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Reconciled at last? Grids of latitude and longitude on two Ottoman portolan charts

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Summary: Two unusual Ottoman maps of the Mediterranean, one kept at the Sylvania Ioannou Foundation and the other sold at Christie's to an unidentified buyer, have become known to historians of cartography only since 2009. Both are large anonymous manuscript maps, probably from the 17th century, drawn on paper but otherwise consistent with the style of the portolan chart tradition. Their most outstanding feature is that they include complete grids of latitude and longitude, something extremely rare on contemporary portolan charts.

This paper studies those grids in detail, comparing each of them with the geographical information contained in the underlying charts. Hypotheses are formulated about how each chart was drawn, as well as the sources that may have been used to locate their parallels and meridians.

The findings of the study suggest that the two analyzed artefacts are the results of experiments with different approaches to reconcile the Mediterranean tradition of nautical charting with the astronomical-mathematical cartography of Ptolemaic inspiration that at the time was increasingly dominant in Europe, a problem that hitherto had had no satisfactory theoretical or empirical solution. These experiments also represent one noteworthy achievement in the long process of Ottoman interpretation, assimilation and adaptation of Western cartography.

Introduction

This article studies two anonymous and undated Ottoman manuscript charts of the Mediterranean focusing on the grids of parallels and meridians drawn on them.

The first of these charts is preserved at the Sylvania Ioannou Foundation (henceforth SIF) in Cyprus. Agamemnon Tselikas (2019) has presented the first detailed description of this artefact, including a comprehensive transcription of all its toponyms.¹ The map was drawn with ink and watercolor on 15 sheets of paper joined together and measures 1.12×2.56 meters. Tselikas has tentatively dated it to 1682-1688, based on the paper's watermark.

The SIF map's toponyms are written in Ottoman Turkish, in Naskh-style Arabic script, with red ink that at some places has darkened to almost black color. According to Tselikas, a few short legends and the shape of the coastline, which exaggerates capes and bays, remind of the *Kitab-i Bahriye* composed by Ottoman seaman and mapmaker Piri Reis in the 16th-century; but many toponyms differ in form from those used by Piri Reis, which rules out a direct copying from that source.

Paper strips with toponyms written in Latin script, mostly in Italian, were pasted on the map to highlight important features such as large cities, key islands or the Mediterranean Sea. It is unclear who made this addition, although Tselikas points out that the pasted paper is "of the same

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¹ A very useful view of all the toponyms overlaid on a high-resolution digital image of the map, made by Tselikas, is available at the website of the SIF: <https://sylviaioannoufoundation.org/en/academic-programmes/research-programmes/ottoman-manuscript-chart-mediterranean/>

era as the paper of the chart itself'. These strips were added later than the lines of the map, as they physically cover stretches of rhumb lines, parallels and meridians.

The second chart analyzed here was sold in 2009 at the auction house Christie's.² It is drawn on paper too, with practically the same geographical scope and size as the SIF chart: two pieces measuring 1.18×1.28 m and 1.20×1.33 m, each of them composed of several sheets of paper. Place names are written in Ottoman Turkish, in small naskh script, with black ink. The map is unsigned and undated but Christie's quoted Beatrice Gründler's opinion that it must date from the first half of the 17th century, based on the type of paper and on the presence of certain toponyms. Unfortunately, the current whereabouts of this chart are unknown and the limited resolution of the available images complicates its study. No publication has ever been devoted to it, aside from the mentioned short description written for its sale.

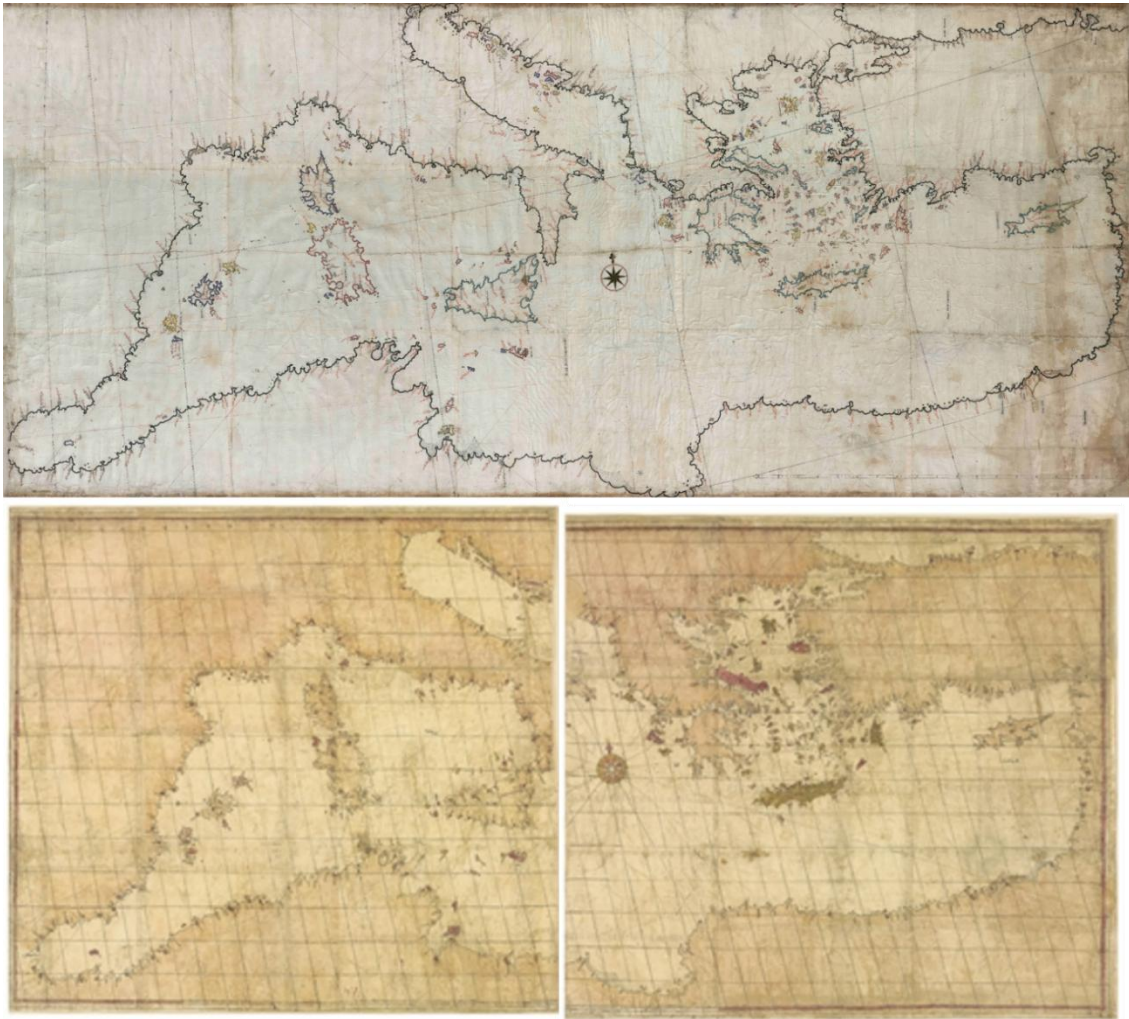


Figure 1. The SIF chart (above) and the chart sold at Christie's in 2009 (below), reproduced at same scale.

