9 · Qibla Charts, Qibla Maps, and Related Instruments

David A. King and Richard P. Lorch

Introduction

For close to fourteen hundred years, the obligation to pray and to perform various ritual acts in a sacred direction toward a central shrine has been of paramount importance to Muslims in their daily lives. Their concern to observe this sacred direction and the means they devised to determine it are unparalleled in the history of human civilization. A verse of the Qurʾān enjoins Muslims to face the sacred precincts of the Kaʿba in Mecca during their prayers: "Turn your face toward the Sacred Mosque, wherever you may be, turn your faces toward it."[1] Accordingly, for fourteen centuries mosques have been oriented so that the prayer wall faces the Kaʿba and the *miḥrāb* (prayer niche) indicates the qibla, or local direction of Mecca. But Islamic tradition further prescribes that certain acts such as burying the dead, reciting the Qurʾān, announcing the call to prayer, and ritual slaughtering of animals for food are also to be performed in the direction of Mecca. On the other hand, bodily functions are to be performed perpendicular to the direction of Mecca.[2]

It is this fundamental importance within Islam of the concept of sacred direction (qibla in Arabic[3] and all other languages of the Islamic world) in ritual, law, and religion, applying wherever the believer was, that gave rise to the charts, maps, instruments, and related cartographic methods described in this chapter. These sources clearly reflect the dual nature of science in Islam.[4] On the one hand there was "folk science," ultimately derived from the astronomical knowledge of the Arabs before Islam, which was devoid of theory and innocent of any calculation. On the other hand there was "mathematical science," derived mainly from Greek sources and involving both theory and computation. The former was advocated by legal scholars and widely practiced over the centuries. The latter was practiced by a select few.

In the first tradition, there developed the notion of a sacred geography in which the world was divided into sections around the Kaʿba and the qibla in each section was determined by the procedures of folk astronomy. In the second, procedures were developed for finding the qibla in any locality by means of geometric construction or the application of trigonometric formulas. Of prime importance, of course, were the coordinates on which such calculations were based.[5] We now consider the charts and maps associated with these two traditions (King), and then mention other graphic methods and instruments for finding the qibla (Lorch).

Qibla Charts Centered on the Kaʿba

The number and variety of texts in which this sacred, Kaʿba-focused geography is represented indicate that it was widely known from the tenth century A.D. onward.[6] Sources include treatises on folk astronomy, treatises dealing with mathematical astronomy (especially annual almanacs), treatises on geography, treatises on cosmography, encyclopedias, historical texts, and, no less important, texts dealing with the sacred law. Sometimes the methods are described in words alone, sometimes the text is clarified with diagrams. All together, more than

1. Qurʾān 2:144.

2. On the legal obligation to observe the sacred direction, see Arnet Jan Wensinck, "Ḳibla: Ritual and Legal Aspects," in *The Encyclopaedia of Islam*, new ed. (Leiden: E. J. Brill, 1960–), 5:82–83. For more information on the sacred direction in medieval Islam, see David A. King's forthcoming monograph titled *The World about the Kaʿba: A Study of the Sacred Direction in Medieval Islam*, to be published by Islamic Art Publications.

3. The term qibla and the associated verb *istaqbala*, "standing in the qibla," appear to derive from the name of the east wind, the *qabūl*. These terms correspond to the situation where one is standing with the north wind (*al-shamāl*) on one's left (*shamāl*) and Yemen on one's right (*yamīn*); see David A. King, "Makka: As the Centre of the World," in *Encyclopaedia of Islam*, new ed., 6:180–87, esp. 181; see also idem, "Astronomical Alignments in Medieval Islamic Religious Architecture," *Annals of the New York Academy of Sciences* 385 (1982): 303–12, esp. 307–9, and idem, "Architecture and Astronomy: The Ventilators of Medieval Cairo and Their Secrets," *Journal of the American Oriental Society* 104 (1984): 97–133.

4. David A. King, "The Sacred Direction in Islam: A Study of the Interaction of Religion and Science in the Middle Ages," *Interdisciplinary Science Reviews* 10 (1985): 315–28.

5. Edward S. Kennedy and Mary Helen Kennedy, *Geographical Coordinates of Localities from Islamic Sources* (Frankfurt: Institut für Geschichte der Arabisch-Islamischen Wissenschaften, 1987).

6. The material in this section is analyzed in detail in David A. King, "The Sacred Geography of Islam," *Islamic Art*, forthcoming; see also King, "Makka," 181 (note 3).

thirty different texts attesting to this tradition have been found, compiled between the ninth century and the eighteenth century. Of these, only five have been published; the rest are manuscripts. Many more such works must have been written that have not survived.

