

FROM THE PORTOLAN CHART TO THE LATITUDE CHART

The silent cartographic revolution

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This paper explains how, following the introduction of astronomical navigation, the transition between the portolan-type chart of the Mediterranean and the latitude chart of the Atlantic was facilitated by the small values of the magnetic declination occurring in western Europe during the Renaissance. The results of two preliminary cartometric studies of a sample of charts of the sixteenth century are presented, focused on the latitude accuracy in the representation of northern Europe and on the evolution of the longitudinal width of the Mediterranean and Africa.

Cet article explique comment, après l'apparition de la navigation astronomique, la transition entre la carte-portulan caractéristique de la Méditerranée et la carte avec latitude de l'océan Atlantique a été facilitée par la faiblesse de la déclinaison magnétique en Europe occidentale, à la Renaissance. Les résultats de deux études cartographiques antérieures sont appliqués à un échantillon de cartes du XVI^e siècle, en centrant le propos sur la précision des latitudes des pays de l'Europe de Nord et sur l'étendue longitudinale de la Méditerranée et de l'Afrique.

1 Introduction

In 1434, after thirteen years during which there were several frustrated attempts involving various pilots in the service of Prince Henry of Portugal, Gil Eanes finally succeeded in rounding Cape Bojador. At that time many dangers and obstacles were associated with the coastal waters facing the Canary Islands: the sandbars emerging at the surface in the strong currents preventing the ships' return, the arid lands where no life form could survive and even the marine monsters that, in the imagination of the pilots, populated the tenebrous sea. In the words of Alvise Cadamosto – a Venetian explorer and trader in the service of Prince Henry – later repeated by others, “whoever rounds Cape Non will come back or not” (*quem passar o Cabo Não tornará ou não*)¹. Most of those fears were psychological and it eventually became clear to the sailors that doubling Cape Bojador did not involve extraordinary difficulties. On the contrary, the southward progression of the ships was facilitated by the trade winds, blowing from the northeast, and by the Canary current, flowing southwards parallel to the African coast. But they were right in one important

respect: that it was much easier to go than to come back, due to the action of those same elements.

At the time Cape Bojador was first rounded by the Portuguese, the ships used in the voyages of exploration found it hard to progress against the wind. This limitation often made the return trips long and arduous, and it was sometimes necessary to use the oars to be able to proceed north. The introduction of the *caravel*, equipped with lateen sails and capable of going closer to the wind (to *luff*), represented a major improvement. Also, a better understanding of the behaviour of the wind and current in the region made the Portuguese pilots realize that a more efficient way of bringing the vessels back home was: first, to sail away from the African coast, so as to avoid the Canary current and the northerly winds, and then to make a westward detour through the open sea before heading for the coast of Portugal. This oceanic route, introduced around 1450, became known as the *Volta do Mar Largo* ('Turn of the Open Sea') and contributed much to the success of the exploratory and commercial voyages along the African coast². However a problem of

¹ Cape Non, present Cape Chaunar, is located on the coast of Morocco, to the east of the Canary Islands, between Tarfaya and Sidi Ifni.

² For a discussion of the introduction of this type of route see Coutinho, 1959, I, p. 97-267, and Peres, 1983, p. 184-7.

a different nature had still to be solved before that route could be adopted safely and effectively.

2 Navigation and charting

During the fifteenth century, navigation in European waters was usually practised near the coast, using the information on the courses and distances between places registered in the pilots' rutters. Sometimes it was necessary to sail away from the coast to reach a distant island or to cross a larger body of water. But these journeys seldom lasted more than a few days. In such situations, the position of the ship was determined on the basis of the course steered, measured by the marine compass, and the distance sailed along the way estimated by the pilot. The position determined in that way became known by the Iberian pilots of the time as the *ponto de fantasia* ('point of fantasy'), a colourful designation that expressed the uncertainty associated with the estimation process. Although considerable errors could be made with this method, they seldom represented a serious problem for navigation because the true position of the ship could easily be known as soon as the coast was again in sight. That was not the case when the ships stayed in open waters for several days or weeks, as when heading from Lisbon to the Azores or returning from the coast of Africa, along the 'Turn of the open sea'. As time passed, the accuracy of the point of fantasy continuously degraded to the point that it became almost useless, especially when the ships were forced to alter course frequently so as to make the best use of the wind. To resolve this problem, a new navigational method had to be found.

