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Hellenistic scholars have been the first to link the geographical description of the known world with a mathematical investigation of the terrestrial sphere. The definition of mathematical concepts devoted to geography and cartography – meridians and parallels, geographical coordinates for example – enabled the development of a specific branch of geographical knowledge. Already in the second century CE, Ptolemy was able to produce maps based on the latitude and the longitude of localities. Compared to more traditional literary geography, mathematical geography did not arise a strong interest among scholars of the Roman and Byzantine periods. This has incited modern historians to impute a global disregard for mathematical sciences to the "Roman geography".

Mathematical geography; cartography; Eratosthenes; Ptolemy; Roman geography; Pliny the Elder

Hellenistische Wissenschaftler haben als Erste die geographische Beschreibung der bekannten Welt mit einer mathematischen Untersuchung der Erde und ihrer Gestalt verbunden. Die Definition von mathematischen Begriffen, die der Geographie und Kartographie gewidmet wurden – wie Meridiane, Parallelkreise oder geographische Koordinaten – ermöglichte die Entwicklung eines spezifischen Zweiges der geographischen Wissenschaft. Aufgrund der Angabe zu Breite und Länge von Orten konnte Ptolemaios schon im 2. Jh. n. Chr. Karten produzieren. Im Vergleich zur traditionelleren literarisch beschreibenden Geographie hat aber mathematische Geographie weniger Erfolg in gelehrten Milieus in römischer und byzantinischer Zeit. Moderne Historiker interpretierten dies als ein Zeichen mangelnden Interesse seitens der „römischen Geographie" an mathematische Wissenschaft.

Mathematische Geographie; Kartographie; Eratosthenes; Ptolemaios; römische Geographie; Plinius der Ältere

1 Eratosthenes and the origins of the mathematical geography

The very beginning of mathematical geography[1] may be traced back to the moment where geographers gave up on describing and explaining the world thanks to the exegesis of Homer's works. Eratosthenes of Cyrene (c. 276–c. 194 BCE) is certainly the first who formulated clearly this separation, contending that "the aim of every poet is to entertain, not to instruct."[2] According to him, studying Homeric texts could not be an appropriate method to understand the world and would not provide any possibility to construct a reliable map of the *oikoumene*. The epistemological break performed by Eratosthenes is by no means to be underestimated. Of course, it does not mean that no critical debate

1 "Mathematical geography" is here understood as the study and description of the known world not only with textual means but also with the help of mathematical and astronomical tools and concepts. If the study is especially intended to build a map, one may speak of "mathematical cartography".

2 Str. *Geogr.* 1.2.3 (C16). Translation H. L. Jones 1917.

on geography involving mathematical and astronomical methods occurred before him.[3] Eratosthenes clearly stated, however, that the study of geography must have proper basis, which would be different than the sole Homeric exegesis.

The elaboration of a world map required, according to Eratosthenes, a mathematical knowledge of the world – "mathematical" being understood in a broad sense, including arithmetic, geometry and astronomy.[4] An estimation of the dimension of the *oikoumene* was thus possible if the circumference of the Earth – its spherical shape being admitted – has been previously accurately (that is, mathematically) determined.[5] In the first two books of Eratosthenes' *Geography* as well as in his treatise *On the Measurement of the Earth*,[6] he defined concepts (such as meridians or *klimata*[7]) which are based on geometrical and astronomical principles. The description and explanation of his map of the *oikoumene* took place only in a later stage, after these preliminaries.

Antique descriptions of the *oikoumene* or of some of its parts generally took the form of a *periplous* (where the sequential description of the coasts was the prime organising principle of the text) or were literary descriptions of inland regions with more or less details about topography, the inhabitants or history of the localities (one often speaks of *periegesis* or *periodos*).[8] Eratosthenes, by contrast, did not choose these describing forms but used abstract geometrical figures – rough quadrilaterals, as far as one knows thanks to Strabo's testimony – which defined portions of the *oikoumene*. These geometrical forms were certainly called *sphragides* (σφραγῖς, pl. σφραγῖδες) or simply "portions", "regions".[9] Eratosthenes defined his *sphragides* by giving their length and width; their limits were, as far as possible, formed by topographical elements (rivers or mountain range, for instance). Thanks to a main parallel circle, which Eratosthenes defined as running from the Strait of Hercules (the modern-day Strait of Gibraltar) to the west, until Rhodes and following the Taurus Mountains as far as Eastern India, the different *sphragides* were located on the map in order to represent the whole *oikoumene* and its parts in good proportions.

