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Indian Ocean Navigation Based on *al-ʿUmda al-Mahriyya fī Ḍabṭ al-ʿUlūm al-Baḥriyya* by Sulaymān al-Mahrī

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ABSTRACT

This paper introduces the life and works of a distinguished sixteenth-century Arab navigator, Sulaymān al-Mahrī, most notable for his magnum opus entitled *al-ʿUmda al-Mahriyya fī Ḍabṭ al-ʿUlūm al-Baḥriyya*. Al-Mahrī was of an Arabian Mahara origin and born in the town of Shihr in Ǧurz, belonging to Ḥadramawt in what is today eastern Yemen. Ḥadramawt was known for its shipbuilding industry and played an essential role in the spice trade in the ancient and medieval Orient. The people of Ḥadramawt were well-acquainted with life at seas and produced some of the best navigators of the Indian Ocean, like Sulaymān al-Mahrī. Al-Mahrī was not just a practicing navigator, he also wrote essential treatises on Indian Ocean navigation. Unfortunately, because Aḥmad ibn Māǧid (d. 1500) was popular in Europe for his supposed role in guiding the Portuguese in the Indian Ocean, his works, particularly *Kitāb al-fawāʾid fī uṣūl ʿilm al-baḥr wa al-qawāʿid*, have overshadowed equally important navigational works on the Indian Ocean. This resulted in a dearth of knowledge and studies on other navigators and their works. While ibn Māǧid's works have been studied in great detail, al-Mahrī and his works have not received the same scholarly attention. It is, therefore, the objective of this paper to introduce al-Mahrī and his works to a broader audience, including his achievements and contributions to Indian Ocean navigation.

Keywords: Sulaymān al-Mahrī, *al-ʿUmda*, Indian Ocean, Navigation, Aḥmad ibn Māǧid

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1. Introduction

The historical advancement of nautical knowledge practiced in the Indian Ocean has provided a continuous unity of human migration. Centuries before the Europeans ventured into the region for trading political, and social activities, the Indians, Chinese, Malays, Persians, and Arabs were already dominant in the opening up of a portion of the Ocean's surface. This long development of naval and commercial fleets led to a chronicling of the important features of crossing of the ocean and the creation of navigational and nautical civilization (Yajima, 1976).

In the early Chinese and Indian texts, the trading practice of this region dates back to the onset of civilization. Indian wood was present at Sumerian[1] sites very early on, and the early Sumerian inscriptions indicate shipbuilding in Oman. Coastal commerce, trading, and exchanging goods under the Harappa civilization[2] of the Indus Valley was established, encompassing a geography which included modern-day Pakistan, the Gulf, the Red Sea, and as far as Egypt. During the expansion of Islam in the seventh century, these major economic and cultural exchanges also included Greco-Roman sailing practices. Within their accounts, we see that they coasted along the ocean's regions, such as the Red Sea, the Gulf, Malacca Strait, and Java Sea in Southeast Asia (Alpers, 2014). The travels of Alexander III of Macedonia to India and his conquest of new territories granted him the power to establish several cities throughout the trade route to India. The route founded a reinvigorating center and inauguration for the Greek merchants in the Indian Ocean who became active in regions as far as Sri Lanka under the Ptolemaic dynasty.

Moreover, the ongoing trade between the Indian Ocean and the Mediterranean in 100 BC has been further indicated by the existence of some archaeological findings of Roman coins and amphora. *The Periplus of the Erythrean Sea,* dated to the first century, offered a guide to the commercial traffic and cultural exchange along the Red Sea, coast of Africa, the southern region, and the peninsula of Asia. It also compiled the navigation of the Indian Ocean, similar to later works compiled in the 15th century (Alpers, 2014). Moreover, Ptolemy's *Geography* had a significant influence on mapmaking for centuries by presenting a description of the world, centering and branching the study of the cartography of the landmasses which surrounded the Mediterranean Sea and the Indian Ocean, using the intersecting lines of longitude and latitude. Before this work, there were no copies of any maps available for common use. Maps associated with his treatises were found in Europe at the beginning of the fourteenth century. However, speculations among historians has sparked debates about whether Ptolemy produced any maps in the second century, after the adjustments and corrections made over the uncompleted versions of Marinus (Dilke, 1987). C. Müller's attempt to reconstruct the world map based on Ptolemy's *Geography* did not achieve further results due to the lack of mapping coordinates. Instead, his work only served as a map of rough positions such as rivers, according to K. Kretschmer (Sezgin, 2005). The dominance of his work in medieval Europe was by no means equivalent to that of the anonymously authored Arabic cosmographical treatise written between 1020 and 1050 AD, known as the *Book of Curiosities*. The importance of this manuscript not only portrays the preserved materials of the 9th and 10th centuries Muslim astronomers, historians, scholars, and travelers, but also showcases the superiority of the Arab knowledge of the Indian Ocean compared to that of the west, stretching from China to Eastern Africa (Alpers, 2014).

Before the Islamic era, Arabs and Persians were indeed engaged in sailing activities. However, the spread of Islam during the Arab conquests witnessed a somewhat inactive course of sailing activities up until the exploring of the Indian Ocean under the Umayyad Dynasty, reaching its epoch under the Abbasid Dynasty (Tibbetts, 1971). During that period, the

1 Sumer (or Šumer) was one of the early civilizations of the Ancient Near East, located in the southern part of Mesopotamia, between the Tigris and Euphrates rivers in modern-day southeastern Iraq, from the time of the earliest records in the mid-fourth millennium B.C.E. until the rise of Babylonia in the late third millennium B.C.E. See Sumerian Civilization. (2020, April 21). *New World Encyclopedia*. Retrieved from https://www.newworldencyclopedia.org/p/index.php?title=Sumerian_Civilization&oldid=1035911.

2 The Indus civilization, also called the Indus valley civilization or Harappan civilization, the earliest known urban culture of the Indian subcontinent. The nuclear dates of the civilization appear to be about 2500–1700 BCE, though the southern sites may have lasted later into the 2nd millennium BCE. See Allchin, F. R. (2021). Indus civilization. *Encyclopedia Britannica*. Retrieved from https://www.britannica.com/topic/Indus-civilization.

Sassanid Dynasty and other Indian maritime states were the leading sea powers in the region, where the former controlled the western part of the Indian Ocean (Tolmacheva, 1980). Moreover, the cultural interaction of the Silk Road routes also played an important landmark in the Indian Ocean, where the open seas served as a channel from India to China through the Persian Gulf and the Red Sea, which caused the latter to become the crossroad connecting the Mediterranean to the Indian Ocean (K. Stein, 2017). Following the expansion of Islam and the rise of the Tang Dynasty (618-907 AD), trading prospered and commerce reached a new height by utilizing the sea route. The Muslims crossed the Persian Gulf and embarked on their presence on the Indian coast, having Muslim traders take control of the region and its oceanic frontier. Accordingly, the maritime trade took place in the Red Sea and the Mediterranean Sea and then shifted to the Persian Gulf route and then to the Indian Ocean, reaching China. Eventually, by the seventh century, trading activities were occurring between the Middle East and China. By the eighth and ninth centuries, there were some Persian settlements on the island of Hainan and a strong Muslim community controlling most of the external trade to China in Canton (Tolmacheva, 2008). Nicobar, Java, and Sumatra also served as places for Arab settlers, mostly of Hadramuti origin, from where they would sail to the Philippine islands afterward (Aleem, 1973). The Muslim maritime activities also reached eastern and southern Africa, where at least 37 ports were identified and located in modern-day Kenya, Tanzania, Mozambique, and Madagascar (Grosset-Grange, 1996).

Consequently, in the ninth century, Sezgin mentioned the presence of Muslims settlements and trade routes from Māssa, near Agadir, in Morocco, along southern Africa, to China (Sezgin, 2004). As reported by an old Chinese manuscript, the Huaisheng Mosque in Guangzhou is considered one of the oldest mosques in the world and was active under the Song Dynasty (960-1279 AD). This can only indicate the increasing Arab and Persian migration in China comprised of people who came to trade, where the city of Guangzhou served as a major port and a direct canal to the Middle East. It was during the establishment of the Abbasid Dynasty when trading with the east, directed by economic stimulation, flourished, and voyages to Africa and China (reaching Korea) thrived, according to the classical Arab geographers (Harley and Woodward Tibbetts, 1992). However, the Huang Chao Rebellion (874-884) in Canton (Guangzhou), orchestrated to increase the power of the Chinese regime overseas, led to the massacre of foreigners under the Tang Dynasty by the Chinese rebels. According to the Arab author Abū Zaid Ḥasan ibn Yazīd Sīrāfī, the death toll was estimated at 120,000, whereas according to al-Masʿūdī, the death toll was as much as 200,000. During that period, China witnessed a cease of its trade activities in the Indian ports and other islands for over a century (K. Stein, 2017).

