How old are Portolan charts really ?

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Abstract

Portolan charts are realistic, accurate charts that appeared suddenly in the Mediterranean world of maritime commerce in the thirteenth century. Their origin is entirely unclear despite an abundance of hypotheses. Recent research, based on geodetic analysis of a number of charts has provided evidence that these charts cannot have a medieval origin, but must be pre-medieval. Their high accuracy and underlying map projection make their construction in the Middle Ages impossible.

Setting the scene

The sudden appearance of portolan charts in the late medieval Mediterranean world of maritime commerce at the end of the thirteenth century ranks as one the most significant events in the history of cartography. Their extraordinary realism contrasts sharply with the qualitative character, often with religious overtones and classical elements, of the contemporary mappae mundi. They represent an unprecedented step forward in cartographic practices, which set the tone for mapping in the Age of Discovery and beyond. Portolan charts are the first maps, perhaps after Ptolemy, to have been drawn to scale.

Apart from their evident significance for the history of cartography, they also constitute a historical, geodetic and cartographic mystery that has so far proven to be unsolvable, notwithstanding claims to the contrary, often made by historians and historians of cartography with a confidence that is unwarranted. Tony Campbell was probably the first who, in 1987, openly admitted that we simply do not know how these charts were made and even who made them:

‘*Among the research problems connected with portolan charts, the question of their origin is perhaps the most intractable. … Despite the thousands of scholarly words expended on the subject, most of the hypotheses about portolan chart origins have remained just that. In the absence of corroborating data they often appear to be less explanations than creation myths*’ [1].

Whilst conceding that it is not understood how these extraordinary charts were constructed, experts on portolan charts show an understandable reluctance to question the postulated medieval origin of the charts. Understandable, because the charts contain no trace of a possible antique origin. The same is true of a possible Arabic-Islamic or a Byzantine origin. They share no characteristics with Ptolemaic maps and only a few Arabic-Islamic portolan charts, which appear to be copies of fifteenth century European charts, are extant. So, by a process of elimination, a European medieval origin is what remains. However recent research documented in my PhD thesis has proven the consensus view incorrect [2]. By applying (numerical) geodetic analysis methods, I have been able to prove that these charts cannot be medieval. Rather than being relatively primitive medieval cartographic products they are geodetically constructed charts of a higher accuracy than has been acknowledged until now. The construction of such sophisticated charts is far beyond the capabilities of medieval cartographers. The charts cannot be falsifications of a later date; too many survive for that to be an option. Additionally the impact they had on later cartography is too clearly visible.

Why are portolan charts ‘strange’?

Portolan charts are manuscript charts drawn on vellum, a fine quality of parchment. Their dimensions are often dictated by the size of skin, typically about 100 cm by 75 cm. Their scale is approximately 1:5.5 million, i.e. 1 cm on the chart equates to 55 km in the real world. The earliest portolan charts show the Mediterranean, the Black Sea and often the Atlantic coasts between Cape Drâa in Morocco and the south coast of England with remarkable accuracy. Although the North Sea and the Baltic Sea are also often depicted, these areas lack the realism and detail of the core area described above. Portolan charts are clearly nautical charts and as such constitute a new genre of maps. Their characteristics became the hallmarks of all nautical charts until well into the eighteenth century. The names of ports and landmarks are written at right angles with the coastline, important names in red ink and the remainder in black.

[1] Tony Campbell, ‘Portolan Charts from the Late Thirteenth Century to 1500’, in The History of Cartography, Volume 1 – Cartography in Prehistoric, Ancient and Medieval Europe and the Mediterranean. Ed. J.B. Harley and David Woodward, (Chicago: University of Chicago Press, 1987), p380.

[2] Roel Nicolai, A critical review of the hypothesis of a medieval origin for portolan charts, PhD Thesis, University of Utrecht, The Netherlands, (Houten, The Netherlands: Educatieve Media), 2014. This thesis is expected to be published, with revisions, as The enigma of the origin of portolan charts. A geodetic analysis of the hypothesis of a medieval origin, (Leiden: Brill) in October 2015.

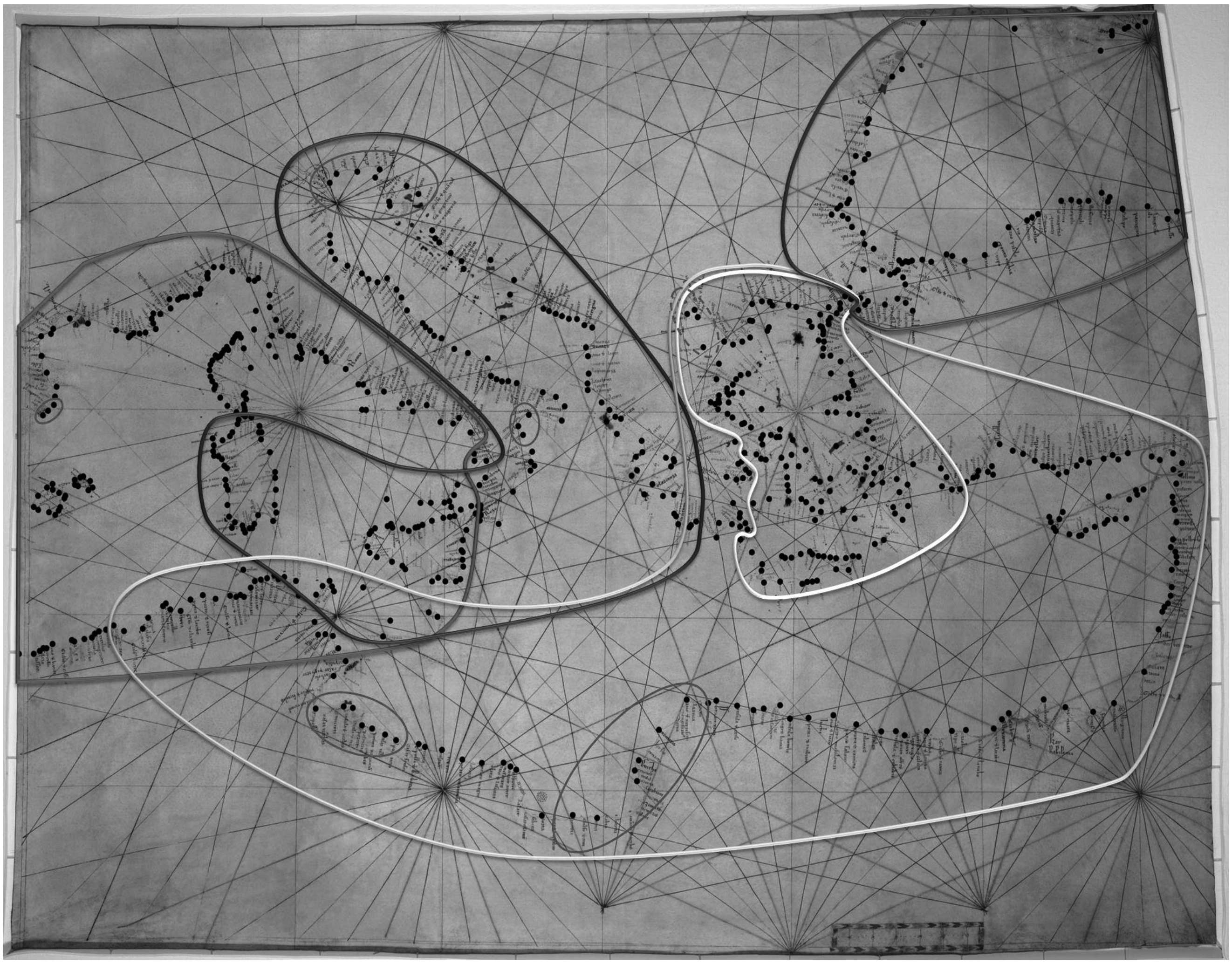

Figure 1 – Anonymous portolan chart from the 2nd quarter of the 14th century, believed to be of Genoese origin
(Image courtesy of Library of Congress, Washington, D.C.- Catalogue nr G567)

A striking characteristic of these charts are the straight lines drawn apparently at random across the entire chart. On closer inspection they form a regular, ingenious pattern, known as a wind rose. This is created by interconnecting sixteen regularly spaced points on a circle, which covers the larger part of the chart.

The wind rose lines were colour coded and named after the eight main 'winds' that the medieval sailor distinguished: the main winds are drawn in black, the eight so-called 'half-winds' in green and the sixteen 'quarter winds' in red. This results in a total of 32 directions, as shown in Figure 2. The intermediate 'winds' were indicated by names such as 'between Greco and Levante' and 'a quarter wind from Greco to Levante'. The colour-coding would have facilitated the identification of the correct compass bearing when laying out a course. The availability of the wind rose on the charts provides an absolute orientation to the charts and reveals that the entire coastline image is rotated anticlockwise by about 9 degrees. This angle remains more or less constant until about 1600, when portolan charts oriented to true North begin to appear. Most surviving charts were decorated with colourful city vignettes and pennants and were probably intended for prestige and display by their (wealthy) owners. But there is sufficient evidence of on-board usage of portolan

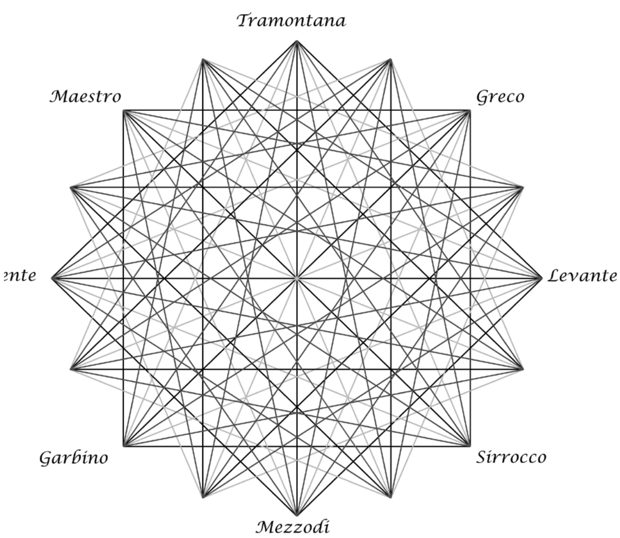

Figure 2 - Wind rose with the names of eight main 'winds'

charts, presumably as a navigation aid [3]. Most of those would have had a limited lifetime in the damp and salty offshore environment and they would probably lack the decorative elements mentioned. The chart shown in Figure 1 may well be a rare survivor from this category; it appears to have been trimmed back, possibly as a result of water damage around the edges.

