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# The Brief History of Early Marine-Navigation

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**ABSTRACT**

This work was supported by Scientific Research Projects Department of Istanbul Technical University. Project Number: 42512. The aim of this study is to examine in the beginnings and development of early navigation systems and to reveal their relationship with disciplines such as astronomy, cartography, horology and map-making. Since prehistoric times, people have been travelling using waterways and highways. Before the transporting by air, oceans was the only way for early intercontinental transportation. Thus, people learned building simple boats to cross seas. As progressing of marine-navigation technologies, the importance of calculating route made it necessary to measure time and distance. Early navigators sailed by observing the celestial bodies such as the sun, moon and stars through the astronomical information. Especially the transition from the earth-centered universe model to heliocentric (Copernican) has astronomically affected the entire early navigation period. Moreover, navigators used early navigation tools such as dead reckoning and cross-staff. And also, they made nautical almanac called ''parapegmata'' in Greek and used primitively designed compasses. Despite all these developments sailors mostly have lost their route due to misinterpreted rotations. Also it has not been easy to make accurate measurements on ships until the eighteenth-nineteenth centuries.

## 1. HISTORY OF NAVIGATION

Transportation has been necessary since the beginning of human history. Human populations who initially settled near rivers, needed to travel more as their population grows and new settlements are needed. Travelling by road was possible up to limited distance because there were not sufficient highways. In addition, oceans was the only way of the intercontinental travel. Thus, travelling on water could be improved faster. The only thing that matters in the first place was to stay on the water and dry. Human firstly learned how to make raft to cross rivers. But as time passed, people learned to build larger boats and galleys, and it became extremely important to take these vehicles from one point to another. So, the history of navigation has begun. Navigation term etymologically derived from the verb *Navigare*[1], which means traveling in Latin, especially traveling in the sea. Today, the term of navigation, which is used in the sense of travelling on both by sea and on land from one point to another, corresponds to all the meanings of navigation, wayfinding, cruising, shipping and to navigate. It is simplest definition is to determine the most suitable way to go from one point to another or to go from a certain point to another point and to navigate on the most convenient route. Nowadays, while the position of a point on the sea or on land can be easily determined by satellites orbiting the Earth, examining the historical development of navigation from past to present provides a holistic new perspective.

In this context, maps have undoubtedly been one of the most important tools among the primary tools, as well as all kinds of tools and methods such as dead-reckoning, compass, mechanical clock and various observation

[1] Navig/o, are, avi, atum. (Lat.)

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methods that have been used for navigation directly or as an aid throughout history. One of the most important tools of navigating on the sea are nautical charts in addition to navigational instruments throughout the history. People were able to divide the land they lived on into meaningful pieces thanks to the maps. Major terms such as ''*map*'', ''*charta*'' or ''*karte*'' and ''*mappa mundi*'' stand out in the history of cartography. It is important to separate these terms from each other for reading history. While the map represents maps made in a more general sense, charts in most sources represent nautical charts. It comes from the word - χάρτης (kartes) which means paper in Greek. The term '' *karte*'' was first used in the history of cartography by the German cartographer Laurent Fries. And the map term come from the word ''*mappa*'' in Latin, meaning a napkin, table-napkin or cloth. The term of '' *mappa mundi*''[2] in Late Latin, it may represent the boundaries of the known world of that time, and this *mappa* could contain texts, surveying notes and pictures. The term ''*mappa*'' was used because of them who called *Gromatici* in Latin, recorded drawings and notes of their surveying on cloth, parchment or pieces of *vellum*[3].