The long-distance sea travels of the Muslim sailors contributed to a trading system that connected regions from central Asia, the Mediterranean to the western shores of the Indian Ocean. In 1000 AD, this connection expanded to the eastern coast of Africa and east Indian Ocean (K. Stein, 2017). Under the rule of the Fatimids (969-1171 AD), the Islamic Caliphate had spread across the Mediterranean coast to the Red Sea, with Fustat serving as the center of its dynasty. The coast of Aden, on the other hand, served as the main port for traders, which extended towards India (Alpers, 2014). This port also played a great role for the Ottoman Empire when they sought full control of the Suakin, Mocha, Aden, and Hejaz ports in the first half of the sixteenth century. Other strategical ports in western India that served as choke points for the coastal trade to China were on Konkan coast and the Gujarat coast. The Somnath port in Gujarat was recognized by the Persian scholar al-Bīrūnū as the layover for seafarers navigating between Sofala in Zanj and China (Alpers, 2014). Hence, the largest cultural community of the Indian Ocean was comprised of the major seafaring Arab and Chinese communities until 1500 AD. Thereafter and during Ming Dynasty (fl. 1368-1644 CE), the Chinese reached Africa under the expedition led by Admiral Zheng He in 1417 AD, returning between 1431 AD and 1433 AD (Grosset-Grange, 1996).

For several centuries, maritime routes empowered and accelerated the emergence of the Islamic civilization from the mid-seventh century to the 15th century, extending throughout the four points of the compass and connecting the Arabs of Yemen, Hadramuti, and Oman with Persia and India on one hand, and with eastern Africa on the other (Constable, A.R. & Facey, W., 2013). Moreover, Islam advanced through the Gujarati and Bengali merchant groups who converted to Islam, resulting in the penetration of Islam in Sumatra, Malaya, and coastal Java by the 15th century (Lewis, 1973). Consequently,

the knowledge of each region as well as mathematical and astronomical geography flourished, with information of nautical matters stretching from the Atlantic Ocean coasts of Iberia and North Africa to Asia. This expansion resulted in the Arab contributions in arithmetic, algebra, and astronomy, which further led to the adjustment of sea routes, modification of the Greek instruments (such as the astrolabe and quadrant), and the furthering of understanding of the winds, currents, tides, and monsoons. A legacy that traces back to Ancient Greece, India, and Persia, to the remarkably detailed descriptions which included the necessary information for coastal navigation (for both islands and mainland coasts) can be found in the writings of Sulaymān al-Mahrī and Aḥmad ibn Māğid (Issawi, 1952).

2. ‘Ilm al-Bahr (Knowledge of the Sea)

“He it is who hath appointed for you the stars that ye guide yourselves thereby in the darkness of land and sea; we have made the signs distinct for a people who have knowledge.” *Quran, Chapter 6, Verse 97*

The advent of Islam and the teachings of the Quran associated with science, nature, and other personal challenges related to the individual responsibilities of each Muslim presented a new interest in analytical observation for commercial and political interests, as well as the religious motivations of the calculation of prayer times and the requirement of the annual pilgrimage (Hajj) to Mecca. The latter was an action of worship that contributed to the rise of the Jeddah port in the first half of the 15th century, replacing Aden as the main trading port (Alpers, 2014). The Quran also provided encouragement for devotees in mapping the heavens and understanding the celestial phenomena that employed the adoption of a new calendrical system, the lunar calendar.

The lack of ancient texts make it difficult to retrace the history of Arabic nautical science. Knowledge transmission in the Arab tradition was either oral or written, carried from one generation to another for posterity, a custom that has survived in manuscripts, indicating that the oral tradition goes back to the 12th century (Richards M. & O’Connor M., 1993). Whereas, as stated by Ibn Mağid, Arab navigation began during the Abbasid dynasty, and the practice of navigation was written from at least the 11th century (Ibn Mağid, 1576). Hence, the nautical knowledge founded by theoretical and empirical navigational development and measurement references which were composed and accumulated by the seamen and sailors who traversed and operated in the Indian Ocean throughout centuries grew to become regarded as a science that embraces and encompasses many different disciplines, such as geography, astronomy, mathematics, and meteorology, which in turn led to the rationalization of navigation into a science *(ʿIlm al-Baḥr)*. Accordingly, a sailor ought to possess certain principles and observations on his voyage in order to attain his position (whether north or south) at all times in order to reach land. These principles required fundamental knowledge, such as the accurate use of instruments, dead reckoning, and celestial sightings, since the sailors had to navigate for weeks with their vessels far from land. That said, these measurements should maintain a comparison to nautical charts or mathematical tables, otherwise an accurate latitude should be provided (Swanick, 2005). There were further applicable attempts to secure dependable information while sailing, such as: *ishārāt*, to display other means and symbols for coastal localities, anchorages, shoals, reefs, and also to avoid danger; *siyāsāt,* the control over the ship and the crew; *masāfāt*, longitudinal measurements; *dīra*, the route between two positions; *qiyāsāt*, stellar altitudes; *mağrā*, the compass bearings; and *mawāsim*, monsoon dates and related techniques (Tibbetts, 1969). These technical performances were the branches that shaped a big part of the navigational science and elucidated Muslim nautical knowledge.

Geographical knowledge and literature were therefore represented and exchanged between the coastal communities when the circumstances related to seasonal nature-imposed seafarers to have long layovers in Asia’s great port cities. Thus, navigational methods were mutually used by all peoples of the Indian Ocean (Richards & O’connor, 1993). The Arabian seas, in particular, realized a great account of records that reveal contact with other nations in the historical ages (Hourani, 1995). This dissemination of knowledge in the Muslim world was obtained from the ancient Persians, Greeks, and Chinese (K. Stein, 2017). Yet, they dismantled themselves from those of ancient Greek theories when documenting their own experience on geography (Aleem, 1973). Existing medieval sources that display this knowledge were transmitted

into geographical works such as *Kitāb al-Masālik wa al-Mamālik* (*The Book of Routes and Provinces*) by Ibn Khurdādhbih written around 870 AD, followed by *Akhbār al-Ṣīn wa al-Hind* (*Account of China and India*) authored by Abū Zaid Ḥasan ibn Yazīd Sīrāfī in 1173 AD. The former is the earliest descriptive treatise on the main trade routes to the Far East, whereas the latter cites Sulaimān al-Tāğir, who is believed to be an early navigator who was later mentioned by Ferrand in his book *Voyage du Marchand Arabe Sulayman en Inde et en Chine*, a work ascribed to Ibn Wahab in 851 AD and considered to be the oldest written sea voyage book. Its great significance lies in it being a source on Indian and Chinese ethnology, which also includes the description of the route from Siraf to Canton taken by Persian and Arab sailors from the seventh to the ninth centuries. The books entail information on navigational science by displaying a geographical and historical encyclopedia and can be traced back to the works of Ibn Fakih, al-Masʿūdī, al-Balkhi, Istakhari, and Ibn Hawqal. The sailors Omani and Sirafi were particularly praised by al-Masʿūdī, emphasizing the difference between their knowledge in regard to the areas and dimensions of the oceans to that of the Greek philosophers (Aleem, 1973). These detailed routes, on the other hand, could be extracted from the recorded oral accounts of sailor guides, such as the sources handed to us by Ibn Mağid in his treatise *al-Fawaid*, on the brief survey of the history of Arab navigation going back to the 11th century (Tibbetts, 1961). The latter relied not only on his experience, but also on the earlier works of famous captains like the three *mu'allims* of the Abbasid period namely: Muhammad b. Shadhani, Sahl b. Aban, and Layth b. Kahlan (Issawi, 1952). In addition, the treatise by Buzurg ibn Shahriyār entitled *Kitāb ʿAğāʾib al-Hind* (*The Book of the Wonders of India*) was compiled in 1000 AD. This work incorporates the nautical tradition and technical words which detail the existing aspects of the 15th and 16th centuries (Tibbetts, 1971). Other important works include *Taqwīm al-Buldān* (Locating the Lands), which was compiled in 1321 AD by the geographer Abū al-Fidā and was presumably used by Ibn Māğid as well (Sezgin, 2007). Following that, the great work of descriptive geography, *Nuzhat al-Mushtaq*, was compiled in 1154 AD by al-Idrisi. This magnum opus is a work of combined materials of astronomical and mathematical geography from Arabic and Greek works obtained through firsthand observation and eyewitness accounts, resulting in a world map which consists of 70 sections. Lastly, one should not forget the lasting historical and geographical documentary value of the travelogue of Ibn Battuta, which portrays the description of the Indian Ocean and its social customs (Aleem, 1973).

