

Tides and the Catalan Atlas [1375]

Vicenç M. Rosselló i Verger*

Universitat de València

Original source:

***Cuadernos de Geografía*, 86: 165-182 (2009)**

(<http://147.156.169.228/cuadernos/index.php>)

Translated from Catalan by Mary Black

Abstract

The Catalan Atlas [1375], attributed to Cresques Abraham, a Jew buixoler, is preceded by a long geographical, astrological and oceanographic text, part of which refers to the tides and is accompanied of the oldest known graph which shows 14 circumferences and 16 orientated sectors. In this article, we identify toponyms and discuss the sources of the theories of the lunitidal interval or establishment of a port and the texts (Isidorus, Honorius d'Autun or of Regensburg) and the classic roots of the theory.

Key words: Catalan Atlas, Cresques Abraham, historical cartography, tides, lunitidal intervals, medieval commentators, Isidorus

The Catalan Atlas is a portolan chart expanded in a luxurious fashion which has almost unanimously been attributed to the “*buixoler* and master of navigation charts”, Cresques Abraham, a Jew from Mallorca, in around 1375. It consists of a large, foldable parchment measuring 65 x 300 cm reinforced with six support posts. The first sheet contains not only the calendar that has helped us to date it but also a long geographic, astrological and oceanographic text on which we shall focus in this article. The document, which comes from the royal library, is conserved in Paris (Bibliothèque Nationale de France, *Ms. Esp. 30*) and has been the subject of numerous facsimile reproductions.

1. The text by Cresques Abraham

“Oceanus vol aytant dir com lim de correjes o [fferres],¹ car la gran mar les.V.correjes o pertides [enferre] axí com a lim environa. L'escalfament de la mar, ço [és con] entra e con se'n torna, segueix la luna, axí que con la luna és

¹ The etymology that Isidorus (15.1) gave from the past, “*eo quo in circuli modum ambiat orbem*” (“because [the ocean] wraps around the globe like a circle”), is the one that aims to translate document with “lim de correjes”; going to “fferres” is more problematic.

minva, que torna-sse'n la gran mar, e con la luna creix o és plena la gran mar entre e s'escampa; emperò con la luna és en equinocci lavors les ones e aygües de la gran [mar] més decorren, e açò per lo vehinesc de la luna; e con la luna és en lo solstici ladonchs són menors les aygües e menys decorren, e açò per la lunyària de la luna; axí que per.XIX.anys aquesta gran mar fa son cors, axí con és dit; axí con fa la luna, e puys està en agual crexement e torna fer son cors axí con fa la luna. Emperò la gran mar, con la luna ix, lavors fa ella antipotis, que vol dir devorament, car lavors tira ella les aygües e les gita ab gran poder. [...] Devets saber de la luna que con ela deu pendre la volta que ela està sots lo sol.VI. hores e.DCCXCIII.punts.....

“Devets saber que les marees si créxan e minven per una via del ras sant mein tro en boca d'aver, jatsia açò que per unes pertides són pus qurens e pus forts que per altres. Con devets saber que con la luna és per grech les mares comensen a muntar, e aquela luna és per exeloch, que són.VIII.quartes de vent e són.VI.hores. Ítem con la luna és per axeloch les aygües comensen a muntar tro que la luna és per lebeg lebeg, e són.VIII.quartes de vent que són.VI.hores. Ítem con la luna és per lebeg les aygües comènsan a muntar tant tro que la luna és per mestre, e són.VIII.quartes de vent que són.VI.hores. Ítem con la luna és per mestre les aygües comènsan a muntar tant que la luna és per grech, e axí aquestes marees del ras de sant maén tro en boqua d'aver fan aquest cors nit i jorn dues marees munta[n]ts i qrexen[n]ts e dues marees munta[n]ts e basa[n]ts e quascuna.VI.hores, sí que quatre vegades. VI.valen e són.XXIII.hores. Mas en aquesta rahó vós me puriets dir e demanar: «Com sabré yo hon és la luna?» Vós davets saber de la luna quantes hores aurà, car lo comte devets saber e per quascun jorn una quarta, donchs si la lun[a] ha.VIII. jorns serà luny del sol .VIII. quartes de vent; donchs si lo sol és per ponent la lu[n]ja ne serà .VIII. quartes de vent luny e serà per migjorn; donchs podets entendre que les aygües munten e qrexen; e per aytant[s] jorns con la luna aurà aytantes quartes de vent ne serà luny del sol. E ab aquesta rahó podets saber lo conte si les aygüe[s] crexen ho minven tota vegada sabent e avent lo conte de la luna, e ab aquel comte de la luna o podets saber verament e justa si és de nit, si és de jorn, ho en clar ho en asqur, ab que lo dit comte [sapiats]. Sapiats que aquestes marees crexen axí an rius con an astanys con an mar e minven per aquest[a] rahó matesa verament. Devets saber encara que si és tems clar encara que si volets saber quantes hores avets de la nit que ho podets saber ab çerta rahó e bona e breu. Devets saber que la tramuntana ha .VII. astellas que la vogen de nit i de jorn e aquestes han nom.....

*“Asò és lo cors de les marees incomensand del mont de gíbetària entró astach de pomarch chi és in bretagna, luna in grech e lebeg P[lena] mar in mestre e vent forà B[aixa] mar”.*²

² This is the English-language version (translated from modern Catalan) of the basic passages:

“The heat [the inflow] of the sea, that is, when it enters and when it ebbs, follows the moon; as the moon wanes, the great sea ebbs, and as the moon waxes or is full, the great sea flows in and spreads; however when the moon is in equinox, then the waves and waters from the high sea flow more because of the proximity of the moon; and when the moon is in solstice, then the waters are low and the currents are slower because of the distance of the moon; so every 19 years the high tide completes its cycle, as mentioned; as the moon does and then it follows in equal growth and once again completes its cycle as the moon does. But the great sea, when the moon comes out, serves as an *antipotis*, which means maelstrom, because then the sea attracts the waters and launches them with great force”.

Figure 1. The first panel of the Catalan Atlas by Cresques Abraham. Below is the tide wheel which we are discussing, while the corresponding text is in the column on the right. (Paris, Bibliothèque Nationale, Ms. Esp. 30).