## 2. DEVELOPMENT OF NAVIGATION INSTRUMENTS

The development of technology over time, the distance traveled on the sea has begun to be measured. Primitive measurements on the sea are based on determining time intervals starting from a certain point. Lack of instruments measuring time as we know it today required calculations over time intervals. Instruments such as the hourglass and sundial play an important role in ancient navigation as primitive timers for measuring time over elapsed time. One of the most primitive scientific instruments for measuring time are water clocks called *Clepsydra* (κλεψύδρα)[4] in Greek. Water clocks have been developed to be used at night when the sunlight does not reach the Earth. The most primitive form of water clock is a bowl-shaped outflow form date back to Egypt. One of the most advanced examples of water clocks in ancient times belongs to the famous mechanist and inventor of principles of pneumatic science *Ctesibius* (Fig. 1). The instrument developed by *Ctesibius* also works over time intervals and an alarm system. Knowledge about the primitive water clocks also called *Horologium ex Aqua* in Roman Literature is known through the Roman author, architect and engineer Marcus Vitruvius Pollio's work *''De Architectura Libri Decem*'' written in Latin (Pollio M. V., 2017). In Vitruvius' book, *Ctesibius*'s work on air pressure is mentioned as well as the water clock. *Ctesibius* also put forth the principles of natural air pressure and instruments working with air pressure.

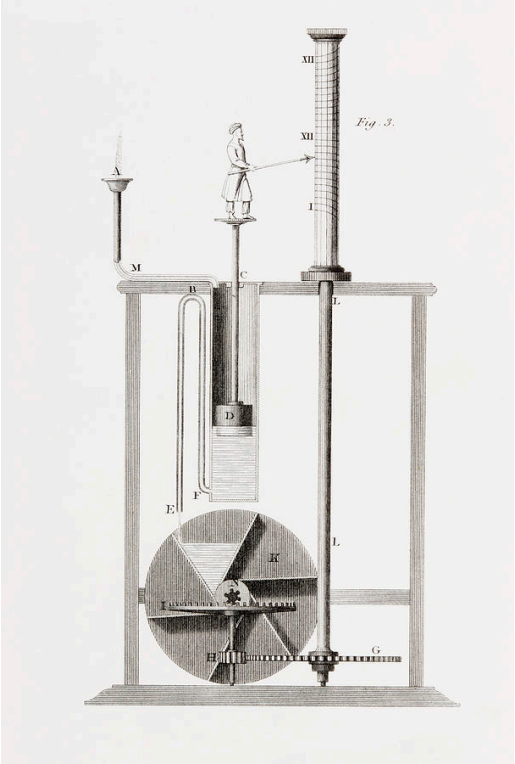


**Figure 1.** An early 19th century illustration of Ctesibius's clepsydra from the 3rd century BC, the illustrator was probably an English mechanical engineer John Farey Jr. figure in public domain: http://www.antique-horology.org/_editorial/clepsydra/

Measuring certain time periods is not enough for journey on the sea. In order to achieve a useful result, the starting point must be positioned. This is exactly the point that expresses the inseparable part of the history of cartography and navigation. We cannot create a route on the sea without knowing where we are right now. And confirming this thesis, we can witness that mapmaking and navigation technologies are growing simultaneously on the stage of history. It can be said as follows to be more precise: Mapmaking made the development of navigation possible. Besides the science of cartography, astronomy and horology have been the main supporters of navigation science.

With the developing trade and the discovery of new continents, map-making has become more important. From the most primitive symbols and signs used on maps to today's Global Positioning Systems (GPS), the contribution of map making and cartography fields to navigation cannot be disputed.

The oldest known maps are dated to the sixth and seventh centuries BC in the Middle East. Greek geographer Eratosthenes, made one of the earliest scientific world maps. Eratosthenes divided the entire known world according to 5 climate zones. The oldest scientific map of the known world, made by Eratosthenes, covers the from Gibraltar to India and from Somalia to the arctic circle (Fig. 2).

[2] Mundus word could be used to mean the world in Vulgar Latin but that is the meaning of "order" in Latin.

[3] Vellum, i (Lat) : a cloth or calf.

[4] Clepsydra : Water Thief; water-clock, a water-butt with a narrow orifice underneath, through which the water trickled slowly, for measuring periods of time, used to time speeches in the law-courts. (Liddell & Scott, 2009), [κλέπτω (kléptō, "steal") + ὕδωρ (húdōr, "water"].