The solution was the introduction of astronomical navigation, during the second half of the fifteenth century³. That was made possible by the simplification of the observation instruments used by astronomers on land – the quadrant and the astrolabe – and the development of simple procedures that could be used by the uninstructed pilots to observe the Pole Star or the Sun and determine the latitude. The earliest source referring to the use of

astronomical observations at sea is in a report by Diogo Gomes, of ca. 1460, allegedly dictated to Martin Behaim, where the Portuguese pilot describes how he measured and registered in a quadrant the height of the Pole Star near the island of Santiago, in the archipelago of Cape Verde:

And I had a quadrant when I went to those parts and wrote on the face of the quadrant the height of the arctic pole and found it better than the chart⁴.

Other sources refer to the use of instruments and the practice of astronomical navigation during the voyages of Bartolomeu Dias (1487-88), Vasco da Gama (1497-98) and Pedro Álvares Cabral (1500)⁵.

When the systematic exploration of the African coast began, the nautical charts used by the European pilots were technically identical to the portolan charts of the Mediterranean. They were constructed using the navigational information collected at sea and the places were represented according to the compass courses and distances between them. In the earliest phase, during the first half of the fifteenth century, all charts used by the Iberian pilots were probably of Majorcan origin⁶. The foundation of an autonomous school of nautical cartography for the Atlantic is supposed to have taken place in about 1443, when Prince Henry of Portugal ordered the newly discovered lands beyond Cape Bojador to be added to the charts (Verlinden, 1979). At that time the Portuguese explorers had just doubled Cape Blanc and were progressing further south.

The earliest extant chart of Portuguese origin was made around 1471 (fig. 1). It is relatively sober in terms of decoration (when compared with most extant portolan charts of the time) and represents only part of the Atlantic, which suggests that it was constructed with the specific purpose of supporting or documenting navigation along the coast of Africa. Together with Pedro Reinel's chart of ca. 1492, now kept in the Archives départementales de la Gironde, Bordeaux, and Jorge de Aguiar's chart of 1492,

3 For a good summary of the development of astronomical navigation during the fifteenth century in Albuquerque (1971; 2001, p. 185-293).

4 Translated from the Portuguese version in Albuquerque (2001, p. 199). The original Latin version is in Costa (1997), p. 200. The text suggests that astronomical navigation at that time consisted in comparing the height of the Pole Star observed on board with the corresponding heights at reference places, registered in the instrument's scale.

5 See Albuquerque (1965, p. 59-67).

6 The earliest extant reference to the subject is in the *Treatise in defence of the nautical chart (Tratado em defensam da carta de marear)*, of the mathematician and cosmographer Pedro Nunes. Discussing the errors affecting the representation of the Mediterranean on the charts of his time, Nunes refers to 'these charts of the Levant [...] came from Majorca, where they were formerly made'. The Portuguese reads: *estas cartas de leuant [...] vinham de Malhorca: onde ellas anti-guamente faziam*. See Nunes (2002, 134).

housed in Yale University, they are the sole examples of the Portuguese nautical cartography of the fifteenth century.

With the introduction of astronomical methods of navigation, the point of fantasy, based on compass courses and estimated distances, gave way to the 'set point', where the observed latitude became the prevailing element of navigational information. None of the Portuguese charts of the fifteenth century present any evidence of astronomically-observed latitudes: no latitude scale is shown and their geometry is identical to that of the traditional portolan charts. Still, and because they belong to a period when astronomical navigation was already being practised, it is likely this type of chart was used together with the set point method. In order for that to be possible it would only be necessary to add a scale of latitudes to the charts in such a way that the latitudes of the places along the coast were approximately respected. To test the possibility, an experiment was made by António Barbosa in 1938, who overlaid a scale of latitudes on a facsimile of the Catalan atlas (fig. 2). With few exceptions, all the latitudes between Cape Bojador (in the south) and Cape Finisterre (in the north), measured in that scale, have errors smaller than $\frac{1}{2}$ a degree (Barbosa, 1938, 191-3).