Portolan charts have a number of curious characteristics. They appear out of nowhere, almost fully developed. No cartographic products are known that might have served as precursors or prototypes. Consequently there is no 'breadcrumb trail' in the historical record that might shed light on how these charts were constructed and how they acquired their high levels of accuracy. Equally strange is that hardly any development appears to have taken place after their first appearance: their key characteristics do not change. It is clear that they were copied from chart to chart. Portolan charts did not become gradually more accurate, nor were their typical shortcomings and defects resolved over time. Shortcomings they do have: they exhibit regional scale and orientation differences that are subject to some change, but no gradual improvements are visible. Other shortcomings concern persistent errors in the details of the coastline. This is strange, because if medieval cartographers were capable of making such accurate charts, why did not the same skills permit them to resolve these shortcomings? The strangest property of these charts, apart from their accuracy, is the fact that the image of the coastlines of the Mediterranean, the Black Sea and the Atlantic coasts closely resembles the map image of a modern map or chart on the Mercator projection. The Mercator projection was invented by Gerard Kremer in the middle of the sixteenth century, whilst the oldest extant portolan chart, the so-called Carte Pisane, is dated to the end of the thirteenth century. Moreover, the accuracy of portolan charts is much higher than that of any contemporary or earlier map. It is even higher than the accuracy of maps from the centuries that followed. It would take until the eighteenth century before new maps of comparable accuracy were produced.

Consensus elements on the origin of portolan charts

Despite the abundance of different hypotheses on the origin and the construction method of portolan charts – these two aspects are interrelated – experts do agree broadly on a number of things. Firstly there is unanimous agreement that portolan charts are based on actual measurements, rather than on a mental image of the world. Their accuracy leaves no room for other explanations. Contemporary maps, the European mappae mundi and Arabic-Islamic maps, are based on a mental model of the world. There is almost unanimous agreement that portolan charts are original products of medieval European culture; only a small minority regards Greek-Roman antiquity as their origin.

[3] Ramon J. Pujades I Bataller, Les cartes portolanes: la representació medieval d'una mar solcada, trans. Richard Rees, (Barcelona: Lunwerg Editores, 2007), p439.

Because the charts appeared in the maritime-commercial milieu the commonly accepted hypothesis is that medieval mariners made measurements of distance and course direction during their trading voyages. The data collected in this way is assumed to have provided the geometric basis of chart construction. Most authors find support in the fact that the anticlockwise rotation angle of about nine degrees that all charts exhibit roughly agrees with magnetic declination in the Mediterranean in the thirteenth century, estimated from paleomagnetic models. Some researchers even consider this to be incontrovertible proof that the charts were drawn from magnetic compass measurements. After this point most hypotheses become more vague. Those that are specific enough usually postulate central collation of all data somewhere along the Ligurian coast of Italy. Genoa and Pisa are prime candidates, because it is from this area that the oldest extant portolan charts originate. Additionally some unspecified schema of accuracy improvement is assumed, often expressed in vague terms such as 'progressively better estimates of distances became available over time', but some authors explicitly mention a process of averaging.

Whatever the process of accuracy improvement might have been, the next step that is assumed is the drawing of the first portolan chart from these improved estimates of distance and direction. This presumes organisation and perhaps sharing of the body of marine measurements. It is assumed by many that an intermediate role was played by so-called portolans, written sailing instructions containing navigation instructions of the form: 'From A to B, so-many miles along such-and-such a course'. This assumed causal relationship has given portolan charts their name, which is therefore a modern invention. In the Middle Ages they were known under a variety of names, but not as 'portolan charts'. More recently some authors have become more cautious regarding the relationship between the two and some, including myself, deny that the charts were drawn from data, collated in portolans.

Only the so-called plane charting technique may be assumed for the construction of the chart: distances and bearings were transferred to the map as if the earth were flat. More sophisticated methods cannot be assumed to have been available in the Middle Ages. Furthermore it is assumed that some form of graphical adjustment was carried out by the cartographer in order to deal with the contradictions in the data due to the inevitable random errors in the measurements. The effects of ignoring earth curvature are generally downplayed as 'negligible' or 'relatively minor'.

David Woodward was courageous enough to be fairly specific on how he thought this process of chart making might have taken place (please note he doesn't mention directions):

'*The cumulative experience of several centuries of coastal and other shipping in each of these (sub-) basins could have led to the independent recording of traditionally known distances. The average distances derived from both coastal traverses and cross-basin routes could then have been used in the construction* *of a series of separate charts of the individual basins. If these routes were plotted to form networks in each of the basins, each network might have assumed the form of a self-correcting closed traverse of each basin. The rigidity of this structure would, however, have depended on the availability of cross-basin distances, acting as braces to the framework. It is thus postulated that some system of empirical or stepwise graphic method of correcting these frameworks was used to achieve a 'least-squares' result.'* [4]

accuracy of these charts to be estimated. A best-fit of the portolan chart with a modern Mercator chart needs to be established first. Only then can the deviations of points on the portolan chart from corresponding points on the Mercator chart be considered to be representative of the accuracy of the portolan chart. This accuracy can be captured in the concept Mean Square Error (MSE), or rather the square root of that, the RMSE.

Table 1 - Five portolan charts analysed

Name	Cartographer	Date of creation	Location	Catalogue Number	Identical points
Carte Pisane	Anon. Genoese	End 13th c.	BnF, Cartes et Plans, Paris	Ge B 1118	444
Ricc 3827	Anon. Genoese	1300-1325	Bib. Riccardiana, Florence	3827	1015
Dulcert 1339	Angelino Dulcert	1339	BnF, Cartes et Plans, Paris	Ge B 696	836
Ristow- Skelton No 3 (RS-3)	Anon. Genoese	1325-1350	Library of Congress, Washington	G5672.M4P5 13	742
Roselli 1466	Petrus Roselli	1466	James Ford Bell Library, Minneapolis	bell001281466 mRo	860

A recent trend appears to be to deliberately avoid any specific statements about the charts' origin and construction method [5]. Portolan charts are then seen as the 'products of medieval Mediterranean culture in its entirety, characterised by multiple cultural exchanges'. The accuracy of the charts is downplayed and the close agreement with the Mercator projection is glossed over, as are other historical facts that do not fit in this picture.

Controversial aspects of the charts that cry out for a rational explanation are firstly their accuracy and secondly the regional scale differences on each chart. Finally, for me, as a geodesist, the key characteristic to be explained is their agreement with the Mercator projection. As explained above, the consensus explanation of the accuracy of the charts is that some form of averaging took place, either as the calculation of the arithmetic mean of series of observations of the same distance or bearing, or the averaging was integrated in the assumed graphical adjustment of all data when the first chart was plotted. There is considerable consensus that the scale differences are caused because the sub-basins of the Mediterranean were charted first and the resulting partial charts were stuck together in a second step. The Mercator projection is almost unanimously considered to be an accidental by-product of the plane charting process.

The accuracy and composition of portolan charts

The close agreement of the coastal outlines on portolan charts with the Mercator projection also enables the accuracy of these charts to be estimated.

Many researchers have performed numerical ('cartometric') analysis of one or more charts, but all have approached the charts as single, coherent units. If portolan charts are mosaics of partial charts, each with its own different scale, that approach is methodologically incorrect. In my own PhD research I subjected five early charts to cartometric analysis as described above, but treated them as mosaics. All cartometric analysis begin with the identification of a large number of 'identical points', i.e. pairs of points on the portolan chart and the reference Mercator chart where the position differences are measured. I established the boundaries of the partial charts empirically, by identifying groups of identical points that formed coherent subsets. I associated each coherent subset with a partial chart.

This yielded some surprising results:

- the accuracy (RMSE) of each subset was surprisingly good; on average an RMSE of 10-12 km was computed;
- there are differences between the scales and orientations of the subsets;
- the boundaries between the coherent subsets of points did not align with the boundaries between the sub-basins of the Mediterranean;
- there were overlaps, but also some gaps between adjacent subsets of identical points.

[4] Campbell 1987, 388. Campbell states that Woodward wrote the relevant section.

[5] Patrick Gautier Dalché, 'Cartes marines, représentation du littoral et perception de l'espace au Moyen Âge. Un état de la question.', in Castrum VII. Zones côtières et plaines littorales dans le monde méditerranéen au Moyen Age (Rome: École française de Rome, 2001), p20.