Traversing the ocean and coasting along its borders were made possible due to the different elements that were incorporated by Indian Ocean sailors. These sailors were directed by seasonal winds and monsoons, currents, tides and the study of the earth's surface. This was a knowledge that allowed seafarers to integrate and coast along the surroundings of the Indian Ocean, up to Southeast Asia, together with Persian, Malay, and Arab traders. The semiannual system of orientation for setting out in miscellaneous seasons using the calendar system is called *Nairuz*[3] and was used up until the 12th century. It dominated the region of the Indian Ocean from East Africa to Southeast Asia (Tibbetts, 1971). The discovery of this seasonal shift allowed sailors to prevail over the long distance traveled across the breath of the region which takes part from October through March. This Northeast Monsoon *(rih al-qabūl or al-azīb)* dominates the entire Indian Ocean region from north to south, comprising the South China Sea. From April to September, the blow of the winds reverses, causing the Southwest Monsoon *(rih al-dabūr or al-kaws)*. In addition, while the lands surrounding the oceanic basin bestowed an environment for the emergence of a primary navigational experience, the tradition of astronomy in pre-Islamic Arabs was discussed by al-Biruni (c. 1000) in his treatise *"Chronology of Ancient Nations."* Their knowledge of the stars, moon, and winds were also found in poetry which were later commented on by al-Jahiz, al-Dinawari, and al-Sufi (Aleem, 1973). The level of astronomical knowledge passed down by the two navigators Aḥmad ibn Māğid and Sulaymān al-Mahrī deals with the basics and principles of nautical astronomy in accordance with the formation of the celestial sphere and its cosmological models. Eventually, the study of the formation of the stars used for stellar navigation provided a theoretical introduction to the angular measurement used in the navigation systems. The star *Al-Ğāh*, as referred to by sailors during medieval Islam, was the main point of orientation which provided sailors crossing the ocean valuable guidance between the coastlines of India and East-Africa. Other essential stars, including their risings and settings, were also dealt with as references needed for the astronomical experience. Consequently, it became necessary

3 The Persian term for the New Year that dates back to the Sassanid Empire.

for navigators to possess knowledge of the stellar configuration of both the northern and southern hemispheres in order to undergo these long voyages (Constable, A.R. & Facey, W., 2013). For instance, Sulaimān al-Mahrī stated the height or distance of the fixed stars from the celestial equator in the northern and southern hemispheres in degrees (Sezgin, 2007). Due to the fact that Ursa Major, commonly known as the Big Dipper, is a constellation that presents a massive 24-hour sky clock, the recognition of Polaris became a simple matter. It is in line with two stars from the Big Dipper, Merak and Dubhe. Accordingly, the Pole Star and the surrounding circumpolar stars display the path for sailors on their sea voyages. Yet, the circumpolar stars at lower latitudes decrease in number and diminish at the Equator. Nevertheless, the position of the Polar star can still be predicted through the circumpolar stars of Ursa Minor if their position is above the north celestial pole. Since the polar axis was obtainable in both hemispheres, the navigators below the Equator can use it as a primary navigational support for directions. Thus, the determination of the polar axis occurs through the observation of the southern constellations (Constable, A.R. & Facey, W., 2013). The stars and star group names became associated with each rhumb (*khann*) and interval of the compass, each of which represents the 32 points congruent to the arcs of the horizontal circle (Sezgin, 2007). The latter is divided into 360 sections, whereas the angle between adjacent points is 11 1/4°. The term used for these horizontal angles is *tağziʾat al- dāiʾra*. These were named after the rising and sitting of 15 fixed stars, with the addition of the North and South. Both navigators (Ibn Māğid and Sulaimān al- Mahrī) point out the inaccuracy of the settings and risings of the stars on the horizon allotted to the reference points that only implement an approximate value (Tibbetts, 1971).

Nautical instruments, on the other hand, used by seafarers to operate in the ocean, served as tools to overcome their objective, enabling them as navigators to set their course safely in the open seas and to ascertain an accurate guidance during their voyages, day or night. Their practice resulted in the development of important navigational skills and instruments, such as the compass, astrolabe, quadrants, and the woods (*khashabāt*), engaging the usage of triangulation, determination of distances in accordance to the equator, altitude measurements, and the like. The compass is considered one of the primary components of nautical instruments used during maritime activities in the Indian Ocean, improving the method which adhered to orientation based on fixed stars. The theory of latitude on the other hand, extracted from a meridian altitude, was masterfully demonstrated by al-Mahri, who nevertheless omitted an adaptation of the formula for the southern latitudes (Grosset-Grange, 1996). Technical instruments used for the determination of star altitudes and other angular distances between the stars can be traced back to al-Khwarizmi's Stick. The latter was based on trigonometric functions and was later replaced by wooden plates referred to by the term *Khashaba*. Another scholar who was accredited for setting the basis of modern trigonometry was al-Battani. The astronomical tables used by the Spanish and Portuguese during their maritime discoveries were also attributed to the Arab astronomer, a feat which reveals more advanced knowledge than that of al-Khwarizmi (Aleem, 1973). *Khashaba* is a piece of wood that has a string with several knots stretching from a hole in the center of the plate. Those knots served as a measuring ruler for the altitude of standard locations. This tool, however, can only be used within latitudes 20°N and 40°N, according to Piri Reis in his *Kitāb al-Baḥriyya* (Polat, 2017). To further illustrate, a different size rectangular board graduated in fingers was held in such a way that its lower edge had to be aligned with the horizon. Polaris, for instance, was aligned with the upper edge. The knots stretching from the hole in the center of the *khashaba* served as a measuring ruler for the altitude of standard locations (Constable, A.R. & Facey, W., 2013). The equation used in order to acquire the proper measurement using the wooden plate is as follows:

> First, he should hold the wooden plate so that it entirely fits in the apparent distance between the Pole Star and the horizon. We assume that the navigator holds the board vertically and that the angle between the horizon and the Pole Star is equal to 2θ. Because the rope passes through the middle of the board, the length of the board is divide d into two. So, the length of the board (2h) gives the altitude of the Pole Star from the horizon. On the other hand, the distance of the observer's hook from teeth to the board is x. Thus, when operating with the instrument, an isosceles triangle is formed. Hence, the following equation obtained is: 7 x=h cot θ. (Polat, 2017)

These instruments were known and used, whereas existing charts were different from the portolans that the Western mariners operated with (Lewis, 1973). A system of orientation by the Arabs was acquired by means of compass bearings, with star altitudes being used as coordinates. Their position in the open seas was pinpointed with the aid of a chart. A course was plotted by the Arab navigator which served a comparison between their intended destination and the altitude derived from the stellar altitude (Tibbetts, 1992). The mapping system structured in respect to longitude coordinates was not only practiced by Arab maritime trade to China and Sofala. This east-west sailing technique was also practiced by Indians, Malayans, and possibly Chinese. Throughout history, the latitudes were attained by measuring the angle between Polaris and the horizon with the usage of a measuring device. However, longitudinal measurements were not easy to achieve, which necessitated the application of trigonometric methods. According to Ibn Mujāwir, the system of orientation employed by the people of Qumr was superior to that of the Arabs. Tolmacheva stated that this was a seafaring activity that was improved in the equatorial waters (Tolmacheva, 1980). Other important references worth mentioning are those compiled by al-Hanaoui (1250 AD) and Abu Feda (1321 AD). The former commented on the navigational instruments used by the Arabs, whereas the latter contributed to the northern latitudes, such as those of the Baltic Sea (Aleem, 1973). The Indian Ocean basin was of a particular importance to a variety of maritime peoples, sailing side by side with Arabs, Persians, East Africans, Goans, Tamils from Coromandel, Klings, Bengalis, Burmese, and Javanese (Lewis, 1973).