Hipparchus of Nicaea (c. 190–c. 126 BCE) criticized at length Eratosthenes' geographical writings. He was, however, like his predecessor, convinced that any geographical knowledge was impossible without understanding some fundamental mathematical principles:

> Hipparchus, too, in his treatise *Against Eratosthenes*, correctly shows that it is impossible for any man, whether layman or scholar, to attain to the requisite knowledge of geography without the determination of the heavenly bodies and of the eclipses which have been observed; for instance, it is impossible to determine whether Alexandria in Egypt is north or south of Babylon, or how much north or south of Babylon it is, without investigation through the means of the *klimata*.[10]

3 In all likelihood, Eratosthenes' geography and cartography were rooted in the works of Eudoxus of Cnidus (c. 395–342 BCE), Dicaearchus (a disciple of Aristotle) and Pytheas of Massalia – both of the fourth century BCE – all of whom seem to have already developed mathematical and astronomical concepts, orientated towards the study of the Earth and the known world. See Harley and Woodward 1987b, 140–147, and Harley and Woodward 1987c, 148–153.

4 See the acceptations in Plato, *Lg*. 817e and Aristotle, *Phys*. 2.2 [193b23], *Metaph*. 6.1 [1026a14], for example.

5 On the antique measurement of the terrestrial circumference, see Geus and Tupikova 2013 and their updated bibliography.

6 Among a vast bibliography on Eratosthenes' geographical writings, see Geus 2002 and Roller 2010.

7 The Greek term κλίμα (pl. κλίματα) means "inclination", referring to the inclination of the pole above the horizon, by which one can determine the latitude of a place.

8 Arnaud 1998, 8–11; Marcotte 2002, LV–LXXII; Dueck 2012, 6–10.

9 Marcotte 2006; Geus 2002.

10 Str. *Geogr.* 1.1.12 (C7). Translation H. L. Jones 1917 modified.

Hipparchus' criticism against Eratosthenes was mainly focused on astronomical and mathematical arguments. Strabo (c. 64 BCE–c. 23 CE) as well, although he credited Homer as the prime geographer against Eratosthenes' claim, asserted:

> Most of all, it seems to me, we need, as I have said, geometry and astronomy for a subject like geography; and the need of them is real indeed; for without such methods as they offer it is not possible accurately to determine our geometrical figures, *klimata*, dimensions, and the other cognate things.[11]

Nevertheless, aside from his prolegomena in the first two books of his *Geography*, Strabo followed on with a detailed description of each part of the *oikoumene*, where reflections on mathematics and astronomy have the smallest share compared to historical, economical or ethnological discussions.

2 Antique maps and Ptolemy's *Geography*

2.1 Ptolemy as a cartographer

In clear continuity to Eratosthenes' definition of the geographical science, Claudius Ptolemy (c. 95–c. 170 CE) intended to represent the *oikoumene* thanks to mathematics.[12] Ptolemy was above all an astronomer, who composed a comprehensive work on astronomy (the *Almagest*), turning to the discipline of geography relatively late in his life. Ptolemy defined "geography" as an imitation (μίμησις), via a picture, of the known parts of the world.[13] He specified:

> Geography [deals] with the quantities more than the qualities, since it gives consideration to the proportionality of distances for all things, but to likeness only as far as the coarser outlines and only with respect to mere shape. [… Geography] enables one to show the positions and general shapes by means of simple lines and labels.[14]

The prime concern of Ptolemy was thus the construction of a picture where each part of the *oikoumene* would be in correct proportion, a concept that Ptolemy called *symmetria* (συμμετρία). As A. Jones noticed, the word does not mean exactly "symmetry" or "proportionality":

> *Symmetria* means having the parts of something scaled appropriately to the whole entity, or having the entity scaled appropriately for its setting or application; in particular, the things that we make ought to have the right size and proportions for human use.[15]

To achieve such a picture, a cartographer would require, in Ptolemy's mind, the use of mathematics and astronomy. Ptolemy's *Geography* supplies a thorough discussion on the

11 Str. *Geogr.* 1.1.20 (C11). Translation H. L. Jones 1917 modified.

12 Note that despite the proximity of Eratosthenes' and Ptolemy's geographical practices, the latter made no allusion to Eratosthenes' geographical works. Ptolemy mentioned him only once, associated with Hipparchus, in the *Almagest* (1.12), concerning the obliquity of ecliptic.

13 Ptol. *Geogr.* 1.1.1.

14 Ptol. *Geogr.* 1.1.5. Translation Berggren and A. Jones 2000 modified.

15 A. Jones 2012, 117. Ptolemy's use of the word reminds somehow Aristotle's own definition of the mathematicians' activity (*Metaph.* 11.3 [1061b]).

different ways of depicting the spherical Earth's surface on a plane map.[16] Considering that an appropriate framework is necessary to represent the *oikoumene* with "*symmetria*", Ptolemy developed new methods of map projection (in the broad sense), that is, new ways of constructing a grid of parallel and meridian circles.