Despite the multiplicity of ways that Muslims have used over the centuries to ensure they were facing the Kaʿba, these sources allow us to make some generalizations. It is immediately clear from their contexts that the qibla lies at the heart of Islamic cultural and religious life. Although this concept has obvious parallels in medieval traditions of a world centered on Jerusalem, the Islamic treatment is more sophisticated than either the Jewish or the Christian. It was true that, as in the Judeo-Christian view of Jerusalem, Mecca was regarded as the center and navel of the world, but in early Islamic cosmography the entire inhabited world outside this central point came to be precisely and constantly related, through astronomical determinations, to Mecca and to the Kaʿba itself.

The Kaʿba is a cube-shaped monument in the heart of the city, formerly a pagan shrine of uncertain historical origin. It is a simple structure on a rectangular base, and its two axes indicate significant astronomical directions.[7] The first generation of Muslims who were familiar with the structure at first hand knew, as they stood before it, which astronomical direction they faced. Similarly, Muslims in any part of the world could know which wall of the Kaʿba they wanted to face and, when required, could turn to face the direction as if they were standing directly in front of that wall of the Kaʿba. This is the basic notion of "direction" underlying Islamic sacred geography. Remember that the definition of direction toward a distant point is to some extent arbitrary.

From the ninth century onward, various sections of the perimeter of the Kaʿba came to be associated with areas in the Muslim world.[8] In the time of the Prophet Muḥammad (d. 13/632) the four corners of the astronomically aligned base had already been named according to the geographical regions they faced, which the Meccans knew from their trading contacts: Syria, Iraq, Yemen, and "the West." In due course, architectural details were used to define subdivisions. Thus, while the four walls and four corners of the structure indicated a division of the world into four or eight sectors, giving rise to a number of four- and eight-sector schemes, features such as the waterspout on the northwestern wall and the door on the northeastern wall were used to demarcate smaller sectors. In this way the sacred geography of the inhabited parts of the earth comprised a variable number of sectors (*jihah* or *ḥadd*), all directly related to the Kaʿba. The twelfth-century Egyptian legal scholar Zayn (?) al-Dīn al-Dimyāṭī, author of the illustration in figure 9.3 below, summed it up thus: "The Kaʿba with respect to the inhabited parts of the world is like the center of a circle with respect to the circle. All regions face the Kaʿba, surrounding it as a circle surrounds its center, and each region faces a particular part of the Kaʿba."[9]