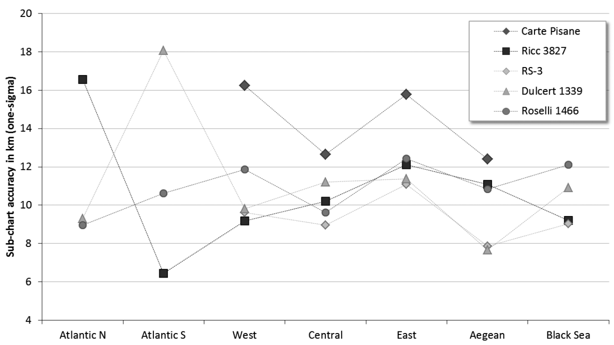

Figure 3 - Mean accuracies per sub-chart for the five charts analysed

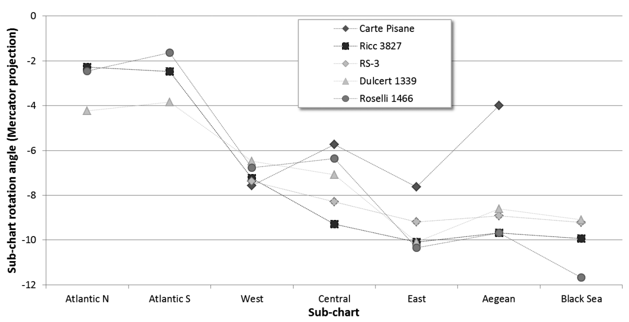

Figure 4 - Mean rotation angle per sub-chart of the five charts analysed

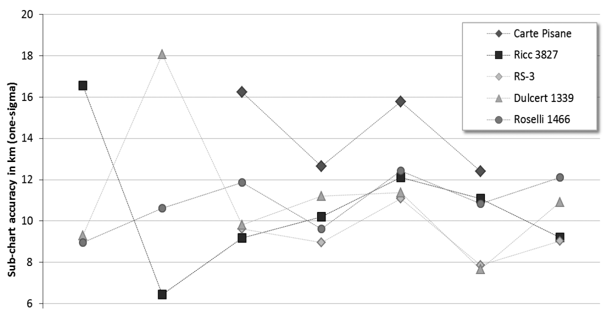

Figure 5 - Mean scale per sub-chart of the five charts analysed

The consensus opinion that portolan charts are mosaics of partial charts can therefore be confirmed, but their accuracy leads to a renewed question.

The assumption of most researchers is that distance was measured by estimating the speed of the ship at regular intervals, for example at every change of watch, i.e. about four hours. As no instrument was available to measure speed objectively until the sixteenth century, it is generally assumed that a wood chip was thrown in the water at the bow of the ship. The navigator, positioned near the stern, would estimate the time it took for the wood chip to pass a marker, by taking his pulse, saying a rhyme or pacing up and down the deck. Two markers on the bulwark, at the bow and stern respectively and at a calibrated distance apart, might have been used as baseline. It will be clear that to convert this to a distance estimate for the whole journey would have involved enormous extrapolation. And how accurately can one estimate time in this way? I developed a statistical model for medieval navigation, taking into account all relevant phenomena that would have influenced this process of distance estimation. The result is that, even when many effects are ignored and highly optimistic assumptions are made, one cannot estimate distance in this way better than about one third of the distance traveled (95% confidence level). Available space prevents me from discussing this subject in more detail, but it will be clear that averaging a significant number of measurements of the same journey (i.e. distance) would have been required to get anywhere close to the accuracy of portolan charts. At this point I must introduce an aspect of the history of mathematics that has simply been overlooked or ignored until now. The calculation of the arithmetic mean of a series of measurements of the same variable with the intention of improving its accuracy was not known in the Middle Ages: it was not introduced into scientific practice until the end of the seventeenth century![6]

Accurate direction measurements from one coastal point to another constitute an entirely different problem. The only possible instrument for measuring such directions would have been the magnetic compass. For the last one and a half centuries it has been a matter of debate whether the magnetic compass, in a form that could have been used to obtain meaningful direction measurements, was introduced in the Mediterranean early enough to have allowed collection of a large number of direction estimates covering the entire Mediterranean and Black Sea. A simpler form of compass, consisting of a magnetised needle made to float in a bowl of water by sticking it through a piece of straw or cork, had been used for a long time to provide some directional help to mariners when the sky was overcast. In medieval documents this is referred to as 'the needle' ('acus'). Later the needle was placed on a spindle so that it could pivot freely and placed in a wooden box on which a compass card with the thirty-two 'wind' directions was engraved. Presumably later still the compass card was attached to the needle so that both could rotate freely. The latter innovation concerns the development of the mariner's compass. The resulting compass was treated as a unit and indicated with the term 'bussola' ('little box'). Only such a compass would in principle have been suitable to measure course directions. The transition of the name from 'acus' to 'bussola' is widely accepted as indicating the adoption of the compass as a single unit in the maritime world. Most researchers simply ignore the vital question whether the magnetic compass was introduced in time to have contributed to the development of the portolan chart, but recently (2007) Ramon Pujades showed that the first use of the of the term 'bussola' in a medieval notarial document

[6] Robin L. Plackett, 'Studies in the History of Probability and Statistics: VII The Principle of the Arithmetic Mean'. Biometrika 45 (1958), 131, p132.
Stephen M. Stigler, The History of Statistics. The Measurement of Uncertainty before 1900 (Cambridge MS: Harvard University Press)

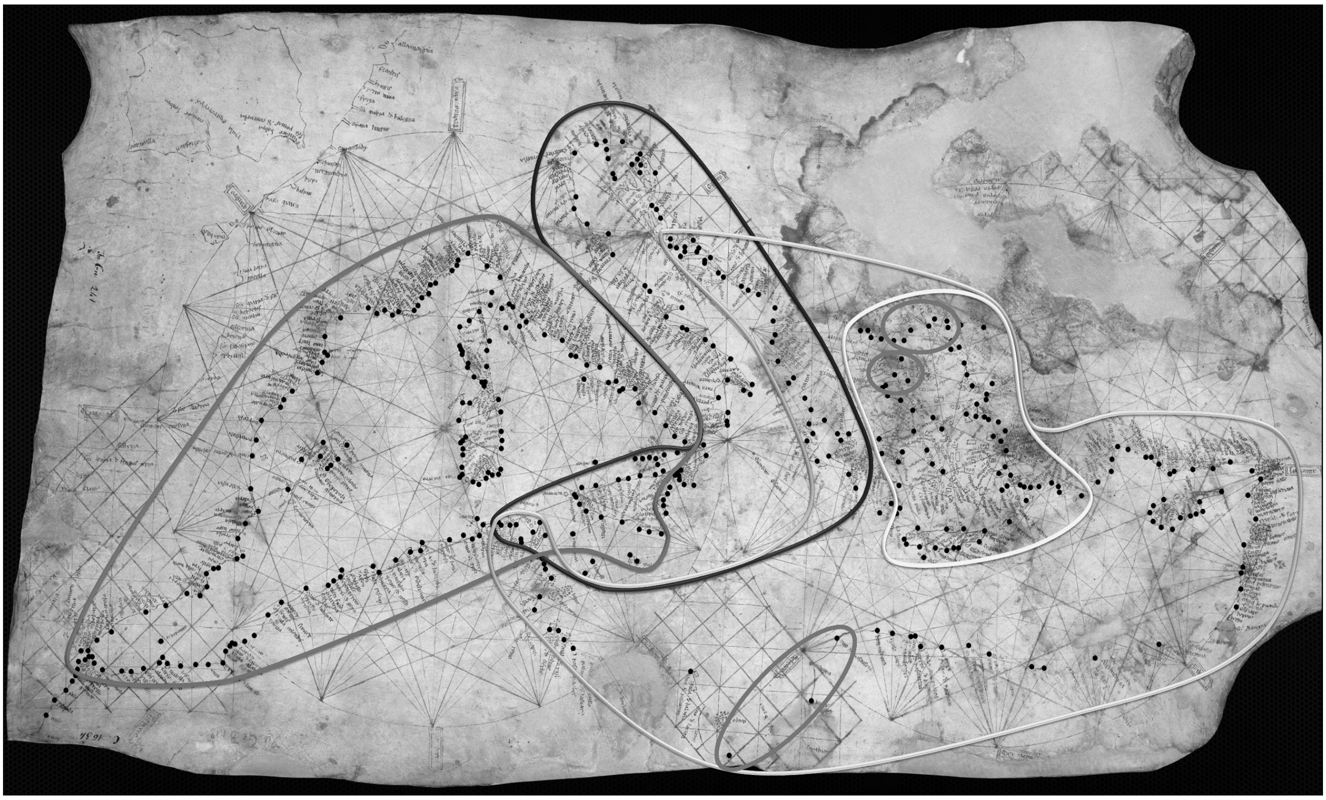

Figure 6 - Tracing of the portolan chart known as Carte Pisane with identical points and outlines of sub-charts. (Image courtesy of Bibliothèque nationale de France)

occurs in 1349.[7] Before him Peter Pelham had shown that the description of the compass in literature shows a transition 'well into the fourteenth century'[8].The conclusion must therefore be that the charts were already in existence before the mariner's compass became firmly established in the maritime community.

The 'accidental' map projection

The information presented above justifies the conclusion that portolan charts cannot be original medieval creations. However, the idea that the map projection can be an accidental by-product of the plane charting technique does not make sense to a geodesist such as myself and I felt obliged to investigate that. My approach was to describe a hypothetical network consisting of directions and distances between coastal points that might conceivably have been measured in medieval times. This implies that I have taken into account the established trade routes in the Mediterranean. I created three networks, two for the western and eastern Mediterranean and one for the Black Sea. I calculated the true values of the directions and the distances on the sphere and factored in estimates for magnetic declination, i.e. the deviation of the compass needle from true North, for 1250 using a paleomagnetic model. I then computed the positions of all coastal points from these 'measurements' by plane charting, as a hypothetical medieval cartographer might have done, except that I used a computer to do this. The resulting positions of points along the Mediterranean coast may be seen as the framework or outline of a synthetic portolan chart, generated by ignoring the earth's curvature. Next I subjected this synthetic chart to the same cartometric analysis as the five real charts I analysed. If the synthetic portolan chart would correspond automatically to the Mercator projection, its Mean Square Error (MSE) would have to be zero or nearly zero, because I used error-free values of distance and directions.