“You should know that the tides ebb and flow in an expanse that spans from Cape Sant Mein [Pointe de Saint Mathieu] to the outlet of l’Eure [Havre], although they are quicker in some places and stronger in others. Likewise, you should know that when the moon is northeast, the tides begin to rise; the moon heads southeast, which are eight quarter winds, or six hours. Likewise, when the moon is southeast, the waters begin to rise [wane] until the moon is southwest, which is eight quarter winds, or six hours. Likewise, when the moon is in the southwest, the waters begin to rise until the moon is in the northwest, which is eight quarter winds, or six hours. Likewise, when the moon is northwest, the waters begin to rise [wane] until the moon is northeast. Thus, the tides between Cape Sant Maén [Pointe de Saint Mathieu] and the mouth of l’Eure [Havre] follow this course day and night: two rising tides and two ebbing tides six hours each, so that four times six equals and is twenty-four.”

“You should know that these tides rise equally in rivers and lakes as in the sea and that they truly wane for this same reason”.

“This is the course of the tides, from Mount Gibraltar to the Stoc de Pomarch [Beg ar Penmarc’h] which is in Brittany. The moon NE and SW: high tide; NW and with outward winds: low tide”.

The text accompanies the oldest diagram of the tides of which we are aware, which consists of a circle with fourteen concentric circumferences subdivided into sixteen sectors (each of which corresponds to an hour and a half). The northern orientation is marked by a symbolic star, as is the east (Maltese cross) and the south (half-moon). Initials are applied to the other winds and half-winds: *Grego*, *Scilocho*, *Labetzo*, *Ponente* and *Magistro*, in the style of the compass roses on portolan charts. The sector between N and NNE (the only one labelled; the others only have blue undulations and the red initials P and B) lists the following port or coastal names from outside to inside (Table 1).

Table 1

Toponym on the circle	Toponym on the chart	Current toponym
	BRITTANY	
-----	stoc de pomarch	Beg ar Penmarc'h (Pointe de...)
sayn	sein	Enez Sun (Île de Sun)
sanmae	sa mae	Pointe de Saint Mathieu
forndartus	[forno]	Le Four (canal on the Îles Molène)
insula de bas	Base	Enez Vaz (Île de Batz)
setrilles	-----	ar Jentilez (les Sept Îles)
	NORMANDY	
granexo	granexo	Guernsey (Guernesey)
ras branzard	-----	Raz Blanchard (Cap de la Hague)
	ENGLAND	
porlam	cauo (de) Porlan	Portland
uhic	huic	Wight
beocef	beacep	Beachy Head
gillsalexeo	guinsalexeo	Winchelsea
romaneo	romaneo	Romney
sanux	samux	Sandwich Bay
sayna	sayno	Seine River?

The initials P and B are arrayed around the respective circular crowns to indicate the time of high tide (P) and low tide (B) in each place depending on the position of the moon.

One example of how to read it can be applied to *sayn* (Enez Sun), which is located in the outermost circle: the P is at NNE and SSW, indicating that in full moon and new moon the high tide arrives at 1:30 am and pm; four sectors or six hours afterwards we find B, which shows low tide. The brief introductory text refers to the coasts falling between Beg ar Penmarc's (Brittany) and Gibraltar [?], and along these coasts high tide is recorded with the moon NE/SW (at 3 o'clock sharp) and low tide when the moon is NW/SE (at 9 o'clock sharp), a largely accurate observation (Howse, 1993).

2. Theory of tides and lunitidal intervals or establishments of a port

2.1. Theory of tides

It seems like tides have perennially been regarded by the author of the Catalan Atlas text as an oceanic phenomenon which has no actual importance in the Mediterranean. Indeed, classical authors, as we shall see, only mention tides on the Atlantic coasts and the Red Sea, the name that was applied by extension to the Persian Gulf, while the majority of the mediaeval authors focus on the ocean and, more specifically, on the English channel.

Setting aside the first few sentences in the chapter (the extravagant supposed etymology of the word *Oceanus*),³ it begins by outlining the relationship of dependence, causality or coincidence between the phases and movements of the moon and the rhythm of the tides: “The sea... when it enters and when it ebbs, follows the moon”. The alternations in sea level which we tend to call the flow tide or ebb tide appear repeatedly in the passages cited with the verbs *entrar*, *créixer* and *muntar* and the nouns *gran mar* and *antipotis*⁴ for the positive oscillation; while the negative is expressed with the verbs *minvar*, *baixar* and *escampar* and with the adjective *menor*. We should note that “these tides rise equally in rivers and lakes as in the sea and that they truly wane for this same reason”; the effects on coastal rivers and lakes, which is important from the standpoint of port navigation, is observed with the same attention as the sea currents, when the sea “pulls and agitates the waters with great force”.

Regarding the daily tide cycle – 24 hours and 50 minutes – it says that it flows and ebbs every 12 hours (it is actually 12 hours and 25 minutes), leaving six hours between high tide and low tide, considering that the moon travels 90°, “eight quarters of wind”,⁵ every six hours. With a reiterative statement of the position of the moon every 90° and every six hours, he refers to the semi-diurnal astronomical tide and applies the cycle to the English Channel: “*Con devets saber que con la luna és per grech les mares comensen a muntar..., e axí aquestes marees del ras de sant maén tro en boqua d’aver fan aquest cors nit i jorn dues marees muntants i grexents e dues marees muntants e basants e quascuna .VI. hores, sí que quatre vegades .VI. valen es són .XXIII. hores*”. The incoming tide begins when the Moon is in the direction of NE and SW; to the contrary, the tide begins to ebb when the orientation is NW and SE.⁶ Either

³ Revisited by Honorius Augustodunensis, who borrowed it from Isidorus: *faixa de corretges = V partides que environen l’escalfament [el flux] de la mar*.