² The map is briefly described at Christie's website, with comments by Beatrice Gründler: <https://www.christies.com/lotfinder/Lot/a-large-ottoman-navigational-chart-of-the-5236270-details.aspx> I thank Prof. Gründler for the digital images of the chart she has kindly shared with me. A low-resolution image is available online at <https://www.christies.com/lotfinderimages/d52362/d5236270r.jpg>. A conversation about this map in the MapHist listserv can be consulted at <https://www.mail-archive.com/maphist@geo.uu.nl/msg00191.html> and <https://www.mail-archive.com/maphist@geo.uu.nl/msg00218.html>.

Both maps have many of the features of traditional nautical charts, also called portolan charts, such as a network of rhumb lines, a clear focus on coastal geography and the writing of toponyms roughly perpendicular to coastlines and on the land side. While some portolan charts depicted inland rivers, mountains and cities, many others limited themselves to the coast, leaving the interior regions empty. This is the case of both these maps, and this emptiness of the interior is not necessarily a sign of the maps being “incomplete” as has been suggested by Pinar Emiralioğlu (2019) for the SIF chart.³

Authors of portolan charts tended to copy coastal profiles from one work to another. The two Ottoman maps studied here are one example of that practice, as they are extremely similar in size and geographical scope, the two coastal profiles practically overlap in most regions, and in both charts rhumb lines emanate from a single central wind rose located in the Ionian Sea and form the same angle of around 6 degrees with the horizontal and vertical edges of the map. The great majority of toponyms are written in the same places in both charts (I cannot check if spellings differ, due to the limited resolution of the Christie’s chart image), and the most important localities are highlighted with similar signs.

The two charts are not identical though. Discrepancies can be found between their coastal profiles, particularly along the east shore of the Adriatic, which rules out that one of the charts was mechanically copied from the other. The SIF chart has a scale, not present in the Christie’s chart, while the latter has a pink frame that is absent from the former. Furthermore, the artistic styles of the two artefacts are very different. For instance, the wind rose of the SIF chart has eight points colored in black and green with an outer rim skillfully filled with a red-line pattern, whereas the rose of the Christie’s chart is a 16-point one and was decorated with less attention to detail. The Christie’s chart’s coastlines are simple black outlines that contrast with the elaborate and colorful patterns of the SIF chart.

While these two artefacts are typical portolan charts in many aspects, they are also atypical cases because of their very large size and because of having been drawn on paper, instead of the parchment that was the usual support of that type of maps. But their most unusual feature is the grid of parallels and meridians that criss-crosses each of them.

Medieval portolan charts of the Mediterranean were generally alien to the concepts of latitude and longitude. By the 17th century, however, it had become relatively common for mapmakers to add scales of latitude to their nautical charts and to sometimes trace parallels on them. It is however extremely unusual to find indications of cartographic longitude on Mediterranean nautical charts. Tselikas’s description of the SIF chart’s latitude-longitude grid was rather succinct, and neither him nor Emiralioğlu connected it with the Christie’s chart, which they did not mention. This article aims to fill this gap, studying the grids of parallels and meridians of the two charts so as to gain insights about how they were drawn, by whom and for what purpose.

The first step for that will be a factual and detailed analysis of the lines drawn on each map.

Parallels and meridians on the SIF chart

The SIF chart includes two parallels —30 and 40°N— and six meridians — 25, 30, 40, 50, 60 and 70°E. The values of the latitudes and longitudes of these lines were indicated by numbers written

³ “There are almost no markings on the interior regions in the map, suggesting that the map is incomplete.” Emiralioğlu also states, puzzlingly, that “the chart does not have rhumb lines emanating from its wind rose”. She may have lacked access to images of the map with high enough resolution.

in Eastern Arabic numerals. In addition, every meridian was graduated by indicating latitude values at one-degree intervals, from 29 to 46°N. No indication was provided of the reference taken for longitude or the location of the zero meridian.

While the chart's rhumb lines were drawn in red as single lines, parallels and meridians were traced as double lines in black. This makes it easier to visually distinguish the rhumb network from the latitude-longitude grid. The only exception is a red double line that runs north-south between meridians 25 and 30 and has latitude markings along its whole length. As will be shown below, this red double line stands out not only because of its different color but also because of its inconsistent orientation and latitude markings.

Figure 2 below highlights the grid of the SIF chart, with longitude and latitude values 'translated' into Western Arabic numerals. In order to analyze it, I have compared the location and orientation of parallels and meridians with the chart's rhumb line network and with the actual coordinates of 57 Mediterranean localities.

