55.

22. Shcheglov, 'Ptolemy's system' (see note 20), 26–27.

23. The frequency of different fractions of a degree in Ptolemy's catalogue of coordinates conforms to a normal distribution: the coordinates in integer degrees, without fractions, are the most frequent, those with ½° are less frequent, those with ⅓° or ⅔° are still less, those with ¼° or ¾° and $^{1}/_{6}$° or $^{5}/_{6}$° are, respectively, still less, and those with $^{1}/_{12}$°, $^{5}/_{12}$°, $^{7}/_{12}$° and $^{11}/_{12}$° are the rarest. On this, see Wurm, *Marinus of Tyre* (note 5): 25–27; Isaksen, 'Lines, damned lines and statistics' (note 2): 254–60; and Christian Marx, 'On the precision of Ptolemy's geographic coordinates in his Geographike Hyphegesis', *History of Geo- and Space Sciences* 2:1 (2011): 29–37.

24. Examples of his rounding include: 1° of longitude at the latitude of Rhodes (36°) equals 500 stades × cos 36°, or 404.5 stades, but Ptolemy always rounds the figure to 400 stades; for the road from Hierapolis to the Stone Tower, Ptolemy (1.12) uses the scale of 400 stades to 1°, despite the fact that the latitude of the Stone Tower was 43° (where 1° long. is approximately 366 stades) and a large part of the road passed closer to this latitude than to 36°; for India and Indochina, Ptolemy (1.13) presumes that a degree of longitude on these latitudes (10°–15°) is almost the same as on the equator, that is 500 stades, when in fact 1° of longitude at these latitudes is equal to 490–480 stades. Despite all such rounded figures given in Book I, it should be recalled that these are liable to contradict the coordinates assigned to the same points in the following Books; see Rinner, *Zur Genese* (note 5), 116, 122–24. The discrepancies could indicate that Ptolemy was using slightly different, and probably more accurate, methods of mapping in the other Books.

25. Thus, Eratosthenes claimed that, since the length of India from east to west was 16,000 stades in the north and 19,000 stades in the south, its southeastern extremity was situated 3,000 stades east of the northeastern one. In fact, owing to the difference in latitude, these 16,000 stade and 19,000 stade measurements corresponded to nearly equal longitudinal intervals. Compare with Strabo's Geography 2.1.34, 39, C86, 91.

26. On these distances see Wurm, *Marinus of Tyre* (note 5), 20–21; Berggren and Jones, *Ptolemy's* Geography (note 6), 153–54. On Marinus see Ernst Honigmann, 'Marinos 2', in *Paulys Real-Encyclopädie der classischen Alterthumswissenschaft*, Bd. 14:2 (Stuttgart, J.B. Metzler, 1930), 1767–94.

27. Gaetano M. Columba, *Gli studi geografici nel i secolo dell' impero romano. Ricerche su Strabone, Mela e Plinio*, pt. I: *Le dimensioni della terra abitata* (Torino, 1893), 124–29. The edition of Strabo's Geography that I am using is Stefan Radt, *Strabons Geographika: mit Übersetzung und Kommentar*, vols. 1–10 (Göttingen, Vandenhoeck & Ruprecht, 2003–2011).

28. In effect, it is Wurm who has supplied the most important contribution to Ptolemy's use of Eratosthenes' scales for this part of the map. For the sake of justice, he should be considered a co-author of this section. For references see note 12. See also Friedrich Sarre and Ernst E. Herzfeld, *Archäologische Reise im Euphrat- und Tigris-Gebiet*, vol. 1 (Berlin, D. Reimer / E. Vohsen, 1911), 143–53; Shcheglov, 'Ptolemy's system' (note 20): 30–31.

29. There is no evidence that Eratosthenes ever created a map of the world; his Geography is, like Ptolemy's Book I, a description of how to draw one, although clearly he had a map in his mind.

30. Strabo, Geography, 2.1.1–38 C68–91. On *sphragides*, see Berger, *Die geographischen Fragmente des Eratosthenes* (note 10), 224–64.

31. Translation is by H. Rackham (with a slight alteration): Pliny, *Natural History*, vol. II: *Books 3–7*, Loeb Classical Library 352 (Cambridge, MA, Harvard University Press, 1942), 414–15; the Latin text reads as 'ab Syagro Arabiae promunturio Patalen favonio, quem Hippalum ibi vocant, peti certissimum videbatur, XIII XXXII p[assi] aestimatione'. On the Greek navigator Hippalus, see Scott

Hatcher, 'The birth of the monsoon winds: on the existence and understanding of Hippalus, and the 'discovery' of the Apogeous trade winds', *Terrae Incognitae* 45:1 (2013): 19–29.