However, this expedient could only work in the areas where the relative north-south positions of the places shown on the charts were more or less conserved. That was the case with the Atlantic coasts of Europe and Africa, from the British Isles to approximately Cape Verde, but not with the Gulf of Guinea and the southern Atlantic, where the distortions due to the effect of magnetic declination on the point of fantasy were much larger. These distortions can be easily observed in the anonymous Portuguese chart of ca. 1471, where the geographic grid of meridians and parallels implicit in the representation was interpolated using a sample of control points of known geographic coordinates (fig. 1)⁷. In contrast to the region between Cape Verde and Ushant (Ouessant), where the parallels are approximately equidistant and orientated east-west, allowing a scale of latitudes to be overlaid, the geographic grid is clearly deformed in the Gulf of Guinea. The same happens in the planisphere of Juan

de la Cosa, made in 1500 (fig. 3). Again, note the counterclockwise tilt of the parallels to the south of Cape Verde, which is caused by the effect of magnetic declination on the compass directions observed by the pilots at the time the information was collected.

To represent latitude faithfully a new cartographic solution was needed. In such a model, places were to be represented according to their latitudes and the courses to other locations, instead of estimated distances. In other words, the portolan-chart model, based on the point of fantasy method, was to be replaced by the latitude-chart model based on the set point procedure. An important point to note is that these two methods would produce exactly the same result in the absence of any errors affecting latitudes, courses and distances – which is not the case when magnetic declination was present. While in the portolan-chart model magnetic declination is reflected in the orientation of both meridians and parallels, in the latitude-chart model parallels are always shown as east-west orientated and equally-spaced segments⁸. The reason why the charts based on the portolan-type model could be used to support astronomical navigation in certain regions is because magnetic declination in those parts was small at the time the information was collected. That is exactly what happened in western Europe and northwestern Africa during the fourteenth and fifteenth centuries, when magnetic declination reached a local minimum⁹.

3 The latitude chart

Although astronomical navigation had already been in use for some time when those early Portuguese charts were made, the full development of the new cartographic model would still have to wait for an extensive astronomical survey covering the areas where the latitudes were not known with accuracy. We know from a handwritten note attributed to Columbus, or to his brother Bartolomeo, that such a survey was indeed ordered by King John II of Portugal, around 1485¹⁰.

The earliest extant chart to incorporate astronomically-observed latitudes is the Cantino planisphere, drawn by an anonymous Portuguese cartographer in

7 The geographic grid of meridians and parallels was estimated using the freeware application MapAnalyst, by Bernhard Jenny and Adrian Weber (<http://mapanalyst.org/>). No nautical charts of the fifteenth and sixteenth centuries, prior to the Mercator projection, depict meridians or parallels.

8 For a detailed explanation of the geometric features of the charts and their relation to the navigational methods of the Renaissance, see Gaspar, 2010, ch. 2, p.11-44.

9 See figure 4.6 in Gaspar, 2010, p. 97.

10 The note was written in the margin of a biography of Pope Pío II, 'Aenea Sylvii episcopi Sinensis, postea Pii Papae II Historia rerum Friderici tertii imperatoris' (Venice, 1447). For a facsimile see 'Autografi di Cristoforo Colombo', in *Raccolta di documenti e studi pubblicati dalla Commissione Colombiana*, ed. Cesare de Lollis, vol. 3, part 1, Rome, 1892.

1502. Although no graphical scale of latitudes is explicitly shown, the depiction of the Equator, tropics and Arctic Circle suggests that places are represented according to observed latitudes¹¹. A sample of control points in the Cantino planisphere was chosen along the coasts of western Europe and Africa, and their latitudes were measured using the implicit latitude scale of the chart. Those latitudes were then compared with the exact values and the corresponding errors were determined (fig. 4). Notice how the errors are usually less than one degree along the coast of northwest Africa (between the equator and 35° N), which is the area where King John II ordered the astronomical survey to be made. On the other hand, the latitude errors in northern Europe are much larger and increase strongly with latitude. This means that the representation of the region was copied from an older non-astronomical source, with little concern for the scale difference. We will see how this mistake was to be corrected in the charts made during the first half of the sixteenth century.