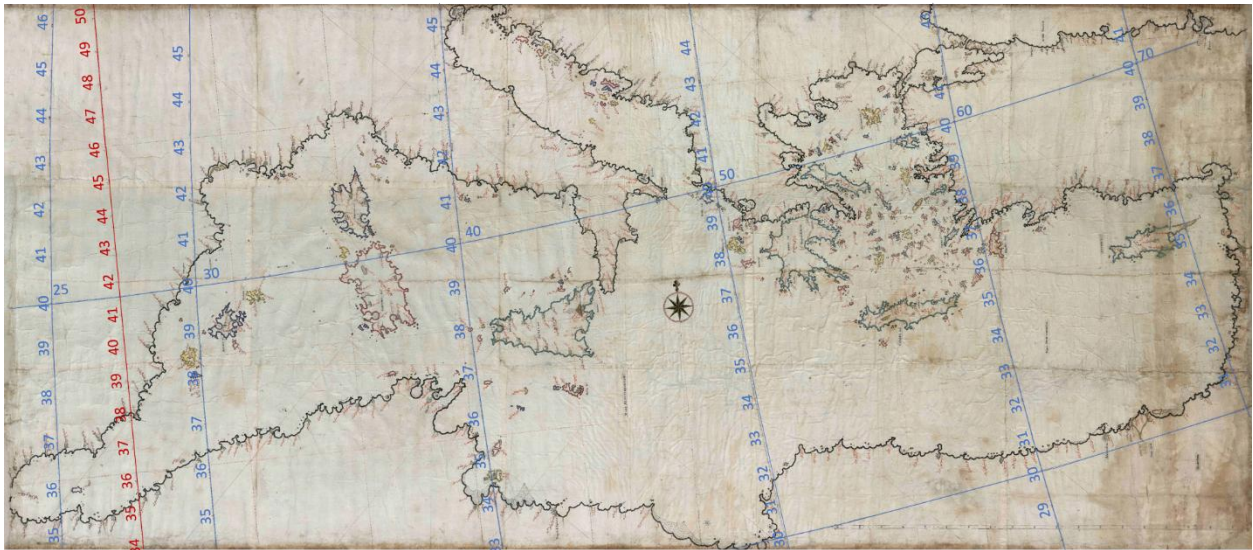


Figure 2: Parallels and meridians of the SIF chart, with latitude and longitude values translated into Western Arabic numerals.

Parallels

A first observation is that the two parallels drawn on the SIF chart are not aligned with east-west rhumb lines. While the rhumb lines are straight and form a six-degree angle with the horizontal edge of the map, the two parallels are more diagonal and slightly curved. To be precise, the curvature is an optical illusion obtained by drawing a series of straight segments.

Both parallels are quite accurately located with respect to the depicted cities and islands. Parallel 30°N is accurate to within less than one degree while parallel 40°N only has errors slightly higher than one degree in the region near Istanbul.

The intermediate graduation of latitudes along the six meridians is also generally consistent with the latitude of localities nearby. However, the graduation of each meridian does not seem to align smoothly with that of the other meridians. The result is that, if one plots intermediate parallels based on the degrees of latitude written on the map, those parallels turn out not to be smooth curves but broken lines. This phenomenon is particularly visible in the region of the central Mediterranean, between Tunisia, Libya and Sicily (see Figure 3).

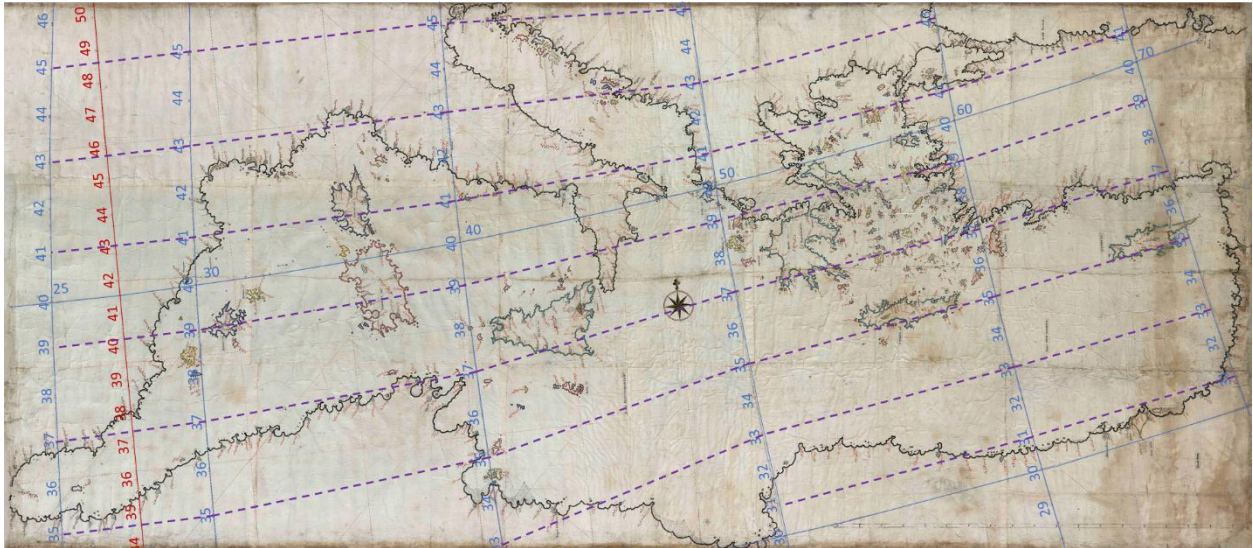


Figure 3. Intermediate parallels plotted on the SIF chart.

Meridians

The SIF chart's meridians differ in orientation from the north-south rhumb lines, similarly to what has been explained for parallels. Meridians are slightly curved too, and form different angles with the horizontal edge of the map: while meridian 40° is practically aligned with a north-south rhumb line, meridians east of it are increasingly diagonal and meridians west of it are increasingly vertical. In other words, if one defines magnetic declination as the angular difference between a meridian and a north-south magnetic rhumb, the map seems to postulate a smooth gradient of magnetic declination, with approximately zero declination between meridians 30 and 40° and increasing declination of opposite signs east and west of it.

The meridians are quite precisely drawn, in the sense that each individual meridian connects places that truly lie at similar longitudes. However, the meridians of the map are not evenly spaced, meaning that the distance between consecutive lines decreases as one moves eastward; and they are not accurately distributed, as their positions imply a difference in longitude between the eastern and western shores of the Mediterranean Sea that is $18 \pm 3\%$ larger than the actual value (see Appendix 1 for an explanation of this calculation). The difference between the two conventional extremities of the Mediterranean —Gibraltar and Iskenderun— is 49.1 degrees on the map, instead of the actual value of 41.5 degrees.

A detailed look at the errors in longitude shows that in fact the western half of the map, between the Strait of Gibraltar and meridian 50°, is quite accurate. Practically all of the map's error stems from a substantial overestimation of the longitude difference between Greece and the Levant by the person who drew the meridians.

The red double line

The red double line located between meridians 25 and 30 of the SIF chart is straight and runs parallel to north-south rhumb lines, at a six-degree angle with the vertical edge of the paper support. Its orientation is therefore inconsistent with that of numbered meridians.

The numbers along the red double line form a latitude scale that is also inconsistent with that of the meridians and does not even match the position of parallel 40°N, which crosses the red double line between the latitude markings for 41°N and 42°N.