The major innovation of Ptolemy's *Geography* concerned the way a cartographer must transfer localities on a map. Ptolemy observed that the common mapmaking practice at his time was source of serious imprecision:

> After all, continually transferring [a map] from earlier exemplars to subsequent ones tends to bring about grave distortions in the transcriptions through gradual changes. If this method based on a text did not suffice to show how to set [the map] out, then it would be impossible for people without access to the picture to accomplish their object properly.[17]

As remedy to the problem, Ptolemy conceived a catalogue where localities were determined by a longitude and a latitude data. Mapmaking by plotting localities on to a grid, on the basis of coordinates, was, Ptolemy believed, a much more reliable way of mapping than some of the "artistic" imitations of earlier models. Longitude and latitude are thus not only geographical properties of localities on the Earth's surface, but also – and maybe first of all – a way of constructing a map.

2.2 Ptolemy's judgment on the maps in his time

Both requirements – accurate proportions and reliable mapmaking technique – can be seen as an implicit description of maps in Ptolemy's time or before him. The copying process was source of errors creating "grave distortions" but the designers of the maps themselves did not use map scales to adapt the picture to the size of their material:

> For in the case of an undivided map, because of the need to preserve the ratios of the parts of the *oikoumene* to each other, some parts inevitably become crowded together because the things to be included are near each other, and others go to waste because of a lack of things to be inscribed. In trying to avoid this, most [mapmakers] have frequently been constrained by [the limited frame] of their maps themselves to distort in diverse manners both the measures and the shapes of the countries, as if they were not guided by [geographical] reports.[18]

Ptolemy supplied here an invaluable testimony on the history of antique cartography: very few sources allow to get a comprehensive view of Greek and Roman cartography. Strabo's report of Eratosthenes' geography gives only a partial idea of the kind of map that the latter might have imagined.[19] Moreover, we do not know whether Strabo actually realized the world map that he outlined himself in his *Geography*, although he seemed having a very concrete overview of the aspect of a map of the *oikoumene* must have.[20] Evidences are even thinner when it comes to discuss the geographical work of Marcus Agrippa (c. 64–12 BCE) and his supposed world map. His fragments enable to reconstitute some aspects of his geographical work but any reconstitution of the shape of

16 Ptolemy also stated that his predecessor and main source, Marinos of Tyre (first or second century CE), "paid considerable attention to this problem and found fault with absolutely all the [existing] methods of making place maps." (Ptol. *Geogr.* 1.20.3).

17 Ptol. *Geogr.* 1.18.2–3. Translation Berggren and A. Jones 2000 modified.

18 Ptol. *Geogr.* 8.1.2.

19 Str. *Geogr.* 1.4.1–9 & 2.1.1–41. See Aujac 2012, 155–157; Roller 2010; Geus 2007; Geus 2002, 276–288; Stückelberger and Mittenhuber 2009 254–256.

20 Str. Geogr. 2.5.9–10 & 16.

the map that he possibly drew (or let draw) contains an important part of speculation.[21] The sketch included in the so-called Papyrus of Artemidorus does not supply much more reliable information.[22]

The Peutinger Map, however, does present some of the features reported by Ptolemy: the landmasses are distorted, so that golfs and seas appear as narrow channels and some countries are over-sized compared to others, certainly to fit the particular format of the folios. Despite its late date and the specificities of its history (which are anyway still debated), the Peutinger Map may give us some indication on the aspect of the maps that Ptolemy was perhaps referring to.[23]

2.3 Ptolemy's sources and methods

Ptolemy compiled the information that was required to construct a map of the whole *oikoumene* as well as regional maps, the latter covering only smaller territories. The invention of double geographical coordinates enabled Ptolemy to put in practice the cartographical requirements he gave to himself. He explained how both longitude and latitude of localities can be determined thanks to sky observations and the use of measuring instrument, which required on-site procedures.[24] His methodological explanations were, however, mainly focused on the ideal way of determining a locality's coordinates and he himself admitted that he had not been able to do this for each locality listed in his catalogue. He also claimed that very little information on longitude and latitude was available in his sources.[25]

Ptolemy determined the coordinates of the localities in his catalogue, therefore, by dealing with approximate or insufficient sources: travel reports, topographical descriptions, distances, data on orientation, for instance. He did not explain, though, how he determined geographical coordinates from this information. In the introduction to the *Geography*, Ptolemy discussed and corrected the dimension of the *oikoumene* calculated by Marinos of Tyre. By correcting both the longitudinal and latitudinal extent of the known world, Ptolemy was able to get longitudinal and latitudinal intervals in degrees (c. 80° from north to south and c. 180° from west to east)[26] on the basis of distances in stadia and information on the orientation of routes. His argumentation as well as the procedures he used in this discussion, however, were not intended to get the coordinates of localities but to estimate approximately large distances at the scale of the whole *oikoumene.* Moreover, the intervals in degrees given in the introduction do not correspond to the coordinates transmitted in the catalogue.[27]

One of the objectives of Group D-1 "Space of Nature" of the Excellence Cluster Topoi is a better understanding of Ptolemy's sources and methods, starting from the idea that

21 See chiefly Brodersen 1995, 269–270, and Arnaud 2007–2008 for a recent synthesis of the historiographical debates on Agrippa and his map.