Towards the end of the third century BC, Eratosthenes was the scientist who reached the closest results to the truth in calculating the circumference of the Earth and the dimensions of known world. It is known that in the second stage, he also benefited from astronomical observations, distance measurements and ship routes on sea (Wright, 1923). Eratosthenes used a special terminology to describe the visual, spatial, epistemic and communicative actions of geography. Therefore, the philology of the language used, Greek, is very important in order to understand and convey the *Geōgraphia* of Eratosthenes (Connors, 2016). In this respect, while the science of geography is examined historically, the fact that philology helps the history of science with a multidisciplinary approach makes it possible to reach the most accurate scientific reality.

He is also the inventor of the geographic coordinate system (GCS). Eratosthenes has determined latitude using stallers and longitude with the lunar eclipse method. GCS is vital in development of sea navigation. Although the science of astronomy emerged and developed in civilizations such as Egypt, Mesopotamia and China, Ancient Greek offers a wider field to research in terms of the abundance of written sources that have survived to the present day. Greek philosophers/scientists[5] travelling to Egypt and China, they learned the science of astronomy and mathematics belonging to that geography and carried it to their hometown. The final step is the transfer of all this knowledge to the west by the Romans and so the historical background of the scientific revolution is almost formed.

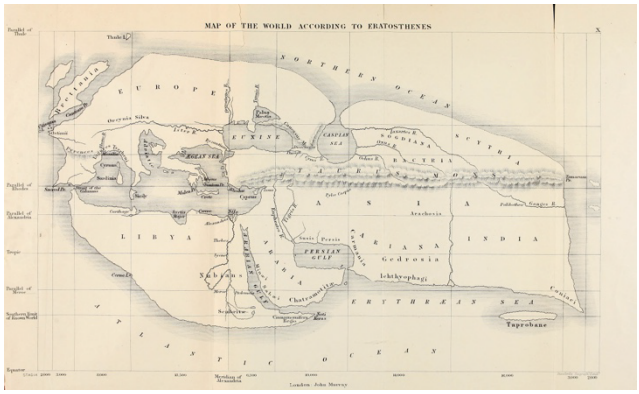


**Figure 2.** 19th century reconstruction of Eratosthenes' map of the known world. A History of Ancient Geography among the Greeks and Romans from the Earliest Ages till the Fall of the Roman Empire, page 667, London: John Murray, 1883.

The beginning of Ancient Greek Astronomy dates to the Ionian Age. Mesopotamia is rarely mentioned in the Ancient Greek writing sources, but astronomy studies in the Mesopotamian Seleucids era and Ionian age were on the same period. (Unat, 2013). The Greeks who first explained planetary motions with geometric-kinematic systems, were able to describe planetary systems at a level that could explain astronomical phenomena (Unat, 2013). Thus, it did not take long for the μῦθος (myths) and λόγος (*logos*) to separate in Ancient Greek. People used myths and epics for knowledge (getting information, and oral tradition. Information from mythological narratives remained valid even after the emergence of sciences. The term '' *logos* '' (reason) represents scientific thinking. Logos word was used in various meanings.[6] It was used especially by the Sophists and Greek philosopher Heraclitus in the sense of the first power, the first principle in the universe. It was the force that brought order to the primordial chaos. This corresponds to the first people thinking over the epic tradition. In this sense, it represents the cosmic flux in the meaning of a transition from chaos to order corresponds to the human thought which evolving from mythos to the logos phase[7]. Scientific thought and rational knowledge fully formed in Greek created a background that Western science. Greek curiosity (*periergia*)[8] creates the roots of the tree of science. Theories about the cosmology of philosophers can be accepted as the beginning of astronomy in Greek. It has an important role to play in history of astronomy. The image of perfection reached the peak in Ancient Greek and it was accepted and carried to later times, especially through Aristotle's universe and Platonic ideas. The main reason why geocentric universe model which is Ptolemy placed the earth at the center of the universe cannot be rejected is expulsion of human from center of the universe (Fig. 3). This means acceptance of heliocentric universe model (Copernican) (Fig. 4).