The spacing between consecutive numbers along this red line is shorter than for the meridians next to it, which makes the red line ostensibly reach 50°N whereas meridians 25 and 30 only get to 46°N. Nevertheless, the latitudes written along the red double line are accurate at its southern end, between the coastlines of the Iberian Peninsula and Northern Africa.

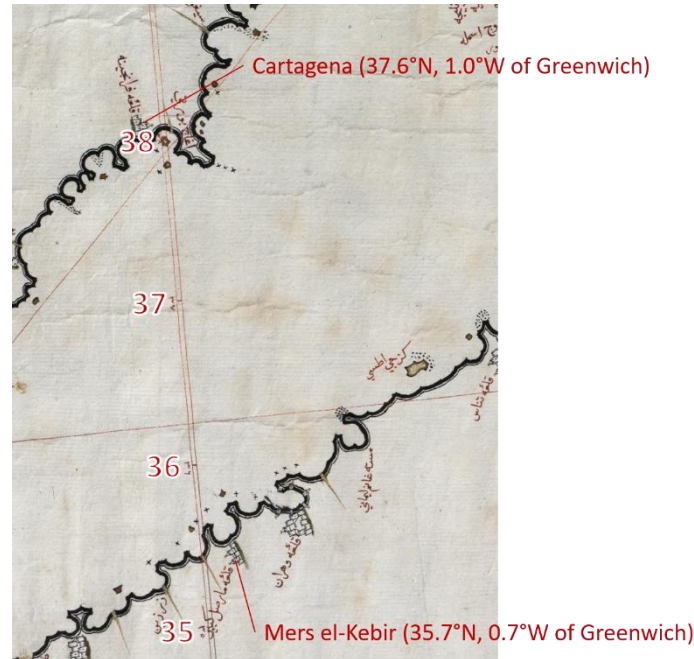


Figure 4. Detail of the SIF chart showing the red double line between Cartagena and Mers el Kebir.

Parallels and meridians on the chart sold at Christie's

In the chart sold at Christie's, the grid of latitude and longitude is much denser than in the SIF chart, consisting of 14 parallels and 54 meridians, all drawn in black. Several meridians and parallels are numbered along the edges but due to the limited resolution of the images available for study, I can only make out a few numbers at the northeast corner. As far as I can see, there are no markings of latitude or longitude along meridians or parallels.

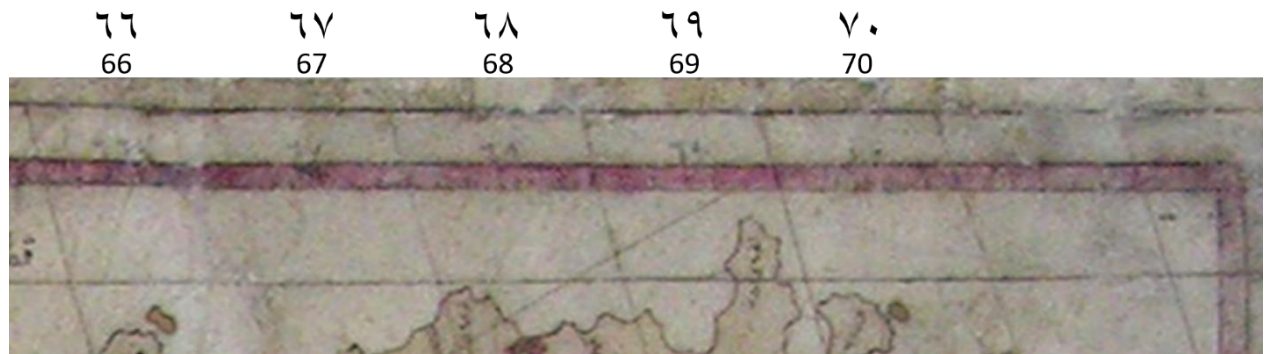


Figure 5. Detail of the Christie's chart showing longitude numbers at the northeast corner.

Parallels are drawn as straight lines parallel to the horizontal edges of the map, evenly spaced from north to south. Meridians are also straight and form an angle with the vertical edges that varies from around 9 degrees in the west to around 15 degrees at the eastern edge. Therefore, neither parallels nor meridians are aligned with rhumb lines, which form an angle of 6 degrees with the vertical and horizontal edges.

Meridians are evenly spaced, except for the very slight effect of their varying angle, and this is a significant difference with respect to the SIF chart, where as we saw the distance between consecutive meridians varies substantially. The spacing between meridians of the Christie's chart is around 1.5 times smaller than the spacing between parallels. This means that the scale ratio between north-south and east-west directions is accurate for parallels 48 to 49°, which corresponds to the latitude of Paris and therefore lies well outside of the scope of the map.

The horizontal alignment of the parallels drawn on this chart makes them very inaccurate. Traditional portolan charts usually depicted the Mediterranean Sea with a counterclockwise 'tilt' of its axis, which means that for example the Strait of Gibraltar was horizontally aligned with Alexandria even though the Egyptian city lies five degrees south of the strait. This tilt is believed to be due to the use by mapmakers of magnetic north as reference, instead of geographic north. From the 1520's onwards, an increasing amount of portolan charts 'corrected' that tilt, so that parallels would look horizontal if plotted and vertical rhumb lines would be aligned with geographic north (Astengo 1995). However, this is not the case of the two Ottoman maps studied here, which show the typical tilt of traditional charts. As a result, drawing parallels as horizontal lines makes their latitudes very erroneous either at one edge of the map or the other.

By the 17th century, it had become quite frequent to add scales of latitude to portolan charts of the Mediterranean. Most often, they were drawn along the west edge of the map or over the Atlantic Ocean. It is possible that the latitudes of the parallels of the Christie's chart are in fact accurate along one particular meridian if the author took as a model one portolan chart that included a latitude scale.

The orientation of meridians is more accurate than that of parallels, and their progressively varying inclination implies that the person who plotted them believed that magnetic declination increases uniformly as one moves eastward. This is qualitatively similar to what is observed on the SIF chart, but the Christie's chart shows two major differences: 1) declination has the same sign across the entire Mediterranean, and 2) declination varies by only six degrees between the opposite ends of the map whereas in the SIF chart the difference is of almost fifteen degrees.