22 The debates on the Artemidorus Papyrus and his map cannot be exposed in detail here; among an insanely huge bibliography, one may suggest Gallazzi, Kramer, and Settis 2009; D'Alessio 2009; Gallazzi, Kramer, and Settis 2012 (especially Moret 2012); Marcotte 2010 – and Canfora 2012 for a different point of view.

23 Salway 2005; Albu 2008; Talbert 2010. See the digitalized map at www.cambridge.org/us/talbert/ (last accessed 17/07/2020).

24 Ptol. *Geogr.* 1.2.1–1.3.5. See Rinner 2013, 92–100.

25 Ptol. *Geogr.* 1.4.1–2.

26 Ptol. *Geogr.* 1.10.1 & 1.14.10.

27 Rinner 2013, 106–127.

the catalogue of localities (and not Ptolemy's introduction) must be the prime object of the study.[28]

Ptolemy explained that he structured his catalogue of localities by organizing the entries following a spatial principle, which was meant to make the cartographer's task easier: countries are described from the most northern and western ones to the most southern and eastern ones.[29] The organization of each list of localities within each country makes clear that this spatial principle was also applied at every level of the catalogue. This strongly suggests a composition of the catalogue *after* the realization of a first working map.

In her 2013 study on Ptolemy's work and on the genesis of the coordinates of Asia Minor's localities listed in the *Geography*, E. Rinner puts forward a method for understanding the way Ptolemy constructed his maps and determined the geographical coordinates.[30] From the clearly visible distortions that appear when one compares Ptolemy's coordinates with their equivalent modern-day locations, E. Rinner has developed a model (based on antique sources and cartographical procedures) that can explain the origins of the coordinates in the light of these distortions. The latter generally do not concern isolated cities but large groups where localities, for example, are all shifted toward the same direction.

The main localities of the western coast of Asia Minor – Byzantium, Tenedos, Chios and Rhodes – were certainly situated on the map using both the latitude values transmitted by Hipparchus and distances (which can be found in Strabo's work) thanks to a simple geometric construction involving a ruler and a compass. The coordinates could be directly read on the map thanks to the graduations of the parallel and meridian circles. This kind of construction inevitably created some discrepancy compared to the actual locations. Other localities were constructed in relation to the main ones, transferring to the former similar discrepancies. This construction explains the apparition of large groups of localities with a common distortion, which could not have come out if the coordinates of each locality were determined or calculated independently from each other. In other words, this characteristics of Ptolemy's map hints at a progressive, multi-stage procedure to determine the coordinates, mainly performed through geometrical constructions and based on common geographical information which circulated at Ptolemy's time. The localities' coordinates were then recorded in the catalogue so that anyone could re-draw the same map than Ptolemy's and, potentially, correct, ameliorate or update his data.

3 Alexandria, Rome and the mathematical cartography

3.1 Widening horizons

Eratosthenes and Ptolemy belonged to the same scientific tradition, which mostly developed in Alexandria, which can arguably be described as the birthplace of mathematical geography. From its foundation around 331 BCE until Late Antiquity, Alexandria was one of the most important intellectual and scientific centres of the Mediterranean world. Alexander the Great's expeditions and conquests as well as those of the Seleucid and Ptolemaic rulers widened the known world's horizons. Alexandria not only developed into a major political centre but also, from the third century BCE, became an important cultural centre, where scholars and scientists studied and taught at the same locations, influencing each other and attracting the leading minds of the Hellenistic world. At

28 www.topoi.org/project/d-1-6/ (last accessed 17/07/2020). The project on Ptolemy's *Geography* undertook at the Excellence Cluster Topoi falls within a long-time research initiated by the former Karman Center for Advanced Studies in the Humanities of the University of Bern.

29 Ptol. *Geogr.* 2.1.4–5 & 7.

30 Rinner 2013.

Alexander's death in 323 BCE, his successors used the sciences as a way of politically legitimising the rivalry for his legacy. In this context, the Ptolemies made Alexandria one of the most dynamic cultural and scientific centres of the Mediterranean world.