3. Life and Works of Sulaymān al-Mahrī

The second representative of navigational geography, Sulaimān b. Aḥmad b. Sulaimān al-Mahrī, was born in 1480 AD and was originally from southern Arabian Mahara and a native of Shihr (modern-day Yemen). According to the Turkish admiral Sīdī ʿAlī, he was one of the most important Arab navigators of the 16th century throughout the region of the Indian Ocean, and one of the inheritors of the traditional and historical development rediscovered in our present knowledge (Grosset-Grange, 1996). That said, during his activity in the Indian Ocean, the Portuguese had already been settled in the region since 1498 AD. Yet, al-Mahrī's scientific doctrine was not influenced by them, rather it was based on purely Eastern-Arab writings (Sezgin, 1992). The reflection of the works handed down to us by Sulaimān al-Mahrī proved the interpretation of the knowledge resulted from both the practice and experience of the Islamic geographers. This was a knowledge that superintended as an independent science which served the tasks and prerequisites of the seafarers operating in the open sea, which further shaped the science of navigation along with geography and cartography as a whole. The mathematical and astronomical methods adopted since the eighth century processed an essential account of measurements which expanded on a great development devoted to the countless navigation practices being made in both the open seas and coastal routes, exhibiting the interoceanic maritime display of the Indian Ocean. Eventually, Sulaimān al-Mahrī's achievements on the surveying of the Indian Ocean were composed in several treatises and short works, five of which were first discovered by Baron De Slane in 1883 and are available in the catalogue of Bibliothèque Nationale de Paris under the manuscript number 2559. Al-Mahrī's most concise and clear work, entitled *al-ʾUmda al-Mahriyya fī Ḍabṭ al-ʾUlūm al-Baḥriyya*, has new versions which were compiled under two different treatises entitled *al-Minhāǧ al-fākhir fī ʿilm al-baḥr al-zākhir* and *Tuḥfat al-fuḥūl fī tamhīd al- uṣūl*. Aiming to omit some of the theory in the former and focusing only on the descriptive materials, lists of new values for the coasts of the Indian Ocean, such as *qiyās* measurements, compass bearings, and longitudinal distances *(masāfāt)*, as well as sections which recounted voyages in the South-East Asia and the Bay of Bengal, and sections dealing with cyclones and symbols for coastal localities were given (Tibbetts, 1971). Technical works on Arab navigation written in the ninth and tenth centuries are not available as such, which makes it difficult to retrace the history of Arabic nautical science. Therefore, the rebirth of his works in the Islamic world to the navigational science as an expanding discipline established the knowledge acquired for the understanding of geographical documents of that period under the nautical framework of the Indian Ocean. He possessed both empiricism *(tağriba)* as a practical experienced seafarer in the Indian Ocean and theoretical *(naẓar al-ʿaql)* knowledge of the works on navigation, as he himself considered it the nature of science *(Aṣl al-ʿIlm)*. Gabriel Ferrand was the first to introduce Sulaymān al-Mahrī in his article entitled *Les Instructions Nautiques de Sulayman al-Mahri (XVIe siècle)* published in *Annales de Géographie* in 1923. This was followed by another article on al-Mahrī published in Encyclopaedia of Islam in 1927. In 1925, Ferrand published the works of al-Mahrī as a facsimile after the Paris manuscript Ms. Arabe 2559, which

form part of Volume II of his *Instructions Nautiques et Routiers Arabes et Portugais des XVe et XVIe Siècle*. Although Ferrand intended to work on the translation and annotations of al-Mahrī's works, it did not materialize due to his sudden demise. In the 1970s, Ibrahīm Khūrī attempted to make a critical edition of al-Mahri's treatises in Arabic entitled *al-'Ulūm al- Baḥriyya 'inda al-'Arab,* which is composed of three volumes as part of the series dedicated to the Arabic navigational literature. The first volume was on *al-'Umda al-mahriyya fī dabṭ al-'ulūm al-baḥriyya* and was followed by the second volume on *Al-Minhāǧ al-fākhir fī ʿilm al-baḥr al-zākhir,* both published in 1970. The third volume was on *Risālat qilādat al-Shumūs wa-stikhrāǧ qawāʿid al-usus*, *Tuḥfat al-fuḥūl fī tamhīd al-uṣūl fī uṣūl 'ilm al-baḥr*, and *Kitāb sharḥ Tuḥfat al-fuḥūl* and published in 1972. Unfortunately, his critical edition of *al-'Umda* has some shortcomings that Shumovsky had mentioned in his work. Shumovsky also prepared a critical edition and translation of *al-'Umda* in the Russian language in the 1970s, but the work has remained in typescript. An English summary of Theodor Shumovsky's work was prepared by Alexander Matveev and was published in Greco-Arabica in 2009. Tibbetts, who authored a critical edition on Aḥmad ibn Mājid's *Kitāb al- Fawā'id,* spoke about Sulaimān al-Mahrī as part of the section on Indian Ocean navigation after ibn Māǧid. He was aware of al-Mahrī's works. In fact, he used al-Mahrī's sailing directions for the regions "below the winds" in his *A Study of the Arabic Texts Containing Material on Southeast Asia* published in 1979. However, it is well-known that he was more interested in the works of ibn Māǧid than al-Mahrī. Lunde added two articles that talks about *al-Mahrī* and his works. That said, his works were more like an introduction compared to what Tibbets has accomplished in his work on ibn Māǧid. This minimal scholarly study on the works of Sulaimān al-Mahrī was also acknowledged by Shumovsky. Nevertheless, the works of Ibn Magid and his contemporary Sulaimān al-Mahrī are considered as the most complete document on Arab navigation in the Indian Ocean during the medieval period. Their contributions entail sailing instructions based on astro-navigation and descriptions of routes from South Arabia to East Africa until Sofala, to Madagascar, to Sind, Malabar, and the East Coast of India (Aleem, 1973). Details of favorable times for sailing with regards to winds and currents are given for all ports and seasons of the year. Complete knowledge of stars and constellations are also included, including their altitudes and relative angles for determining the latitudes and adjusting the ships course. This together with the mansions of the moon were utilized to determine the time at night. Useful signs were used as navigational aids, such as soundings, the nature of the bottom, dangerous reefs, descriptions of approaches, and observations of birds, fish, seaweeds, and the color of the water. A maritime code incorporating a set of rules and regulations to be observed by pilots and crew was also included (Aleem, 1973). The works of these two navigators, especially those of Sulaimān al-Mahrī, were also the sources that played the fundamental part in the writing of *al-Muhīt*. This exceptional systematic book written by Sīdī 'Alī Reʾis was produced after much research into nautical instructions from the sailors among his crew. His main reason for being in the Indian Ocean was to expel the Portuguese who sought full control of the strategic fulcrum of the port cities in the early 16th century. These attributions accomplished by the scholars, especially those of Sulaimān al-Mahrī, shaped the cartographical image of the Indian Ocean coastal lines and islands.

Sulaimān al-Mahrī's treatise entitled *al-'Umda al-Mahriyya fī Ḍabṭ al-'Ulūm al- Baḥriyya* is an undeniably important work on nautical science sailors within the Indian Ocean. Its importance in the field compelled me to work on it, whereby I have translated the text completely from Arabic to English. While Gabriel Ferrand pioneered this attempt to translate *al-'Umda*, his untimely demise caused the work to never be materialized, nor was there any printed form made available. In this article, I referred to the Paris Manuscript No. 2559 (11b-59a, 961 H.) with a publication date given between 1601-1700. The manuscript is in good condition. It is composed of 187 sheets, and each page has 15 lines. It measures 22 cm in height and 15 cm in width. I have consulted different works on nautical science, including the work of Ibn Māǧid, to orientate me into the maritime practices and nautical terminologies. I also traced the knowledge of Muslim astronomical navigation that beheld numerous procedures dominated by the mathematical-astronomical determination of localities in the Arabic-Islamic world, as well as the procedures taken for the measurement needed in the open sea and coastal sailing in order to come up with a closer translation of *al-'Umda* in English.

Here we witness the expansion and advancement of navigational practices in Indian Ocean by the Arabs. This development did not go unnoticed in the Occident. They have kept mathematical records which involved employing