With the Cantino planisphere a new cartographic standard was established, which was promptly adopted for many other world maps of the time. The Caverio chart, drawn by the Genoese cartographer Nicolò de Caverio in 1504-5 is one of a relatively large group of nautical planispheres made at the beginning of the sixteenth century, which also includes the King-Hamy chart (ca. 1504), the chart by Vesconte Maggiolo (1504) and the Pesaro map (ca. 1505-8).

Another important step towards the adoption of the new cartographic model can be seen in Pedro Reinell's chart of ca. 1504, one of the earliest known with a scale of latitudes (fig. 5)¹². Surprisingly, not one but two different scales are shown: the main latitude scale, which applies to the eastern side of the chart; and the oblique scale close to Newfoundland, applying to this region only. There is a simple explanation for such an ingenious solution, which is that Newfoundland was represented on the chart using a magnetic course and an estimated distance with its origin in the Azores, that is, on the basis of the point of fantasy. Being aware that it was not possible, due to the large value of the magnetic declination, to reconcile this course and distance with the latitude

measured in the main scale, the cartographer added a new one. If the set point method were adopted to represent Newfoundland on the chart, using the main latitude scale, the distance from the Azores would be grossly underestimated, as shown in figure 5. Other European charts of the sixteenth century depict multiple latitude scales. That is for example the case with an anonymous Portuguese chart of ca. 1560, with two scales, as well as the Atlantic chart of Diego Gutiérrez, of 1550, with three, both kept in the Bibliothèque nationale de France.

Very little is known about the technical evolution of nautical cartography during the sixteenth century, following the introduction of the latitude chart. The preliminary results which are presented next, about the representation of Europe and Africa in those charts, only scratch the surface of a very large and almost unexplored field of research.

4 Latitude errors

We have seen how, in the Cantino planisphere, the latitude errors in northern Europe increase with latitude (fig. 4). This was the result of copying the representation of the area from non-astronomical charts, without taking into account the scale differences. In the Cantino planisphere, as in many other charts of the sixteenth century, a model of the Earth was adopted in which a degree of latitude measured 18 Iberian leagues, a value which is about 12% smaller than the correct one¹³. This choice was probably driven by political, rather than scientific reasons, related to the negotiations between Portugal and Spain in connection with the Treaty of Tordesillas. If a standard of 20 leagues per degree, which is implicit in the older non-astronomical charts, had been adopted instead, the latitudes in northern Europe would have been much closer to the correct values. I have selected, in a more or less arbitrary way, a sample of nautical charts of the first half of the sixteenth century and measured the latitude errors of a group of places from Cape Finisterre, in the south, to the Strait of Dover, in the north. In figure 6, each individual graph shows the latitude errors in one specific place, for the seven charts organized in chronological order. With a few exceptions, the errors become less than one

11 For a detailed cartometric analysis of the Cantino planisphere see Gaspar 2010, p. 129-82 and Gaspar 2012.

12 At least four other undated charts from the beginning of the sixteenth century show latitude scales: the anonymous planisphere known as King-Hamy, attributed by some historians to Amerigo Vespucci (ca. 1504); the Caverio planisphere of ca. 1504-05; the anonymous chart of the Atlantic known as Kunstmann III (ca. 1506); and an anonymous Portuguese chart of the northern Atlantic and Mediterranean (ca. 1510), now kept in the Bayerische Staatsbibliothek, Munich. Because all those dates are approximate it is possible that one or more of these charts might be older than Pedro Reinell's.

13 The exact metric length of the Iberian league is unknown. I am assuming here the value of 5573 m indicated by García Franco 1957, p. 186; 200.

degree from about 1504, with the chart of Pedro Reinel (fig. 5), and tend to decrease with time. How this correction was made, either by a scale adjustment or by incorporating observed latitudes, is uncertain.