Roman conquests as well have widened the antique geographical horizon. During the Augustan period, Strabo compared both historical moments on the perspective of the geographical knowledge:

> Indeed, the spread of the empires of the Romans and of the Parthians has presented to geographers of today a considerable addition to our knowledge, just as did the campaign of Alexander to geographers of earlier times, as Eratosthenes points out. For Alexander opened up for us geographers a great part of Asia and all the northern part of Europe as far as the Istros River; the Romans have made known all the western part of Europe as far as the River Albis (which divides Germania into two parts), and the regions beyond the Istros as far as the Tyras River; and Mithridates, surnamed Eupator, and his generals have made known the regions beyond the Tyras as far as Lake Maeotis and the line of coast that ends at Colchis; and, again, the Parthians have increased our knowledge in regard to Hyrcania and Bactriana, and in regard to the Scythians who live north of Hyrcania and Bactriana, all of which countries were but imperfectly known to our predecessors.[31]

Plutarch's description of the three triumphs of Pompey in September 61 BCE gives the same impression – strengthened by the political propaganda – of a sudden opening of the *oikoumene* to a new geographical dimension.[32] Greek-speaking geographers like Strabo or Ptolemy took benefit from the Roman horizon widening. By contrast to Alexandria, however, Rome never became a central place for mathematical geography, less because of a "purely Roman" lack of interest in theoretical and mathematical sciences than of a different evolution of a Greek *and* Roman scientific context.

3.2 Roman reception of Hellenistic mathematical geography

From his letters addressed to his friend Atticus, one knows that Cicero (106–43 BCE) did undertake during the spring in 59 BCE the writing of some geographical treatise, certainly by the request and on the advice of the former:

> As to geography [*de geographia*], I will try to satisfy you, but I promise nothing for certain. It is a difficult business, but nevertheless, as you bid me, I will take care that this country excursion produces something for you.[33]

However, during his journey in Antium, and despite the lectures suggested by Atticus, Cicero seems having rapidly given up:

> As to my promise to you in a former letter that there should be some product of this country excursion, I cannot confirm it to any great extent: for I have become so attached to idleness that I cannot be torn from its arms. Accordingly, I either enjoy myself with books, of which I have a delightful stock at Antium, or I just count the waves – for the rough weather prevents my shrimping! From writing my mind positively recoils. For the geographical treatise [γεωγραφικά], upon which

31 Str. *Geogr.* 1.2.1 (C14). Translation H. L. Jones 1917 modified. Pliny (*Nat.* 2.167–170) drew up a similar parallel.

32 Plutarch, *Pompey*, 45.

33 Cic. *Att.* 2.4. Translation Shackelton Bailey 1965.

> I had settled, is a serious undertaking: so severely is Eratosthenes, whom I had proposed as my model, criticised by Serapion and Hipparchus: what think you will be the case if Tyrannion is added to the critics? And, by Hercules, the subject is difficult of explanation and monotonous, and does not seem to admit of as much embellishment as I thought, and, in short – which is the chief point – any excuse for being idle seems to me a good one.[34]

In spite of Cicero's later claim that he "will keep thinking about the geography",[35] he obviously renounced to the task. More than the monotony, it seems that Cicero had trouble with the mathematical or astronomical skills that were required to understand and study works such as Eratosthenes and Hipparchus ones.[36] Among the authorities he mentioned, Cicero alluded to Tyrannion of Amysus (c. 100–25 BCE), a character who is familiar to readers of Cicero's writings. Tyrannion was born in Pontus, like Strabo, and was a close friend of both Atticus and Cicero.[37] If Tyrannion's role was certainly important in the dissemination of grammatical studies in Rome,[38] one guesses from Cicero's testimony that he also participated to the diffusion of Alexandrian geography works in the same time. Roman élites from the end of the Republic period knew about works of Hellenistic geography – Julius Cesar himself referred once to Eratosthenes[39] – but they seem, though, not having made a large use of them.

3.3 Pliny and the *subtilitas* of Eratosthenes

A men with great knowledge such as Pliny the Elder (23/24–79 CE) acknowledged the contribution of Hellenistic mathematical geography to the study of the *oikoumene*. In his *Natural History*, Pliny distinguished Latin-speaking from Greek-speaking authorities. Among the latter, the name of Eratosthenes sometimes appears but, compared to the other authorities mentioned in the books devoted geography, he is absolutely not predominant.[40] It is only at the very end of the geographical part of the *Natural History* as well as in the section devoted to astronomy that Pliny resorted – in laudatory terms – to Hellenistic mathematical geography.

As a conclusion to his geographical books, Pliny presented a sort of appendix inspired by "Greek science":

> To these we shall add a Greek discovery [*graecae inuentionis scientiam*], and indeed of the most acute ingenuity [*uel exquisitissimae subtilitatis*], so that nothing may be wanting in our survey of the geography of the world, and so that now the various regions have been indicated, it may be also learnt what alliance or relationship of days and nights each of the regions has, and in which of them the shadows are of the same length and the world's convexity is equal. An account will therefore be given of this also, and the whole earth will be mapped out in accordance with the constituent parts of the heavens. The world has a number of segments to which our countrymen give the name of "circles" [*circuli*] and which the Greeks call "parallels" [*parallelos*].[41]

34 Cic. *Att.* 2.6. Translation Shackelton Bailey 1965 modified.
35 Cic. *Att.* 2.7.
36 Haushalter 2015, 221.
37 Haushalter 2015, 220.
38 Montana 2015, 165.
39 Caes. *Civ.* 6.24.
40 Arnaud 2007–2008, 59.
41 Pl. *Nat.* 6.211. Translation Rackham 1938–1950 modified.