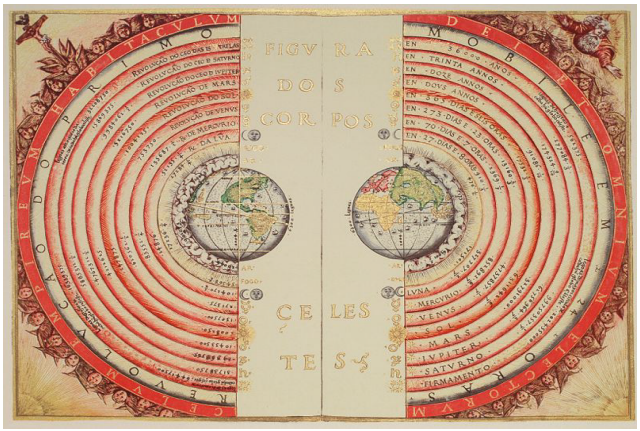


**Figure 3.** Heavenly bodies from an illustration of the Ptolemaic geocentric (earth-centered cosmography) system by Portuguese cosmographer and cartographer Bartolomeu Velho, 1568, Bibliothèque Nationale, Paris.

[5] φῖλο- (philo-, "beloved, loving") + σοφός (sophós, "wise") – the term of φῖλόσοφος in Ancient Greek includes the title of scientist in today's sense

[6] reason, word,expression

[7] For more reading : Kahn, C. H., Heraclitus, ., & Kahn, C. H. (2004). The art and thought of Heraclitus: An edition of the fragments with translation and commentary. Cambridge [England: Cambridge University Press]., Dürüşken, C., & Bayrak, M. F. (2014). Antikçağ felsefesi: Homeros'tan Augustinus'a bir düşünce serüveni., Gregory, A. (2013). Ancient Greek cosmogony., Laks, A., Most, G. W., Journée, G., Iribarren, L., & Lévystone, D. (2016). *Early Greek philosophy*., In Laks, A., In Most, G. W., In Journée, G., In Lévystone, D., Protagoras, ., Protagoras, ., Gorgias, ., ... Harvard University. (2016). *Early Greek philosophy: Volume VIII, Part 1*.

[8] For more reading: Assmann, J. (2017). Periergia: Egyptian reactions to Greek Curiosity.

Tens of thousands of years ago, peoples sailed across open oceans. More recently, within the past four thousand years, Egyptians and other peoples in the Mediterranean Sea, Persian Gulf, and Indian Ocean dared longer-distance sea travel. Early mariners navigated from island to island by observing the sun and stars, the wind and waves. They noted some objects such as large rocks as guiding points. They observed the behavior of fish and birds. They sailed into the winds, making use of winds that blow east to west just north and south of the equator.

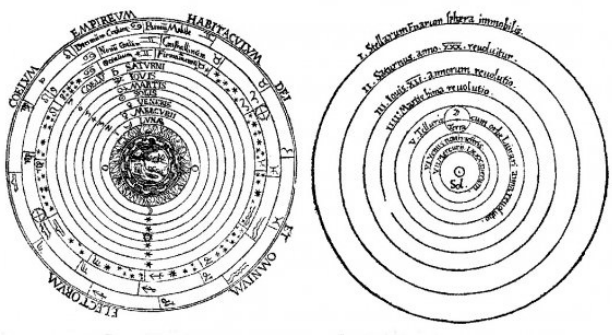

**Figure 4.** A comparison of the geocentric and heliocentric models of the universe. history.ucsb.edu

The navigation benefitted from the position of the sun with the knowledge of astronomy. Early navigators prepared handbooks of recorded ocean routes and nautical almanacs. Almanac, known as *parapegmata* in Greek, had been composed for centuries. *Parapegmata* or nautical almanacs are the publication describing the cyclical phenomena such as stellar phases, weather, lunar cycles, and more. The Almanacs or *parapegmata* as astronomical diaries, were not enough alone to travel by sea. Therefore, various technological instruments and navigational systems were additionally used.