If a real portolan chart were drawn by plane charting, its accuracy, as evaluated by cartometric analysis would have two main components: the propagation of the accuracy of medieval navigation into the charted positions of coastal points and the influence of ignoring earth curvature.

I calculated the latter effect as the MSE of the synthetic portolan chart described in the previous paragraph. In fact there is a third component. A characteristic of all portolan charts is that all significant coastal features, such as capes, promontories and bays are shown larger than they would have been when drawn to scale. I have estimated this effect of feature exaggeration to be about 4 km, which, squared, amounts to the figure shown in the table. The accuracy of a portolan

[7] Pujades 2007, 444.

[8] Peter T. Pelham, The Portolan Charts: Their Construction and Use in the Light of Contemporary Techniques of Marine Survey and Navigation. Master's Thesis, (Manchester: Victoria University of Manchester, 1980), p58.

Piecewise rectified portolan chart by Angelino Dulcert, 1339, with coastline traced in blue and a modern Mercator map (red outline)

	Western Mediterr.	Eastern Mediterr.	Black Sea
MSE Navigationn accuracy	...	...	...
MSE plane charting	100	256	39
MSE feature exaggeration	16	16	16
MSE potolan chart	121	121	121

Table 2 - Mean Square Errors in km² based a nominal chart RMSE accuracy of 11 km

chart can therefore be described as the sum of three components, which are all greater than zero:
MSEportolan chart = MSEnavigation accuracy + MSEplane charting + MSEfeature exaggeration

Table 2 shows the results of this computation. A nominal RMSE value of 11 km has been assumed for the total accuracy of a portolan chart (the square of which is 121 km^2). The real values of the five charts analysed are shown in Figure 3.

The large figures for the effects of ignoring earth curvature, the second component, indicate that plane charting results in a significantly different shape from the Mercator reference chart, hence a different shape from a portolan chart. It is clear from Table 2 that the summing of the three components can never result in the accuracy figure of 11 km (=121 km2) of a real portolan chart. For the eastern Mediterranean the contribution of plane charting alone is larger than the entire accuracy of the real charts. For the western Mediterranean no room is left for a realistic estimate of vessel navigation. The conclusion is therefore that the Mercator map projection does not automatically emerge as an accidental by-product of plane charting. In the absence of any realistic alternative explanation the conclusion must be that portolan charts were designed to be drawn on the Mercator projection. This is one more powerful piece of evidence that portolan charts are pre-medieval.

Analysis and conclusions

Rather than being simple, relatively realistic charts, as they are often described, portolan charts are copies of sophisticated, accurate charts, intentionally drawn on the Mercator projection or a similar map projection. The construction of these source charts was well beyond the means of medieval mariners and cartographers.

It appears that the original portolan charts consisted of a collection of separate partial source charts, from which a mosaic was created by medieval Italian cartographers. These cartographers appear to have had only a vague notion of the real scale of the charts. The overlaps of the subsets of identical points indicate that the mosaic chart was created by overlaying common sections of coast on the partial charts. This accounts for the regional differences in scale and orientation in each chart.

The intriguing question is: where do these charts come from if they are not medieval?

I cannot answer that question, but I consider it to be the duty of science to re-evaluate the possibility of an origin in Greco-Roman antiquity. One should not 'default' to the conclusion that if their origin cannot be medieval, it must therefore lie in antiquity. This has to be carefully investigated.

Ulla Ehrensvärd 1927 – 2015

We just learnt about the death, on 17 April, of Ulla Ehrensvärd, aged 88. A well-known map historian, formerly of the Military Archives in Stockholm, she received, among many other distinctions, the prestigious Helen Wallis Award from IMCoS in June last year – see our congratulatory note in Maps in History No 50, September 2014. Lisette Danckaert, who knew her quite well, adds: *She will be remembered through her many significant contributions to the History of Cartography as 'La Grande Dame du Nord'.*

How old are portolan charts really?

That question was asked in our last issue in an article by Roel Nicolai, summarising his Ph. D. Thesis. His challenging conclusions on the origin of portolans (‘their construction in the Middle Ages [is] impossible’) triggered some reactions. We have the privilege to publish below reviews of this article by two specialists who took up the challenge: Tony Campbell (former Map Librarian at the British Library, chair of Imago Mundi Ltd) and Joaquim Alves Gaspar (Researcher at the University of Lisbon Centre for the History of Science and Technology).

No doubt that this interesting debate will continue at the First International Workshop on the 'Origin and evolution of portolan charts' (Lisbon, 5-6 June 2016). To be followed…

Jean-Louis Renteux

Review of Roel Nicolai’s article by Joaquim Alves Gaspar

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Of all the classical themes in the History of Cartography, the origin of the nautical chart is among the most popular and the one which has inspired a larger variety of theories. Emerging suddenly at an uncertain date of the thirteenth century, the portolan chart predated by about two centuries the translation and dissemination of Ptolemy’s Geography, which marked the re-birth of scientific cartography in Europe. That happened at a time when the cartographic representation of the world was mostly symbolic and had no practical intent other than illustrating the Christian conception of the world. The research on the portolan chart of the Mediterranean is dominated by two major works:

- Tony Campbell’s ‘*Portolan Charts from the Late Thirteenth Century to 1500*’ (1987)[1], where an extensive review is made of the various theories pertaining to the birth and construction of the first charts, and
- Ramón Pujades’s ‘*Les Cartes Portolanes*’ (2007)[2] where a detailed study is presented about the historical context in which the medieval nautical cartography was born, as well as about the main questions concerning the when, where, who and how the first charts were made. As for the when, it is shown that the first nautical charts could not have appeared before the beginning of the 13th century, when some specific developments in mathematics took place. A rediscovered manuscript portolano from c.1200, the ‘*Liber de existencia riveriarum*’, providing distances and directions between places in the Mediterranean and explicitly referring to a chart, is a strong confirmation of the close relationship between the *portolani* (the rutters) and the charts, as well as of the involvement of pilots in their making (Gautier-Dalché, 1995)[3].

The possibility of a precise match between the sailing directions recorded in the *portolani* and the geometry of the nautical chart, hypothetically based on them, was investigated by Lanman(1987)[4]. This is the earliest work where a systematic analysis of a sample of charts was made using cartometric techniques. Although the theory proposed by Lanman - who tried to reproduce the geometry of the charts by transferring to the plane the courses and distances registered in the early *portolani* - is clearly an oversimplification, his research was a pioneering step in the right direction. A new quantitative approach was introduced some twenty years later by myself (Gaspar, 2008; 2010)[5], where novel analytical tools and numerical modelling techniques were proposed. In these works a meaningful connection between the geometry of the old portolan charts and the underlying navigational methods was first established.

[1] Campbell, Tony, ‘Portolan Charts from the Late Thirteenth Century to 1500’, in David Woodward & J.B. Harley (ed.), *The History of Cartography, Volume One: Cartography in Prehistoric, Ancient and Medieval Europe and the Mediterranean*. Chicago & London: The University of Chicago Press, 1987, pp.371-463.

[2] Pujades, Ramón, *Les Cartes Portolanes. La representaciò medieval d’una mar solcada*. Barcelona: Institut Cartogràfic de Catalunya, 2007.

[3] Gautier-Dalché Patrick. C*arte marine et portulan au XIIe siècle. Le ‘Liber de existencia riverierarum et forma maris nostri Mediterranei’ (Pise, circa 1200)* Rome: École Française de Rome, 1995, 326 p. (Publications de l’École française de Rome, 203). The interpretations of Gautier-Dalché and Pujades on whether the portolano was made from an existing chart or a chart was made from a portolano are irrelevant in the present context. The important points to stress are the connection between charts and *portolani* and the use of information collected by mariners.

[4] Lanman, Jonathan, *On the Origin of Portolan Charts*. The Hermon Dunlap Smith Center for the History of Cartography. Occasional Publication No 2, 1987.

[5] Gaspar, Joaquim Alves, ‘Dead reckoning and magnetic declination: unveiling the mystery of portolan charts’. *e-Perimetron*, Vol. 3 No. 4, 2008, pp. 191-203; *From the Portolan Chart of the Mediterranean to the Latitude Chart of the Atlantic: Cartometric Analysis and Modeling*. Doctoral thesis, ISEGI - UNL, 2010.

More recently Roel Nicolai (2014)[6] completed a cartometric study of a series of portolan charts in his PhD dissertation, using geodetic techniques, and concluded: first, that the earliest charts were made by assembling five or six regional representations; second, that those representations were constructed on the basis of geodetic surveys and using the Mercator projection; and, third, that medieval navigational methods cannot explain the high level of accuracy of the charts. Having demonstrated that portolan charts could not have been conceived in the Middle Ages, Roel Nicolai postulates that earlier geodetic surveys must have been carried out, probably in Greco-Roman times, and that was where the medieval charts were constructed. The article that is commented here by Tony Campbell and myself is a summary of the most important arguments and conclusions of Nicolai's dissertation.

The medieval theory

Two main facts support the hypothesis that the first portolan charts were constructed near the beginning of the thirteenth century, using information collected by mariners at sea: the text of the manuscript '*Liber de existencia riveriarum* '(c. 1200), which explicitly refers to a nautical chart and to the involvement of pilots in its making; and the average tilt of the Mediterranean basin, as shown in all charts up to 1600, which matches the average value of the magnetic declination in the region, during the first half of the thirteenth century. Assuming that the portolan chart is indeed a medieval creation, an additional circumstance suggests that its birth may have occurred well before the drawing of the oldest extant charts (all made around 1300), namely the fact that the geometry of most of the Mediterranean basin on these charts remained approximately invariant up to about 1600. One would expect some relatively long period of development to have taken place before 1300, during which the accuracy and detail of the charts progressively improved. The absence of such on work charts is invoked by Nicolai as evidence that they never existed.