Without mentioning his precise source(s), Pliny referred to the Hellenistic practice of mathematical geography, in particular to the concept of parallel circles and *klimata*. A. Haushalter has recently put light on Pliny's judgment and personal use of "Greek" authorities of mathematical geography. The *subtilitas* ("ingenuity" or "finesse") is not only credited to the theory of *klimata* but also to Eratosthenes himself in two other passages of the *Natural History*.[42] Hipparchus did not miss Pliny's praise either.[43] More generally, the qualifying *subtilitas* or *immensa subtilitas* is a recurring pattern in Pliny's appraisal of Greek authorities or science: Plato,[44] Aristotle[45] or the Greek mathematics in general.[46] Cicero himself used the very same word to praise Socrates or the achievements of the Attic eloquence for example.[47]

The "ingenuous" geography of Eratosthenes and his successors were relegated, though, to the very end of Pliny's work, as an addendum to a treatise already finished and coherent. A. Haushalter showed that Pliny's praise of Hellenistic achievements was somehow ambiguous:

> La géographie tardo-républicaine et impériale a fait siens les acquis de la science alexandrine, au premier chef la figure globale de la carte, construite autour du parallèle fondamental, et dont l'achèvement n'avait été possible que grâce au concept de *climat*. Mais quelques siècles plus tard, le climat apparaît pour ainsi dire comme une pratique empaillée: révérée, mais inusitée [...]. Pline, en la qualifiant de *subtilitas*, lui rend un hommage empoisonné. En effet, s'il relève, en historien de la géographie, tout le progrès apporté par la science alexandrine à la connaissance du monde, c'est surtout pour théoriser un partage des rôles entre les Romains et les Grecs, qui fait de ces derniers les dépositaires d'une science ancienne, désormais improductive.[48]

Pliny's distinction between Romans and Greeks certainly influenced a certain number of historians who have tended to use this judgment to accredit the idea of a fundamental and essential separation between a Roman geographical knowledge oriented toward practical purposes on the one hand, and a Greek "theoretical" science only guided by for the sake of knowledge to the other.[49] Such radical distinction cannot explain the specificity of the development of mathematical geography in Antiquity.[50]

42 Pl. *Nat.* 2.164: "The total circumference [of the Earth] was given by Eratosthenes (an expert in every refinement of learning [*in omnium litterarum subtilitate*], but on this point assuredly an outstanding authority – I notice that he is universally accepted) as 252,000 stadia [...], achieved by such subtle reasoning [*subtili argumentatione*] that one is ashamed to be sceptical." Translation Rackham 1938–1950. See also Pl. *Nat.* 6.171. See Haushalter 2015, 213–214.

43 Pl. *Nat.* 2.95: "Hipparchus, who can never be sufficiently praised, no one having done more to prove that man is related to the stars and that our soul are part of heaven [...]". Translation Rackham 1938–1950.

44 Pl. *Nat.* 22.111: "[...] in harmony with the very ingenious theory [*ratio subtilitatis immensae*] that had its origin in Plato." Translation W. H. S. Jones 1951.

45 Pl. *Nat.* 18.335: "[...] but Aristotle, a man of immense acuteness [*uir immensae subtilitatis*], who took that very view, also gives the Earth's convexity as the reason why the north-east wind blows in the opposite direction to the African wind." Translation Rackham 1938–1950.

46 Pl. *Nat.* 2.164: "On the other side the Greek finders [*inuentores graeci*], greatly to their delight and to their glory, prove by subtle mathematical reasoning [*subtilitate geometrica*] that is cannot possibly be the case that the seas are really flat and have the shape that they appear to have." Translation Rackham 1938–1950.

47 Cicero, *Brutus* 31 & 67; *De Oratore*, 3.60.

48 Haushalter 2015, 224–225.

49 See for example Harley and Woodward 1987a, 161.

50 In the section "Greek and Roman Geography" of her *Geography in Classical Antiquity*, D. Dueck has difficulties to let emerge clear characteristics of a "Roman" and a "Greek" geography. See Dueck 2012, 12–16.