Dead reckoning is one of the primary and oldest method of marine navigation. It was first developed by Mediterranean navigators. The word *Parakete*, which is the Turkish word of dead reckoning, reflects its etymological origin. It is based on the word *barchetta*, which is thought to have passed from Vulgar Latin[9] to Italian Language (Selbesoğlu, 2021). While the word *barchetto* is mostly used for ships to fishing in the Adriatic Sea, the word *barchetta* is used to describe the wooden piece of dead reckoning instrument (F.Fleck, 2018). The nautical term, which corresponds to the dead reckoning is exactly as *solcometro a bar*chetta in the Italian maritime terminology. This transition of term to the Turkish terminology was realized with the use of the second word, which means small ship.

The oldest dead reckoning chart is *Carta Pisana* dating back to thirteenth century. The oldest surviving nautical chart called *Carta Pisana*, because it was acquired by the Bibliothèque Nationale from a family old-established in Pisa. Dead reckoning that preferred method when celestial observation is unavailable, is a method of navigation relying on estimating one's current position using a previously obtained position. In earlier versions of reckoning, during the cruise, a floating object was thrown into the sea from the fore and the time of this object until it reached the stern of the ship was determined. Then, with the proportionality method, the distance the ship traveled in an hour, in other words its speed was calculated.

In later times, different instruments using properties such as hydrodynamics and electromagnetic, have been made to determine the speed of the ship.

Development of navigation instruments continued throughout the history of ancient maritime. The backstaff is one of them that was used to measure the altitude of a celestial body. Scientific navigational instrument that especially used to measure the altitude of the moon and sun, was invented by English navigator John Davis (Seaman's Secrets in 1594). Therefore backstaff was called Davis quadrant which is the most dominant tool in the history of navigation instruments evolved from the Cross-staff. And Cross-staff also called Jacob's Staff or '' baculum'' (bone) or '' radius'' (staff) in Latin words (Rossi & Russo, 2009).

The Cross-staff, which was originally based on the Greek word βάκλον etymologically, took place in the literature with its Latin version, baculum (Liddell & Scott, 2009). This observational instrument was invented by the astronomer Levi ben Gerson (or Gersonides) who lived in France in the fourteenth century. The Cross-staff instrument is mentioned in Levi ben Gerson's book on astronomy written in Hebrew and translated into Latin while he was still alive. The book, which is one of the most important works written in Hebrew on astronomy in the Middle Ages, contains poems introducing and celebrating the invention of the instrument. In the following parts of the book, Gerson described different versions of cross-staff and explains in detail how to use the instrument (Goldstein & Gerson, 1985, p.155). But Gerson does not make any reference to the use of the Cross-staff in marine-navigation. After Levi ben Gerson, the most detailed descriptions of the Cross-staff in Latin were published in manuscripts dating to the fifteenth century and book that published in 1531 of the mathematician and astronomer Regiomontanus. As He mentioned in his work ''*De cometae magnitudine, longitudineque, ac de loco eius vero problemata XVI*'', the primitive cross-staff basically consists of two parts. Regiomontanus explains that instrument consists of two wooden bars, one movable and one stationary. He used the Latin word *regula*, meaning stick, for the movable rod and used the term *regullela mobilis*[10] for the movable middle part. Although no reference was made in the sources mentioned about the use of navigation, the Cross-staff was widely used by sailors due to its portability (Selbesoğlu, 2021).

Compass also was one of the major instrument for marine navigation. The invention of the compass was made possible by the development of knowledge about magnetism. There are invisible magnetic field lines wrapped around the world. The north and south poles are aligned with the Earth's axis. Thus, magnetic objects

[9] Barca, ae, f (Lat.): small ship, boat, barge. A Latin Dictionary. Founded on Andrews' edition of Freund's Latin dictionary. Revised, enlarged, and in great part rewritten by. Charlton T. Lewis, PhD. and. Charles Short, LLD. Oxford. Clarendon Press. 1879.

[10] This term may have been used to mean a moving little stick.

such as a compass needle or magnetic stone align themselves along a north-south axis (Geary, 1995). The oldest known types of compass work on the principle of the Earth's magnetic property.