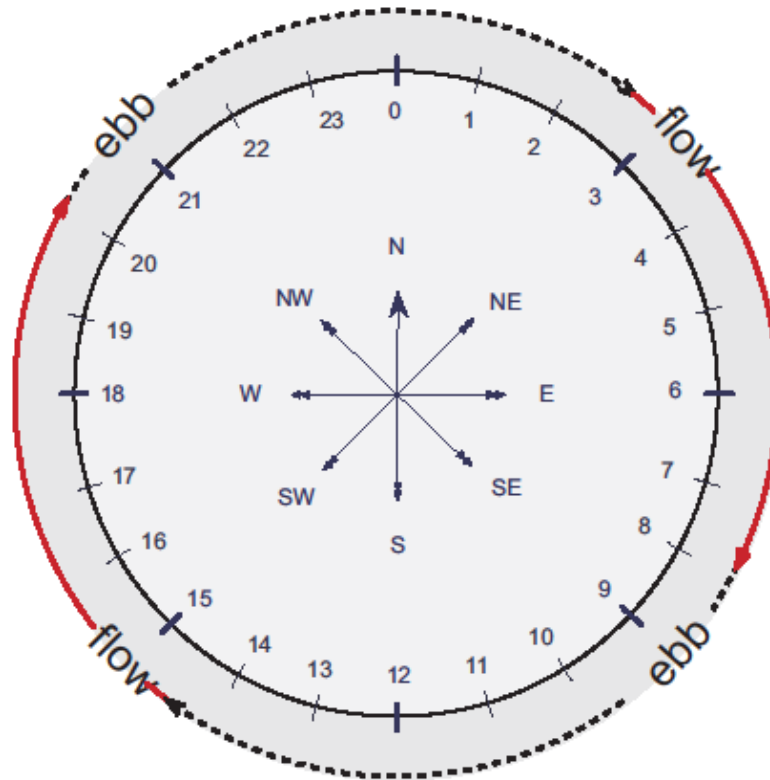
⁴ I have not found this word in any dictionary; it must have referred to the drink (ποτήρις); thus, we should find a meaning that is the opposite of “devouring”. However, it is more likely a misreading or inaccurate transcription of *amipotis*, an archaic seafaring term that was used in mediaeval and modern English to refer to ebb tides. There is actually a somewhat unusual Greek word, ἀμπωτις (ἀνάπωσις), with the same meaning. The error in Cresques’ text, or by Honorius’ translator, might be due to a cross with ἀντιπαθής or ἀντιπάθια, which appears in the texts of Posidonius and Strabo when they talk about the tides and the well at the temple of Hercules in Gadir.

⁵ The word *quarta* did not mean ‘quarter wind’ but each of the 32 divisions of the nautical compass rose, that is, 11° and 15’. Eight quarters is therefore 90°.

⁶ The “Reglas de las mareas” by Diego García de Palacio (Mexico, 1587) is formulated in a similar way: “... when the moon is in the southwest or northeast, it is high tide; and when it is in the southeast or northwest, it is low tide. And therefore, when in the east or west, it would be between high and low tide”. (*Instrucción nautica para el buen uso, y regimiento de la nao...*, facsimile 1944).

the translator of the Latin text – which I have not located – or the copyist erred when giving four rising or incoming tides and no ebb.

Figure 2. Semi-diurnal astronomical tide between Sant Mein and Eure. The scheme refers to the position of the Moon and the hours of the day.



The monthly cycle of 28 days can be deduced from the coincidence with the phases of the moon.⁷ “The sea enters and when it ebbs, follows the moon; as the moon wanes, the great sea ebbs, and as the moon waxes or is full, the great sea flows in and spreads”. Indeed, even though the text does not mention the sun, it does posit the syzygies (conjunction or opposition of two heavenly bodies: the new and full moon, which determine the maximum high tide) and the quadratures (waxing and waning quarters which reflect the minimum high tide) as a justification of spring tides and neap tides.

The author or inspiration behind the Atlas also recognises an annual cycle or period related to the equinox (maximum flow and ebb) and the solstice (minimum range and minimum extreme levels): “when the moon is in equinox, then the waves and waters from the high sea flow more because of the proximity of the moon; and when the moon is in solstice, then the waters are low and the currents are slower because of the distance of the moon”. Astronomically this is an accurate observation, regardless of whether or not it was inspired by the classical or mediaeval sources which we shall see below: the maximum tides

⁷ Exactly 27 days, 7 hours and 43 minutes, which equals 13° per day.

dovetail with the equinoxial syzygies. What is more, the text stresses that the tidal currents are indeed stronger in the English Channel – referring to all the texts furnished – with a clear west-to-east direction during the flow tide and from east to west during the ebb tide.

The Metonic cycle, discovered in the 5th century BC and widely used to adjust the calendar, reflects the proof of the reiteration of the time of the tides parallel to the phases of the moon within a fixed period of time, that is, after 235 lunations, which corresponds to 19 tropical years. The text states: “*Axí que per XIX anys aquesta gran mar fa son cors, axí com és dit; axí con fa la luna, e puy està en equal crexement e torna fer son cors axí con fa la luna*”.

2.2. Lunitidal intervals or establishments of a port

“Qui pot saber què d’ell los fats ordenen,
quan com e on finarà los seus dies?

.....
Ell va de nit sens brúixola o carta,
menys de pilot, en la canal de Flandes...”
(Ausiàs Marc, poem 113, verses 201-206)
1425-1450⁸

Between the astronomical tide – which would imply an exact correspondence with the position of the moon and the sun with regard to the Earth – and the real tide observed on the coast, there tends to be a difference, at times notable, which in the case of the English Channel leads to a major shift of mass, “the course of the great sea”, eastward, when it flows, in the description provided in the Catalan Atlas. Furthermore, the tidal oscillation varies considerably depending on whether the coast is more or less rugged (map, Fig. 3).

The extreme observation points mentioned in the text – with the exception of a disconcerting *Gibetària*⁹ – and the toponyms written on the illustrative wheel fall between what we now call the English Channel and the coast of Brittany, an area that at the time was plied by the galleys of Mallorcan and Genovese merchants. *Stoc de pomarch*, Beg ar Penmarc’h and *boca d’aver*, the outlet of l’Havre or Eure, are the only references that appear in the text but not on the aforementioned wheel, but they form a coherent, orderly whole.¹⁰

⁸ “Who can know what the fates ordain,/ when how and where their days will end? / He goes by night without compass or chart, / less a pilot in the English Channel...”