4 Ptolemy and the resurgence of the Hellenistic mathematical geography

Admittedly, one can hardly maintain the idea that Roman scholars did manifest a strong interest in mathematical geography or followed Eratosthenes' project. By praising Eratosthenes and Hipparchus, Pliny incidentally highlighted the fact that their practice of geography did not produce any significant work since them. Strabo put together a thorough presentation of Eratosthenes and Hipparchus but did not continue with their research. Ptolemy belonged to the Roman period on a chronological point of view; in his geographical practice, he was, however, the heir of the Hellenistic science. He observed himself the scarcity of the tradition of mathematical geography and deplored the difficulty of finding sources that could supply useful information on the latitude and longitude of localities:

> These things being so, if the people who visited the individual countries had happened to make use of some such observation, it would be possible to make an absolutely reliable map of the *oikoumene*. But Hipparchus alone has transmitted to us elevations of the North Pole for a few cities, few indeed compared to the multitude of places to be recorded in a geography, and also localities that are situated under the same parallels. And a few of those who came after him [have transmitted] some of the localities that are "oppositely situated".[51]

The way Ptolemy practiced geography in the second century CE differed quite markedly from the methods of the other geographers of his time. Ptolemy did, though, refer to Marinos of Tyre, who slightly pre-dates him, and who practiced mathematical geography. Marinos worked for example on the concept of longitude and provided some tables of hour-intervals, on the model of the *klimata*, which should be understood as longitudinal sectors in to which localities were classified.[52] Each zone, which Marinos numbered, covered a longitudinal interval of 15°, allowing Marinos to locate approximately some places at a longitudinal interval, no matter which parallel circle they occupy.[53]

Nevertheless, Ptolemy's *Geography* falls within a resurgence of interest in the scientific tradition of a description of the world that had been dormant since Hipparchus and before him Eratosthenes. Ptolemy's preference for Hipparchus was less a matter of personal taste than of practical necessity. It is not known to what extent the descriptions of the *oikoumene* and its parts by Artemidorus and Posidonius – two great geographical references in Antiquity – were linked with mathematical and astronomical concepts. Gnomonic procedures (that is, measuring a locality's latitude with the help of specific instruments) as well as theories on climatic zones for example had been developed from the period of Classical Greece until Roman times. However, these concepts and theories had been merely abstract studies of the Earth as a sphere and had rarely been connected to the realization of a map of the *oikoumene*. Thus the relative disregard for mathematical geography during the Roman period was not a question of the fundamental cultural difference between practical Roman knowledge and pure theoretical Greek science. During the time of Pliny the Elder and the Antonine era, mathematical geography was still considered a valid subject; it was just that it belonged to the past rather than to current scholarship, be it in Latin or Greek.

Another aspect shows the gap between Ptolemy's mathematical geography and the Greek and Roman geographical literature of his time. The Antonine era gave over much

51 Ptol. *Geogr.* 1.4.2. Translation Berggren and A. Jones 2000.
52 Ptol. *Geogr*. 1.15.5.
53 Ptol. *Geogr*. 1.14.9.

space to rhetoric and panegyrics and geography was also a matter of politics and history. Descriptions of the world – that is, the Roman world, ruled by the *Princeps* – rarely missed to praise Rome and acknowledge its greatness, as reflected by Aelius Aristides' *On Rome* (143 or 144 CE) or the incipit of Appian's *Roman History* (c. 150 CE), for example.[54] Arrian of Nicomedia dedicated to Hadrian a *Periplous of the Euxine Sea* (c. 132 CE), which was in most part the result of an exploratory sea journey ordered by the latter, for diplomatic and military purposes. Combining this experience with his personal lectures, Arrian produced a geographical treatise that fulfilled a political and a scientific aim.[55]

By contrast, the tone of Ptolemy's *Geography* seems almost uninterested.[56] As A. Jones has noted: "Ptolemy gives not the slightest indication that there exists such an entity as a Roman empire."[57] His *Geography* seems totally dissociated from Roman politics and the contingencies of history. The *terrarum caput*, Rome, which enthralled geographers and inspired the most laudatory descriptions was described by Ptolemy with a laconic: Ἄστυ Ῥώμη with its geographical coordinates.[58] While his contemporaries acclaimed Rome, its emperors and its glorious history, Ptolemy exalted atemporal mathematics. When he considers the possibility of adding improvements to the catalogue of localities, Ptolemy contemplates improving the values of the coordinates rather than adapting the catalogue to political and historical changes.