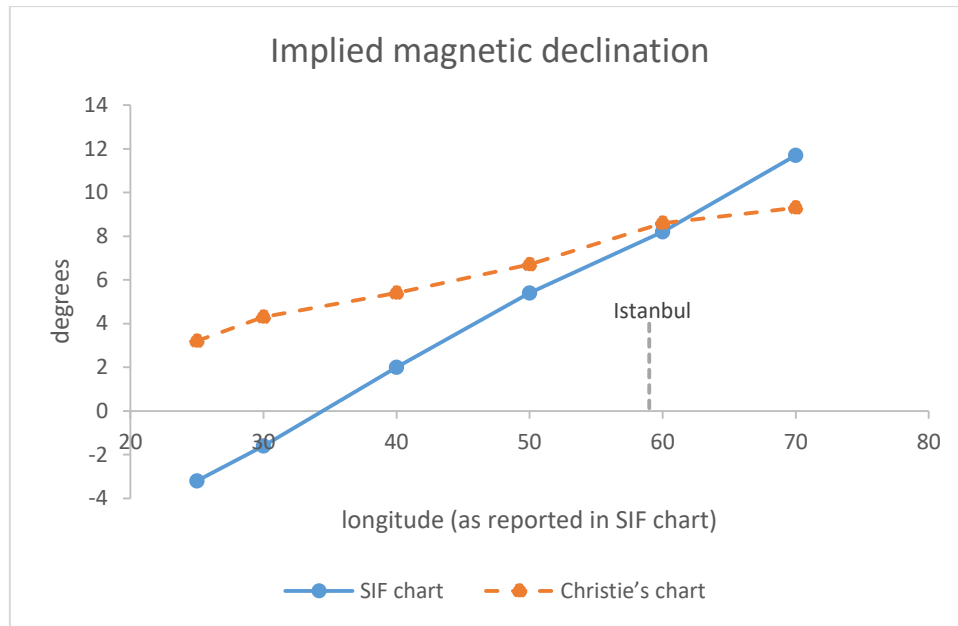


Figure 6. Implied magnetic declination, calculated as the angular difference between meridians and north-south rhumb lines, on the SIF (blue full line) and Christie’s (orange dashed line) charts. The horizontal axis is based on the meridians drawn on the SIF chart. The longitude of Istanbul is indicated for reference.

The two curves of magnetic declination cross at a single point, which corresponds to the meridian labeled 60° on the SIF chart. Perhaps not by coincidence, this is very close to the longitude of Istanbul, the city where the two charts were presumably made.

The number of meridians drawn on the Christie’s chart reveals an overestimate of the longitude of the Mediterranean Sea. The longitude difference between Gibraltar and Iskenderun implied by the map’s meridians is 49.5 degrees, almost identical to the SIF chart, and the average error of the longitude of the Mediterranean is $21 \pm 2\%$, which statistically overlaps with that of the SIF chart. The exaggerated longitude explains the distorted vertical-horizontal scale ratio that was mentioned above.

Nevertheless, one important difference with the SIF chart lies in the geographical distribution of the longitudinal overestimate, as the western half here has a non-negligible error, as can be seen in the following table.

| Parameter | SIF chart | Christie’s chart |
|---|----------------|------------------|
| Longitude difference between Gibraltar and Iskenderun | 49.1 degrees | 49.5 degrees |
| Overall longitude error | $18 \pm 3\%$ | $21 \pm 2\%$ |
| Longitude error in western half | $-2\% \pm 6\%$ | $15 \pm 1\%$ |
| Longitude error in eastern half | $37 \pm 9\%$ | $30 \pm 4\%$ |

How were the charts drawn?

Coastal profiles

The standard way to draw a map based on longitudes and latitudes is to first trace a grid of parallels and meridians and then add localities, coastlines and other geographical features based on

their known coordinates. This method was originally proposed by Claudius Ptolemy and is still applied by today's mapmakers.

However, in the two studied charts everything suggests that coastal profiles were drawn first and the grid of parallels and meridians added later. The black ink of parallels and meridians in the SIF chart clearly sits atop the yellow, red, blue or gold contours of all the islands they cross (except for Cyprus, which thus may have been repainted at a later time). The red double line is clearly visible above black coastline contours too, and one of its latitude numbers was written precisely on the blank space available between an islet off Cartagena and the mainland, which suggests that coastal profiles were drawn earlier (see Fig. 7). Similar observations lead to conclude that rhumb lines were also drawn after the coastal profiles.



Figure 7. Bay of Cartagena on the SIF chart.

Furthermore, it would have been very impractical for the author of the SIF chart to start by drawing the grid of meridians and parallels in the way it appears on the map. The curved shape and unequal angle, spacing and graduation of meridians would have meant the choice of a very complicated projection, which would have rendered calculating the position of any locality a time-consuming and error-prone exercise. If the mapmaker had deliberately chosen a projection, he or she would have graduated meridians homogeneously, unlike what is observed in the SIF chart.

Ottoman polymath Katip Çelebi reported that, in 17th-century Istanbul, maps for mariners were routinely made at eight workshops (Soucek 1992). The close similarity of the coastal profiles between the SIF and Christie's maps suggests they were both drawn at the same workshop. However, the proposed date ranges for the two charts differ by at least three decades. So, either the dating of one of the maps is not entirely accurate or the same coastal profiles were imitated from map to map for a very long period of time.

The SIF chart

What criterion was followed to add the grid of meridians and parallels to the SIF chart? Two hypotheses can be formulated. The first one is that the positions and orientations of meridians and parallels were inferred from the geographical information contained in the chart itself, somehow

emerging from the coastlines, rhumb lines and scale bar depicted on it. A second hypothesis is that the mapmaker copied the latitude-longitude grid and/or its numeric values from some external source, possibly another map or a table of coordinates, and then overlaid it on the nautical chart.

Several arguments support the second hypothesis. The most decisive evidence is the fact that neither the parallels nor the meridians are aligned with rhumb lines. If a mapmaker wanted to deduce the position of parallels and meridians from what is depicted on the chart, the obvious choice would be to draw them as straight lines parallel to the east-west and north-south directions that are clearly indicated by the rhumb lines. Drawing the parallels and meridians as curved lines with varying angles means that the mapmaker was clearly ignoring and contradicting the information given by the chart's rhumb line network.

A second revealing element is that latitude numbers are differently spaced along each meridian, and those numbers look as if the mapmaker wrote them along each individual meridian by fitting them to places he or she knew the latitude of, such as Venice, Crete or Tunis. This implies the reliance on an external source of latitude data.