⁹ I have carefully combed both sides of the Channel and the Breton coastline for any homonym which might match this name and I have found none. All the transcribers of the Catalan Atlas have reduced it to Gibraltar (which on the cartographic sheet is written *mont gibeltar*), but the leap in considering the tides from the coasts of Andalusia to the coasts of Brittany would be unlikely, unless the text has been mutilated. However, we should not lose sight of the role played by the Columns of Hercules (Strait of Gibraltar) in the observation and interpretation of the tides by classical authors, especially Posidonius and Strabo.

¹⁰ Of the 16 sectors in the wheel, which are marked with the eight primary winds, only one or two have been used, the NE ones. Might this suggest that there were others in the model (coast of Gascony, Galicia, Portugal or Cadiz)?

From southwest to northeast and after *stoc de pomarch*,¹¹ we have *sayn*, which is the little island called *Enez Sun* ('low island'), in Breton, located across from *Raz de Sun* point, a channel which is sadly well-known on the map of shipwrecks in the Atlantic; *raz* or *rash*, in Old English *ræsć*, means both 'storm', 'violent current' and 'strait' or 'channel', which is true in this case (Guilcher, 1950; 1979). *Sanmae* – initially 'holy stone' – corresponds to Pointe de Saint Mathieu, an outcropping which also supports a large lighthouse next to the ruins of a Benedictine abbey. *Forndartus*, *forno* in the Atlas itself, has been identified as what is currently known as Le Four, applied to the very dangerous channel separating the extreme point of Brittany – Pointe de Saint Mathieu and Kerk-Leon = Le Conquet – from the Molène and Ushant islands; P. Vesconte (1321) wrote *fornato*, while the most common spelling in the 15th century was the one used by Cresques Abraham; afterwards, misreading may have led to *torno* or *torn*.¹² *Insula de bas* is currently still used in Breton as *Enez Vaz*, across from Rosko. *Setrilles* correspond(s) to the Sept Îles, *ar Jentilez* in Breton; the archipelago only has five islands and many reefs, such that 'seven islands' is a false etymology which was not valid even back in 1375. *Granexo* is the British island of Guernsey, which sailors often ran into by chance before reaching *ras branzard* (Raz Blanchard). This toponym has a clear aetiology based on the strong current commonly found between the island of Alderney (Aoeur'gny or Aurigny) and Cap de la Hague on the extreme end of Cotentin; the average speed is eight knots, and during high tide at the equinox it can reach twelve. Mediaeval sailors were no doubt aware of this.

¹¹ *Stoc de Pomarch* is the transcription from the Breton *beg ar dorchenn*, 'torch point', a possible allusion to a kind of lighthouse. The first element in the toponym, which has Indo-European roots, is the Old Norwegian *stack* and in varied forms, including *tuc*, *cuc*, *cucq*, etc., it means 'cape', 'point' or 'key'. *Penmarc'h*, however, means 'horse head'. I owe many of the explanations of the toponyms to Ofis ar Brezhoneg (Karaez-Plougêr) and personally to Hervé Guéguen and Marc Cochard, whom I would like to thank.

¹² The so-called Mer d'Iroise (French nautical chart 7149) notes the strong tidal currents due to the funnel effect from Raz de Sein to Chenal du Four and especially at Fromveur. While the currents register at 3 to 4 knots in running water at sea filled with reefs, they can surpass 8 knots, and 5 at Le Four. The passes referred to include some of the most dangerous ones in the world because of the considerable tidal range, which is higher than 7 m, and the many reefs and seafloors less than 5 m deep (*Atlas des courants de marée de l'EPSHOM*, no. 560, by Goulven à Penmarc'h). A lamppost built in 1874 occupies the *Roche du Four*, across from Argenton.

Figure 3. Map of the English Channel with the toponyms contained in the Catalan Atlas and the cotidal lines. The continuous lines represent cotidals (same tide height) in lunar time and the broken lines represent the tidal range (height difference) in metres.

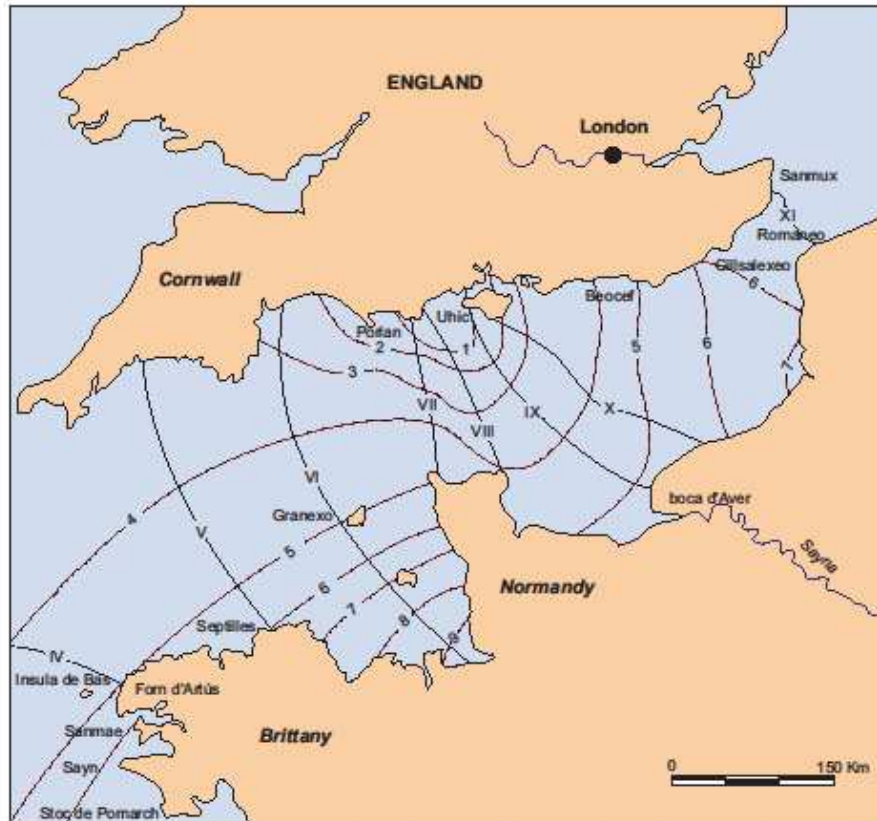
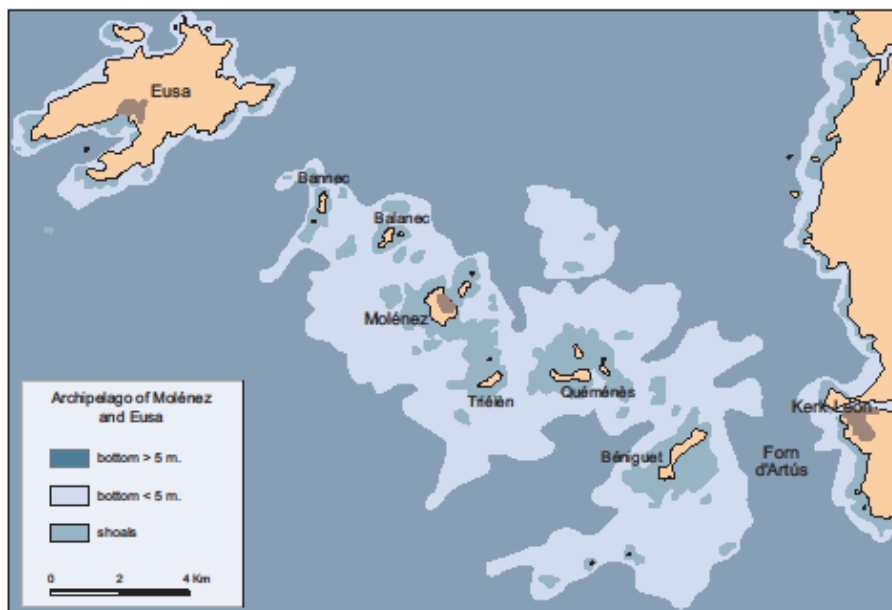


