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# *KAMAL*, AN INSTRUMENT OF CELESTIAL NAVIGATION IN THE INDIAN OCEAN, AS DECRIBED BY OTTOMAN MARINERS PIRI REIS AND SEYDI ALI REIS*

*Gaye Danışan Polat***

*Kamal* (كمال)[1] is a traditional nautical instrument that was commonly used both by seamen in the Indian Ocean to determine the latitude, and by travelers crossing the deserts. It has been suggested that this instrument has been employed since the 15th century: Ibn Majid (d. after 1500) and Sulaiman al-Mahri (d. 1511), mariners sailing in the Indian Ocean, used it on their ships and referred to it in their texts. Chinese books on seafaring also refer to this instrument as from the 16th century on. Although the scope of the cultural exchanges between Indian and Chinese navigators has not been elucidated, plausibly it was the Chinese navigators who first learned about *kamal* from their Indian peers.[2] Likewise, Portuguese navigators learned about the instrument from Indian navigators.[3]

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* This paper is the enlarged version of the chapter on *kamal* from the author's Ph.D. thesis titled *16. Yüzyılda Osmanlılarda Deniz Astronomisi ve Astronomi Aletleri* (Nautical Astronomy and Astronomical Instruments of the Ottomans in the 16th Century), Istanbul, Istanbul University, 2016.

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1 *Kamal* literally means 'perfection' or 'guide'. The other term used to denominate *kamal* was *al-khashaba* (wooden plate in Arabic, pl. *al-khashabat*). *Kamal* was known as *Tavoleta da India* (Indian little wooden plates) by the Portuguese from the end of 15 th century on. There is some discussion about the misuse of the term *kamal* in the writings related to this nautical device. Moreover, *kamal* was not a term used among navigators. For details see S. Q. Fatimi, "History of the development of the Kamal," *Tradition and Archaeology: Early Maritime Contacts in the Indian Ocean, Proceedings of the International Seminar Techno-Archaeological Perspectives of Seafaring in Indian Ocean 4th cent. B.C.–15th cent. A.D.*, New Delhi, February 28-March 4, 1994, pp.283-292; Gerald Randall Tibbetts, *Arab Navigation in the Indian Ocean before the Coming of the Portuguese: Being a Translation of Kitāb al-fawāid fī usūl al-bahr wa'l-qawā'id of Ahmad b. Mājid al-Najdī,* Royal Asiatic Society of Great Britain and Ireland, 1971, p.317; E. G. Ravenstein, *Martin Behaim: His Life and his Globe*, London, 1908, pp. 16-17; Abdul Sheriff, "Navigational methods in the Indian Ocean," *Ships and the Development of Maritime Technology on the Indian Ocean*, vol.II, eds. Ruth Barnes, David Parkin, Abingdon, Oxon, Routledge, 2002, p. 219.

2 D. A. King, "Astronomy for landlubbers and navigators: The case of Islamic middle ages," *Revista da Universidade de Coimbra,* vol. XXXII, 1985, p.215. Tibbetts, *op.cit.*, p. 215.

3 For more detail see. E. G. Ravenstein, *op.cit.*, pp. 16-17; K. M. Mathew, *History of the Portuguese Navigation in India,* New Delhi, Mittal Publications, 1988, p. 17; Richard A. Paselk, "Medieval Tools of Navigation: An Overview," *The Art, Science, and Technology of Medieval Travel,* eds. Robert Odell Bork, Andrea Kann, Aldershot, England; Burlington, VT, Ashgate, 2008, p. 178; Bartolomeo Crescenzio, *Nautica Mediterranea,* Roma, Bonfadino, 1607, p. 455; Eva Germaine Rimington Taylor, *The Haven-Finding Art: A History of Navigation from Odysseus to Captain Cook,* London, Hollis and Carter for the Institute of Navigation, 1971, p. 129.

Studies on the *kamal,* which are mostly based on Arabic and European literary sources, describe two versions of the instrument. The earliest version of the *kamal* consisted of wooden rectangular plates of different sizes with a rope passing through their middle. The number of wooden plates corresponded to different geographical regions.[4] The second and more advanced version of the instrument consisted of a single board and a knotted rope passing through its middle.

The 16th century Ottoman sources, namely Piri Reis's *Kitab-ı Bahriye* (The Book of Seafaring, 1526)[5] and Seydi Ali Reis's *Kitabü'l-Muhit* (The Book of the Ocean, 1554) provide additional information both about the construction and the utilization of this instrument. By focusing on these descriptions, this paper aims to reveal the physical characteristics of the instrument.