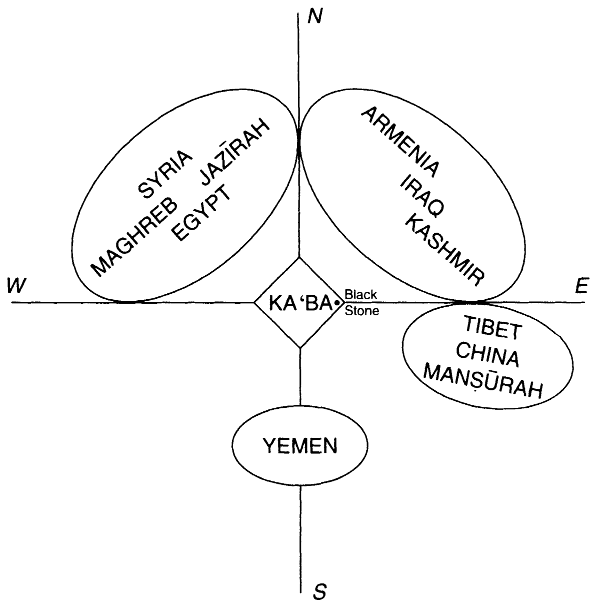


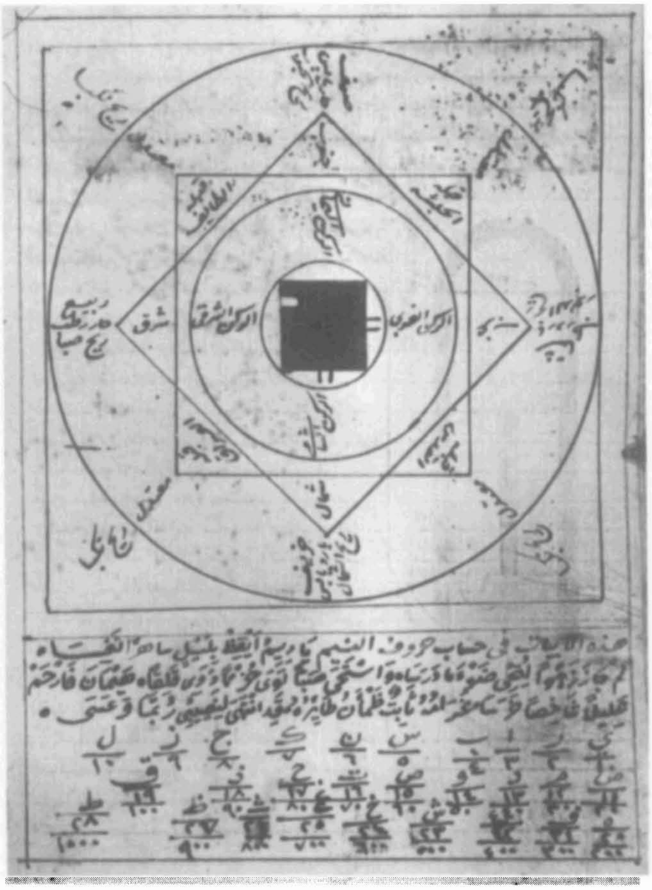
FIG. 9.1. RENDITION OF A SCHEME OF SACRED GEOGRAPHY. Described by Ibn Khurradādhbih and based on the edition of his text by Michael Jan de Goeje, *Kitâb al-masâlik wa'l-mamâlik (Liber viarum et regnorum)*, Bibliotheca Geographorum Arabicorum, vol. 6 (Leiden: E. J. Brill, 1889; reprinted 1967), 5.

The earliest known Kaʿba-centered geographical scheme is recorded in a manuscript of the *Kitāb al-masālik wa-al-mamālik* (Book of routes and provinces) by the ninth-century scholar Ibn Khurradādhbih. It may not be original, but it is most certainly early. It involves a simple four-sector scheme (fig. 9.1): each part of the

7. Various medieval Arabic texts inform us that the major axis of the Kaʿba points toward the rising of Canopus, the brightest star in the southern celestial hemisphere, and that the minor axis points toward the summer sunrise. For the latitude of Mecca, these directions are roughly perpendicular. A modern plan of the Kaʿba and its environs, based on aerial photography, essentially confirms the information given in the texts, but reveals more: for epoch 0 A.D., the major axis is aligned with the rising of Canopus over the southern horizon to within two degrees, and the minor axis is aligned with the southernmost setting point of the moon over the southwestern horizon to within one degree. This last feature of the Kaʿba is not specifically mentioned in the texts, and its significance, if any, is not yet clear. More detailed information can be found in Gerald S. Hawkins and David A. King, "On the Orientation of the Kaʿba," *Journal for the History of Astronomy* 13 (1982): 102–9.

8. See King, "Makka," 181–82 and fig. 1 (note 3) for the different schemes dividing the perimeter of the Kaʿba that gave rise to these permutations in the diagrams.

9. Oxford, Bodleian Library, MS. Marsh 592; al-Dimyāṭī wrote a shorter treatise on the qibla that was copied ca. A.D. 1350 (Damascus, Dār al-Kutub, Ẓāhirīyah 38).



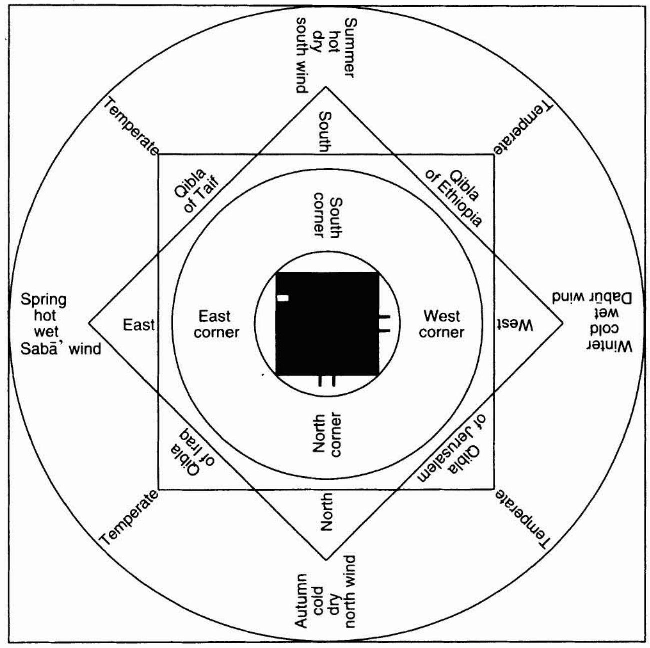


FIG. 9.2. FOUR-QIBLA SCHEME. Representation taken from an anonymous eighteenth-century Ottoman treatise (see also figs. 9.5 and 9.13), with translation to the right.
Size of the original: 18 × 13 cm. By permission of the Dār al-Kutub, Cairo (Ṭalʿat *majāmiʿ* 811, fol. 60r).