techniques and instruments in order to determine the calculation of stellar altitudes along with the longitudinal distances and other practices that fulfilled this knowledge into an independent science encompassing geography, cartography, and meteorology. The most distinct progress that shaped Sulaimān al-Mahrī's treatise *al-'Umda* is the accurate determinations composed and arranged under theory, followed by its practical results. His comments in the first chapter clearly show the growth of the corpus on the astronomical and nautical knowledge attained in the Islamic world. Melding the empirical knowledge accumulated by the experienced seafarers with his own scientific investigation, important elements in the texts, such as star altitude measurements *(qiyas)* and the compass bearings *(majra)* were the subjects that enabled a route *(dira)* to be laid down. This treatise is divided into several chapters. Chapter 1 deals with the basis of nautical astronomy under several sections dealing with: the form of the heavenly stars, the rhumbs *(akhnān)*, star declinations *(abʿād)*, the parallels or the lines of latitude *(madārat)*, star altitudes *(irtifāʿ)*, star culmination *(ghāyat irtifāʿ)*, horizontal positions of two or more stars *(iʿtidāl)*, *iṣbaʿ* measurements, *zām* measurement placed between rhumbs, *tirfa* measurements, routes *(dīra)*, *qiyās* measurements, and longitudinal measurements *(masāfāt)*. The second chapter characterizes the efficiency of the practical side of al-Mahrī's books as a source of seeking experience for the learned man. This section includes the names of the 15 essential stars for a navigator to use when sailing in the open sea of the Indian Ocean. In describing the qualities required by a navigator, Sulaimān al-Mahrī concluded this chapter with the following conditions for the navigator to be proficient in: the theory of knowing the routes *(dīrāt)*, calculating latitude *(qiyāsāt)* and longitudinal measurements *(masāfāt)*, retaining knowledge over the use of the compass *(majra)*, knowing the routes he is sailing *(dīrāt)*, attending to the right seasons *(mawāsim)*, and to be adept to the management and the insight of the boat *(siyāsāt wa-madārāt al-markab)*. Thus, intellect and experience are the basic qualities required by a navigator. Each of which are either dependent or independent from each other (Ferrand, 1928). Chapter 3 discusses the description of the coasts and islands under and above the wind, on the west and east of the Cape Comorin, by means of compass bearings preceded by relevant theory (Tibbetts, 1971). This chapter is divided into seven sections dealing with: the Red Sea, the route along the southern coast of Arabia, the northwest coast of India, the east coast of Africa from Bāb al-Mandab, from the southern Arabian coast to Socotra, the eastern coast of the Indian, the Siam coast, the western and eastern coast of Malay peninsula, and the coast of Indochina and western China. In the fourth chapter, Sulaiman carries on with the description of the route, focusing on certain islands, such as the island of Madagascar, Comoros Archipelago, Socotra, Maldives, and Ceylon. The following chapter indicates the latitudes (Pole Star altitudes) based on the heights of the Polar star, the *Farqadān* (β Y of the Little Bear), and *Naʿsh* (α β ɣ δ of the Great Bear) for all the coasts of the Indian Ocean, also covering the theory of *qiyās* determination (Tibbetts, 1971). Accordingly, Sulaimān al-Mahrī discusses the science of taking the latitude of the principal ports by measuring stellar altitudes *(qiyās)* and introduces the traditional nautical instrument, *kamal*, which he refers to by the term *khashaba*. He dealt with it as a basic instrument and provided additional information about its utilization. The type of *kamal* that Sulaimān al-Mahrī addresses is of several wooden plates of different sizes. This type was referred to by Sīdī 'Alī as *alet*. It is to be noted that although the Arabs perfected the astrolabe and quadrant at an early age, they scarcely used these instruments in navigation at sea, for the error resulting from the movement of the ship interferes with the correct readings. Instead, they used wooden tablets which depended on measuring the angle between the celestial body, the observer's eye, and the horizon. The distance between the observer's eye and the adjusted tablet is calculated according to trigonometric functions as stated earlier. It is upon this principle that the instruments known as *Kamal, Balisti,* and *Arablete* were produced (Aleem, 1973). Sulaimān al-Mahrī ended this chapter by discussing the *bāshī* of the 28 lunar mansions. The knowledge of the *bāshī* values for all the lunar mansions was regarded as essential. It was the measurement of how far the Pole Star was above its measurement at lower culmination (Constable, A.R. & Facey, W., 2013). They varied from zero *bāshī* at the lowest position when Polaris is at the exact same altitude as the celestial pole to 4 isba', when the star is at its maximum position at the same meridian of the observer. On the other hand, a lunar mansion was often used as part of their calendar system. The nautical calendar system they operated with used the Persian *Nairuz*. This brings us to the sixth chapter, where Sulaimān al-Mahrī spoke in depth on the monsoons of the Indian Ocean. That is the ideal time to set sail to a specific destination from a specific port. Chapter 6 offers a list of the seasons for the major ports in the Indian Ocean trading network. The closure of the seas, on the other hand, is the season

when navigation stops and where the vessels were fitted out. Overall, besides astronomical charts and measurements, these manuals possess information about every important element a captain would need to know. One of the elements that progressed to a branch of navigational science is *ishārāt*. As sailing the Indian Ocean requires celestial navigation, the usage of other techniques was not excluded. Thus, in daytime and during poor weather, other expertise would replace the sailor's astronomical skills. Such expertise was the detailed knowledge over signs and landmarks such as sea animals, color, and depth of the water, the wind breeze, the waves, whirlpools, and tides, among others. Chapter 7 discusses several sets of voyages accompanied with directions encompassing the whole Indian Ocean, including the islands and islets off the Arabian and African coast of the Red Sea, followed by detailed routes of some regions, such as Malabar, Aden, and Jeddah (Sezgin. 1992). The author concludes his book by dealing with the dangers a navigator might encounter and the dangers he ought to avoid in certain places and seasons.

After his most important treatise *al-'Umda*, Sulaimān al-Mahrī was not pleased with the outcome of his results after subsequent practice and apprenticeship. Therefore, he compiled a new version in two different treatises entitled *al-Minhāǧ al-fākhir fī ʿilm al-baḥr al-zākhir* and *Tuḥfat al-fuḥūl fī tamhīd al- uṣūl,* aiming to omit some of the theory in *al-Minhāǧ* and focusing only on the descriptive materials, but yet, finding himself with an inferior work and not as a rewarding achievement compared to *al-'Umda* (Tibbetts, 1971). I shall first start with the most interesting substantial changes and progress realized in his second work *al-Minhāǧ*. These developments were given as lists of new values for the coasts of the Indian Ocean, such as the *qiyās* measurements of Jeddah, Ras al-Ḥadd, and Chittagong. The treatise includes also new lists of compass bearings, longitudinal distances *(masāfāt)*, sections modifying sets of voyages in South-East Asia and Bay of Bengal, and sections dealing with cyclones and symbols for coastal localities (Tibbetts, 1971). *Al-Minhāǧ al-fākhir fī ʿilm al-baḥr al-zākhir* is made up of seven chapters. The introduction presents a brief theoretical note on *zām* and *tirfa* measurements followed by the first chapter. The latter discusses the maritime routes of: the coast of Arabia, Makrān, Sind, Gujarat, Konkan, Tulwān, Malabar, the coast of Somalia and eastern coast of Africa, the eastern coast of India, Bengal, Siam in the western coast of Malaysia, Malacca, the eastern coast of Malaysia, Indochina, western China, and other routes on the high seas (Sezgin, 1992). Chapter 2 deals with the latitudes of the ports of the known and inhabited coasts of the Indian Ocean, as well as the theory of *bāshī* and *qiyās* measurements. This chapter is similar to the fifth chapter of his earlier work *al-'Umda*. Chapter 3 focuses on the longitudinal measurements *(masāfāt)*, mainly on the values of the inhabited islands across the ocean. These islands, according to Ferrand, are Madagascar, Seychelles, Socotra, Laccadive Islands, Maldives, Ceylon, Andaman and the Nicobar Islands, Takwā on the western coast of the Malay peninsula, Sumatra, Java, and the south-eastern islands. Chapter 4 approaches the theory of the winds and its dangers. It also deals with the distances between Arabia and western India, the Gulf of Bengal ports, the eastern coast of Africa, and certain ports of Sumatra, Java, and Bali. This was followed by the fifth chapter, which dealt with *ishārāt* such as winds, cyclones, and other dangers one may encounter either on land or sea (Sezgin, 1992). Chapter 6 deals with the astronomical material. Lastly, the seventh chapter discusses the movements of the sun and the moon and their relation to the zodiac signs. In this chapter, Sulaimān al-Mahrī concludes his treatise dealing with sea voyages and its detailed routes from Diu to Malacca, Malacca to Maldives, Diu to the western coast of Sumatra, and the return to Marṭabān, Tenasserim, and Bengal. His other work, on the other hand, *Tuḥfat al-fuḥūl fī tamhīd al-uṣūl* comprises seven chapters that served as a work which combined all the theory needed for a sailor to navigate in the open seas. These chapters deal with the description of the heavenly spheres and the stars, compass bearings and its rhumbs, *zām* measurements and the study of *tirfa*, *dira*, the theory of *qiyās* measurements, *masāfāt*, the theory of the winds, and the conditions for a navigator to be a good pilot.

Consequently, all the texts during that period comprise the necessary information for the coastal navigation, both islands and mainland coasts and several detailed routes that are remarkably accurate. These positions display an inter-oceanic maritime sailing, given their latitudes in form of star altitudes or their compass bearings from the eastern coast of Africa stretching across the Red Sea, Arabian Sea, Persian Gulf, and the great archipelago of Asia and China Sea (Ferrand, 1923). Nonetheless, Sezgin stated that al-Mahrī presents everything necessary for the compilation of accurate charts. His list of places using two units of length, *tirfa* and *zām*, to measure distances on sea covers almost all the frequented areas of the

Indian Ocean. These measurements were given by primitive finger-system, a measurement that originated from several voyages of meridional and longitudinal extension according to Tomaschek (Sezgin, 2007). *Iṣbaʿ* was the angle obtained by one's finger held at the length of the arm. Its value is extracted by dividing the circle into 210 or 224 parts. The latter is that of ibn Māğid, which corresponds to 1 *iṣbaʿ* being 1°36'26'', a value adhered by the ancient people. The contradiscts the value of an *iṣbaʿ* according to his successor al-Mahrī, which is 1°42'51''. *Iṣbaʿ* was divided into eight divisions called *zām*. Hence, *zām* represents an eighth of an *iṣbaʿ*, which is the angular measurements to calculate the estimated distances when sailing due north in order to raise the Pole Star by 1 *iṣbaʿ*. In addition, *zām* was originally a three-hour sail, with eight *zāms* being the distance sailed in a 24-hour day. Thus, this unit was also used for linear measurements. The latter, according to al-Mahrī, is referred to by the technical term *zām*, whereas the former is referred to as the definite (or customary) *zām* (Grosset-Grange, 1996). The author in this work, however, does not appear to distinguish between these types by name, which give the impression that he combined the two (Sezgin, 2007). Eventually, the accuracy of these courses and the altitude of the stars, depicting the most important guide for the mariners, were established by the mathematical unit *zām* as a standardized finger value handed to us by al-Mahrī, which according to Grosset-Grange, is valued at 12.82 nautical miles. To further illustrate, here I quote what Grosset-Grange stated:

> the astronomers are well aware that the revolution of the Pole Star (taken by mariners as a standard of 4 fingers) is 6° 6/7' [which is correct for 1505], thus 1 finger=1° 5/7' and 1°=1 zam less a third […] (Grosset-Grange, 1996).

to reproduce the nautical chart of the Indian Ocean compiled by Arab navigators, one would anticipate star altitudes and bearings as the measuring coordinates, using *tirfa* measurement, and place upon them the ship's position without the necessity of using longitude. *Tirfa* measurement according to Grosset-Grange is:

> […] the distance covered in each rhumb before the meridian value of a celestial body varies by one finger (Grosset-Grange, 1996).