Figure 4. The Molène and Ushant islands, the location of the Forndartus, of the most dangerous passes in the English Channel because of the tidal currents.



Porlam or *porlan*, the next name, belongs to the United Kingdom, Portland, and it curiously followed the cotidal order on the other side of the channel. Then comes or *uhic* or *huic*, which brooks no doubts: Wight, the large island situated across from Portsmouth. The other points noted, all of them English, are *beocef*, Beachy Head, referring to the impressive cliff in Eastbourne where Cretaceous limestone justifies the false etymology of the classic Albion (Pliny and Ptolemy). After that comes *gillsalexio* or Winchelsea, an old fishing port and Saxon castle that was rebuilt in 1200;¹³ *romaneo*, which is Romney today, a marsh that is currently enclosed with the evading and changing Dungeness, and finally *sanux* or *sannux* (Sand-vik, ‘sand gulf’) corresponding to Sandwich Bay on the easternmost point of the county of Kent, before winding towards London.

We are left with one toponym still hanging, *sayna*, which must be the French Seine River, although this is out of context if we are following the coastline which *should* end in London. Did he confuse it with the *tamixa* or Thames? Besides *gibetèria* and *sayna*, all the rest match the tidal observations.

Table 2

Ports	Notation in the Catalan Atlas [1375]	Hour of high tide sc. Norie, 1844*	Cotidal in Moon hour sc. Proudman, 1953**
[Biscayne Bay]	NE – 3:00	3:00	[2:45]
<i>Sayn</i>	NNE – 1:30	3:15	3:30
<i>sanmae</i>	NE – 3:00	3:00	3:45
<i>fordartus</i>	ENE – 4:30	5:00	3:45
<i>insula de bas</i>	E – 6:00	3:45	4:30
<i>setrilles</i>	ESE – 7:30	7:30	4:45
<i>granexo</i>	SE – 9:00	6:30	6:15
<i>ras branzard</i>	SE – 9:00	7:45	7:00
<i>porlam</i>	SE – 9:00	7:15	7:30
<i>uhic</i>	SSE – 10:30	9:45	9:30
<i>beocef</i>	S – 12:00	11:00	10:15
<i>gillsalexio</i>	S – 12:00	12:45	10:30
<i>romaneo</i>	NE – 3:00	10:50	10:45
<i>sanux</i>	NE/N – 2:15	11:00	11:15
<i>sayna</i> [?]	NE – 3:00	10:30	9:00

* Taken from Howse (1993).

** Note that the progression of the time of the moon on the list from 1375 is totally accurate.

The lunitidal interval or establishment of a port, as we said, is the time difference between the moon’s passage over the local meridian and the maximum tide waves. If we compare a modern map of cotidal lines and amplitude (mean level difference in metres) of the English Channel (Proudman, 1953) to the list of ports in Cresques Abraham’s wheel (Fig. 5), we may be surprised by the similarity. *Sayn*, *sanmaen* and *fordartus* belong to the 3-hour cotidal, while *insula de bas* and *septilles* have a delay of 4 hours. This time