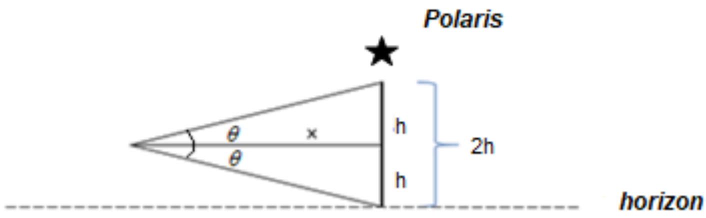


Fig. 1. Measuring the altitude of the Pole Star by means of the *kamal*.
(Drawing by Gaye Danışan Polat)

### Technical details about *Kamal*

The *kamal* enabled sailors to find a specified latitude by measuring the altitude of the Pole Star. The operating principles of the two above-mentioned versions of *kamal* are similar, and based on simple geometry. If a sailor wishes to determine the altitude of the Pole Star by using *kamal* with one wooden plate and a rope, he has to proceed in the following way: 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 $2\theta$. Because the rope passes through the middle of the board, the length of the board is divided 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

4 Fatimi, *op.cit.,* p.289.

5 The first version of *Kitab-ı Bahriye* was completed in 1521. A reviewed and updated version, partly written in verse, was presented to Sultan Sulaiman I in 1526. This second version is used in the present study.

board is $x$.[6] Thus, when operating with the instrument, an isosceles triangle is formed (See Fig.1). Hence, the following equation is obtained:[7] $x=h \cot \theta$

The technique of finding the latitude by measuring the altitude of the Pole Star was widespread among mariners sailing in the Indian Ocean. Moreover, in 15th and 16th centuries, Indian Ocean mariners used two units of length, namely *tirfa* and *zam* to measure distances on sea.[8] These units were related with another unit, the *isba'* (finger, fingerbreadth) used to measure the altitude of the Pole Star. A change (increase or decrease) of one *isba'* in the altitude of the Pole Star corresponded to 8 *zams*. Besides, the sailors usually knew about the nautical distances corresponding to the fingerbreadths for key locations / ports from north to south.[9] Thus by measuring the altitude of the Pole Star in *isba*' the sailor could find the distance he has sailed in *zam*. This technique was equivalent to the one used in the Mediterranean and the Atlantic Ocean, by which the sailor measured the altitude of the Sun at noon. However, measuring the altitude of the Pole Star was more convenient than measuring Sun's altitude, because the altitude of the Pole Star above the horizon is equivalent to sailor's/observer's geographical latitude. On the other hand, the Sun's noontime altitude varied from day to day throughout the year obliging the sailor/observer to use tables which give the precise altitude for a particular day. There is however a disadvantage of *kamal*: it is only reliable for measuring small angles, and more the angle increases, more the instrument becomes impractical. Besides, because the Pole Star becomes closer to the horizon in tropical latitudes, the *kamal* can only be used between the latitudes 20˚N and 40˚N.[10]

### *Kamal* in Piri Reis's *Kitab-ı Bahriye*

Piri Reis (d.1554) referred to the *kamal* in two of the sections of *Kitab-ı Bahriye.* Both of these sections were devoted to navigation in the Indian Ocean.

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6 Seydi Ali Reis expresses clearly that the sailor should hook the knot between his teeth. For details see Seydi Ali Reis, *Kitabü'l-Muhit,* Süleymaniye Library, Nuruosmaniye MS 2948, fols. 8b-9a; J. M. M. Pereira, *The Stellar Compass and the Kamal: An Interpretation of its Practical Use,* Lisboa, Academia de Marinha, 2003, pp.31-32.

7 Taylor, *op.cit.,* pp. 128-129.

8 For *tirfa* and *zam* see Henri Grosset-Grange, "Arabic nautical science," *Encyclopedia of the History of Arabic Science,* ed. Roshdi Rashed, London, Routledge, 1996, Vol.1, pp. 214-221; Sean McGrail, *Boats of the World: From the Stone Age to Medieval Times*, Oxford University Press, 2009, p. 84; Gaye Danışan Polat, *op.cit*, pp. 194-197.

9 Seydi Ali Reis gives the distances (in the unit of length *zam*) between the places / ports that correspond to the altitudes of the Pole Star, ranging from 11 to 1 *isba*'. Seydi Ali Reis, *op.cit.*, fols. 46a-46b.

10 For detailed information about *kamal* see J. M. M. Pereira, *op.cit.*, pp. 10-11, 21-32; D. Fisher, *Latitude Hooks and Azimuth Rings: How to Build and Use 18 Traditional Navigational Tools,* International Marine, 1995, pp. 17-21; Tibbetts, *op. cit.*, p.331.