The longitudinal error of the map is the third piece of evidence pointing to the construction of the latitude-longitude grid from an external source rather than from the portolan chart. We have seen that the mapmaker drew the meridians of the eastern half of the map closer to each other than those of the western half, resulting in an overestimate of the longitude of the Eastern Mediterranean. Such geographic misconception was widespread in the 17th century (Robles Macías 2014), so the mapmaker may have copied it from some contemporary source. Furthermore, when one measures the underlying nautical chart it turns out that the Eastern Mediterranean is drawn at a slightly larger scale (i.e. one unit of distance on the map represents a shorter actual distance of terrain) along the east-west direction than the western half of the map but the difference is only between 9 and 10%. This means that the overall longitudinal error of the Mediterranean induced by the shape of the coastlines on the portolan chart would be just below 5%, which is much smaller than the 18% error that affects the map's meridians (see Appendix 2 for detailed calculations).

Comparing the grid of parallels and meridians of the SIF chart with those found in maps drawn or published before 1800 reveals that it is extremely similar to that of the monumental world map published by Joan Blaeu in Amsterdam in 1648.⁴ Not only is the spacing of meridians identical between the two maps but also their absolute values, which implies the use of the same reference meridian for zero longitude. The only innovation in the SIF chart is the addition of a meridian at 25°E. Regarding latitudes, it is noteworthy that Blaeu's map significantly overestimates the latitude of the Sea of Marmara, as is also the case of the SIF chart.

Blaeu's world map became an influential model in the second half of the 17th century. It was published again in Amsterdam by Frederick de Wit in the early 1660's, in an amended and somewhat reduced form,⁵ and other versions were produced later in cities like Bologna and Rome (Cesari 2012). It is thus plausible that an Ottoman mapmaker of the 1680's would have access to a copy of at least one of those works.

⁴ Joan Blaeu, *Nova Totius Terrarum Orbis Tabula*, 21-sheet printed world map in two hemispheres, 1710 × 3030 mm (Amsterdam, 1648)

⁵ Frederick de Wit, *Nova Totius Terrarum Orbis Tabula*, 12-sheet printed world map in two hemispheres, 1285 × 1995 mm (Amsterdam, ca 1660)



Figure 8. Detail of the Mediterranean basin in Frederick de Wit's *Nova Totius Terrarum Orbis Tabula*. Boxes with values of latitude and longitude have been added for clarity.

Based on the mentioned elements, it would already be possible to postulate how the parallels and meridians of the SIF chart may have been drawn, but before that I would like to analyze the red double line, that awkward element that seems to be at odds with the rest of the map. As we saw, the red double line is straight and runs parallel to north-south rhumb lines. That would have been the natural way to draw a meridian if the grid of parallels and meridians had been deduced from the portolan chart. The red double line crosses two stretches of coastline at the locations of Cartagena (actual coordinates: 37.6°N, 1.0°W of Greenwich) and Mers el Kebir (35.7°N, 0.7°W). These two cities actually have almost the same longitude, so the orientation of the red double line is correct if it is meant to represent a meridian. In addition, the latitudes of both cities match the numbers written along the red double line to within less than half a degree. The rest of the latitude scale seems to have been extrapolated from these two correct values, as it is homogeneously spaced along the entire line. All this suggests that the red double line was intended to represent a meridian, and combining this observation with those made above about the black-ink grid of parallels and meridians allows me to propose a more complete reconstruction of how the SIF map was made.

First of all, the coastal profiles were drawn, and then rhumb lines and possibly the scale were added. This “pure portolan chart” was either copied from the Christie’s chart or made in the same workshop as the Christie’s chart as part of a series of identical large-scale charts of the Mediterranean on paper.

In a second stage, a probably different person (which I will call ‘he’ for simplicity) attempted to draw a grid of parallels and meridians on the chart in a manner consistent with the rhumb lines

and geographical information contained in it. He was most likely Ottoman, based on how he wrote numbers on the map, and had access to a table of coordinates that gave at least the latitudes of certain localities. This person started from the western end of the map and looked for two cities that were located on a north-south axis and for which he had latitudes available. He found Cartagena and Mers el Kebir, which were two important ports of the Spanish navy — a traditional enemy of the Ottoman fleet— and must therefore have been listed in that Ottoman table of coordinates. The cartographer thus drew a first meridian through those two cities, aligning it with north-south rhumb lines, and then graduated it based on the latitudes read from the table for Cartagena and Mers el Kebir. However, as he extrapolated the latitude scale northwards, he realized something was wrong: he had reached 50°N at a place that should in fact be close to the latitude of Venice, which he knew from his table was only around 45°N. This obvious error led him to suspend the work and think of a different way to draw the meridians and parallels.

Our anonymous researcher then came up with the idea of copying the entire grid of parallels and meridians from a printed world map that he had seen and was deemed highly reliable at the time: one of the derivatives of Blaeu's world map of 1648. He thus transferred the positions of two parallels and five meridians from the printed map onto the chart, and added an extra meridian at 25°E, using for all these lines ink of a different color than for the first failed attempt. He then took out his table of latitudes and used it to graduate each meridian separately, based on the cities located nearby. In doing this, the mapmaker unknowingly transferred to the portolan chart the misconception held by Dutch cartographers about the longitude of the Eastern Mediterranean, a region that paradoxically had always been depicted with accurate proportions by the portolan chart tradition.

Finally, at a later stage and perhaps at a different location, someone pasted strips of paper with place names in Latin characters on the map.

The Christie's chart

For the chart sold at Christie's, a similar process can be proposed. The coastal profiles and rhumb line network were drawn first, probably at one of the workshops mentioned by Katip Çelebi. Then someone decided to draw parallels as horizontal lines and meridians as diagonal lines at slightly varying angles with the vertical direction.

The horizontal alignment of the parallels suggests that the author of the grid was unaware of the attempts to correct the counterclockwise tilt of the Mediterranean. Perhaps he spaced the parallels looking at some portolan chart with a latitude scale drawn on it, not realizing that those latitudes were valid only for the western edge of his chart. In any case, he spaced parallels homogeneously, implying a uniform scale along the north-south direction.