32. When computed by formula (1), the distance between Cape Syagros and the Indus delta on Ptolemy's map ranges between 20.29° = 10,145 stades (to the westernmost mouth at 110⅓° long., 19° 50′ lat.) and 23.13° = 11,565 stades (to the easternmost one at 113⅓°, 20¼°), which agrees with Pliny 6.101.

33. Compare with Sarre and Herzfeld, *Archäologische Reise* (see note 28), 147 n. 2; Wurm, *O vzniku* (see note 12), 24.

34. Wurm, *Mathematické základy* (see note 12), 11; idem, *O vzniku* (see note 12), 7.

35. Schnabel, 'Entstehungsgeschichte' (see note 4), 218–19. This explanation was accepted by Wurm, *O vzniku* (see note 12), 9; Polaschek, 'Klaudios Ptolemaios' (see note 5), 682; Neugebauer, *A History of Ancient Mathematical Astronomy* (see note 4), 939; Berggren and Jones, *Ptolemy's* Geography (see note 6), 20; Dennis Rawlins, 'The Ptolemy *GEOGRAPHY*'s Secrets', *DIO* 14 (2008): 37 n.13.

36. In the Almagest the latitude of Babylon is not stated explicitly. But the angle between the horizon and the ecliptic calculated by Ptolemy for Babylon (13.7, 8; see note 20) corresponds to the latitude of 35°.

37. Bear in mind that Eratosthenes placed Alexandria and Babylon at about the same latitude.

38. Schnabel, 'Entstehungsgeschichte' (see note 4), 219; Wurm, *O vzniku* (see note 12), 9.

39. See note 36.

40. The astrological *klimata* are known in several variants: Vettius Valens, *Anthologia* 1.7; Firmicus Maternus, *Mathesis* 2.11; *Michigan papyrus* 149: XI 38–47. See Honigmann, *Die sieben Klimata* (note 20), 31–50; idem, 'Die Anaphorai der Alten Astrologen. Ein Versuch, die Anaphorai und Klimata des Michigan-Papyros 149 zu erklären', in *Michigan Papyri*, vol. 3: *Papyri of the University of Michigan Collection. Miscellaneous Papyri*, ed. J. G. Winter (Ann Arbor, University of Michigan Press, 1936), 301–21; Neugebauer, *A History of Ancient Mathematical Astronomy* (note 4), 706–33. Hipparchus F 11, 22, 26. See Honigmann, 'Die Anaphorai' (above in this note); Shcheglov, 'Hipparchus' table of climata' (note 19), 185–87; Rawlins, 'The Ptolemy *GEOGRAPHY*'s secrets' (note 35), 49.

41. Strabo placed Babylon on the parallel of Alexandria in his account of Hipparchus' table of *klimata* (2.5.38 C133). But since elsewhere Hipparchus is confidently stated to have placed Babylon much further to the north, the former evidence is considered as an insertion from Eratosthenes (F 60); for details, see Berger, *Eratosthenes* (note 10), 192–93, 264; Dicks, *The Geographical Fragments of Hipparchus* (note 19), 137; Shcheglov, 'Hipparchus' table of climata' (note 19), 182.

42. Compare Florian Mittenhuber, 'Falsche Breitenwerte und ihre Folgen', in Stückelberger and Mittenhuber, *Ergänzungsband* (see note 1), 251, fig. 3; Gerhard Winkler and F. Mittenhuber, 'Die Länderkarten Asiens', in ibid., 294–95.

43. F 83; compare F 63, 87.

44. Measurements of the angles between different parts of these lines and the parallel in JOSM (Java OpenStreetMap Editor) gives Babylon–Susa, 10.3°; Susa–Persepolis, 9°; the boundary between Media and Persis, 10.4°; the boundary between Parthia and Carmania Deserta, 10.6°; Teredon–Bagradas, 9°; the boundary between Carmania and Carmania Deserta, 10.9°; the boundary between Drangiana and Gedrosia, 11.3°. Thus, all values, except the last, lie between 9° and 11°.

45. The line through Ctesiphon (80° long., 35° lat.)–Axima (87¾°, 33° 50′)–Persepolis with the inclination of 10.4° measured in JOSM (see note 44) can be taken instead. Whichever is used, it is reasonable to assume that Axima was initially connected with the line Babylon–Susa–Persepolis.

46. F 60. On this parallel, see Berger, *Die geographischen Fragmente des Eratosthenes* (note 10), 192–93; and Dicks, *The Geographical Fragments of Hipparchus* (note 19), 137.