While he only mentioned the terms *qiyas (kıyas)* and *Indian qiyas* (*Hint kıyası*) in the first section,[11] he provided a description of *qiyas* in the other section. The description makes clear that the term *qiyas* denotes an instrument.[12] Piri Reis named the pieces of instrument *tahta* (wood in Turkish), instead of *khashaba*. He indicated that this instrument consisted of 12 wooden plates of different sizes, and that the first plate was equal to 1 *arsh* (*erş, ereş*, *araş*), that is the length of the forearm.[13] Each wooden plate was as thick as the back of a sword (*kılıç sırtı*) and its width was equal to a sword's width.[14] All wooden plates were of different sizes (lengths) corresponding to different latitudes. As reported by Piri Reis, a ship can travel about 200 nautical miles by using only one wooden plate. After having covered this distance the navigator has to switch to another plate of different size to continue navigation. Piri Reis also noted that the longest wooden plate was used around Yemen, and the shortest in the Indian Ocean, because the altitude of the Polaris was higher in Yemen, and lower in Southern India. By virtue of this instrument the masters (*üstadlar*) used to determine the latitude between Yemen and the Indian Ocean and set their course.[15] Piri Reis's statements reveal that the upper limit latitude of the geographical area in which the instrument could be used was Yemen. He does not, however, mention the lower boundary of the Indian Ocean for the feasibility the *kamal*.

According to Piri Reis, navigators often practice this method when navigating in the Indian Ocean: The pilot/navigator (*muallim*) first takes one of the plates and directs it to the north. The lower end of the plate is pointed to the horizon and the upper end to the Pole Star. If this wooden plate does not entirely fit in the apparent distance between the Pole Star and the horizon, he should try another plate which fits the mentioned distance. Piri Reis also noted that any

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11 Piri Reis, *Kitab-ı Bahriye*, transliterated by Ahmet Demir, Ankara, T.C. Başbakanlık Denizcilik Müsteşarlığı, 2002, p.58.

12 The term *qiyas* has long history dating from the pre-Islamic and early Islamic period (mid-7th century) to the 15th and 16th centuries, the time of the Indian Ocean sailors such as Ibn Majid (d. after 1500) and Sulaiman al-Mahri (d. 1511). Fatimi suggests that Ibn Majid used excessively the term *kamal*. However, Ibn Majid also used *qiyas* in addition to *kamal.* Ibn Majid and Sulaiman al-Mahri both used *qiyas* in their treatises with the following meanings: stellar measurement as a verbal noun; the plural of the word *qaws* for a measurement instrument. From here, Fatimi deduced that the instrument had a series of plates. However, this deduction conflicts with the suggestion of Tibbetts who translated and commented the treatise of Ibn Majid, the *Kitāb al-fawā'id fī usūl al-bahr wa-l-qawā'id* (The Book of Benefits in the Principles of Navigation). He described the *qiyas (or qiyasat)* as the science of taking latitude by measuring stellar altitudes. For detailed information see Fatimi, *op.cit.*, p. 286; 289 and Tibbetts, *op.cit.*, p. 540.

13 Piri Reis's definition clearly indicates a forearm: The *Kitab-ı Bahriye* reads "bir erşdir … bilek eğinden dirsek eğine" [it is one *arsh* … from wrist to elbow] (Piri Reis, *op.cit.*, p. 56). According to W. Hinz this unit was not common in Iran and would measure about 64 cm. Walther Hinz, *Islamische Masse und Gewichte Umgerechnet ins metrische System*, Leiden, E. J. Brill, 1955, p. 54.

14 Piri Reis, *op.cit.,* p. 56.

15 *Ibid*., pp. 56-58.

navigator wishing to sail in the Indian Ocean should master this method, or refrain from sailing in oceans.[16] Piri Reis also pointed out that the instrument is not suitable for use in the equatorial region, and that, instead, the pilot should make use of an astrolabe to take altitudes (*irtifa almak*). Piri Reis did not mention a particular celestial object to observe for this purpose. As the altitude of the Pole Star is too low to be observed in the equatorial region, this celestial body should be the Sun. It should be noted that if the Sun is chosen to determine the local latitude, the observer needs to know Sun's declination, which he can find by means of an astrolabe.[17]

### The two types of *kamal* in Seydi Ali Reis's *Kitabü'l-Muhit*

Information provided by Seydi Ali Reis (d. 1562) on *kamal* is more detailed than that given by Piri Reis. In *Kitabü'l-Muhit* (The Book of the Ocean, 1554), Seydi Ali Reis describes two different types of *kamal.* The first one is a device with nine plates and a rope, the other is made up of a single plate and a rope with knots.