Tirfa calculation, according Tibbetts, was believed to be the most accurate method of obtaining longitudinal measurements, using departures known among the Arab navigators. According to Tibbets:

> [...] the departures, i.e. the longitudinal distances between the respective rhumbs on covering one unit of latitude which were known to the Arabs as the number of zām between rhumbs (Tibbetts, 1971).

Consequently, having a north oriented voyage and a latitude determination based on star observation, but when sailing in the southern hemisphere or across the equatorial region, the Pole Star can no longer be sighted. Hence, the measurement could be estimated through the stars in the southern hemisphere or through another equatorial star. However, as the discussion concerning longitudinal measurements, referred to as *masāfāt*, could not be attained through star observation, but through measuring departures, as it represents the linear measure covering the distance between two points due east or west placed at the same geographical latitude line. The sum of the *zams* was considered as the general concept for such measurements. The attempt of longitudinal measurement, according to Tibbetts can be found in:

> The Arab navigational guides had a standard set of values for "departures" for each compass rhumb as well as a set of values for the distance sailed along the rhumb (Tibbetts, 1992).

Around the 15th century, mariners navigated these vast seas based on their abundant and detailed nautical instructions and experience. Their works provided a glimpse into the data accumulated throughout the years of calculated positions of each celestial body at regular intervals (Grosset-Grange, 1996, p.221). According to Ibn Māğid, the circumstances of the works dated back to the tenth century did not hold any systematic order to their material, unlike the work presented by the latter and his successor. These astronomical observations on the height of the stars and information regarding the listing of the ports using star altitudes and bearings produced by the Arab sailors do indicate the usage of accurate charts

and maps. Yet, there were no records nor evidence that proves their existence in the Arab texts of that period (Ferrand, 1928), except that of Sīdī ʻAlī in his *Kitāb al-Muḥīt*, particularly in section 4 chapter 7, where references to charts and maps were given (Richards M. & O'Connor M., 1993). These Arab maps of different kinds, according to Sezgin, were also adhered by European seafarers based on the assessment provided by Grosset-Grange, similar to the ones used by Vasco de Gama on his first voyage (Sezgin, 2007). Accordingly, Tibbetts stated that the Portuguese did supply us with an account mentioning the use of charts among the Arabs. Here I quote what Tibbets said:

> The Arab texts never mention charts unless the word rahmānī could stand for the chart. The rahmānī was the only written document the Arab navigators possessed, and as the only written documents that have survived are the texts in the form of navigational treatises and mnemonic poems corresponding to European roteiros, it is assumed that this is what is meant by the term rahmānī (Tibbetts, 1969).

The highly accurate values and figures given by the Arab navigators which reflect reality indicate incredible research, which gives an impression by some authors that they possessed maps and charts even though none of the scholars mentioned any maps nor charts for distances in their works. P. Dinse and Tomaschek argue that a map (or maps) of the Indian Ocean was or were in the hands of Arab navigators around the turn of the 15th/16th century. W. Tomaschek regarded the entire *isba'* chapter of Sidi ʻAli's *al-Muhīt* as a result of a mere reading of a map enclosed in the latest sailor's book, produced if not by Sīdī ʿAlī himself, at least by Sulaimān al-Mahrī (Sezgin, 2007). Accordingly, the documents that reached the Portuguese which display the mapping of Africa and the Indian Ocean and were illustrated by eminent circles of latitude and longitude and accompanied by other instruments and encouraged them to penetrate through the routes leading to the Indian Ocean from Malindi to Calicut were revealed by a Muslim navigator. The Muslim navigator according to Quṭb al-Dīn al-Nahrawālī was Aḥmad ibn Māğid (Tibbetts, 1971). In his work *al-ʿUmda*, Sulaimān al-Mahrī quoted the earlier work of the former, al- Ḥāwiya, once and did not further comment, praise, or give any clarification to their status or relationship. It is, therefore, not known whether the two scholars had any connection or maritime relation. Aḥmad ibn Māğid was one of the first authors of nautical science, known as the descendant of the three lions. His full name was Shihāb al-Dīn Aḥmad ibn Māğid b. Muḥammad b. ʿUmar b. Faḍl b. Duwaik b. Yūsuf b. Ḥasan b. Ḥusain b. Abī Maʿlaq al-Saʿdī b. Abī al-Rakāib al-Naǧdī. He was referred to by the Turkish admiral Sīdī ʻAlī as:

> Reliable among the sailors, the pilot (*muʿallim*) of the sea of India, most worthy of belief among modern (navigational writers) (Tibbetts, 1971).

Ibn Māğid indicated that he compiled *al-Fawāʾid* after 50 years of experience in the ocean as a navigator. According to Ferrand, his birth date is between 1427 and 1432 AD. As for the date of his demise, it cannot be determined. Yet, the last date mentioned in his books is 1500 AD (906 AH) (Tibbetts, 1971). Aḥmad ibn Māğid was a religious man, as he always refers to several Quranic verses and Hadith convenient for sailors in order to avoid danger. The Manuscript No. 2292 in the Bibliothèque National de Paris indicates some references regarding his family, where he refers to his father as *Muʿallim al-Baḥrain*. Ibn Māğid was a very competent sailor, also sailing mainly in the same region, centered on Raʾs al-Ḥadd, along the Arabian and Red Sea, and along the Indian Ocean and China Sea.

The knowledge he obtained from his family goes back to his grandfather who gained a flourishing reputation in the 14th century. His grandfather's legacy was inherited by his son Māğid b. Muḥammad and was later transmitted to Aḥmad ibn Māğid. His experience and the practice of repetition enabled him to be and to become classified among the most famous Arab sailors up to the present day. Moreover, he does not fail to warn the seafarers over the errors made by his predecessors in some aspects. According to Ibn Māğid, the navigational works composed by the three lions, Muḥammad ibn Shādhān, Sahl b. Abbān and Laith b. Kahlān, were based on earlier works dating back to the 11th century compiled by two sailors, the enduring Persian names Aḥmad ibn Tabrūya and Khawāshir b. Yūsuf b. Ṣabāḥ Al-Arīkī, who sailed on an Indian ship in the 11th century. The three lions, on the other hand, were not navigators, but were rather writers on navigational knowledge and literature according to the Turkish admiral. Other names that were mentioned are those of

Ibn ʿAbd al-ʿAzīz b. Aḥmad al-Maghribī, Mūsā ibn al-Qandarānī, and Maimūn b. Khalīl as sailors and ʿAbd al-Raḥmān b. Abuʾl-Faḍl b. Abuʾl-Mughaira as a *nākhōda*. Yet, according to Tibbetts, these sailors were mentioned as sources in Ismāʿīl b. Ḥasan's manuscripts and have not composed any works. The latter is said to have written on one of the most complex techniques in navigational theory, which is the *tirfa* measurement. Ibn Māğid claimed that his results were wrong, yet, according to Tibbetts, the outcome possessed by the latter were also of faulty results. Since the 14th century onwards, other navigators were also known, such as ʿAlī al-Ḥubbī; Muḥammad b. Marʿī al-Iskandarānī, referred to by ibn Māğid as a sailor; Sheikh ʿAbd al-Raḥmān b. Sheikh ʿAlī al-Ḥamawī and his father Sheikh ʿAlī; Red Sea, referred to as captains; ʿUthmān al-Ğāzānī, Kāʾin b. Maḥmūd al-Thaʿālibī, and the *muʿallim* Ḥasan al-Mahāʾimī (Tibbetts, 1971).

Aḥmad ibn Māğid left a geographical heritage, most of which were composed before the arrival of the Portuguese. However, one can notice the efficiency of the practical side of al-Mahrī's books and can also reveal the approach adhered by Ibn Māğid as a whole that serves more as an encyclopedia for the learned man rather than a source in seeking experience for the learned man. Unlike Aḥmad ibn Māğid, Sulaimān al-Mahrī shows a great form of practical writing by reducing theory and focusing more on explaining his thesis, for more concise results. The former, for instance, when dealing with the *qiyās* measurements for the coasts of the Indian Ocean in *al-Fawāʾid*, ends up omitting and avoiding the practical results, whilst al-Mahrī provides us with the complete lists of these places at regular intervals (Tibbetts, 1971). Another comparison presented is by Grosset-Grange:

> Finally, we note that Majid, the traditional practitioner, remains silent on the theory of latitude extracted from a meridian altitude (although he refers to declination tables), whereas al-Mahri demonstrates this point masterfully, but betrays himself by omitting to adapt the formula to southern latitudes: thus he never crossed the equator, which explains certain of his results (Grosse-Grange, 1996).