According to Nicolai's thesis, 'the accuracy of [the early] portolan charts is much higher than that of any contemporary or earlier map and is even higher than maps made in the centuries that followed'. However the idea that portolan charts didn't improve over time is not accurate and needs clarification. Although the initial outline for the Mediterranean was adopted in all subsequent nautical charts up to 1600, some developments did occur. Not only during the earliest phases (up to about 1330), when the depictions of the Black Sea, Western Europe and the British Islands were much improved, but also from the fifteenth century on, as a result of the exploration voyages made by the Portuguese, along the coast of Africa. These were reflected in contemporary portolan charts, such as the one by Andrea Bianco of 1448, where a long stretch of coast beyond Cape Bojador is represented for the first time. If Nicolai's interpretation is to be accepted, how can one explain the improvements made at the beginning of the thirteenth century and the additions introduced before the advent of astronomical navigation?

An additional element reinforcing Nicolai's thesis that the portolan chart could not have been created using data collected by pilots at sea, is the lack of textual evidence, prior to the fourteenth century, referring to the use of the magnetic compass in navigation. However other examples exist in the history of cartography and navigation where new developments remained absent in textual sources until they were already in force for a long time. Inverting Nicolai's argument, we could well support the thesis of an early introduction of the magnetic compass in the Mediterranean by citing the very existence of portolan charts.

How charts were made

According to Nicolai's article, the only way to explain the accuracy of the extant charts is to consider that they result from joining together several regional surveys, each of them represented in the Mercator projection. Nicolai's approach to the problem is the following. First he shows that there are spatial variations in the overall accuracy of the charts which can be explained by the assembling of regional representations. After identifying those regions he then proceeds by adjusting a Mercator projection to each of them. As part of the adjustment, a previous correction is made to the counterclockwise tilt of the pieces, and some control points, considered as outliers, are eliminated. The claim about the extraordinary accuracy of the charts is based on the comparison of these regional parts with the corresponding Mercator representations, after having been corrected for tilt and outliers. Incidentally no reference is made to the navigational accuracy of the resulting composite chart. Neither is it explained how the joining of the various pieces resulted in a representation whose counterclockwise tilt matched the average value of the magnetic declination in the area: a happy coincidence? Moreover nothing is said about the surveying methods supposedly used to determine latitudes and longitudes in each of the regions, so that a Mercator projection could be applied to their representations. In this respect it should be stressed that only after the longitude problem was solved, well into the eighteenth century, was it possible to construct accurate Mercator charts.

As explained in early modern textual sources, portolan charts were constructed by transferring directly to the plane the directions and distances measured on the curved surface of the Earth, as if it were flat. The resulting geometric inconsistencies, which were relatively minor when representing small regions like the Mediterranean, tended to be further minimized over time. Not by making arithmetic averages of distances

[6] Nicolai, Roel, *A critical review of the hypothesis of a medieval origin for portolan charts*. Doctoral thesis. Uitgeverij Educatieve Media, Houten, 2013.

Carte Pisane

c. (1258 - 1291)

1045 mm x 502 mm

Paris, Bibliotheque Nationale

and courses, as suggested by Nicolai, but by a graphical optimization process in which the relative positions of the places were gradually adjusted over time using the superabundant information. That is probably what happened during the earliest phases of the portolan chart development, of which no physical evidence has survived to our days.

Many researchers before Roel Nicolai have tried to adjust various map projections to the old portolan charts, especially the Mercator projection. And all have concluded that a very good match could be achieved, after the average tilt of the charts was eliminated. What none of those researchers has mentioned is that such result is to be expected. In a previous work, I have shown how a set of rhumb-line courses defined on the curved surface of the Earth and plotted on the plane as straight segments produces an exact Mercator projection[7] . If rhumb-line distances are also included, a hybrid representation results whose geometry depends on the relative weight given to courses and distances. According to my own numerical simulations, which took into account the

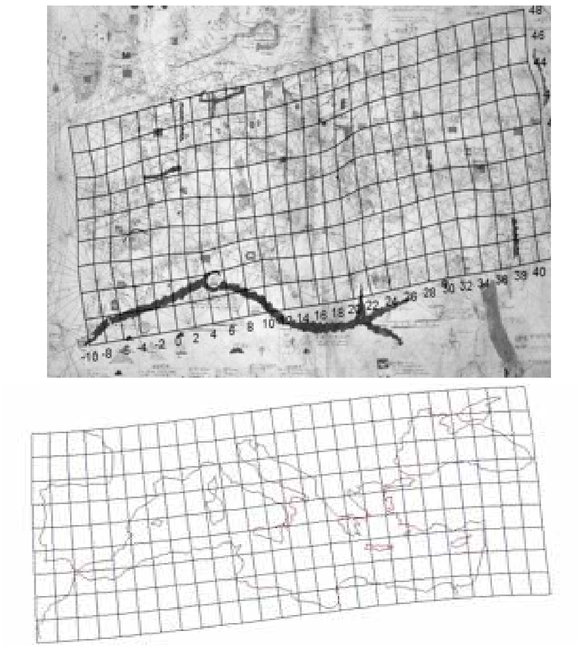


Fig. 1 - On top: geographical grid of meridians and parallels implicit in Angelino Dulceti chart of 1339 (Bibliothèque nationale de France), interpolated on the basis of a sample of control points of known latitudes and longitudes.

On the bottom: output of a numerical model, in which the geometry of a portolan chart was simulated using a sample of courses and distances between places, under the influence of magnetic declination, as of 1300. In the present case, weights of 80% and 20% were given, respectively, to courses and distances between places.

Results reproduced from Gaspar, 2008 (note 5).

navigational methods described in the textual sources and the influence of magnetic declination, the best matches are obtained when a larger weight is given to directions. This outcome is not surprising because pilots have always attributed, for navigational reasons, more importance to measured directions than to estimated distances. Indeed, my results have clearly shown that the main geometric features of portolan charts, including the counterclockwise tilt and the slight convergence of meridians, are well explained by the use of uncorrected magnetic courses and distances in their construction [8] (Fig. 1).

Nicolai assigns great relevance to the errors made by the pilots in the determination of distances and goes to the point of considering that it would have been impossible to make estimates better than one third of the distance travelled[9] . From this assumption he further concludes that the only way to get close to the accuracy of the actual portolan charts would be by averaging a large number of measurements of the same courses and distances. However, he notes, that would be impossible because 'the calculation of the arithmetic mean of a series of measurements of the same variable with the intention of improving its accuracy was not known in the Middle Ages: it was not introduced into scientific practice until the end of the seventeenth century!'. This is an extraordinary claim considering, for example, the testimonies of Portuguese pilots, from the beginning of the sixteenth century on, where references to similar procedures in astronomical observations are made.

Final remarks

The author's approach to the subject appears to be negatively affected by a strong preconception about the origin of the portolan charts. Such prejudice is manifested in various assumptions and partial conclusions, where historical evidence and the relevance of previous works are often minimized or distorted, in order to support his claim that the first charts were based on surveys produced by a higher and older technology. By making this suggestion Nicolai is replacing a respected theory – supported by some strong pieces of historical evidence – with a bizarre one, without providing a single piece of positive evidence. I have shown above how fragile some of Nicolai's arguments are, especially those concerning the accuracy of navigational methods, the accuracy of the charts and the alleged use of the Mercator projection in their construction.

This kind of quantitative approach to the study of old charts is to be encouraged, as it has proven to contain an enormous potential for improving our knowledge on the origin of portolan charts. However mathematical methods are not magical boxes from which historical truth can be read, and conclusions derived from quantitative modelling techniques have to be carefully scrutinized and validated by historical reasoning and evidence. That doesn't seem to be always the case here, where some of Nicolai's hasty assumptions and conclusions are detrimental to an otherwise thorough and careful work.

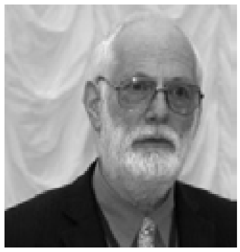
[7] See Gaspar, *From the Portolan Chart of the Mediterranean to the Latitude Chart of the Atlantic* (note 5), pp. 76-81.

[8] Gaspar, 'Dead reckoning and magnetic declination' (note 5).

[9] By suggesting such a conservative value he was probably unaware that a significant proportion of the ships navigating in the Mediterranean during the Middle Ages were oar-propelled galleys.

How old are portolan charts really?

Review of Roel Nicolai's article by Tony Campbell



Tony Campbell
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I have been invited to comment on the article by Roel Nicolai, 'How old are portolan charts really?' (BIMCC Newsletter 52, pp. 16-24). I am happy to leave to Dr Joaquim Alves Gaspar a parallel critique of the technical aspects of that article, which constitutes a summary of Dr Nicolai's forthcoming book, itself based on his recent PhD thesis. Instead, I will try to place the Nicolai arguments - that the earliest marine charts appeared fully formed, and that they betray a hydrographic sophistication beyond anything that could have been achieved in the Middle Ages - into the context of what little we *do* know about the history of these remarkable documents.

In terms of any theory about their origin, the identity of the earliest surviving portolan chart is clearly crucial, and I will therefore confine my comments to the formative period. Even there, the issues are many and complex and can only be selectively reviewed here. I will endeavour to avoid both speculation and assertion.

A portolan chart historian is now faced with a major problem. Until recently, there was broad agreement that the Carte Pisane, acquired in 1839 by what is now the Bibliothèque nationale de France, should be dated to the late 13th century. However, in December 2012, Ramon Pujades presented a paper (at the BnF) arguing strongly that it was a poor quality copy datable no earlier than about 1380 and possibly as late as the 1430s[1]. Given the undisputed link between the Carte Pisane and the supposedly very early anonymous charts surviving in Cortona and Lucca, the Pujades 'earthquake' (if it is generally endorsed) removed the entire first chapter of the accepted portolan chart history. With those unsigned works out of the way, the story would begin with the dated charts of Pietro Vesconte (from 1311 to around 1330).