*The kamal with nine plates*

In *Kitabü'l-Muhit,* Seydi Ali Reis introduced a nautical instrument that Indian navigators use to perform *qiyas*. He simply called this device *alet* (the instrument) and he did not use the term *kamal.* He named the wooden plate *levh*[18] and also used its plural form *elvah*. Like Piri Reis, he avoided to use the term *khashaba* or its plural *khashabat.* This *alet* is a device which consists of 9 *elvah* (plates) of different sizes and a *hayt* (rope). The sizes of the plates are given in *isba'* (finger, fingerbreadth). Each *levh* (plate) was different in size: the smallest being 4 *isba*' in length and 3 *isba*' in width, and the largest plate being 12 *isba'* in length. Seydi Ali Reis does not give information about the width of the largest wooden plate. He does, however, indicate that surveyors took 360° as equal to 224 *isba',* and navigators as equal to 210 *isba*'. A navigator himself, Seydi Ali

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16 *Ibid.*, pp.56-57.

17 Piri Reis also mentioned that the sailors used the astrolabe in navigation in the *Bahr-i Azam* (the Great Sea; sometimes it was used instead of *al-Bahr al-Muhit* which means the Encircling or Surrounding Sea, i.e. Indian Ocean). Likewise, Seydi Ali Reis noted in his *Kitabü'l-Muhit* (1554), a guidebook for Ottoman navigators aspiring to sail the Indian Ocean, that apart from *kamal*, astrolabes and sine quadrants could be used to measure the altitude of the Sun. On the contrary, Ibn Macid's *Kitab al-Fawaid* advises navigators to use the sine quadrant besides *kamal*. However, David A. King suggests that Indian Ocean navigators only used the *kamal* and a compass for the same purpose. For detailed information see D. A. King, "Astronomy for landlubbers and navigators: The case of Islamic middle ages," *Revista da Universidade de Coimbra,* Vol.XXXII, 1985, p.215. Tibbetts, *op.cit.*, p.303. Piri Reis, *op.cit*. p. 42, 58; Seydi Ali Reis, *op.cit.,* fol.45a.

18 *Levh* is a plate on which one can write or draw. Ferit Devellioğlu, *Osmanlıca-Türkçe Ansiklopedik Lûgat,* ed. Aydın Sami Güneyçal, Ankara, Aydın Kitabevi, 2009, p. 549.

Reis also opted for 210 *isba'*. Thus, 1 *isba'* corresponds to 1° 42′51′′.[19] Accordingly, the length (12 *isba'*) of the largest wooden plate, corresponds to about 20° 34′ 12′′, and the length (4 *isba'*) of the smallest wooden plate, corresponds to about 6° 51′ 24′′. Besides, the width (3 *isba'*) of the smallest plate, corresponds to about 5° 8′ 31′′.[20]

Seydi Ali Reis indicated that, when all wooden plates were piled up, there was a difference of 'one finger' between each successive plate.[21] If this difference is applied to the plates of 4 to 12 fingers, the number of wooden plates come up to 9 *levh.* This explains why *kamal* consists of a set of 9 wooden plates. On the other hand, Seydi Ali Reis gave some clues about the construction of the instrument. A rope (*hayt)* runs through a hole made in the middle of the plates (*elvah*). The sailor holds the plates (*elvah*) against the horizon with an outstretched arm and measures the altitude of the *Cüddey* (the Pole Star). At its highest point, the altitude of *Cüddey* is equivalent to 12 fingers. Therefore the navigator first uses a plate of 12 *isba'* respectively. When cruising from north to south, he then switches to the plates of 11, 10, 9, 8 *isba'*. Switching to a smaller plate means that the ship moved to a lower latitude – each plate representing a difference of latitude of 1 finger. The operation is completed when the smallest plate, the plate of 4 fingers long, is used. Consequently, the system of 9 plates helps the navigator to reach to the latitudes of the 9 localities by measuring the altitude of the Pole Star.[22]

Seydi Ali Reis, also pointed out that the width of a finger differed from one individual to another, and thus the size of the instrument varied according to the maker's fingerbreadth. Thus the navigator should calibrate the instrument by comparing the width of 4 fingers with the distance between *Aiyuk* (*α* Aur) and *Dhubban el-Aiyuk* (*β* Aur).[23] Because when these stars reach *Cebhe (al-Jabha)*[24] which is the 10th house of lunar mansions, the angular distance between these stars becomes the standard which is exactly four *isba'*. Moreover, four *isba'* is

[19] Tibbetts, *op.cit.*, p. 70; Fuat Sezgin, *İslam'da Bilim ve Teknik III: Coğrafya, Denizcilik, Geometri, Saatler, Optik*, Ankara, Kültür ve *Turizm* Bakanlığı, TÜBA, 2007, p.39.