5 The legacy of the Alexandrian school

The posterity of Ptolemy's *Geography* from the second century onwards denotes a manifest lack of interest in mathematical geography, be it in the western part of the Empire or in the Byzantine world. Admittedly, his *Geography* was known, certainly read and consulted from time to time for specific topics, and certainly more than one have thought.[59] As an example, it seems that Ptolemy and his conception of the *oikoumene* were among the topics of the exegetical debates that occurred in Alexandria, in the middle of the sixth century, between John Philoponus and Cosmas Indicopleustes. In his *Commentary on the Cosmogony of Moses* Philoponus discussed briefly the Nile and its origins[60] and referred to the following passage of Ptolemy's *Geography*:

> The Ethiopian Anthropophagites inhabit around the [Barbarian] gulf; to the west is situated the Mountain of the Moon, from which the Lakes of the Nile receive water from the snow.[61]

Philoponus noted that some scholars had misunderstood the passage by having read the end of the sentence as αἱ τοῦ Νείλου πηγαί ("the sources of the Nile"), whereas the actual text of the *Geography* reads αἱ τοῦ Νείλου λίμναι ("the Lakes of the Nile"). The extant manuscripts of the *Geography* rule indeed in Philoponus' favor.[62]

However, if the *Geography* could have served as reference work for a certain number of scholars, Ptolemy did not find any heir in Greco-Roman Antiquity and Middle Ages to

54 Appian, *Roman History*, preface 7: "From the advent of the emperors to the present time is nearly two hundred years more, in the course of which the city has been greatly embellished, its revenue much increased, and in the long reign of peace and security everything has moved toward a lasting prosperity." The whole preface consists of an idealized portrait of Rome at this time.

55 Stadter 1980, 32–41.

56 Aujac 2012, 185–191.

57 A. Jones 2012, 127.

58 Ptol. *Geogr*. 3.1.61.

59 Gautier Dalché 2009.

60 John Philoponus, *Commentary on the Cosmogony of Moses* (= *De opficio mundi*), 4.5.

61 Ptol. *Geogr*. 4.8.3.

62 See Inglebert 2001, 58–60 and 85–88; and Gautier Dalché 2009, 54–56.

develop further his geographical and cartographical project. The coordinates of Ptolemy's catalogue of localities were never really discussed – though sometimes quoted[63] – while it was foremost the picturesque details it contains which arose some interest. Ptolemy's "Table of Noteworthy Cities"– a geographical table with important localities and their coordinates, included in the *Handy Tables* – found its way in Byzantine circles; to the cities originally listed by Ptolemy, the extant manuscripts from the ninth century shows later additions. All the additions comes from information provided by *Geography* itself though it is not known how and for which purpose the scholars who dealt with this table used and completed them. The description and representation of the *klimata* had huge success in antique and medieval scholarship, but their original function – a way of characterizing a locality's latitude – were (not always but) often diverted, the *klimata* being used as a simple way of structuring world descriptions, a "practical framework to categorize groups of peoples"[64] where the link with mathematical geography and cartography almost disappeared. The Arabic word *iqlīm* (pl. *aqālīm*), based on Greek κλίμα, still preserved its astronomical meaning – in the work of al-Khwārizmī (c. 780–c. 850), for example – but acquired rather soon the common sense of "region" or "province", especially in the works of the Balkhī school authors (in the tenth century onwards).[65]

A real interest in studying and developing mathematical geography is nonetheless to be found among Arabic-writing scholars. Although several allusions to different ninth-century Arabic translations of Ptolemy's *Geography* can be found in sources, none of them passed down to us.[66] It is clear, however, that the geographical works of al-Khwārizmī and al-Battānī (c. 850–929) for instance, fell within the scientific tradition of Ptolemy. Both were less interested in Ptolemy's mapmaking methods than in his catalogue of localities. In his *Kitāb surat al-arḍ*, al-Khwārizmī used the form of a catalogue, where localities are listed with latitude and longitude, the latter being computed from the western limit of the known world, as Ptolemy did. Al-Khwārizmī's list shows many corrections to Ptolemy's values, additions and up-dated information (such as the coordinates of Baghdad for example) but always preserving the form of the catalogue.[67] In some way, the continuation of Eratosthenes and Ptolemy's geographical projects is thus to be credited to astronomers and geographers of the medieval Islam world.

List of Abbreviations

Caes. *Civ*.: Julius Caesar, *The Civil War*

Cic. *Att*.: Cicero, *Letters to Atticus*

Pl. *Nat*.: Pliny the Elder, *Natural History*

Ptol. *Geogr*.: Ptolemy, *Geography*

Str. *Geogr*.: Strabo, *Geography*

63 Syriac scholars of the seventh and eighth centuries have used Ptolemy's Geography not only for its list of toponyms but also for its geographical coordinates, see the *Hexaemeron* of Jacob of Edessa (633–708) as well as the *Treatise of the Constellation* wrote by Severus Sebokht in 661 for example. See Defaux 2014; Ducène 2015.

64 Ducène 2015, 30. J.-Ch. Ducène makes this observation when discussing the *Hexaemeron* of Moses bar Kepha, written in Syriac in the ninth century. One may use the same assessment in many other instances.

65 Tibbetts 1992b, 93–94; Tibbetts 1992a, 111–114.

66 Karamustafa 1992, 10–11.

67 Tibbetts 1992b, 96–105; Stückelberger and Mittenhuber 2009, 336–345.

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