5 The shape of Africa

The second group of results, presented next, concerns the shape of Africa. The exaggerated longitudinal extent of the continent, making the Isthmus of Suez enormous, is a distinctive feature of the Cantino planisphere and of many other charts of the time (fig. 7). In 1537 the Portuguese mathematician and cosmographer Pedro Nunes wrote about this subject in his *Treatise in defence of the nautical chart*. According to him the two reasons for the apparent distortion were the counterclockwise tilt of the Mediterranean and its under-estimated length on the charts. While he was theoretically correct in both points, the influence of those two factors is relatively small and Nunes was unable to identify the main reason for the distortion, which is the effect of magnetic declination. I have shown elsewhere how the coastline of Africa was drawn in the nautical cartography of the sixteenth century, using the latitudes and courses associated with a maritime route around the continent (Gaspar, 2010, p.157-74). In the absence of magnetic declination affecting these courses, the position of Cape Guardafui, at the entrance of the Gulf of Aden, would have been more than 250 leagues (about fourteen equatorial degrees) to the west of its position in the Cantino planisphere. As Pedro Nunes correctly pointed out in 1537, adjusting the position of Cape Guardafui on the charts could not be done because it would make them unfit for navigation¹⁴.

I have compared the width of Africa at the latitude of Cape Guardafui (A, in fig. 7), as well as the longitudinal distance between the eastern margin of the Mediterranean and Cape Guardafui (B), in a series of charts of the sixteenth and seventeenth centuries. This group included Waldseemüller's *Carta Marina* of 1516 and a planisphere by Diogo Ribeiro (1529), made in the *Casa de la Contratación*. The results are surprising. While, as expected, the position of Cape Guardafui remained more or less constant up to end of the sixteenth century, the distance between Cape Guardafui and

the eastern margin of the Mediterranean steadily decreased during that period and beyond (fig. 8). This means that the longitudinal shrinking of the Red Sea on the charts originated, not because of any corrections made to the position of Cape Guardafui but by adjusting the width of the Mediterranean.

The procedure becomes obvious when we put, side by side, the Cantino planisphere, of 1502, and a chart by Sebastião Lopes of 1590 (fig. 9). Knowing that no similar adjustment was made on the portolan charts of the time and that these planispheres were not used for sailing in the Mediterranean, it seems obvious that the reason for the correction was aesthetic rather than technical.

Concerning the longitudinal width of Africa, a quick assessment of later charts reveals that corrections started to be made in the position of Cape Guardafui from about 1600 onwards. Whether these corrections were motivated by the secular change of magnetic declination in the area or by an attempt to make them conform to true geographical direction is still uncertain.

6 Final remarks

The transition between the portolan chart of the Mediterranean and the latitude chart of the Atlantic, which occurred during the second half of the fifteenth century, after the introduction of astronomical navigation, is one of the most intriguing and less studied processes of the nautical cartography of the Renaissance. Surprisingly, little attention has been given to the subject in the specialized literature. Two closely connected reasons contributed to the situation: first, the lack of interest among many traditional historians of cartography in the technical aspects of the discipline; and second, the almost consensual acceptance of the theory of the so-called 'square chart', which claimed that the latitude charts of the sixteenth century were constructed according to the principles of the equidistant cylindrical projection. This mistake, which I have called elsewhere 'the myth of the square chart', may have originated in a mis-interpretation of Pedro Nunes's words in his *Treatise in defence of the nautical chart* (1537). This misconception has managed to survive to the present, being still repeated in important international

14 On this subject Nunes writes: 'Now it is manifest that the Portuguese did not choose this longitude [for Cape Guardafui] so as to conform with Ptolemy [...] furthermore our charts are so well delineated that to do so it would be necessary to change all routes: which cannot be done' (Author's translation). The original reads: *Ora manifesto he: que os portugueses nam lhe foram por esta longura; pera conformarem com Ptolomeu [...] tanto mais que andam as nossas cartas tam gizadas: que pera fazer isto era necessário mudar totalas rotas: o que nam poderá sofrer* Nunes, 2002, p. 137-38.

publications¹⁵. In my opinion its acceptance by prominent historians of the twentieth century has seriously distorted our understanding of the geometry of pre-Mercator charts and prevented a systematic study being initiated. Why take the trouble to analyze the complex geometric features and evolution of pre-Mercator nautical charts when the great historians of the past had no doubts about how they were made.