Term of ''compass'' etymology derives Latin verb ''*compassare*" (in italian and also may be in Vulgar Latin) combines with ''com'' (with) and the ''*passus*'' (step). In addition to meaning such as measuring with steps, it can be thought to be etymologically related to circular motion because of the name similarity with the drafting compass. The compass as an instrument of navigation and measuring based on stones with magnetic properties. Loadstones which referred to as ''*magnetum*'' in Late Latin writings, made the development of the compass with magnetized needle possible.

Loadstones and their properties were known in Greek. The first known compass is dated to China, during the Han Dynasty (between 2nd c. BC - 2nd c.AD). Chinese realized that the lodestone always points in the same direction when floated in a bowl of water but it isn't unclear whether the Chinese understood that this direction was north, as little was known about global direction finding at that time (Fig. 5). Also, it is not certain that the earliest knowledge about lodestones is dated to China. Fundamental property of the lodestone of attracting iron was certainly known before. The close of the seventh century B.C, loadstones and their magnetic properties were known by the Ancient Greek. Even a legend attributed to the Ida Mountain confirms the existence of information about magnets (the legend of magnes the shepherd).[11] In the texts of many ancient authors such as Thales (640-546 B.C.) and Pliny (23-79 A.D.), the mentions of ''*loadstones*'' were frequently cited. But the first reference to the use of the compass for navigational purposes is found in a Chinese encyclopedia in probably during the Han or Tsin Dynasty. But there was no definite mention of the use of the compass until ''*De Utensilibus*'' written by an English monk, Alexander Neckam. This work occurs in middle ages around the twelfth century (Author, 1919). It became difficult to find the first inventors for advanced compasses (as mariner's compass or advanced magnetic compasses), which spread over many geographies and was developed by different people after the middle Ages and the period of discoveries. Peregrinus is the first that describes the compass with pivoted needle. The first writer to attribute a special knowledge of the compass to the Amalfians was Flavio Biondo, was later cited in other works as the inventor of the mariner compass (Nelson, 1962). The four chief improvements applied to Peregrinus compass in late times: the cap-and-pivot support, the movable fly, the divided needle, and the gimbal suspension (Nelson, 1962). Next developments of compass extend to modern period and technologies developing in time of war.

The first scientists to scientifically reveal the magnetic property of the magnetic stone and Earth magnetism was William Gilbert (1540-1603) in the sixteenth century. He clarified the distinction between electricity and magnetism which until his time were seen as similar principles and also he is regarded as the founder of magnetism as a science. He describes the Earth as a giant magnet. He also has an important place in the history of science and technology, as it was the first to use experimental methods to support his theories. He conducted his magnetic experiments on a instrument that small model of planet Earth which he called the terrella (Fig. 6). This instrument was a spherical magnet like the world Gilbert described. According to William Gilbert, among the known substances, the most similar (element) to that of the Earth is lodestone and iron (Freudenthal, 1983). Gilbert thus paved the way for the development of magnetic science with all these theories and assumptions. In the light of this new approaches, the known cosmology and the relative positions of the planets were also affected by new magnetic science.


**Figure 5.** Loadstone floated in a bowl of water, Lapis Polaris Magnes, invention of the compass by Flavio Amalfitano (Flavio Gioja or Gioia) in the 1300s from series *Nova Reperta*, Museo Galileo.