If the broadly plausible Vescontian outlines did indeed provide our earliest glimpse of a portolan chart, that might, as Nicolai claims, indicate that they emerged almost fully formed. However, that would not explain the obvious further developments up to about 1340, even if from that point onwards there was no significant general improvement - check, for example, the coastal outlines of the seven largest Mediterranean islands up to at least the 1460s.

Because this issue is so important - arguably the most dramatic development in some two centuries of research into these charts by numerous commentators - I spent a year examining the evidence. Published online in March, this concludes, without hesitation, that the Carte Pisane is much the oldest extant chart. [For the detailed evidence, please see that extended essay[2].]

With the original first chapter of the portolan chart story confidently restated (in my supported opinion) and the Carte Pisane restored to a date of c.1290 (since it is evidently considerably older than the work of Vesconte), and the Cortona and Lucca charts placed a little later, it is possible to see its lack of sophistication, not as evidence of a late copy by an ignorant amateur, but as confirmation of its pathfinder status.

The Carte Pisane's toponymy alone marks it out from Vesconte and all who followed him, in terms of its significant omissions and rare or even unique place-names. It also contradicts Nicolai's statement that "hardly any development appears to have taken place after [the charts'] first appearance." It is generally true that the charts' "key characteristics do not change", but a number of elements were added in the formative period, by Pietro Vesconte and his immediate successors, such as the provision of schematic island shapes for easy recognition and their differential colouring. These clearly demonstrate the innovative abilities of the first named chartmaker.

The clumsy construction of both the Carte Pisane, and the Cortona chart whose network of 32 differently-coloured compass directions failed to provide any assistance to mariners sailing in the Adriatic, betrays 'works in progress'. But it is the hydrographic development that reveals most clearly an evolutionary pattern of growing experience and knowledge in the period before 1320. This can be seen on those two works, along with the Lucca chart, as well as the very

[1] Ramon Pujades, 'The Pisana Chart: really a primitive portolan chart made in the 13th century?' *Cartes et géomatique*, 216 (June 2013): 17-32 (paper delivered at the international conference, 'D'une technique à une culture: les cartes marines du XIIIe au XVIIIe siècle', Paris, 3 December 2012): http://www.lecfc.fr/new/articles/216-article-3.pdf

[2] Tony Campbell. 'A detailed reassessment of the Carte Pisane: A late and inferior copy, or the lone survivor from the portolan charts' formative period?' (2 March 2015): http://www.maphistory.info/CartePisaneMenu.html

early chart in the Biblioteca Riccardiana in Florence (considered by Nicolai), which in some respects seems to anticipate Vesconte.

Most of the Carte Pisane's coastal outlines are fully recognisable but they are far from perfect. The misplacement of Italy (too wide and thus shrinking the Adriatic) could seem to fit into the Nicolai hypothesis about separately surveyed basins, which would confirm David Woodward's suggestion in 1987. But a number of other, less immediately visible Mediterranean details confirm that Vesconte had access to more detailed information than that used by the Carte Pisane's unknown author.

However, it is the Atlantic coasts that supply the clearest evidence of the minimal knowledge available to the Carte Pisane's creator and give us a close-up view of the way that those coastlines, at least, were actually surveyed over the period c.1290-1330. The Carte Pisane's Britain, no more than a rectangle, and a continental European coastline that fails to recognise the Bay of Biscay, must have been based on vague verbal descriptions, coupled with a sparse and erratic selection of toponyms. By the time of the Lucca chart, a linear descendant of the Carte Pisane, semi-recognisable coastlines can now be seen, before Vesconte embarks on a process of improvement, over a series of five surviving iterations (1313-c.30). The difference between the first and last of those provides clear evidence of informants (he would never have travelled himself) capable of steadily revising the first sketchy attempt. Might we be seeing here a similar process to that which had already produced the assured Mediterranean and Black Sea outlines of the Carte Pisane?

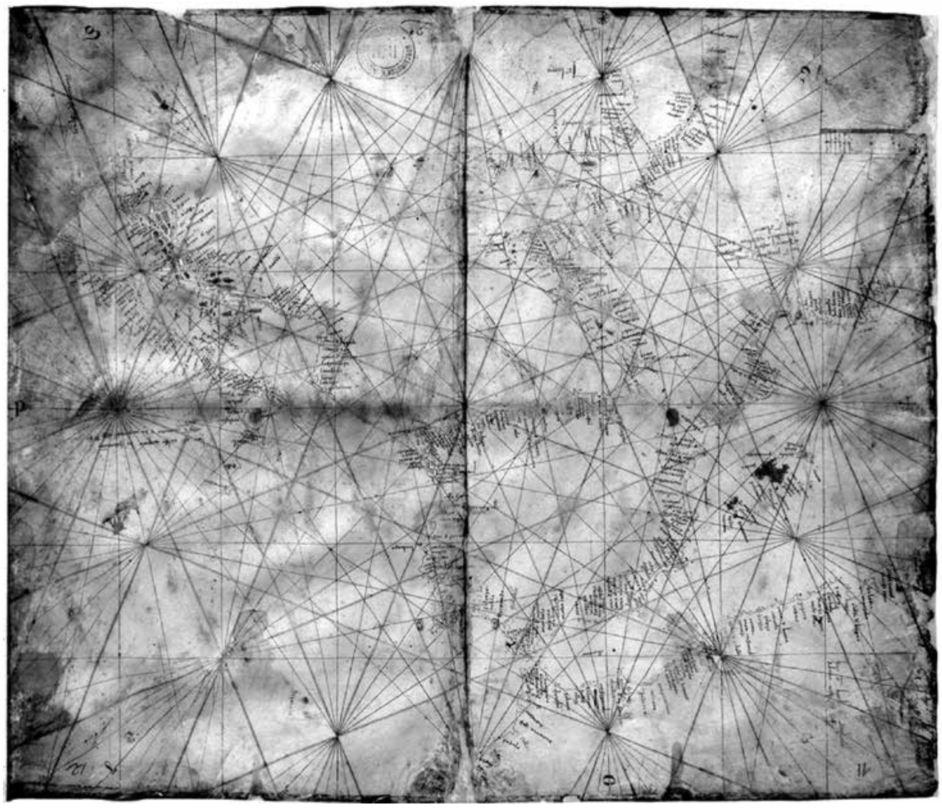

Fig. 1: Sheet covering the Atlantic coasts from early Pietro Vesconte's 1313 atlas, with the Adriatic separately to the left (BnF Rés. Ge. DD687). It is the earliest dated depiction of those shores, whose sophistication provides a very clear contrast to the Carte Pisane, and demonstrates the progress made during the formative period.
Source: http://gallica.bnf.fr/ark:/12148/btv1b5901108m - (image 12)

How can that be bolted on to the Nicolai thesis that the portolan charts represent a rediscovered survey from an unidentified, but much earlier period, or that they fell into the hands of those who were incapable of creating such a work themselves? Even if that might seem (though at first glance only) to be applicable to the Mediterranean, how can it be denied that, in the early years of the 13th century, the capacity existed, *de novo*, to create a reasonably adequate survey of the Atlantic coasts, since there are no known models for those?

The alternative, traditional view of portolan chart origin is that they were initially constructed with the use of the magnetic needle, probably in the early 13th century, somewhere in Italy. Nicolai's assertions about the late development of the magnetic needle in Mediterranean navigation rely on the supposed lack of evidence, which, like the charts themselves, are not likely to be mentioned in official archival records until they had already become commonplace.

Nor does the hydrographical and mathematical analysis in the Nicolai thesis take adequate account of the *portolani* (or, more confusingly, 'portolans'), the written sailing directions which document, in the form of a coastal itinerary, the names of the headlands, gulfs, estuaries, towns and harbours encountered, giving the distance and direction from one to the next. The earliest survivor, the *'Liber de existencia riveriarum*', probably dates from the early 13th century and is hence considerably older than any surviving chart, or indeed the confirmed existence of one, though in the opinion of its editor, Patrick Gautier Dalché, the text implies that there was already some kind of marine chart then [3].

It is natural to assume a close connection between the toponymy of the *portolani* and the charts but the evidence contradicts that. Anyone proceeding along a coastline, whether to write in at the appropriate point on a chart the name of what they saw or to make a purely textual record, would have a similar experience. It is therefore surprising that the overlap between the two *portolani* that survive from the 13th century, the '*Liber*' and '*Lo compasso de navegare*' (1295/6), is less than half, and that the Carte Pisane repeats only about 60% of the toponyms from either text.

Not only must there have been at least three separate information-gathering exercises taking place during the 13th century, but both of those *portolani*, and by implication the early charts, devote considerable space in their respective coastal itineraries to open-sea, sometimes long-distance voyages (*pelagi*) between the headlands or ports in question. From Tripoli (Libya) to Crete's prominent Cape Ákra Spátha, for example, was about 1000 km. See Gautier Dalché (1995) for comparison between the two texts and diagrams of those *pelagi* [4]. Why would such information have been included if it was not a reflection both of past experience and of potential future use?

Two strands argue against the likelihood of a portolan chart origin outside Italy and earlier than say 1200. First is the entire lack of any documentary evidence (and Nicolai agrees that the charts 'contain no trace of a possible antique origin'). Second, more speculatively, extrapolating backwards from the successive stages of visible progress between, say, 1290 and 1311, and taking into account the elements of rawness in the construction of the Carte Pisane and Cortona chart, it is hard to envisage a century's worth of hypothetical development over the 13th century or, conversely, 100 years of stasis. Which is not to deny that the issue of portolan chart origin remains unresolved.