The overestimate of the longitude of the Mediterranean by around 21% suggests that the position of the meridians was also influenced by contemporary West European conceptions, but the absolute values of longitude reveal that the source must have been different from that of the SIF chart, as the values are shifted by three degrees. In effect, on the Christie's chart the city of Iskenderun lies between meridians 69 and 70 whereas in the SIF chart its longitude is between 72 and 73 degrees. Furthermore, the even spacing of meridians indicates that the author probably did not copy a grid as such from some earlier map, as in that case the spacing would have been different between the western and eastern halves of the chart (i.e. meridians would have been closer together in the eastern half). It seems more likely that the author of this grid simply read on some map, globe or table of coordinates the longitudes of two localities at opposite ends of the Mediterrane-

an, drew the meridians that ran through those localities and then interpolated the rest of the grid from those two references. Several localities of the chart lie very close to or directly on top of a meridian, and may thus have been the ones selected by the author of the grid: Gibraltar, Valencia or Algiers in the west, and Yumurtalik or Gaza in the east. Coordinates for those localities must have come from some contemporary Western source, but it is difficult to pinpoint the exact one.

For what purpose?

A more difficult question about the latitude-longitude grids of the SIF and Christie's chart is why they were drawn. Actually, this is part of a broader question: what was the purpose of these two charts, in general?

No information has been published on the provenance of either chart, so we do not know who they were made for or where they were kept. Beatrice Gründler proposed that the Christie's chart could have been "a tool for plotting campaigns" by the Ottoman military, rather than an instrument for navigation. One of the points supporting her statement was that there are castles drawn along the coastlines of that chart. Looking at the SIF chart, it turns out to contain an equally large number of small drawings of 'castles' but in my opinion, these might just be conventional symbols for cities and towns, not necessarily military markers. On the other hand, the drawing on the SIF chart of the red double line through Cartagena and Mers-el-Kebir may indeed reflect an interest in the ports of an enemy navy and therefore a possible military context for the production of that chart.

The latitude and longitude numbers written on the two charts are all in very small script, like the text of toponyms and legends; they can only be discerned from close even though the maps themselves are huge. This means that these numbers were not intended for public contemplation or for the teaching of mapmaking in a classroom. They were useful only for the person who wrote them or for someone who would consult the map in detail. To me this evokes a military engineer or a scholar working within a limited circle of specialists.

The Ottoman workshop that, around 1685, made the SIF chart, and which probably also made the Christie's chart and other similar large maps of the Mediterranean, was one of the few still keeping alive the old Mediterranean tradition of nautical cartography. By that time, most workshops in the Christian shores of the Mediterranean had shut down or were issuing their very last portolan charts. Actually, the SIF chart is highly unusual for its time because it is very detailed and accurate whereas most extant 17th-century portolan charts of the Mediterranean had become ornamental objects with crude coastlines and outdated information. By 1685 the portolan tradition was coming to an end after what has been called "a long twilight punctuated with many flashes of brilliance", and its products were being replaced by printed maps and atlases based on latitudes and longitudes, made primarily in northwest Europe (Astengo 2007, 235–37).

This northwest European cartography was at the time an object of study for several Ottoman intellectuals. Between 1653 and 1655, Katip Çelebi (along with French convert Mehmet Ikhlas) translated and adapted Jodocus Hondius's *Atlas minor*,⁶ in a work entitled *Levami' al-nur*. Two decades later, between 1675 and 1685, Al Dimashki adapted Joan Blaeu's *Atlas maior*,⁷ an exemplar of which was offered as a present to the sultan (M. P. Emiralioğlu 2019; Brentjes 2014).

⁶ Jodocus Hondius, *Atlas minor Gerardi Mercatoris*, 682-page atlas, 190 × 240 mm (Arnhem, 1621)

⁷ Joan Blaeu, *Atlas Maior, sive Cosmographia Blaviana, qua solum, salum, coelum, accuratissime describuntur*, 11-volume atlas with 594 maps, 370 × 570 mm (Amsterdam, 1662)

Karamustafa (1992) called these translations a “watershed in the Europeanization of Ottoman geographical literature”, stating that “these translations mark the entry of the European terrestrial atlas into Ottoman culture” and the beginning of “a period of transition in which the Ottomans adopted Western geographical science and cartographic practice”. This view has however been tempered by later scholarship, which now tends to see Çelebi’s and Al-Dimashki’s work as “a continuation rather than a drastic change” with respect to earlier trends (M. P. Emiralioğlu 2007). In effect, the concepts of Ptolemaic cartography were far from novel in Ottoman lands. Ptolemy’s works had been translated into Arabic many centuries before they became available in Latin, and sultan Mehmed II is known to have owned several manuscripts of the *Geographia*, commissioned a new translation of it into Arabic and encouraged the production of maps in Ptolemaic style, as Karamustafa himself documented. In the 16th and 17th centuries, world maps with explicit grids of parallels and meridians, inspired of works by Western mapmakers like Giacomo Gastaldi, were often included in Ottoman nautical atlases such as the one signed by Ali Macar Reis or the anonymous ones at the Walters Art Gallery and the Istanbul Arkeoloji Müzesi (Goodrich 1985; 1986). Furthermore, Çelebi’s version of the *Atlas minor* reproduced the parallel and meridians grids of the original in only a few maps; for most, *in lieu* of a grid, latitude and longitude numbers were simply written along the edges of the map. Sonja Brentjes (2005) has observed that Çelebi “did not start with constructing the frame, gradation and grid when drawing the maps, but began with outlining the boundaries of the terra firma and of islands.” Al Dimashki’s work seems to have followed a similar approach, according to Brentjes, copying Blaeu’s maps without much regard for meridians and parallels, which often are only partially drawn and sometimes entirely missing. In both works, “mathematical constructions, geographical coordinates and scales were only of minor importance for the translators, writers and consumers.”

So, it would be mistaken to imagine Ottoman mapmakers of the 17th century as ignoramuses stuck in the practices of traditional portolan charting waiting to be illuminated by Dutch cartographers on the use of latitude and longitude. The concepts of Ptolemaic cartography were probably as well understood in Istanbul as in Livorno or in Amsterdam, but many mapmakers in those cities just kept on opting for portolan-style techniques to draw their nautical charts. What was challenging was how to blend the teachings of the two schools.



Figure 9. Ptolemy in the frontispiece of an edition of Joan Blaeu’s *Atlas maior*.