The nautical traditions of the Arabs display strong influence on nautical instructions and maritime navigation. This impact was found to have a considerable impact on the Portuguese and Turkish navigation. The Ottoman navigational manual for the Indian Ocean, *Kitāb al-Muḥīt* (*The Encompassing*), is an exceptional systematic book written by Sīdī ʻAlī Reʾis (1498–1562), known as the Ottoman admiral and navigator of the 16th century, who lived under the reign of the magnificent Sultan Sulaimān (1519-1566). Sīdī ʻAlī adopted the naval campaign and was connected to the Ottoman marines as a naval engineer and a seaman. Sīdī ʻAlī was appointed by Sultan Sulaimān as a commander of the Ottoman Indian Ocean fleet, which was previously under the command of Piri Reis, his predecessor in this rank. Having the fleet abandoned by the latter after it was attacked by the Portuguese near Hormus, the admiral was charged to bring back the vessels from Basra to Suez, Egypt. However, Sīdī ʻAlī confronted the Portuguese fleet and was attacked at the Persian Gulf. After the outbreak of a great storm, the Ottoman fleet was scattered. They were driven back eastwards, and were exposed to strong winds that lead only few members of the crew to reach the shore of Gujarat in India. According to Sīdī ʻAlī, during those eight months, the admiral sought for nautical instructions among the learned and practiced men associated with the Ocean. He was endowed with collections of Arab and Persian works on navigation, such as the ancients' pilots of Hormuz to India. His *Kitāb al-Muḥīṭ* has been available and under research in parts since 1834. It was from the work of Hajji Khalīfa, in his *Bibliographic Dictionary*, that the Baron Joseph von Hammer-Purgstall discovered the navigational work *al-Muḥīṭ*. Renaud considers this book as a substantial source for the understanding of Arab navigation. It is a work of the highest importance because the author used various Arab treatises that have not reached us (Ferrand, 1928). Accordingly, it was acquired through the rearrangement of given sections from major surviving works of the preceding authors mentioned by the admiral. However, even though the admiral mentioned the names of the ancient navigators, such as Sahl b. Abān, Lait b. Kahlān, and Muḥammad b. Sadān, and treatises of which they were attributed to, the two great exponents and representatives Aḥmad ibn Māğid and Sulaimān al-Mahrī were his only sources in his compilation of his book, followed by his own comments on general chronology and an analysis of the books (Tibbetts, 1971). One can easily detect the influence of the books involved in the making of *al-Muḥīṭ* as the following: *Kitāb al-Fawāʾid*, *al- Ḥāwiya*, *Kitāb al-Minhāğ al-Fākhīr*, *Tuḥfat al-Fuḥūl*, *al-ʿUmda*, and *Qilādat al-Shumūs*. Yet, the sources of these Arabic texts

that played the fundamental part in the writing of *al-Muḥīṭ* were not revealed until 1912 by M. Gaudefroty-Demombynes. Consequently, around the turn of the 15th and the early 16th century, the extensive development realized by the Arab navigators on the Indian Ocean endured the decline of their epoch. However, the leading contributions of the Occidental were favored and will remain the leading sources adhered to by the Arabs (Hourani, 1995).

Ibn Māǧid witnessed the arrival of the Portuguese in the Indian Ocean towards the end of the 15th and the beginning of the 16th century. Immediately after the Portuguese expeditions, the Indian Ocean became an area of great enterprise by the Turks, British, and Dutch. Thus, the age-long sea-faring tradition in the Indian Ocean is difficult to understand without reference to the Arabs (Aleem, 1973). The Portuguese expedition into India was believed to occur under Vasco da Gama in 1498 AD. Their penetration to the eastern waters, reaching Calicut (the present-day Kerala state), was made possible with the help of the Arab navigator Aḥmad ibn Māǧid in a 22 day voyage that was free of obstacles (Grosset-Grange, 1996). Accordingly, the Arabic document that provides us with such information was found by Ferrand in the *Bibliothèque National* and was also published in parts by Fernão Lopez in his book *Historia do descobrimento e conquista de India pelos Portugueses* (*History of the discovery and conquest of India*). This Arabic text was written by the Meccan author Quṭb al-Dīn al- Nahrawālī (1511-1582) in his treatise *al-Barq al-Yamanī fi'l-Fatḥ al-'Othmānī* (*The Ottoman Conquest of Yemen*). There is a passage in this book that talks about the Portuguese crossing of the Arabian Sea:

> [The Portuguese] continually sought information regarding [the crossing of] this sea [Arabian Sea] until a skillful sailor (sakhṣ māhir min ahl al-baḥr) named Aḥmad ibn Māǧid put himself at their disposal; the leader of the Franks called Almilandi (i.e. Almirante) had become friendly with him and he used to become intoxicated with the Portuguese admiral. This sailor being intoxicated showed the route to the admiral, saying to the Portuguese: 'Do not approach the coast on this part [of the east coast of Africa, north of Malindi] steer straight for the open sea; you will then reach the coast [of India] and be sheltered from the waves'. When they followed these directions, a large number of Portuguese ships avoided shipwreck and many ships reached the sea of Western India (Tibbetts, 1971).

In his treatise *al-Sufāliyya* on the route from India to South-east Africa, Ibn Māǧid spoke of the attempt of the Portuguese to venture into the India Ocean. Their first appearance was on the Cape of Good Hope, on the Atlantic coast, south of Africa, in 1495 AD, aiming for Sufāla (Tazi, 1988). The arrival of Vasco da Gama to Malindi on the eastern coast of Africa, modern-day Kenya, came on March 15, 1498 AD. Before da Gama's arrival to Malindi, he was sailing along the coast of Mozambique, where he came across an active region that had relations with Muslim traders and where he witnessed four Arab vessels loaded with diamonds, gold, and spices at Quelimane (Grosset-Grange, 1996). Upon his advent to Mombasa, he was invited and welcomed by the Sultan of Malindi on April 22, having the latter secure the service of a Muslim sailor for da Gama, a native from Gujarat. According to Ferrand, the Moor (Muslim) sailor called Malemo (*muʿallim*) Cana came on board the fleet's flagship accompanied by Hindus, described by the geographer and historian João de Barros as members from Saint Thomas Christians. Based on the report given by Castanheda, the fleet left for Calicut on April 24, 1498 AD. Vasco da Gama anchored in Calicut a month later on May 20 (Ferrand, 1928).

His sojourn was reported by the first Portuguese historians on the expedition namely, Castanheda, Damião de Goes, and João de Barros. A report was given by Sezgin from the latter portraying the meeting between the Muslim navigator and Vasco da Gama, which is as follows:

> Among them came a Moor, a Guzarate by birth, by the name of Malemo Caná, who agreed to travel with them both because of the pleasure that our company afforded him and as a favour to the king, who was looking for a pilot for them. However, when Vasco da Gama had dealings with him, he was very much content with the man's knowledge, especially when he showed him a map of the whole coast of India, which was divided up, in the manner of the Moors, into very detailed meridians [longitudes] and parallels [latitude], without any compass rose. Since the rectangle of these meridians and latitudes was very small, the coast was very

> precisely represented by those two gradations from north to south and east to west, without containing the multiplication of the winds of the normal compass of our chart, which serves as a basis for the others. And when Vasco da Gama showed him the large wooden astrolabe and other metal astrolabes which he used to record the altitude of the sun, the Moor was not at all surprised, saying that some helmsmen (pilots) on the Red Sea employed triangular instruments of tin and quadrants whereby they recorded the altitude of the sun and the star which they particularly needed for navigation, whereas he and the sailors of Cambaya and all of India recorded their distance with a different instrument, not with those, because their navigation was dependent both on specific stars, from north to south and also on other large stars which pass across the firmament from east to west. He showed this instrument to him at once, and it consisted of three plates. (Sezgin, 2004)

Accordingly, Castanheda named the pilot Canaqua, whereas Barros named him Malemo Cana (Sezgin, 1992). The former, according to Ferrand, means an astrologer. This term refers to the *muʿallim* who offers his consultations, mostly to kings and big merchants, over a trip based on a certain timing and direction. Malemo Cana, on the other hand, stands for *muʿallim,* originally a Malay term used throughout the Indian Ocean. These two terms, according to Tibbetts, were used only as nicknames and do not indicate any specific sailor. Consequently, based on the report mentioned above, the sailor who led the Portuguese to the Indian Ocean is a Moor of Gujarat. Yet, Aḥmad ibn Māğid had already claimed that he is originally an Arab descending from Arab Bedouin. Therefore, the report should not have employed the nationality Muslim Gujarati if Barros was referring to Ibn Māğid, because by the time these report documents were written, the Portuguese historians already held knowledge, based on South Arabian coast communities, over the difference between a Gujarati, Malibari, and an Arab Moor (Tibbetts, 1971).