world is associated with a different segment of the perimeter of the Kaʿba. Thus the region between northwestern Africa and northern Syria is associated with the northwestern wall of the Kaʿba and has a qibla that varies from east to south. The region between Armenia and Kashmir is associated with the northeastern wall of the Kaʿba and has a qibla that varies from south to west. A third region, Manṣūrah (India), Tibet, and China (meaning Indochina), is associated with the Black Stone in the eastern corner of the Kaʿba and for this reason is stated to have a qibla a little north of west. The fourth region, the Yemen, is associated with the southern corner of the Kaʿba and has a qibla of due north. Many similar four- or eight-sector schemes are found in other texts (fig. 9.2). The tenth-century geographer al-Muqaddasī's *Aḥsan al-taqāsīm fī maʿrifat al-aqālīm* (The best of divisions on the knowledge of the provinces), for example, contains a description, with a diagram, of a simple eight-sector scheme.[10] Other schemes show a tendency toward a more complex subdivision of the sacred space of Islam.

The principal scholar involved in this further development of a Kaʿba-centered sacred geography is Muḥammad ibn Surāqah al-ʿĀmirī (d. 410/1019), a Yemeni *faqih* (legal scholar) who studied in Basra. Little is known about this man, and none of his works survive in their original form. However, from quotations in later works it appears that he devised three distinct schemes with eight, eleven, and twelve sectors focusing on the Kaʿba.[11] Although these later recensions of Ibn Surāqah's treatises lack diagrams, it is possible to use them to piece together his detailed prescriptions for finding the qibla in each of the

10. See the French translation of Abū ʿAbdallāh Muḥammad ibn Aḥmad al-Muqaddasī's work by André Miquel, *Aḥsan at-taqāsīm fī maʿrifat al-aqālīm* (Damascus: Institut Français de Damas, 1963).

11. Ibn Surāqah's eight-sector scheme is known from the writings of one Ibn Raḥīq, a legal scholar of Mecca who was the author of a treatise on folk astronomy in the eleventh century. Several significant regions of the Muslim world were omitted from this scheme. Ibn Surāqah's eleven-sector scheme is known from a fourteenth-century Egyptian treatise, and in it he has simply added three sectors to his eight-sector scheme. His twelve-sector scheme was used by al-Dimyāṭī, who was upset, however, that Ibn Surāqah put Medina and Damascus in the same sector, and so he himself presented a thirteen-sector scheme. Ibn Surāqah's twelve-sector scheme was also used by the thirteenth-century Yemeni astronomer al-Fārisī in his book on folk astronomy.