Henrique Leitão (2019) has shown how the relationship between nautical and Ptolemaic mapmakers in 16th-century Europe was dominated by conceptual clashes about how maps should be made, and by mutual misunderstandings of how the maps of “the other” school should be interpreted and how erroneous or useless they were. Overall, it seems that not a single cartographer was able to properly understand the methods of both schools simultaneously, or to develop a satisfactory method to convert nautical charts into Ptolemaic maps with meridians and parallels or vice versa. One such attempt is found in an anonymous nautical atlas possibly made in Venice in the second half of the 16th century,⁸ which includes scales of latitude and longitude along the edges of all its maps but with the scales drawn in a way that is not consistent across the two halves of the Mediterranean (Astengo 2005).

The grids on the SIF and Christie’s charts stand out as practical experiments to blend a traditional portolan chart with the astronomical-mathematical cartography of Ptolemaic inspiration. The authors of these documents made three attempts overall to establish a two-way correspondence between the coastlines drawn according to the methods and conventions of Mediterranean nautical cartography and a Ptolemaic grid of parallels and meridians. One of those attempts —the red double line of the SIF chart— was quickly discarded by its own author. Another approach —that of the Christie’s chart— could be identified as blatantly erroneous by anyone with a table of latitudes at hand. Finally, the grid drawn on the SIF chart in black ink gave a result that would have been considered satisfactory per the standards of the time, with their uncertainty about the actual longitude of the Mediterranean. Following a trial-and-error process, Ottoman mapmakers had at last apparently succeeded to reconcile nautical charting with Ptolemaic cartography.

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⁸ Bibliothèque Nationale de France, shelfmark GE EE-5610 (RES). High-resolution image available at <https://gallica.bnf.fr/ark:/12148/btv1b550026159>

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Appendix 1: Definition of the error in the longitude of the Mediterranean

The longitude of the Mediterranean on a cartographic work can be defined as the difference in longitude between the eastern and western extremities of this sea. The longitudinal error is defined as the difference between the longitude measured on the studied work and the actual longitude, divided by the actual longitude.

By convention, the western end is usually taken to be Tarifa or Gibraltar while the eastern end is identified with Iskenderun. However, these extremities are not always obvious to identify on a particular map or are not always listed on a table of coordinates. For this reason, Luis Robles Macías (2014) developed a more robust definition of the longitudinal error based on at least three localities at each end of the Mediterranean Sea, which is applied here. More specifically, an average longitude error (E) and standard deviation (σ) of the longitude of the Mediterranean are proposed to be calculated in the following manner:

1. Determine the longitudes of two sets of localities: one set on or near the Western end of the Mediterranean and another set on the Eastern shores.
2. Take each locality of the Western set, W_i , and compute its difference of longitude on the studied map with each of the localities of the Eastern set, E_j .
3. Calculate the longitudinal error for each couple of localities i - j by subtracting the observed differences, $(W_i - E_j)_o$, from the real differences of longitude for each couple, $(W_i - E_j)_r$, and dividing by $(W_i - E_j)_r$.
4. Calculate the average E and the standard deviation σ of the entire set of individual errors for all i and j .

It should be noted that σ gives an indication of the dispersion of the values of the longitudinal error in each cartographic work and, contrary to other statistical measures like the standard error, does not decrease as the number of localities used to calculate the average increases. High σ means that a map is highly distorted in its shape, or that a list of coordinates contains aberrations due to copyist mistakes; on the contrary low σ indicates that the analyzed cartographic work is internally consistent.

Appendix 2: Difference in scale between east and west half of the SIF chart

On the SIF chart, the scale bar defines certain unit of distance. I have used that unnamed unit to measure the distance between the opposite ends of the Mediterranean and between each end and the center of the Sea. I have then compared each of these measurements with the actual values and found that the apparent scale of the chart along the east-west axis is slightly different between its east and west halves.

For the sake of simplicity, I have defined the east and west ends as single localities, respectively Iskenderun and Gibraltar. For the center of the Sea, I have chosen two representative points: Cape Passero (the southeast vertex of Sicily, which lies at roughly the same latitude as Gibraltar and Iskenderun) and the north-south rhumb line drawn on the SIF chart, which runs through the southeastern end of Puglia, the 'heel' of the Italian boot.

The calculation of the scale could be performed by two methods: based on orthodromic (i.e. great-circle) distances or based on longitude differences. I have applied both methods —orthodromic distances between the Sea's ends and Cape Passero, and longitude differences between the Sea's ends and the north-south rhumb line— and the results are quite similar, as shown in the following two tables.

| | <i>Actual orthodromic distance (nautical miles)</i> | <i>Straight-line distance on SIF chart (map's units)</i> | <i>Actual distance per map's unit of measurement</i> |
|---------------------------|---|--|--|
| Gibraltar - Cape Passero | 990 nm | 27.1 units | 36.5 nm / unit |
| Cape Passero - Iskenderun | 1014 nm | 30.2 units | 33.6 nm / unit |
| Gibraltar - Iskenderun | 1996 nm | 57.2 units | 34.9 nm / unit |

Scale in eastern half is $(36.5-33.6)/36.5 = 8.8\%$ larger

| | <i>Actual longitude difference (degrees)</i> | <i>Straight-line distance on SIF chart (map's units)</i> | <i>Actual degrees per map's unit of measurement</i> |
|---------------------------|--|--|---|
| Gibraltar - central line | 23.9° | 31.1 units | 0.77° / unit |
| central line - Iskenderun | 17.7° | 25.5 units | 0.69° / unit |
| Gibraltar - Iskenderun | 41.5° | 57.2 units | 0.73° / unit |

Scale in eastern half is $(0.77-0.69)/0.77 = 9.7\%$ larger

Therefore, depending on the chosen method, the scale of the eastern half turns out to be around 9 to 10% larger than that of the western half.

Let's now assume that the mapmaker accurately knew the longitude difference between Gibraltar and Cape Passero or between Gibraltar and the central north-south rhumb line, and that he measured distances on the SIF chart to determine the longitude of Iskenderun. The following table shows what values the mapmaker would have found, in each of the two cases.

| Method | Distance to C. Passero | Distance to central line |
|--|------------------------|--------------------------|
| Actual longitude difference center - Iskenderun (degrees) | 17.7° | 17.7° |
| Observed longitude difference center - Iskenderun (degrees) | 22.8° | 19.6° |
| Observed longitude difference Gibraltar - Iskenderun (degrees) | 43.3° | 43.4° |
| Overestimate of the longitude of the Mediterranean | 4.3% | 4.6% |

One concludes that the overall longitudinal error of the Mediterranean induced by the portolan chart contents would have been between 4 and 5%. This overestimate is much smaller than the 18% error that affects the SIF chart's meridians.