[20] Seydi Ali Reis, *op.cit.*, fol.7b.

[21] *Ibid.*

[22] *Ibid.*, fol. 7b-8a.

[23] *Ibid.*, 7b.

[24] The four bright stars of the constellation Leo are altogether called *Cebhe*. These stars are α (Regulus), γ (Algieba), ξ and η stars. Yavuz Unat, "Eski astronomi metinlerinde karşılaşılan astronomi terimlerine ilişkin bir sözlük denemesi," *AÜ Osmanlı Tarihi Araştırma ve Uygulama Merkezi Dergisi OTAM,* No. 11, Ankara, 2000, p. 644; Tibbetts, *op.cit.,* p. 94-95.

called *dhubban* which is an unit itself, and because of that, the star is named as *Dhubban al-Aiyuk*.

*The kamal with a single plate and a rope with knots*

Seydi Ali Reis also described a second type of *kamal*, a device consisting of a single wooden plate (*levh)* and a rope (*hayt)* which goes through the hole made on the middle of that plate, and bearing 7 knots. To name this instrument, Seydi Ali Reis used the term *gez,* a unit of linear measurement. *Gez* was a unit of length which was mainly used in Iran. Although it's length could vary according to regions and times, it was a measure similar to *arşın* (Turkish) and *zira'* (Arabic).[25] Fatimi suggested that *gez* was a *yardstick*,[26] but this term also meant a measuring rope (*ölçü ipi*).[27] The term *gez* was previously mentioned by Sulaiman al-Mahri. By using *gez* as a unit, it was possible to standardise the width and the length of 'the instrument', the *kamal*.

Seydi Ali Reis indicated that 1 *gez* equalled 3-4 *karış* (hand span). *Karış* equals 15 to 20 cms. If we admit that 1 *gez* equals 3 *karış,* the *gez* will measure between 45-60 cms. Likewise, if we accept that 1 *gez* equals 4 *karış,* the *gez* will measure between 60-80 cms. This is important, because Seydi Ali Reis gives the length of the plate in *gez*: the length of the plate equals 1/5 *gez* while the width of the plate equals half of length of the plate. Regarding the given data (Table 1), the probable lengths and widths of the plate will be as follows:

**Table 1.** Sizes of the plate (*levh*) of *kamal*, a device with a single plate and a rope with knots as recorded in Seydi Ali Reis's *Kitabü'l-Muhit* (Süleymaniye Library, Nuruosmaniye MS 2948, fol. 8a.)

| | | **1 *gez* = 3 *karış*** | | **1 *gez* = 4 *karış*** | |
|---|---|---|---|---|---|
| | | 1 *karış*= 15cm →15x3=45cm | 1 *karış* = 20cm →20x3=60cm | 1 *karış*= 15cm →15x4=60cm | 1 *karış*= 20cm →20x4=80cm |
| Plate's length | 1/5 *gez* | 9 cm | 12 cm | 12 cm | 16 cm |
| Plate's width | 1/10 *gez* | 4.5 cm | 6 cm | 6 cm | 8 cm |

25 Walther Hinz, *op.cit.*, p. 62.

26 Fatimi, *op.cit.,* p. 290.

27 Mehmet Zeki Pakalın, *Osmanlı Tarih Deyimleri ve Terimleri Sözlüğü*, vol.1, İstanbul, Milli Eğitim Bakanlığı 1993, p.664; In the 17th century, 1 *gez-i şâhi* was equal to 94.745 cm according to Chardin, and 37.5 inches = 95.15 cm according to J. Fryer. The length of the *gez* used by surveyors was shorter. In surveying, g*ez* meant "iki başlı mühürlü urgan" [a rope sealed at two ends] or "iki başı damgalı zincir" [a chain sealed at two ends]. The exact measure of *gez* in the 16 th and 17 th centuries is not known. In the 19th century, 1 *gez* was equal to 60.74 cm although the general opinion was that it was 66 cm. See M. Şinasi Acar, *Osmanlı'da Günlük Yaşam Nesneleri,* 2nd ed., Istanbul, Yapı Endüstri Merkezi, 2015, p.42.