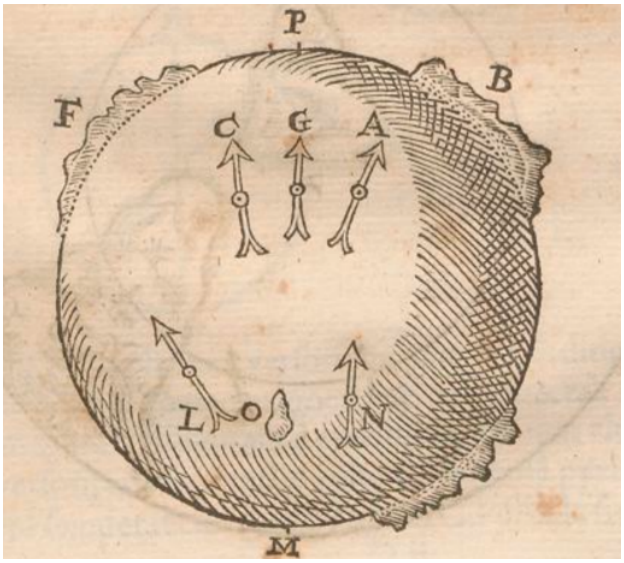


**Figure 6.** Illustration of small magnetized model ''terrella'' representing the Earth as a giant magnet from Guilielmi Gilberti Colcestrensis, Medici Londinensis, De Magnete, Magneticisque Corporibus et De Magno Magnete Tellure; Physiologia nova, plurimis et argumentis et experimentis demonstrata, 1600, s.157.

[11] It is a legend that describes the discovery of the magnetic property of Mount Ida. (*For more reading: Mourino, M. R. (1991). From Thales to Lauterbur, or from the lodestone to MR imaging: Magnetism and medicine.*)

The compass has been modified for use at sea. The mariner's compass which was invented for this purpose, works on the same principle as the magnetic compass. The mariner's compass, one of the oldest instruments used for navigation is also a type of magnetic compass. Unlike traditional magnetic compasses, it is fixed on the feet in order to remain stable on the ship. It is usually mounted on rings made of brass with the help of joints. Liquids are used in some of the marine compasses in order not to be affected by the movement on the ship. Mostly, a mixture of water and alcohol is used as a liquid. Compass is preserved in wooden or ivory boxes, which are mostly produced to protect the compass. Later, brass material started to be preferred mostly because it caused deviations on the magnetic needle. The use of lead material in the compass needle is also common to make instrument heavy and stable (Selbesoğlu, 2021).

The compass card inside instrument is made of paper material and mostly has a drawing of a compass rose which is a figure used in compasses, nautical charts and some monuments (Fig.8). The figure also called wind rose, has become an important symbol in maritime history and marine-navigation. and There are degrees and direction symbols on the compass card or compass rose. The origin of compass rose or wind rose is thought to be based on the wind classifications in Aristotle's (384-322 B.C) *Meteorologica* work (Fig.7).

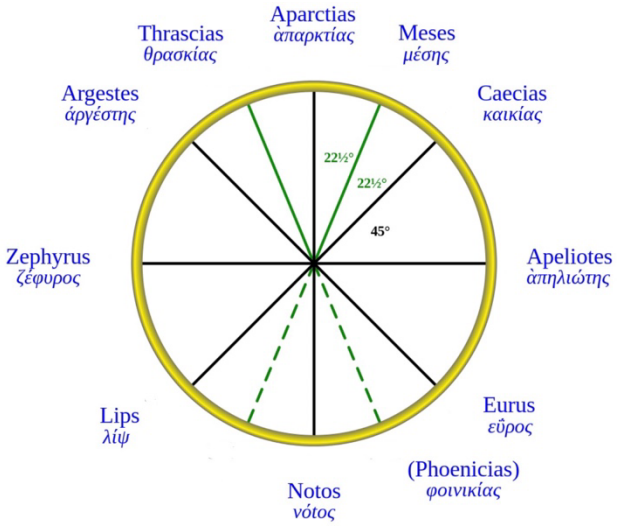


**Figure 7.** Alternative depiction of the wind rose of Aristotle, on the basis of his *Meteorologica*, illustration from,*https://www.wikiwand.com/en/Classical_compass winds.*

The invention of mariner's compass coincides with the period when Aristotle and his works began to be appreciated again in the Christian world and the translation activities accelerated. Although this relation is not certain, it shows that the markings on the card used in the mariner's compass may have been designed with inspiration from the ancient classification of winds (Taylor, 1951).