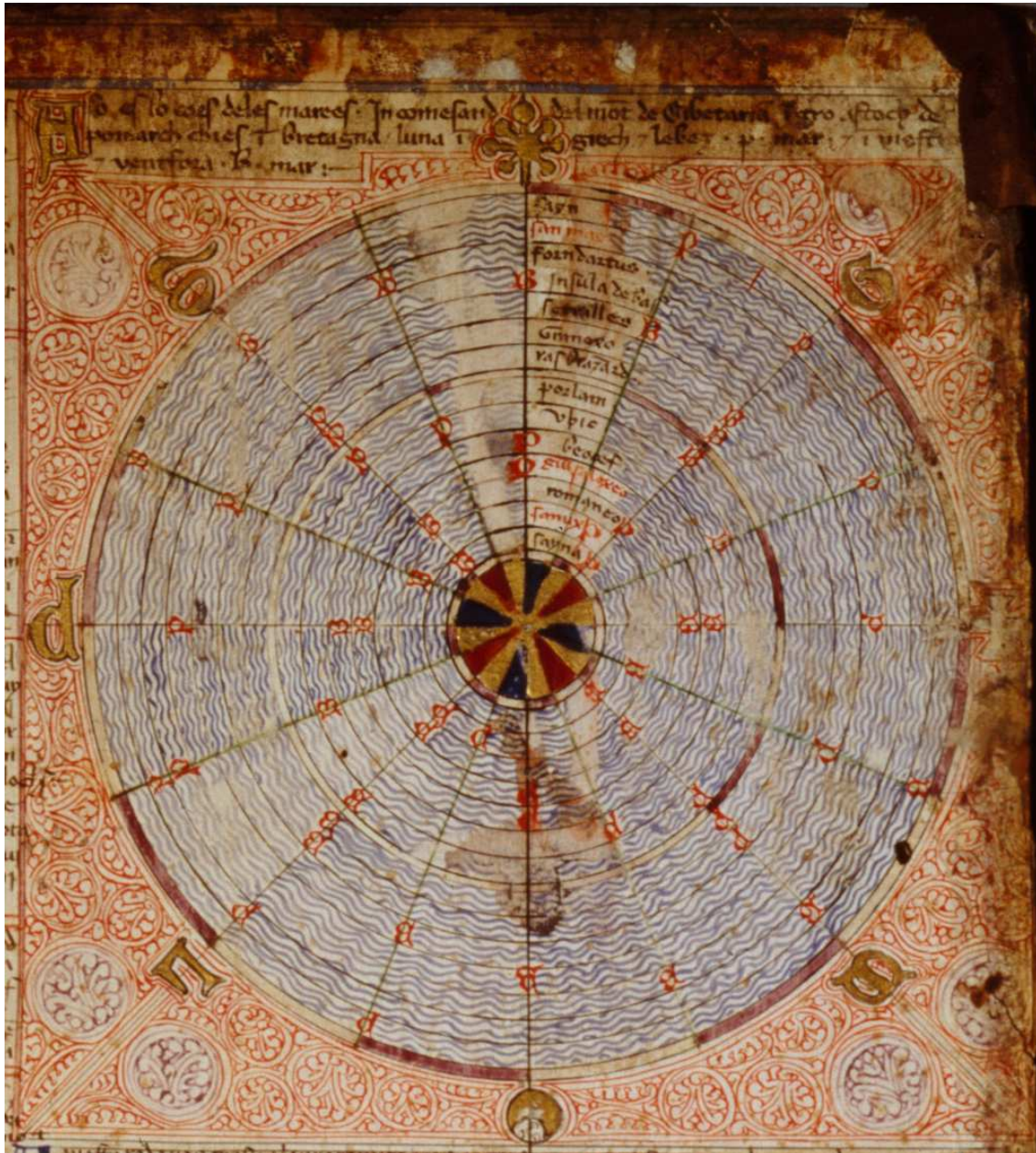
¹³ Winchelsea and Old Romney were part of the *Cinque Ports* which benefitted from high active trade in the post-Norman Middle Ages thanks to the maximum narrowness of the Strait. Major floods and sedimentation in the 13th and 14th centuries led the ports and inhabited nuclei to be moved (Eddison, 2002), as reported in Cresques Abraham’s information or model.

difference is ramped up to 6 hours in *granexo* and 7 in *ras branzard* and *porlan*. *Uhic* is located between the 9-hour and 10-hour cotidals, and the lunitidal interval at *beocef*, *gillsalexio* and *romaneo* is more than 10 hours. Finally, *sanux* and *sayna* (if we interpret the latter as London's estuary) show the extreme value of 11 hours of delay. I do not think it is overly bold to venture that the mapmaker was doing nothing other than tracing the most common seafaring route of the mediaeval merchants through *la canal de Flandes*, precisely along the riskiest stretch, with particular mention of the most treacherous passes.

3. The sources

Broadly speaking, we can venture the hypothesis that Cresques Abraham's text contains two different original parts. One refers to the theory of tides and the other is the passage that mentions the currents and changes with specific geographic references in the English Channel. We should add to the second part the toponyms that appear in the circle, which occupy two sectors, the N-NE ones.

Figure 5. Wheel of the cyclical tide of the English Channel. Close-up of the first panel of the Catalan Atlas [1375] by Cresques Abraham. (Paris, Bibliothèque Nationale, Ms. Esp. 30).



3.1. The theory of tides

The provenance of the observation of the tides and their dependence upon the position of the moon is indisputably classical. We can start with *Posidonius* (130-50 BC) and *Strabo* (54 BC - 20 AD) if we want to know where the mediaeval writers got their theories. Posidonius ultimately tends to be the referent from which the majority of classical and mediaeval authors draw, and he, in turn, begins his discussion of the topic of the tides by contradicting Polybius (200?-118? BC), with a crumpled citation of the fountain or well of Hercules in Gadir (XXXIV.9.5), which, due to “antipathy” (ἀντιπάθεια) would run counter to the flow and ebb of the sea. In his examination of the theme of

the tides and their diurnal cycle, he makes the moon totally responsible, just as he attributes the monthly cycle to the moon (Diggle et al., 1999).

When the moon is more than 30° over the horizon – dovetailing with a zodiac sign – the sea begins to swell and invade the coastline until the moon reaches the meridian. When it turns, the sea ebbs gradually and when it is lower than 30° under the horizon (another zodiac sign), it is low tide. From then on, and with a maximum that matches the passage of the moon – which is now invisible – by the meridian, high tide comes again, and so on successively.

Regarding the monthly cycle, the most accentuated tide comes with the conjunction (ἡ συνοδοσ) of the sun and moon or new moon. From new moon to first quarter, the tide drops and then once again achieves its maximum with the full moon (πανσέληνος). Between the third quarter and the conjunction, the level rises and in consequence the currents of the tide are accentuated. Posidonius reports that the people from Gadir (Cadiz) told him about the maximum tides and ebbs which came with the summer solstice, and he deduced that the neap tide corresponded to the equinoxes and the high tide corresponded to the solstices, following the annual cycle.

Revisiting the texts by Posidonius, Strabo (III.5.7-8 [v. T17]) cast doubt on both the traditional version of a well that ebbs and flows opposite to the rhythm of the tide, and the interpretation that this is due to air pressure within the water veins. He inclined instead towards the presence of different wells and causes of their depletion and filling other than the tide. On the one hand, in terms of the diurnal, monthly and annual cycle, Strabo simply repeated Posidonius' arguments, even the mistake attributed to the Cadiz natives. The maximum high tides do not actually come at the solstices but at the equinoxes. The important role of the moon remains: it is a συμπαῶς τῆ σελήνη phenomenon. In his *Naturalis historia* (II, 99-100), when he discusses why the seas rise and fall, G. Plini (27-79 AD) found the cause *in sole lunaque*, that is, he involves both the sun and the moon; otherwise, he would have been forced to comment on the episode of the well of Cadiz where the tide “is not reasonable”.