Seydi Ali Reis relates the following instructions for tying the knots on the rope passing through the middle of the plate: First of all divide the *gez* into 12. By starting to count from the plate, tie a knot on the 6th point. This knot represents the beginning of the course, and it is equal to 12 *isba*'(finger breadth). This is the closest knot to the plate. Then the subsequent knots are tied. To find the place corresponding to 11 *isba*', divide the *gez* into 11, and tie a knot on the 6th point. This is the second knot. The operation of tying knots on the rope goes on until the 7th knot is tied. This last knot corresponds to 6 *isba*' (see Table 2).

**Table 2**. Distances between the knots of the second type of *kamal*, a device with a single plate and a rope with knots, recorded in Seydi Ali Reis's *Kitabü'l-Muhit* (Süleymaniye Library, Nuruosmaniye MS 2948, fols. 8b-9a)
-The knot nr.1 is the closest one to the plate-

| | | **1 *gez*=3 *karış*** | | **1 *gez*=4 *karış*** | |
|---|---|---|---|---|---|
| **Knots** | **Seydi Ali Reis's instructions** | 1*karış*=15cm<br>15x3=**45**cm | 1*karış*=20cm<br>20x3=**60**cm | 1*karış*=15cm<br>15x4=**60**cm | 1*karış*=20cm<br>20x4=**80**cm |
| 1 | Divide the *gez* into 12, knot the 6th point on the rope. | 45/12=3.75cm<br>3.75x6=**22.5**cm | 60/12=5cm<br>5x6=**30**cm | 60/12=5cm<br>5X6=**30**cm | 80/12=6.6cm<br>6.6cmx6=**39.99**cm |
| 2 | Divide the *gez* into 11, knot the 6th point on the rope. | 45/11=4.09cm<br>4.09x6=**24.54**cm | 60/11=5.45cm<br>5.45x6=**32.7**cm | 60/11=5.45cm<br>5.45x6=**32.7**cm | 80/11=7.27cm<br>7.27x6=**43.62**cm |
| 3 | Divide the gez into 10, knot the 6th point on the rope. | 45/10=4.5cm<br>4.5x6=**27**cm | 60/10=6cm<br>6x6=**36**cm | 60/10=6cm<br>6x6=**36**cm | 80/10=8cm<br>8x6=**48**cm |
| 4 | Divide the *gez* into 9, knot the 6th point on the rope. | 45/9=5cm<br>5x6=**30**cm | 60/9=6.66cm<br>6.66x6=**39.99**cm | 60/9=6.66cm<br>6.66x6=**39.99cm** | 80/9=8.88cm<br>8.88x6=**53.28**cm |
| 5 | Divide the *gez* into 8, knot the 6th point on the rope. | 45/8=5.62cm<br>5.62x6=**33.75**cm | 60/8=7.5cm<br>7.5x6=**45**cm | 60/8=7.5cm<br>7.5x6=**45**cm | 80/8=10cm<br>10x6=**60**cm |
| 6 | Divide the gez into 7, knot the 6th point on the rope. | 45/7=6.42cm<br>6.42x6=**38.52**cm | 60/7=8.57cm<br>8.57x6=**51.42**cm | 60/7=8.57cm<br>8.57x6=**51.42**cm | 80/7=11.42cm<br>11.42x6=**68.52**cm |
| 7 | Divide *gez* into 7, knot the end of the left-out part | 45/7=6.42cm<br>6.42x6=38.52cm+<br>6.42cm=**44.94**cm | 60/7=8.57cm<br>8.57x6=51.42cm+<br>8.57cm=**59.99**cm | 60/7=8.57cm<br>8.57x6=51.42cm+<br>8.57cm=**59.99**cm | 80/7=11.42cm<br>11.4x6=68.52cm+<br>11.42cm=**79.94**cm |

According to the information provided by Seydi Ali Reis, the two devices had different limits. The limit of the first device (with 9 plates) ranged from 4 to 12 *isba*‘, while that of the second (with a single plate and a rope with knots) ranged from 6 to 12 *isba*‘. These limits (4 and 6 *isba*‘ respectively) point to different distances between the observer and the equator. The reason why Seydi Ali Reis gave different limits for these two devices may be his reliance on different sources, and his decision to use the information without alteration. A comparison of *Kitabü'l-Muhit* with the works of Ibn Majid and Sulaiman al-Mahri is needed, however, for finding out Seydi Ali's sources for the limits. We can only speculate that if Seydi Ali Reis gave a comprehensive explanation only for the limitation of the second type of device, this was because he believed in its precision. The descriptions of the instrument with a single plate and a rope with 7 knots is similar to the instrument with 18 knots, reconstructed by Congreve in the 19th century (Fig.2).