47. F 47; F 108; compare Strabo 11.8.1, 12.4 C511, 522.

48. The simple arithmetic calculation—made on the understanding that degrees are not set out as angular values on a sphere, but as linear units on a plane—gives the result: 35° – (111½° – 79°) × (35° – 33⅓°) / (90¼° – 79°) = 30.19°.

49. According to Sarre and Herzfeld, *Archäologische Reise* (see note 28), 151, the distance from Thapsacus to Babylon as measured on Ptolemy's map along the winding course of the Euphrates totals 4,800 stades in Eratosthenes' degrees.

50. The three sections are described in Eratosthenes F 62, 63, 83, 84, 87, 94. In the case of the second section, Nearchus, Eratosthenes' source, gives the more precise figure of 3,300 stades: see also Strabo 15.3.5 C729, 16.1.9 C739–4; Arrian, *Indica* 2.41.8; see Arrian. *Anabasis of Alexander*, vol. II: *Books 5–7, Indica*, transl. by P. A. Brunt, Loeb Classical Library 269 (Cambridge, MA, Harvard University Press, 1983).

51. This conclusion disagrees with Ptolemy's placing of Babylon at latitude 35° in the Almagest (see note 36), which could imply that Ptolemy's information on Babylon came from different sources: its coordinates (79° long., 35° lat.) were of Hipparchian origin, whereas the source underlying Ptolemy's outlines of the Middle Eastern part of the map, with Babylon placed at about 30°–31° lat., went back to Eratosthenes.

52. Eratosthenes F 25, 34, 35.

53. According to Strabo, Hipparchus put Byzantium, probably not mentioned by Eratosthenes in this connection, on this meridian (Strab. 2.1.10, 12 C70, 72; Eratosthenes F 30, 35, 39); Posidonius placed Rhodes and Alexandria on it according to F 202 Edelstein-Kidd; Strabo noted that the whole coast of Asia Minor between Rhodes and Byzantium is situated along this meridian: 2.5.7 C114; 13.1.6 C584; 14.5.22 C677; for Ptolemy, see the Almagest 5.3 (see note 20).

54. Before Ptolemy, Artemidorus could already have placed Rhodes to the west of Alexandria (Strabo 14.3.8 C666), as Marcus Vipsanius Agrippa (63–12 BC) might have done in his geographical commentaries; see Paul Schnabel, 'Die Weltkarte des Agrippa als wissenschaftliches Mittelglied zwischen Hipparchos und Ptolemaios', *Philologus* 90 (1935): 418–20, 424; Wurm, *Mathematické základy* (note 12), 15–6; idem, *O vzniku* (note 12), 17, 20–22.

55. First pointed out by Francis J. Carmody, 'Ptolemy's triangulation of the eastern Mediterranean', *Isis* 67:4 (1976): 606, 608.

56. Almagest 7.3 (see note 20).

57. Schnabel, 'Entstehungsgeschichte' (see note 4), 218.

58. F 47, 51 Roller; F IIIA36 Berger; but see Strabo, 11.11.7, C519, 14.5.22, C677. Eratosthenes' opinion on this point seems to have been criticized by Hipparchus: Berger, *Die geographischen Fragmente des Eratosthenes* (see note 10), 205.

59. Carmody, 'Ptolemy's triangulation' (see note 55), 608–9; Rinner, *Zur Genese* (see note 5), 284 n.VII.1. In rejecting Eratosthenes' prime meridian, Ptolemy disposed of one error, but as a result marred the map even more.

60. The angle of the line Amisus–Issus relative to the meridian, measured in JOSM (see note 44) is 26.3°, and that of the line between the Scardus mountains and the bend in the Danube is 26.7°.

61. Strabo, Geography, 7 F 9–10 and 7.5.1, C313. Strabo, *Geography*, Vol. III: *Books 6–7*, transl. H. L. Jones, Loeb Classical Library 182 (Cambridge, MA, Harvard University Press, 1924), 251, 329.

62. Hipparchus, F 51.

63. For Marinus see Ptolemy, Geography 1.12.11. Further evidence that Cape Tainaron was initially located at about the latitude of Rhodes is provided by ancient estimates of the distance between capes Tainaron and Phycus in Libya as 2,800 stades (Strabo 2.5.20, C83; 17.3.20 C837; Pliny 5.32). In Ptolemy this distance is only 2½° = 1,750 stades in Eratosthenes' degrees.

64. Edward H. Bunbury, *A History of Ancient Geography: Among the Greeks and Romans, from the Earliest Ages till the Fall of the Roman Empire*, 2nd ed. (New York, Dover Publications, 1959), 2: 56, noticed the relationship of Cyprus with this line, as has Jürgen Heß, 'Die Themelioi des Claudius Ptolemaios' (2013), http://www.juergenhess.org/themen/die-themelioi-des-ptolemaios (accessed 19 Feb. 2017).