This paper has shown how the transition between the portolan-chart of the Mediterranean and the latitude chart of the Atlantic, following the introduction of navigational astronomy, was facilitated by the small values of magnetic declination which occurred in western Europe during the Renaissance. The results of two preliminary studies of the cartographic evolution of a sample of Portuguese charts from the sixteenth century were presented and discussed: the

first analyzed the accuracy of the latitudes in the depiction of northern Europe; the second focused on the longitudinal width of Africa. It was found that, while the latitude errors affecting the representation of northern Europe in the earliest charts were promptly corrected in the first years of the sixteenth century, the longitudinal width of Africa remained practically unchanged throughout the sixteenth century. This is because, as noted by Pedro Nunes in 1537, the position of Cape Guardafui on the charts resulted from the magnetic courses observed by the pilots along the coast of Africa. Changing that position would make the charts unfit for navigation. Whether the later changes to the width of Africa that started to be made about 1600 were or were not an attempt to make them conform to true geographic direction is uncertain.

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15 For a refutation of the myth of the square chart see Gaspar 2007; 2010, p. 33-4; 2012, p.186.

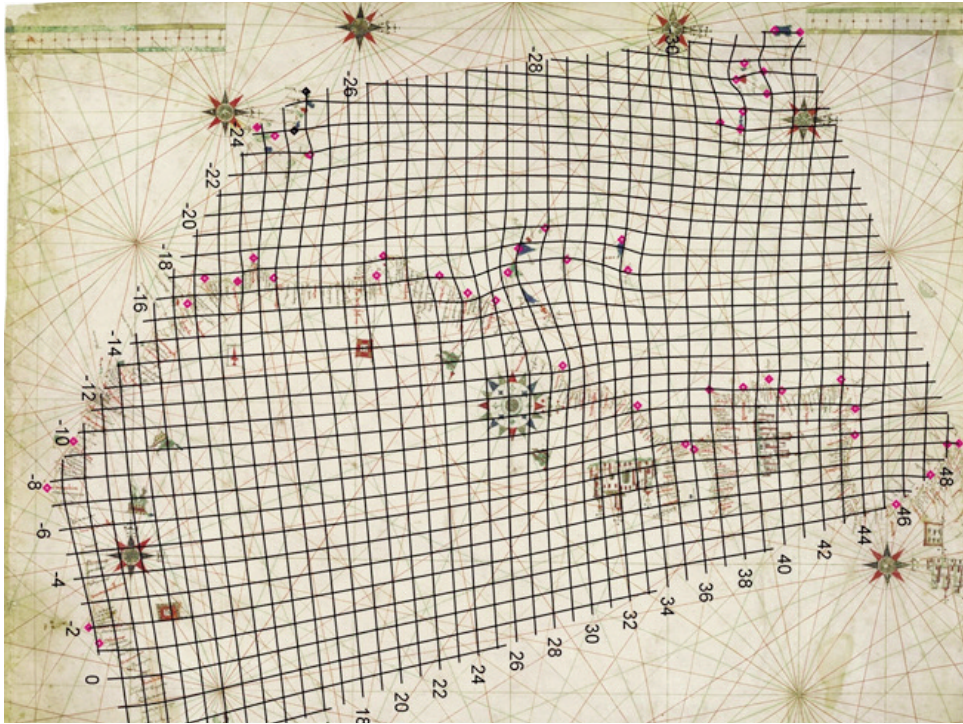


Figure 1 : The geographic grid implicit in the anonymous chart of ca. 1471 (Biblioteca Estense Universitaria, Modena). Note the counterclockwise tilt of parallels and meridians in the coast of the Gulf of Guinea (bottom right)