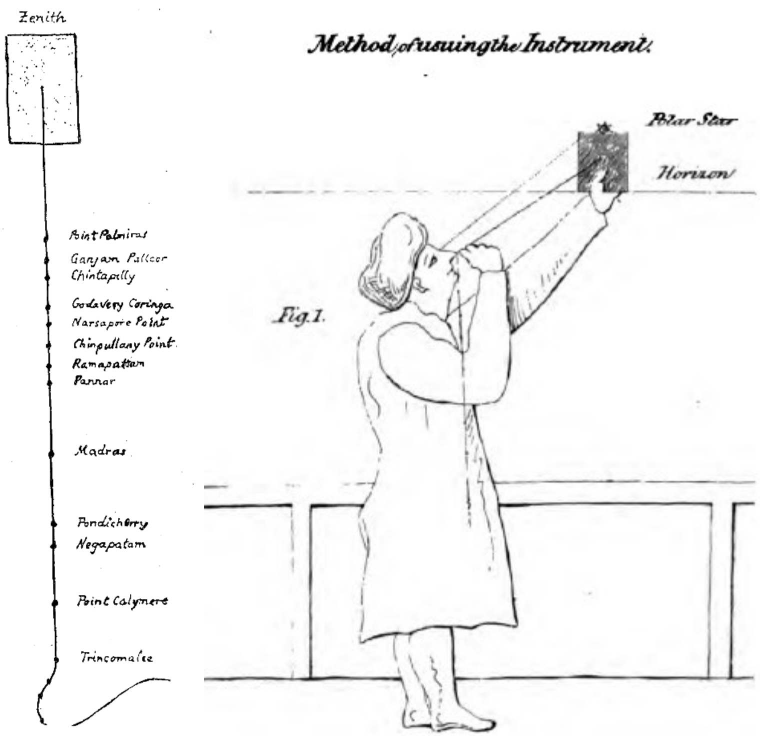


**Fig. 2** A drawing of *kamal*: The knots showing the important ports (on the left) from Point Palmiras to Trincomalee, and the method of using of instrument (on the right). H. Congreve, "A brief notice of some contrivances practised by the native mariners of the Coromandel Coast in navigating, sailing, and repairing their vessels," *The Madras Journal of Literature and Science,* vol. XVI, 1850, pp.103-104.

As the navigator had to organise his route before sailing, and because he usually knew the latitude of the ports he will be heading for, the knotting operation had to be done before sailing. The knots of the *kamal* allowed him to know his location on route.

Seydi Ali Reis gave the following instructions for using this instrument: first, the sailor should hold the plate (*levh*) with his left hand and hook the rope between his teeth at the first knot. Then, he should close his left eye, and move the plate along the rope until the upper edge touches the Pole Star. At that point, the altitude of the Pole Star over the horizon is equal to 12 *isba*‛. When sailing from north to south and each time he moves from a latitude to a lower one, the sailor needs to use another knot which point to the destination port. Holding the plate vertically or horizontally does not alter the information to be deduced. The navigator should only pay attention to the following: if the change in latitude of the vessel has reached 1 *isba*‛(fingerbreadth), and if the sailor has made the estimation by holding the plate vertically or horizontally, In the case the plate is held vertically, the altitude of the Pole Star will be 1 *isba*‛; in the case the plate is held horizontally, the altitude of the Pole Star will be ½ *isba*‛.[28]

Besides the Polaris, other stars such as *Farkadeyn* and *Na'ş* could be used for this operation. The operation with these stars is called the *kıyas-ı asli* (*al-qiyas al-asli,* literally the original measurement). Seydi Ali Reis also pointed out to the instrument's operational limits. The operation ends when the altitude of the Pole Star is equal to 5 *isba*‛ [about 8° 34′ 15′′], that is the observer is about 40 *zam*s or 570 miles to the equator. For Seydi Ali Reis, this is the limit of the operation for a particular instrument composed of a single plate and a rope with knots, and he did not advise to continue any further southwards.[29]

**Concluding remarks**

The analysis of the information given in Piri Reis's *Kitab-ı Bahriye* and Seydi Ali Reis's *Kitabü'l-Muhit* about the navigational instrument *kamal* yielded the following results:

Firstly, both Piri Reis and Seydi Ali Reis stated that Ottoman sailors who would sail in the Indian Ocean without a local pilot had to be knowledgeable in the *qiyas (or qiyasat)* which is the science of taking latitude by measuring stellar altitudes. Therefore, they introduced the *kamal,* an instrument used to practice the *qiyas.* Piri Reis used the term *qiyas* for the instrument, and the term *tahta* for its pieces. Seydi Ali Reis named *alet* the first instrument he described and which consisted of 9 wooden plates. He named *gez* (unit of linear measurement) the

28 Seydi Ali Reis, *op.cit.,* fol. 8b-9a.

29 *Ibid*., fol. 9a.

second type of device he described and which was made of a wooden plate and a rope with 7 knots. He often referred to *qiyas,* a term used for the technique of taking latitude by measuring stellar altitudes.