65. For Hipparchus, see F 51. For Marinus, see Ptolemy, Geography, 1.15.7. According to Ptolemy, Marinus put Amphipolis in the fourth *klima*, which was bounded in the north by the parallel of the Hellespont.

66. Hipparchus, F 52 .

67. F 47, 60. This idea is also attested in the so-called table of *circuli* by Pliny 6.216. On this table see Pierre Schneider, 'Les "climats" de Pline l'Ancien (*N.H.* 6, 212–220): essais de transcriptions graphiques', *Geographia Antiqua* 20–21 (2011–2012): 179–204.

68. Eratosthenes F 47.

69. Ptolemy, Almagest, 7.3 (see note 20).

70. For Ptolemy's Canon, see Stückelberger and Mittenhuber, *Ergänzungsband* (note 1), 162. Geography (3.1.54). Schnabel, 'Entstehungsgeschichte' (see note 4), 218–19, argued that this difference was also due to the switch from the 700-stade to the 500-stade degree, as was the case with the longitude of Babylon. But the recalculation of the longitudinal distance between Alexandria and Rome stated in the Almagest gives 20° × 1.4 = 28°, which is 4° 10′ more than the value stated in the Geography. Wurm in his *Mathematické základy* (see note 12), 15–16, and his *O vzniku* (see note 12), 14–15, 18–21, noted that the longitude of Rome in the Geography agrees with Eratosthenes' distance between Canobus and Carthage, supposed to lie on the same meridian as Rome (F 37): 13,500 stades = 24.1° in Eratosthenes' degrees at the latitude of Rhodes (where 1° = 560 stades), which gives the longitude of Rome as 60¾° – 24.1° = 36.65°.

71. $\Lambda - (60\frac{1}{2}° - 56°) / (43°\ 05' - 31°) \times (41\frac{2}{3}° - 31°)$, where Λ is Ptolemy's longitude of Rome.

72. See note 23.

73. Placing Rome at the same longitude as eastern Sicily raises the question how the whole of southern Italy could have been squeezed in between them? One answer might be that Eratosthenes had placed Sicily further to the south than did Hipparchus and Ptolemy. According to Eratosthenes, the parallel of Rhodes ran through the Strait of Messina (F 47), that is through the northern extremity of Sicily, and not through the southern one, as in Ptolemy (see Fig. 5). The early version of Ptolemy's map might have followed Eratosthenes in this respect.

74. Dioptra 35.27. See Neugebauer, *A History of Ancient Mathematical Astronomy* (note 4), 845–48; Nathan Sidoli, 'Heron's Dioptra 35 and analemma methods: an astronomical determination of the distance between two cities', *Centaurus* 47 (2005): 236–58.

75. Similar observations were made for the Middle East by Wurm, *Mathematické základy* (see note 12), 8–10; idem, *O vzniku* (see note 12), 11–12.

76. Some of these examples have been noted by Berger, *Die geographischen Fragmente des Eratosthenes* (see note 10), 275 n.1; Sarre and Herzfeld, *Archäologische Reise* (see note 28), 142; Wurm, *Mathematické základy* (note 12), 7–8, 13; idem, *O vzniku* (note 12), 7–8, 11.

77. Noted by Wurm, *Mathematické základy* (see note 12), 4, 12; idem, *O vzniku* (see note 12), 7–8; Shcheglov, 'Ptolemy's system' (see note 20), 31.

78. Eratosthenes' source here, Nearchus, gives a more precise figure of 10,200 stades (F 77); compare with 'a little more than' 10,000 stades according to Nearchus in Arrian, *Indica* (see note 50) 2.29.8.

79. For the coast of Carmania, Eratosthenes' F 77 gives an alternative estimate of 3,700 stades. But, as Arrian, *Indica* (see note 50) 33.2, 38.1 shows, this figure referred most probably to the coast of the Persian Gulf from Harmozeia to the border of Persia; on this point, see Berger, *Die geographischen Fragmente des Eratosthenes* (note 10), 250, 275–76.