I fully appreciate the potential benefits of cartometric and mathematical analysis. However, for those, like me without the adequate skills, such findings have to be taken on trust. Contrast that with the differences between myself and Ramon Pujades, which any generalist should be able to understand and evaluate. Our disagreements stem from different assumptions and perhaps different selections of evidence; there are almost no disputes about the facts themselves.

Given that there are a number of people studying the portolan charts from a cartometric angle, and apparently using different methodologies, can I urge consideration of a collaborative attempt to unravel the charts' continuing mysteries, in which different techniques are applied and their results compared?

With good timing, Joaquim Alves Gaspar, Evangelos Livieratos and myself are collaborating over an international meeting on the 'Origin and evolution of portolan charts' (Lisbon, 6-7 June 2016) [5]. This is designed to bring together the traditional historians of cartography and the 'cartometricians' and to seek common ground within, and between, the two groups.

Asked to provide a commentary on an article whose conclusions appear to contradict the best historical and chart-based evidence currently available to us, I am unable to endorse the author's statement that the charts' 'high accuracy and underlying map projection make their construction in the Middle Ages impossible'.

[3] Patrick Gautier Dalché. *Carte marine et portulan au XIIe siècle: le "Liber de existencia riveriarum et forma maris nostri Mediterranei" (Pise, circa 1200)* (Rome: École française de Rome: distributor, Paris: Boccard, 1995).Collection de l'École Française de Rome 203, pp.36-7. Access online via: https://cnrs-gif.academia.edu/PatrickGautierDalch%C3%A9

[4] *ibid*. pp.205-219 & 304-305

[5] 'On the Origin and Evolution of Portolan Charts. First International Workshop'. Lisbon, 5-6 June 2016: http://ciuhct.org/events/portmeeting/

How old are portolan charts really?

Roel Nicolai

Response of Roël Nicolai to Joaquim Gaspar and Tony Campbell

The reviews of Joaquim Gaspar and Tony Campbell (in Maps in History No 53) do require a reply, but I shall limit myself to the main points of their critique. Both Gaspar and Campbell have received a full copy of my dissertation and both respond to the entire thesis and not just to the article in this newsletter, in which I could only describe a few aspects of my extensive analysis.

Gaspar claims two main facts support a medieval origin. The first is the existence of the 'Liber de existencia rivieriarum ...', which indeed refers to a nautical chart and it is the oldest document known to do so. It also states that information in the document stems from observation by the author, but, tantalising as this is, that statement on its own provides an insufficient basis for a conclusion that medieval pilots supplied the observation data for the construction of portolan charts. It might equally refer to the descriptive information about ports and the hydrographic detail found on portolan charts. Quantitative analysis of the Liber is therefore highly desirable and I volunteer to participate in such an analysis.

Gaspar's second 'fact' is that the rotation angle of the chart image, about 9 degrees, appears to agree with the average value of magnetic declination. That may be true or not, but to conclude from that fact alone that the whole of the Mediterranean and the Black Sea must then have been surveyed with the magnetic compass, is, again, premature. My own suggestion is that the orientation of the partial chart of the Western Mediterranean may have been oriented with the help of an early compass, perhaps of the type described by Petrus Peregrinus in 1269, and the rest of the partial charts were fitted together using overlaps of common sections of coastline. This is another explanation of the rotation angle of the charts, and this way of constructing a mosaic chart also explains the strange regional scale variations and orientation variations on a portolan chart, for which no good explanation has been provided until now and which Gaspar does not mention.

Gaspar deviates from good scientific practice in a few places. On three occasions he ignores historical evidence, stating that such evidence does not prove that his hypothetical original story is incorrect. These are firstly his postulated existence of a long development path involving 'working charts', secondly the change of terminology from 'needle' to 'bussola' in notarial documents in 1349 (which is supported by evidence from contemporary literature) and thirdly the computation of the arithmetic mean as a means of improving the accuracy of a distance or direction. To propose something that is not directly supported by historical evidence is not incorrect in itself, but its plausibility will at least have to be demonstrated, otherwise one risks writing one's own private version of history. I accept that the occurrence of the term 'bussola' in 1349 must not be interpreted to say that the mariner's compass was not used before that date. Several decades of assumed prior usage can be justified, but that brings us only to the beginning of the 14th century, not the beginning of the 13th or even earlier! To assume that the compass as a single unit was used extensively for 150 years while in contemporary literature

Evidently only one conclusion can be correct, so an evaluation of the correctness of each method used is required.

only the so-called floating compass is described makes a very unlikely story. Pointing to the charts themselves as evidence for the early availability of the compass as a single unit is an unacceptable way of conducting scientific inquiry. This constitutes circular reasoning: the charts cannot be both question and answer.

The main bone of contention between Gaspar and myself concerns the question whether the Mercator(-like) projection is automatically generated by the plane charting technique. Gaspar concluded 'yes' and I concluded 'no'. Evidently only one conclusion can be correct, so an evaluation of the correctness of each method used is required. Initially Gaspar and I follow the same approach: generate a framework of rhumb-line distances and magnetic

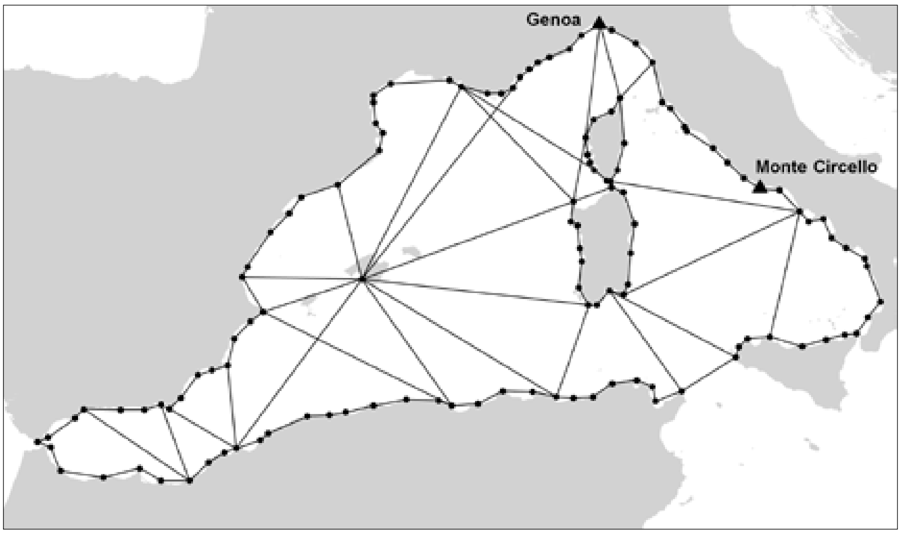

Fig. 1 Geodetic framework of distances and azimuths between coastal points in the Western Mediterranean. Similar frameworks were defined for the Eastern Mediterranean and the Black Sea. Calculation or plotting of the positions of the coastal points yields a 'synthetic' chart that can be compared to a portolan chart.

azimuths between points along the coastline of the Mediterranean, calculate the positions of these points by plane charting and compare the result with a portolan chart. This exercise takes us firmly into the domain of geodesy, my own field of expertise. Geodesy has been defined as the 'science of the measurement and mapping of the earth's surface'. The only available technique to map a significant portion of the earth's surface is to begin by establishing a geometric framework. This is the quintessence of geodesy; it is why geodesy developed as an applied, mathematics-based science in the 18^{th} century. In those days geodesy, together with astronomy, formed the vanguard of science. A rich geodetic tradition exists on the subject of the measurement, analysis and computation of a geometric framework of distances and directions measured on the earth's surface. Gaspar provides no indication that he is aware of this tradition, speaking, as he does, of 'novel analytical tools and numerical modelling techniques' which he introduced. There is no point in my trying to sweeten the pill, so I will start by stating clearly that Gaspar applied this technique incorrectly and his conclusions are therefore invalid. He jumps into least squares estimation, apparently without understanding exactly what the method does and how he should test objectively whether the result is consistent with the (apparent or real) map projection of portolan charts.

His approach has the following flaws:

1. Gaspar does not take into account the established sailing routes. He opts for a framework of 55 regularly spaced nodes with latitudes from 30°N to 50°N and longitudes from 10°W to 40°E, with 5° intervals, i.e. covering most of central and southern Europe. Such a framework is not representative for the Mediterranean. Its symmetry will ensure that the end result will also be highly symmetrical, the only disturbing factor being the spatial variation of magnetic declination.

2. Gaspar used a relative weight factor for distances and azimuths (0=distances only; 1=azimuths only), but is clearly unaware that in least squares adjustment with different quantities (distances and azimuths) the relative weighting should be achieved by using the inverse of the covariance matrix of the observations in the calculation. One unit of distance contributes differently to the position calculation than one unit of azimuth and use of covariance matrix makes azimuths and distances computationally compatible quantities. Gaspar's optimum weight factor of 0.8 reflects therefore partly his omission of accounting for the different units of measure.

3. This optimum factor was achieved by minimising the mismatches in the calculation. There are two disturbing factors in his geometric framework, which cause the simulated observations to fit exactly: the effect of the neglected earth curvature and the spatial variation in magnetic declination. Gaspar optimises these mismatches by compensating them with just enough contributions by the computed distances. The flaw is that he concludes from the optimum found that this is how the medieval cartographer must have done it: giving a four times higher weight to azimuths than to distances.