Furthermore, based on the reputation of Aḥmad ibn Māğid among the sailors, such as Sīdī ʿAlī, a clear account regarding the false results was given, for instance by Shumovsky, where he accused Ibn Māğid of words reflecting him bewailing his actions in his last poem, *al-Sufālīya*, which was written in 1535 after the arrival of the Portuguese to the Indian Ocean. The passage goes:

> [The Franks] arrived at Calicut...
>
> There they sold and bought, and displayed their power, bought off the Zamorin, and oppressed the people.
>
> Hatred of Islam came with them! And the people were afraid anguished.
>
> And the land of the Zamorin was snatched away from that of Mecca, and Guardafui was closed to travelers (Alpers, 2014).

Yet, Sīdī ʿAlī, whose work *al-Muḥīt* was mostly based on the works of those of Ibn Māğid after much research into nautical instructions from the sailors among his crew, day and night, and whose main cause for his presence in the Indian Ocean, was to expel the Portuguese who sought full control of the strategic fulcrum of the port cities in the early 16th century, such as Hormuz, Melaka, and Colombo, would not display any accusations against Ibn Māğid, nor any other Ottoman texts (Tazi, 1988). Rather, he praised him and supported his treatises on his analysis. According to both Ferrand and Tibbetts, the accusations made by Qutb al-Din can only reflect a personal or bad intention towards Aḥmad ibn Māğid, perhaps a feeling of infidelity (Tibbetts, 1971).

These interactions, after the Portuguese expedition of the Ocean, exposed the enrichment and superiority of the nautical science adhered by the indigenous people of the region, expanding the study of this discipline in the history of geography and cartography, the latter being distinguished by Sulaimān al-Mahrī. This access of the Portuguese seafarers to the achievement of advanced astronomical navigation of the authentic Arab discoveries were associated with the names of Vasco da Gama, Christopher Columbus, and Magellan (Sezgin, 2007). This is a technical knowledge that has survived to the present day, featuring the methods used among the navigators of the Indian Ocean (Tolmacheva, 1980).

Conclusion

The fundamental mapping system used for navigation, on land and sea, are structured in respect to the longitude and latitude coordinates. The early navigators used this system for the purpose of defining their positions while sailing across the open sea from a seaport to another (Constable, A.R. & Facey, W., 2013). According to Sezgin, the determination of latitude already witnessed achievements before the works made by the two *mu'allims* (Sezgin, 2007). Based on *Kitab al-Muhit*, the determination of the longitude, for instance, was employed by the Arab geographers since the eighth century. Their works also reveal that they held knowledge of the zero meridian, which was reflected on coordinate tables and maps (Sezgin, 2007). A possible data to draw such maps, according to Sezgin, was handed down to us by Sulaimān al-Mahrī (Sezgin, 2007). Furthermore, the work of Ibn Māğid occupied several latitutindal and longitudinal coordinates of islands calculated from the western prime meridian (or the Equator) which display the level of mathematical and astronomical knowledge the navigators possessed when sailing. According to Sezgin, this knowledge witnessed a discussion in *al-Minhāğ,* which dealt with the record of the progress and the measurements made on the distances covered in the Indian Ocean (Sezgin, 2004). Detailed works enabled the scholar W. Tomaschek to draw 15 maps based on the chapters and researched elements provided in their treatises, 53 other indications of latitude composed by Weiber on the Arabian Peninsula, and the attempt made by Grosset- Grange to draft the coastlines of the Indian Ocean among the neighboring seas (Sezgin, 2007). The data to draw such maps was made possible by knowledge handed down to us by Sulaimān al-Mahrī (Sezgin, 2007). It is further stated that Ibn Māğid mentioned in his *Kitab al-Fawa'id* the island *Guzur as- Sa'ādat* (the Canary Isles) as the point where the longitudinal degree starts. A regulative and a systematic work, which according to Sezgin, may prove the existence of a world map sectioning the Oikoumene into to four sections (Sezgin, 2007). An approach to this was also made by Sulaimān in his works. Similarly, according to Ptolemy's *Geography*, the prime meridian passes through the Canary Isles. Moreover, the limits of the inhabited world described in *Kitab al-Muhit* extend from the northern to the southern tropics in latitude, and from the east coast of Africa to Korea in longitude. The position of the seafarers operating in the Indian Ocean made them direct their observations towards stars in the lower latitudes, apart from the Pole Star (Sezgin, 2007).

The approach given by the Portuguese about charts and copious nautical instructions the mariners obtained in the 15th century was dealt with it in their works. According to Sezgin, it also shows that the discussion over the instruments and data used during that period covering routes between Lat. 4°24'N and Lat. 5°21'S was not necessarily due to the fact that Arabic nautical literature should have been accustomed to by the seafarers of the Indian Ocean (Sezgin, 2007). this is a discussion that formed a conclusion over the possessions of these data and graduated maps being composed from earlier generations collected and originated by the last two navigators and were questioned and later corrected (Aleem, 1973). It was illustrated by H. Grosset-Grange that al-Mahrī and Ibn Māğid did not sail to Madagascar nor had a direct knowledge over any other locations below south 5° latitude North (Sezgin, 2007). Therefore, one may confirm the advance made by their ancestors in the open seas, such as degrees of latitude, in some part of the ocean and specific to certain cases such as coastlines and shorter routes. These values, however, were objected to based on the method in which the navigators had perfected or attained, whether or not they had any possession of any instruments. A later question sparked some debate, which later shaped the position and discussion made by many authors, some of which followed an erroneous depiction relying completely on a wrong translation of few fractions. These claims were strongly opposed by Sezgin, such as the case of W. Tomaschek and those of Tibbetts (Sezgin, 2007). The former claimed that the navigators did not assert any usage of the astrolabe nor the quadrant in 90˚, the latter instrument was clearly mentioned by Sulaimān here:

> And for those who want to attain the validation of the zām between rhumbs easily shall do it with Rubʿ al-mujaiyab (al-Mahri, 1526-1575).

According to Tibbetts, they did not inquire into the knowledge over the meridian or attain latitude by means of measurements adopted from the position of the sun. Yet, the usage of the compass among seafarers in the Indian Ocean has been supported, objected to by the statement of Nicolas di Conti which declared that the Arabs did not use the compass at his time.

Six volumes were intended to be composed by Gabriel Ferrand, titled *Instructions Nautiques et Routiers Arabes et Portugais de XVe et XVIe*, three of which made it to printed form, whereas the rest of the proposed volumes were not made available and did not fulfill the original goal, which was to offer a complete translation concerning the works of Sulaimān al-Mahrī among some sections from the works of his predecessor, Ibn Māğid. Upon the contributions made by Ferrand and in order to accomplish his main aim, the objectivity and dedication of this thesis is to perform and address a rather genuine study over the works of the main author of this work, Sulaimān al-Mahrī. Having Tibbetts translating the main work of Aḥmad ibn Māğid entitled *Kitāb al-Fawā'id*, the study, and translation of these systematic books has been left incomplete to those who have no command of the main language of these treatises. However, more important, is what these works have to bring to the future research made over these two navigators, especially due to the shortage accessibility of the books they have based on their works or used as a handbook when steering.

Parallel to the work of Ibn Māğid's *Kitāb al-Fawā'id*, the treatise *al-'Umda* in particular, among other works composed by Sulaimān, stood out against the rest and emerged as an easily readable book which is considered the most concise work among the books we have at our disposal, a work that attracts scholars such as Ferrand, Princep, De Saussure, and Sezgin. *Qiyās* measurement, for instance, which serves as a method to measure the stellar altitude, was considered as one of the most substantial navigational techniques on sailing. It is a technique that was dealt with in al-Mahrī's *al- 'Umda*, covering all the coasts and ports of the Indian Ocean and stressing the crucial stars for steering and pioneering to provide accurate determination, unlike any other work. He also avoided losing himself in theory as his predecessor Ibn Mağid did. Al-Mahrī's works offer a great deal of information for a cartographical work, which later reflected on *al-Muḥīt*, a work based on *al-'Umda*, *Tuḥfat al-fuḥūl*, and *al-Minhāğ*. The attributions to cartography helped the scholars draw a cartographical image of the coastal lines and islands of the Indian Ocean (Sezgin, 2007). In *al-'Umda*, the author also approached the inclination or the modification of bearing while steering, implemented due to the strength or weakness of the northern winds, known by the term *al-Takkiyya*. *Al-'Umda* offers a list of these position accompanied by a warning over this process in his last chapter.

The importance of the al-Mahrī's *al-'Umda* and his other works definitely needs to be revisited and calls for further studies. I am in agreement with Sezgin and other scholars that a navigational chart can be deduced from the works of al-Mahrī, which will be the focus of my next study.

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