80. That these figures originally referred to the western side of Ariana was shown by Berger, ibid., 263, 276. 'Certain promontories' in the Red Sea are evidently the same as Cape Harmozai situated at the mouth of the Persian Gulf, according to Eratosthenes (F 94, compare. Strabo 15.2.14 C726). The two distances represented the length of Persis and that of Paretacene with a part of Media to the Caspian Gates, respectively. It is worth noting that whereas Eratosthenes located the Caspian Gates at the latitude of the trans-Asiatic mountain range, Ptolemy separates them, placing the Gates at 37¼° and the range at 39°. It is reasonable, therefore, to draw the second distance on Ptolemy's map up to 39°, rather than 37¼°; for further argumentation, see Wurm, *Mathematické základy* (note 12), 7, 13; idem, *O vzniku* (note 12), 7.

81. Sarre and Herzfeld, *Archäologische Reise* (see note 28), 151–52; Shcheglov, 'Ptolemy's system' (see note 20), 30–31.

82. Noted by Aloys Sprenger, *Die alte Geographie Arabiens* (Bern, 1875), 111; Wurm, *Mathematické základy* (see note 12), 7, 13; idem, *O vzniku* (see note 12), 11.

83. Noted by Sarre and Herzfeld, *Archäologische Reise* (see note 28), 147 n.2; Wurm, *O vzniku* (see note 12), 24.

La contribution d'Eratosthène à la carte du monde de Ptolémée

Cet article tente d'éclairer les origines de la carte du monde de Ptolémée, qui demeurent mystérieuses. On fait l'hypothèse que Ptolémée et d'autres géographes de l'Antiquité s'appuyèrent en grande partie sur un ensemble identique ou similaire de sources et de croyances communes. Les ressemblances entre ces sources peuvent donc nous fournir une clé pour comprendre la préhistoire de la carte de Ptolémée. La comparaison des distances sur sa carte avec celles que fournissent d'autres sources conduit à la conclusion qu'une grande partie de la carte, à peu près du Bosphore à l'Indus, reproduit le système géographique d'Eratosthène, avec des distances linéaires converties en degrés angulaires selon la propre échelle d'Eratosthène. On soutient que cette partie constitue un vestige d'une version antérieure de la carte de Ptolémée. L'analyse des latitudes et des longitudes révèle des différences notables entre la carte de Ptolémée et les idées d'Eratosthène concernant la latitude de Babylone et le méridien d'origine d'Alexandrie, et l'on relève l'influence que cela semble avoir eu sur la forme des régions avoisinantes.

Eratosthenes Anteil an der Weltkarte des Ptolemäus

In diesem Beitrag sollen die Quellen der Weltkarte des Ptolemäus beleuchtet werden, die noch immer nicht bestimmt werden konnten. Als These formuliert der Autor, dass sich Ptolemäus und andere antike Geographen weitgehend auf die gleichen oder eine ähnliche Gruppe von Quellen und auf Allgemeinwissen stützten. Ähnlichkeiten zwischen ihren Werken können aus diesem Grund ein Schlüssel zum Verständnis der Vorgeschichte der Ptolemäischen Karte sein. Der Vergleich von Distanzen in seiner Karte mit denen in anderen Quellen führt zu dem Schluss, dass ein großer Teil—in etwa vom Bosporus zum Indus—das geographische System des Eratosthenes zitiert. Hierbei wurden die linearen Distanzen entsprechend den Werten des Eratosthenes in Winkelangaben umgewandelt. Der Autor legt dar, warum dieser Bereich den Rest einer älteren Karte des Ptolemäus wiederspiegelt. Die Analyse der geographischen Längen und Breiten zeigen größere Unterschiede zwischen der Karte des Ptolemäus und den Ideen des Eratosthenes in Bezug auf die Breite von Babylon und den Nullmeridian von Alexandria. Dies hatte Auswirkungen auf die Darstellung der jeweils benachbarten Regionen.

La contribución de Eratóstenes al mapa del mundo de Ptolomeo

Este artículo pretende arrojar algo de luz sobre los orígenes del mapa del mundo de Ptolomeo, que aún hoy sigue siendo un misterio. La premisa es que Ptolomeo y otros geógrafos de la Antigüedad se basaron en gran medida en las mismas o similares fuentes y en creencias populares. Las similitudes entre ellos pueden, por lo tanto, aportar una clave para entender la prehistoria del mapa de Ptolomeo. El cotejo de las distancias en su mapa con las aportadas por otras fuentes permite concluir que en un gran área del mapa, aproximadamente del Bósforo al Indo, reprodujo el sistema geográfico de Eratóstenes, con distancias lineales convertidas en grados angulares según los propios datos de escala de Eratóstenes. Se explica que el análisis de latitudes y longitudes revela diferencias notables entre el mapa de Ptolomeo y las ideas de Eratóstenes sobre la latitud de Babilonia y el primer meridiano de Alejandría, y se pone de relieve el impacto que esto parece haber tenido sobre la forma que las regiones vecinas adoptan.