4. The final question is: 'does the simulated result look sufficiently like a portolan chart?'. Gaspar applies a subjective criterion to the comparison of his simulation and the actual portolan charts. He processes both by the cartometric analysis software package MapAnalyst, which generates a distortion grid (his Fig. 1). What Gaspar appears to be unaware of is that the method MapAnalyst uses to compute these grids has significant smoothing and extrapolation properties. Gaspar presents no quantitative, objective criteria to show what the differences between his network calculation

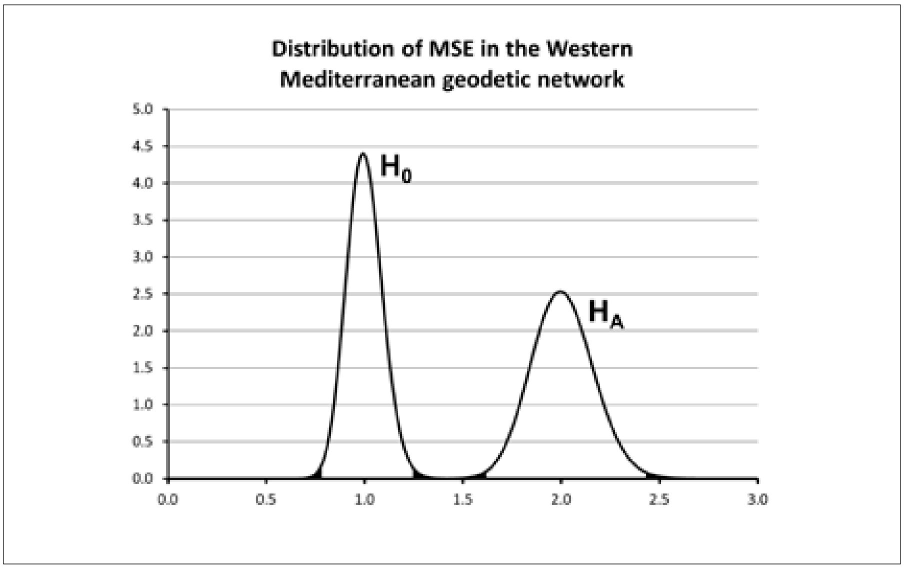

Fig. 2 Result of the statistical testing of the Western Mediterranean 'synthetic chart' against a real portolan chart. The curve on the left is the error distribution of the Mean Square Error of the actual Western Mediterranean sub-chart of a typical portolan chart. The curve on the right-hand side is the error distribution of the MSE of the synthetic chart. No overlap means their shapes are different to a statistically meaningful degree.

> and the original portolan charts are and whether these differences can be explained by the accuracy of the portolan charts or not. His final result consists of two small 1:70 million scale pictures with smoothed distortion grids from which the reader is invited to say: 'yes, I think these look sufficiently identical'.

I shall not repeat a description of my own method here: suffice it to say that I did take into account the actual routes sailed, as well as proper weighting of the observations and it is well documented in my thesis. I furthermore applied objective statistical criteria to the results of the calculation in order to arrive at the conclusion.

Gaspar scolds my 'extraordinary claim' that knowledge of averaging as a way of accuracy improvement was not available in the Middle Ages. However, this is not my claim; it is a research-based conclusion that historians of science have drawn. His counter claim that Portuguese navigators used this technique routinely from the beginning of the 16th century begs a challenge to supply proof. I doubt that such evidence exists, but Gaspar can make a real impact on the history of science by proving his claim. Even if it were true, there would still be a gap of more than two-and-a-half centuries to bridge! Gaspar is scornful of the outcome of the mathematical model I formulated to estimate the accuracy of medieval navigation. One-third of the distance sailed is clearly unrealistic in his view, but what is his view based on? On reverse engineering of the portolan charts, i.e. the same argument as he used for the mariner's compass? I am happy to discuss this navigation model, but the discussion needs to have a bit more substance than the rhetoric Gaspar uses.

Gaspar proposes that the calculation of averages of single observations was unnecessary and replaces it by an assumed 'graphical optimisation process in which the relative positions of places were gradually adjusted over time using superabundant information'. He thus replaces the calculation of the average of a series of single observations by the much more complicated method of deriving the average position of every coastal point, in other words this is averaging in a two-dimensional sense. Such an advanced treatment of observation data is simply not realistic for such an early period. Gaspar's proposed method flies in the face of everything that is known about early (or pre-)scientific thought in the Middle Ages. This is an aspect of the historical context that is not given any attention in research into the origin of portolan charts. Gaspar tries to solve the problem by transposing a modern-looking mentally conceived process back to a medieval setting, assuming the same analytical focus on problem solving existed then as now. Moreover, Gaspar's method is an exclusively mental process. No experimental verification has ever indicated that such a process would be feasible at all. I suggest to discuss such possible experimental verification at the proposed workshop in Lisbon, June 2016.

Gaspar describes my study as a 'cartometric analysis', but that is an oversimplification.

It would take too much space to respond to every detail of Gaspar's critique and I do not wish to reply in detail to unspecific reproaches such as 'preconceived ideas' and the 'minimising or distortion of other studies'. Yes, I do point out methodological shortcomings in other studies, but that does not involve 'minimisation and distortion'. Gaspar describes my study as a 'cartometric analysis', but that is an oversimplification. The cartometric analysis is important, but it covers only one of 12 chapters. The main objective of my analysis was to test the hypothesis of a medieval origin in a scientific manner and to analyse the problem of the origin in a geodetic context. I include many aspects of the historical context in my study that others, including Gaspar himself, have not mentioned, such as an analysis of the meteorological and oceanographic aspects of the Mediterranean, the sailing properties of medieval ships and notably relevant aspects of the history of science. I devote an entire chapter to explaining and justifying the mathematical analysis methods I used in my study. Gaspar's condescending closing remark that 'mathematical methods are not magical boxes from which historical truth can be read' is therefore inappropriate and rather gratuitous.

I have fewer comments to make on Campbell's more constructive critique. Campbell states that he does not understand mathematics well and therefore would have to accept my results on trust only. I appreciate the honesty and agree that complex mathematics are a barrier to the sharing of such results. However, when I sent my thesis to Campbell, I expressed awareness of this and asked him to contact me for clarification if anything in the thesis was unclear to him. He has not come back with a single request, but the offer still stands. The methods I have used can certainly be explained in easier terms. Returning to Campbell's understandable trepidation in accepting my results, I wonder whether he feels the same reservation regarding the results of numerical studies that claim to confirm a medieval origin (e.g. Gaspar's). There is no place for mathematical methods in the study of medieval mappae mundi, but for portolan charts, with their demonstrated quantitative properties, quantitative analysis is, I believe, a mandatory research component.

Campbell states that I have taken inadequate account of portolani (or portolans) in my thesis. I think that is an unfair comment: I devote one 78-page long chapter to a very extensive analysis of the Compasso de Navegare, the oldest surviving complete portolan of the Mediterranean and Black Sea, which is more than any other author has done. A different matter is whether Campbell likes the outcome. Of course I might have included an analysis of the Liber de existencia, but one has to draw a line somewhere.

I have been sceptical from the start about a medieval origin, because it requires assumptions to be made that conflict with geodetic reality, such as assumptions that earth curvature can be ignored in 'small' areas such as the Mediterranean and that the map projection is accidental. This ignores the development of geodesy as the science that deals (mathematically) with these aspects. Being sceptical is not the same thing as being 'prejudiced'. I might equally accuse Gaspar and Campbell of being prejudiced in favour of a medieval origin, but that does not help the discussion in the slightest. Suffice it to say that, if the origin of portolan charts were such a clear-cut case as the picture painted notably by Gaspar, it would not have been such a controversial subject for the past 160 years.

In my opinion the geodetic aspects of mapmaking and the history of science are two important elements that, until now, have been underexposed in portolan chart research. I might add that more attention should be paid to hypothesis testing. Having said that, I am keen to seek ways to bridge the gap between the traditional map historical view and the quantitative geodetic view at the forthcoming workshop in Lisbon.

The description of my work on portolan charts in this newsletter was necessarily brief. My work is described in more detail in a long essay, published in the September 2015 issue of 'Isis', the journal of the History of Science Society and my revised thesis will appear as a book with Brill, Leiden, in March 2016.

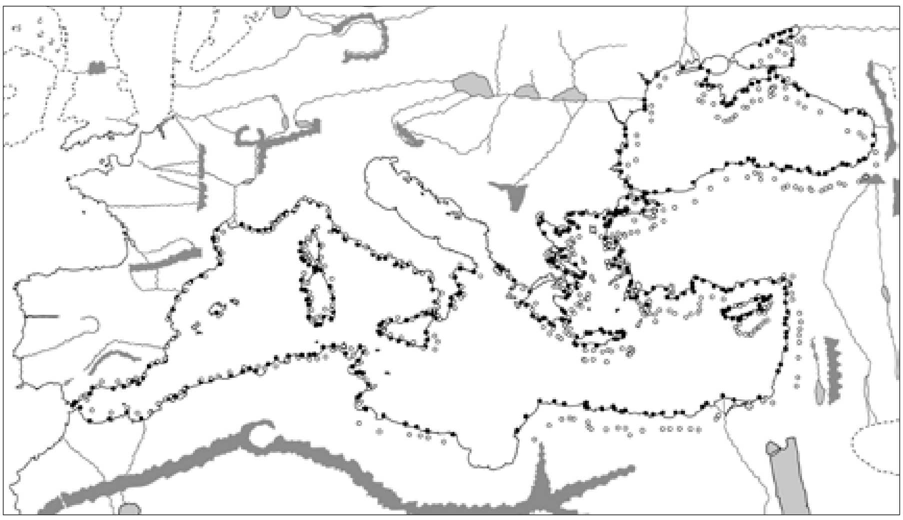

Fig. 3 Composite of the three geodetic frameworks (open circles) when superimposed on the Angelino Dulcert 1339 chart. Each plane-charted geodetic network was corrected for rotation and scale differences with the relevant part of the Dulcert chart, so that te diagram only shows shape differences between chart and plane-charted network.