Secondly, both of these navigators mentioned the boundaries within which the *kamal* could be used. According to Piri Reis, the *kamal* was suitable for sailing between Yemen and the subcontinent, but he did not specify the boundaries of the region. Seydi Ali Reis gave two different limits for the two different types of *kamal* he described, being 4 and 6 *isba'*. Ottoman seamen were well aware that the *kamal* was less useful in the Mediterranean and they did not recommend it when sailing there. Seydi Ali Reis gave more detailed information for a device composed of one plate and the rope with knots, which could have been more popular in the years when Seydi Ali Reis sailed in the Indian Ocean. Whether he used the two devices he described in his *Kitabü'l-Muhit* when cruising the ocean, is still an open question. Seydi Ali Reis mentions his encounters and conversations with Indian Ocean sailors who could have given him specimens of both devices and demonstrated their use. Thus, written sources, such as the treatises of Ibn Majid and Sulaiman al-Mahri may not have been the only sources of Seydi Ali's knowledge.

Finally, the analysis of information provided by Seydi Ali Reis and Piri Reis shows that the former gave more detailed information about the types, structure, and use of the *kamal.* The reason may be that Seydi Ali Reis was more interested in nautical astronomy and astronomy.

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**Osmanlı denizcileri Piri Reis ve Seydi Ali Reis'in eserlerinde Hint Okyanusunda göksel seyirde kullanılan Kemal aleti**

*Kemal* (كمال) aleti, Hint Okyanusu'nda enlem tayini için denizcilerin kutup yıldızı ve sirkumpolar yıldızların ufuktan yüksekliğini ölçmek için kullanıldıkları bir çeşit taşınabilir astronomi aletidir. Aletin yapısı, tarihi ve Hint, Çin ve Portekiz denizcileri arasındaki kültürel alışveriş çerçevesindeki yeri hakkında birçok çalışma bulunmaktadır. Buna rağmen, araştırmacılar arasında aletin ismi, yapısı, üretimi ve kökeni hakkında kesin bir fikir birliği yoktur. Ayrıca yapılan araştırmaların çoğu Arap ve Avrupa kaynaklarına dayanmaktadır. Buna karşılık, 16. yüzyıl Osmanlı kaynaklarından Piri Reis'in *Kitab-ı Bahriye*'sinde ve Seydi

Ali Reis'in *Kitabü'l-Muhit*'in de *kemal* aletine yer verilmiştir. Bu çalışmanın amacı, bahsi geçen eserlerde yer alan *kemal* aleti ile ilgili bilgileri sunmaktır. Bu bilgiler, âletin fiziksel özelliklerini belirlememiz bakımından önemlidir.

**Anahtar sözcükler:** Kemal aleti, levh, kıyas, Piri Reis, Seydi Ali Reis, *Kitab-ı Bahriye*, *Kitabü'l-Muhit*, Osmanlı denizcileri.

## ***Kamal*, an instrument of celestial navigation in the Indian Ocean, as decribed by Ottoman mariners Piri Reis and Seydi Ali Reis**

*Kamal* (كمال) is a kind of portable astronomical instrument which was used by navigators to measure the altitude of the Polaris and the circumpolar stars to determine latitudes in the Indian Ocean. The *Kamal* and its role in the cultural exchange between Indian, Chinese and Portuguese navigators have been already studied, yet no consensus has been reached among researchers regarding its structure, construction, origin or even its name. Studies on *kamal* are mostly based on Arabic and European literary sources. The aim of this paper is to bring into fore the information given about the two different types of *kamal* in the 16$^{th}$ century Ottoman sources, namely Piri Reis's *Kitab-ı Bahriye* (The Book of Seafaring) and Seydi Ali Reis's *Kitabü'l-Muhit* (The Book of the Ocean). An analysis of the information they provided, will reveal the physical characteristics of these instruments.

**Key words:** Kamal, levh, qiyas, Piri Reis, Seydi Ali Reis, *Kitab-ı Bahriye*, *Kitabü'l Muhit*, Ottoman navigators.

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