For a Mediterranean mentality such as that of General Julius Caesar (100-44 BC), the phenomenon of the rise of the water level and currents derived therefore is an *aestus*, a ‘boiling’, which is barely perceptible on the usual Roman shores, and which caught him and his armies off-guard when they had to cross the Channel. In the *Commentarii de bello Gallico* (3, 12), he makes quite a precise observation: “...cum ex alto se aestus incitauisset, quod [bis] semper accidit horarum .XII. spatio”, when he sees that the semi-diurnal tide always happens every 12 hours on the coast of Vannes. Later on, during the disembarkation in England (4.29), he says:

*“Eadem nocte accidit, ut esset luna plena, qui dies a maritimos aestus maximos in Oceano efficere consuevit: nostrisque id erat incognitum”.*¹⁴

¹⁴ “The same evening it happened to be full moon, the day when the tide is at its maximum: we did not know that.”

However, when he embarks, Caesar makes a few more observations of tides and currents (5, 8):

“...et longius delatus aestu, orta luce, sub sinistra Britanniam relictam conspexit. Tum rursus, aestus commutationem secutus, remis contendit ut eam partem insulae caperet, qua optimum esse egresum superiore aestate cognoverat”.¹⁵

Pliny could be used as a transition to Isidorus (560-636), the Venerable Bede (673-735) and the person who affects us the most, Honorius Augustodunensis (Honorius of Regensburg, more than of Autun, † ca. 1157), since the Cresques text is a translation, sometimes a choppy one, sometimes with insertions, of passages from the book *Imago mundi* by the Irish or German monk. Here are the contrasting passages:

39. *de oceano*

*Oceanus dicitur quasi ocior amnis
vel quasi zonarum limbus
quinque enim zonas mundi in modum limbi ambit.*

40. *de estu*

*estus oceani id est accessus et recessus lunam
sequitur
cuius aspiratione retro trahitur
eius impulsu refunditur.
cottidie autem bis effluere et remeare videtur.
cum luna crescente crescit*

cum decrescente decrescit

*cum luna est in equinoctio
maioris oceani fluctus surgunt ob vicinitatem lune*

*cum in solstitio
mitior est ob longinquitatem eius.*

per .XVIII. annos ad principia motus

41. *de voragine*¹⁹

ampotis quoque id est vorago in oceano

[Cresques Abraham]

Oceanus vol aytant dir [...] com lim de correjes o [fferres], car la gran mar les .V. correjes o pertides [enfferre] axí com a lim environa.

L'escalfament¹⁶ de la mar, ço [és con] entra e con se'n torna, segueix la luna, [...]

...] axí que con la luna és minva, que torna.sse'n la gran mar,¹⁷ e con la luna creix o és plena, la gran mar entra e s'escampa; emperò con la luna és en equinocci lavors les ones e aygues de la gran [mar] més decorren, e açò per lo vehinesc de la luna; e con la luna és en lo solstici ladonchs són menors les aygues e menys decorren, e açò per la lunyària de la luna; axí que per .XIX. anys aquesta gran mar fa son cors, axí con és dit; axí con fa la luna, e puy està en agual crexement e torna fer son cors axí com fa la luna.¹⁸

Emperò la gran mar, con la luna ix, lavors fa ella antipotis,²⁰ que vol dir devorament,²¹

¹⁵ “...having been taken further by the tide, he saw that he had left Britain [the island] on the left. With that, near the change in tide and through the effort of rowing, he strived to reach that place on the island which he had found was the best disembarkation point the summer before.”

¹⁶ ‘Warming’ in the literal sense, but it should be translated figuratively as ‘ebb’.

¹⁷ He inverts the order of the sentence.

¹⁸ A much more explicit paraphrase.

¹⁹ The Paris school (Duhem, 1915 [1958]) paid a great deal of attention to eddies (*gulfus*) and voragines, in fact considering them the causes instead of the effects of the tides.

²⁰ Misreading of *ampotis* (‘ebb’).

in exortu lune maiori estu
fluctus involvit car llavors tira ella les aygües
et revomit.
hec autem vorago que totas aquas et naves
absorbet
et revomit
hinc fit.
est in terra abissus profundissima
de qua scribitur
rupti sunt omnes fontes abissi magne (Gen 7, 11)

et ea exundante iterum magno impetu repellent. e les gita ab gran poder.

Honorius Augustodunensis, *Imago mundi* 1, 39-41. (Edition by Valerie I. J. Flint, Paris, 1983).

A writer almost one century after Honorius of Regensburg who might have gone beyond the texts of Cresques Abraham is Robert Grosseteste, the Bishop of Lincoln (†1253), the author of several works already commented on by Duhem (1915), who was not aware of the *Questio de fluxu et refluxu maris*, which was discovered in 1926. The text was published and translated by Dales (1966). In reality, Grosseteste's line comes from the ideas of Seleucus of Babylonia, compiled by Albumassar (9th century) and translated into Latin in 1133 and 1140. The role of the moon and sun is claimed with evidence that is "truthful from experience", which requires an explanation (Laird, 1990). Contrary to Honorius, he never speaks about *aestus* but about *accessio* and *recessio maris* (twice a day). If the word *aestus* meant 'boiling', *s.l.*, now the *accessio* is said to be accompanied by water that has been warmed from the sun's rays and a "condensation" (centripetal tendency) and "rarefaction" (centrifugal tendency) of water. The incoming tide theoretically matches the rising and setting of the moon, the ebb tide with the passage of the moon along the meridian. Even though we can find similarities, the language of the Catalan Atlas does not closely match the language of the Bishop of Lincoln.

Another possibility would be the *Tractatus de fluxu et refluxu maris Anglici*, attributed to Walter Burley (1275-1345).