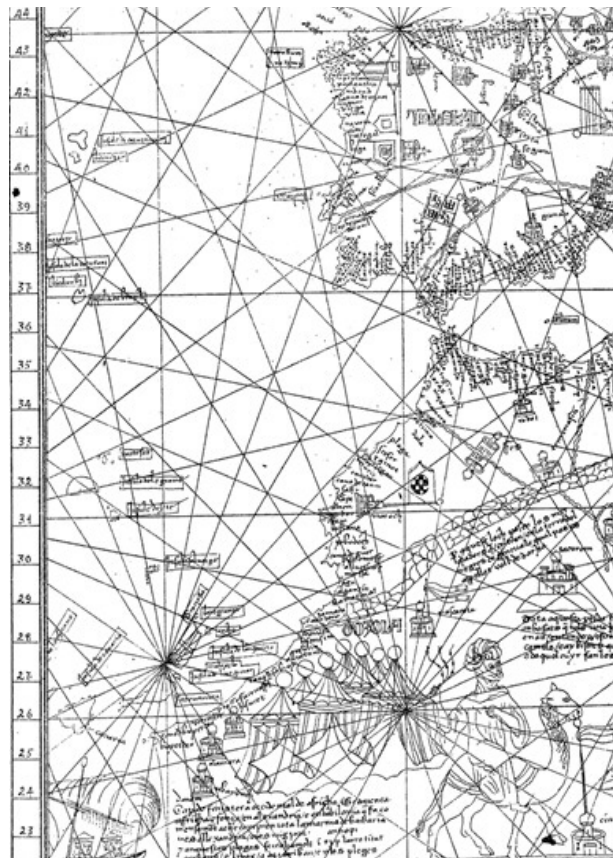


Figure 2 : Facsimile of the Catalan Atlas (detail) with an overlaid scale of latitudes at the left (reproduced from Barbosa, 1938, p. 192)



Figure 3 : The geographic grid implicit in the representation of the western coast of Africa in Juan de la Cosa's planisphere of 1500 (Museo Naval, Madrid). Note the counterclockwise tilt of the parallels to the south of Cape Verde

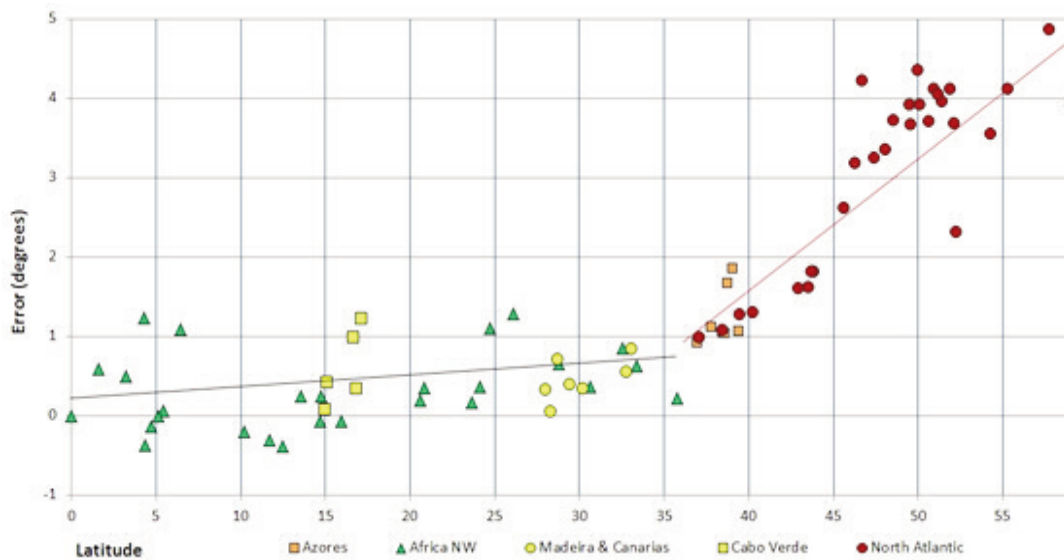


Figure 4 : Distribution of the latitude errors with latitude in the northern Atlantic, in the Cantino planisphere. Note the small errors in the northwestern coast of Africa (0 to 35°N) and the strong increase with latitude in northern Europe. Adapted from Gaspar (2010, p. 151)



Figure 5 : Pedro Reinel ca. 1504 (Bayerische Staatsbibliothek, Munich). Note the secondary latitude scale, close to Newfoundland. The location of that region in the chart was probably determined using a magnetic course and an estimated distance with its origin in the Azores, that is, on the basis of the method of the point of fantasy (PF). If the set point method were used instead (SP), the main latitude scale would apply also to Newfoundland but its distance from the Azores would have been grossly underestimated



Figure 6 : Latitude errors in a sample of nautical charts of the first half of the sixteenth century, for four places in northern Europe. With very few exceptions the errors become less than one degree from about 1504



Figure 9 : Africa and the Mediterranean in the Cantino planisphere (top) and in a chart by Sebastião Lopes (1590). Note how the longitudinal distance between the eastern margin of the Mediterranean and Cape Guardafui decreased substantially, as a result of the stretching of the Mediterranean, while the position of Cape Guardafui remained approximately constant