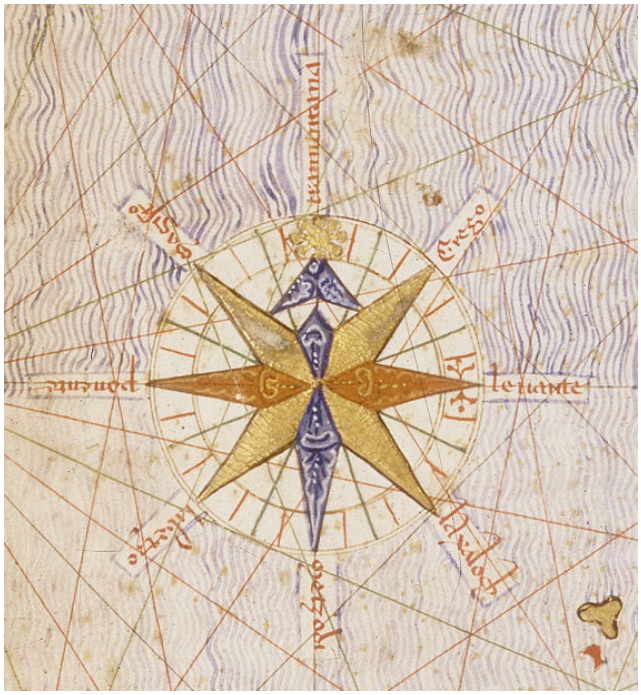

**Figure 8.** First ornate compass rose depicted on a chart, from the Catalan Atlas (1375), with the Pole Star as north mark from Gallica Digital Library.

## 3. RESULT

The aim of this study is to examine the beginnings and developments of early navigation instruments and systems and explain how navigation in the sea emerged and developed. Since prehistoric times, people have traveled by using the seas and land routes, and they have struggled to improve their mobility. Before air transportation existed, the only way of intercontinental transportation was to cross the oceans and open seas. This requires advanced ship technology, developed navigational instruments and advanced knowledge of astronomy science. In this way, humanity has made progress in sea transportation with scientific studies in the historical process. With the progress of sea voyage, the importance of route calculation and more precise measurement of time and distances have become necessary. Early sailors laid the foundations of celestial observation by observing celestial bodies such as the sun, moon and fixed stars through their astronomical knowledge. In this context, related astronomical concepts, traditions of thought and primitive navigation instruments such as compass, cross-staff and system of dead-reckoning were especially examined. Lodestones and magnetic science are of great importance, especially for the invention and use of the compass which was a turning point in history of marine-navigation. In this context, the earliest references to loadstones in the literature and the development of magnetic science are emphasized in this study. In addition, information about development and structure of mariner's compass which is a widely used version of the magnetic compass in maritime, is given in the study. The wind rose figure in relation to the compass which forms the basis of card in the mariner's compass also has an important place in maritime history.

Research on instruments only in technical terms does not bring historical integrity. Furthermore, it is not possible to investigate to the history of navigation without examining their relations between other disciplines such as astronomy, cosmology, cartography, horology and map-making. Philology and History sciences help to see all these in a meaningful framework. Also, a whole history of early marine-navigation has been influenced by understandings of the universe, especially during the transition from the earth-centered model of the universe to the heliocentric model. In this connection, various cosmological figures that have changed throughout history have also affected navigation. In addition to the given instruments, there were early instruments that we cannot include in a brief study, used in marine-navigation such as the mariner's quadrant, armillary sphere and astrolabe. These historical navigation instruments will be examined in future studies.

**Author contributions**

***Hatice Şeyma Selbesoğlu*:** Writing and presenting original draft, writing/manuscript preparation, and commentary, literature search, translation, etymological research of concepts, philological research, scientific preparation, methodology, investigation.

***Burak Barutçu*:** Supervision, validation, access of resources, conceptualization, revision.

***Aytekin Çökelez*:** Project administration, methodology, supervision, validation, access of resources, conceptualization, revision.

**Conflicts of interest**

The authors declare no conflicts of interest.

**Statement of Research and Publication Ethics**

The authors declare that this study complies with Research and Publication Ethics

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