3.2. Tidal tables and lunitidal intervals

A. Morel-Fatio (1875), a Hispanist trained in the École des Chartes, hinted that the *Libro del conocimiento de todos los rregnos...*, attributed to the second half of the 14th century, might have been written with knowledge of the Catalan Atlas. In fact, during the 14th century, several lists or practical descriptions about crossing the English Channel must have been in circulation. The imaginary journey in the *Libro del conocimiento* speaks about the "*punta de sanmae que es en la provincia de bretaña y dende fuy al golfo de samalo...*" and about "*un gran rrio que disen saina*" (Jiménez, 1877: 7). Breton sailors must have made an empirical contribution to the art of navigation in a place that had the heaviest commercial routes at the time, but it dated from earlier and the *cors de la marea* had occupied mediaeval philosophical encyclopaedias.

²¹ *Vorago* in the original more likely refers to the whirlpools caused by the currents, but the text was mutilated.

Based on his own observations, the Venerable Bede (672-735) had enriched classic doctrine by formulating the law on lunital intervals (Duhem, 1915 [1958]). Sailors who frequented the English Channel had noticed the tidal currents and their alternating nature, along with how roiled they became in the straits. In reality, they were more frightened by the current than by the intumescence. The abbot of Jarrow (Northumbria) devoted chapter 29 of his *Opera de temporibus* (703) to “On the harmony of the sea and the moon”, referring to the outlets of the rivers, the penetration of saltwater and the “respiration of the moon”. In twelve lunar months (354 days), the tide ebbs and flows 684 times. However, the Venerable Bede’s most original contribution is that the tides around Great Britain did not reach their maximum at the same time and showed a N-S time difference which was clear on the shelf of the English Channel (Cartwright, 1999).

“Those who inhabit the different coasts of the British Sea know full well that when the tide begins to rise in one place, it ebbs in another at the same time”.

Far from scholarly or monastic discussions, the sailors’ empiricism carved a niche for itself and tidal tables were devised that would lead to the modern printed almanacs that predict the state of the sea level at any given time in determined ports. The oldest tables, dating from around the 11th to 15th centuries, were not like the ones of today, which are temporary or for a specific period of time; rather they contained a simple list of temporal and local rules of “high waters” (“high tide” or “flow”), according to the age or phase of the moon. The age of the moon, estimated at between 0 and 29 or 30 days, was the most crucial factor (Cartwright, 1999).

The expression lunital interval or establishment of a port, in the sense of the time lag of the high tide after the syzygy, dates from the 19th century, but the rules alluded to, which are quite haphazard, strove to express it. The inaccuracy came from considering that the shifting periods of the moon did not gain exactly 48 minutes per day but that they fluctuated, and that the lag of the maximum high tide was not a constant determination. However, in an age when clocks virtually did not exist, the sailors’ needs were mostly met.

The first tidal table known in Europe – the Chinese ones might date from earlier – is a manuscript from the 13th century conserved in the British Museum (Cotton Codex, Julius DXVII, p. 45b) for the “*flood at london brigge*”, which belonged to St Albans and was the work of the abbot John of Wallingford (†1213) (Cartwright, 1999).²²

²² The portolan, veritable rutters or sailing manuals, had to have been in the hands of sailors in the 14th century, as Kretschmer (1909) tries to prove. In the manuscript of Piero de Versi (1445) we can find not only the distances and directions but also the data on the tide records. Here are a few examples:

32. “... *traverse in lo chanal de fiandria...Furno dartus e godester se uarda griego e tramontana e ostro e garbin e sono lege 38...*”

40. “*In forno dartus la luna quarta de siroco al ostro bassa mar e quarta de griego ala tramontana e quarta de garbin alostro piena mar. In barbaracha la luna ostro*

On the other hand, Howse (1993) has described and illustrated diagrams used to predict the tides, guided with the compass, which date back to a period between ca. 1375 – the plausible date of the Catalan Atlas – and 1598. The first printed sailing directions or pilot book, *Le routier de la mer* by Pierre Garcie Ferrande (1430-1520), dates from 1502, and we know that it was reissued 40 times. It contains information on the coasts in the English Channel, including the currents and high and low tides, with information that could not be very different to the data from a century and a quarter earlier. In 1967, David Waters published a facsimile where we can see rich information on the tides based on texts, not figures. In a table, he compares the annotations of C. Abraham and P. Garcie:

Table 3: Comparative lunitidal intervals

	Catalan Atlas [1375]	Pierre Garcie (1502)	Norie (1844)
From Galicia to Bordeaux	3:00		3:00-3:30
Enez Sun	3:00	2:15	3:00
Guernsey	10:30	6:00	6:30
Portland	9:00	9:45	7:15

What is known as the Hague Atlas (Gravenhage Koninklijke Bibliothek, Ms. 129 A.24) contains a diagram with a rotating disk which allows the tides to be calculated for every day in the lunar month at 81 ports or embarkations from Galicia to Normandy, Brittany, Flanders, England and Scotland. This document is attributed to a date sometime before the Almanac (ca. 1546) by Guillaume Brouscon, a sailor from Le Conquet – a port located in the aforementioned ‘Forn d’Artús channel’, now known as Chenal du Four – which he drew up for Breton, French and English sailors. The document at hand is a bound pocket-sized parchment document which contains two kinds of figures: maps and diagrams. The former are cross-sectional charts with the lunar tide flows in each port, represented by lines of subdivided arrows which start at a wind rose corresponding to the port in question (he attributes SW flows to the ports in the Biscayne Bay and W flows to the ports in Brittany and Flanders). The other figures are concentric circles divided radially into 30 sectors which are used to calculate the time of high tide during each age of the moon; each diagram works for a given orientation. The outer crown indicates the moon age (in the Breton version of Roman numerals), and the next ring is divided into 30 days. The following ring shows the phases of the moon and the days of high and low tide; the third and fourth rings show high and low tide in time, hours and quarter hours, for each day in the moon age (Howse, 1993). The layout and content are somewhat similar to the diagram discussed in this paper.

It is not unlikely that the “philosophical” reflections of Bede, Grosseteste (1227) and Buridan (1366), which refer to the ports of Picardy and their lunitidal intervals, as well as the imbalance of the tides, including the tidal tables and the corresponding diagrams in the Breton style, would have reached the hands of Cresques Abraham. Today, if we do not find a more apodictic documents, the

text of the Catalan Atlas seems to be partly the translation of a passage from Honorius of Regensburg, with additions from other mediaeval treatise writers, perhaps Grosseteste, and partly the introduction to a Breton pilotage handbook or a commentary written when seeing it. We could suggest the same about the diagram.

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