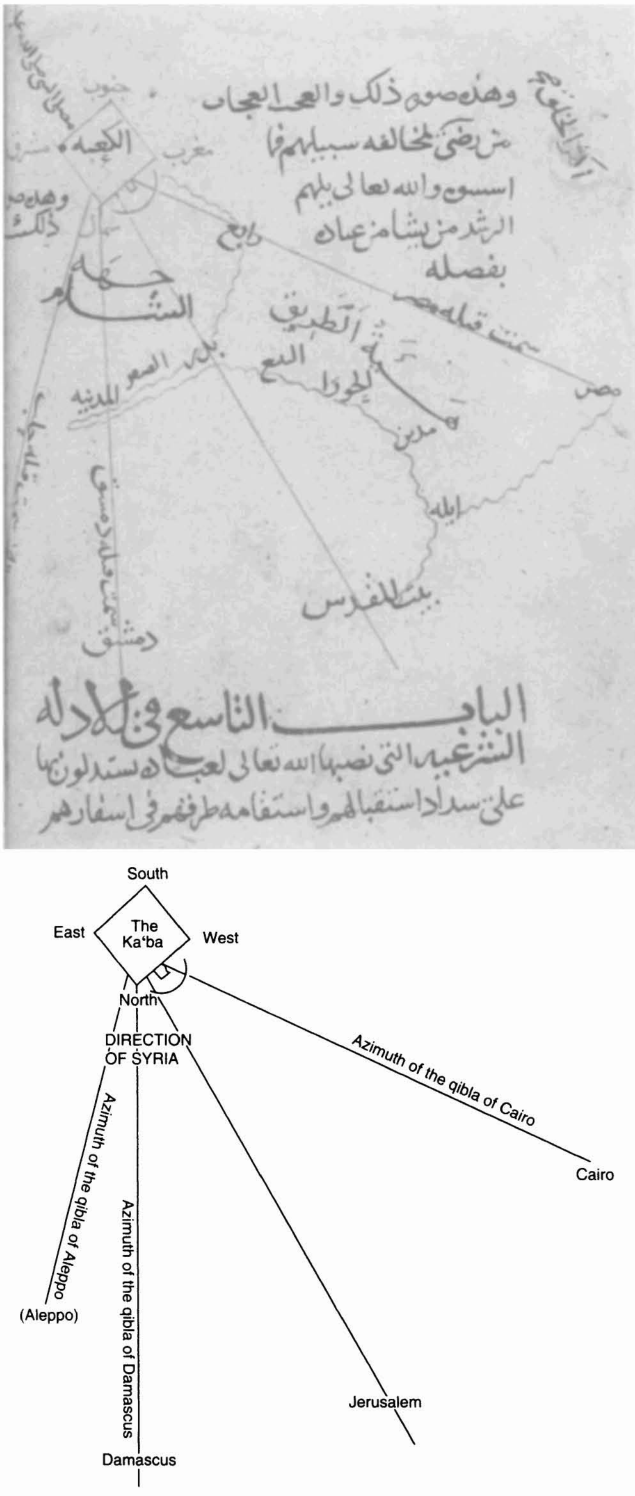


FIG. 9.3. ILLUSTRATION FROM A TREATISE ON THE SACRED DIRECTION BY AL-DIMYĀṬĪ. The diagram shows the directions of the Kaʿba for several locations including Cairo, Jerusalem, and Damascus. It was assumed that people in each locality would face a different part of the Kaʿba (partial translation provided).
Size of the original: 19 × 12.5 cm. By permission of the Bodleian Library, Oxford (MS. Marsh 592, fol. 88v).

various regions associated with his schemes. For each region, Ibn Surāqah explains how people should stand with respect to the rising or setting of four particular groups of stars and the four winds. Thus, for example, we are informed how the inhabitants of Iraq and Iran should stand in relation to the stars of the Great Bear, which rise and set behind the right ear; a group of stars in Gemini should rise directly behind the back; the east wind should blow at the left shoulder, the west wind should blow at the right cheek, and so on. That the stars of the Great Bear neither rise nor set but appear circumpolar in places as far north as Iraq and Iran indicates that Ibn Surāqah's instructions were probably formulated in Mecca. To stand in the position he described would have been to face the winter sunset, though this is not explicitly stated. The ultimate object of the exercise was to face the northeastern wall of the Kaʿba.

The qibla charts themselves do not appear in surviving manuscripts until after the eleventh century. A recurrent interpretative problem is that the charts were often corrupted in the copying process. Even in elegantly copied manuscripts, the corners of the Kaʿba have sometimes been confused. In some copies of the works of Zakariyā' ibn Muḥammad al-Qazwīnī (600–682/1203–83) and Sirāj al-Dīn Abū Ḥafṣ ʿUmar ibn al-Wardī (d. 861/1457) containing the twelve-sector scheme, for instance, Medina occurs in two sectors. In other copies one of these has been suppressed, and only eleven sectors appear around the Kaʿba.

Although the numbers of sectors remain one criterion for classifying the Kaʿba-centered qibla diagrams, there may be significant variations in different versions of the same scheme during the Islamic Middle Ages. Even the same authors could produce charts of different design. Al-Dimyāṭī, for example, records a simple scheme with only four directions, as well as the partial diagram showing only three sectors of a larger scheme, perhaps intended to illustrate the notion of *ʿayn al-Kaʿba* (facing the Kaʿba head on) (fig. 9.3). But he was also responsible for a rather crude eight-sector scheme where the Kaʿba is represented by a circle and each of the eight regions is associated with a wind (fig. 9.4). We may also compare this informal representation—where the scribe has done little more than arrange his text in a wheel-like form—with another eight-sector scheme that appears in an anonymous Ottoman treatise (fig. 9.5). This scheme is much more carefully drafted. The qiblas are defined by means of the Pole Star and by those stars that rise or set behind one's back when one is standing in the qibla.

The same variations also extend to the twelve-sector diagrams. Thus Ibn Surāqah's twelve-sector scheme was used and illustrated by the thirteenth-century Yemeni astronomer al-Fārisī in his book on folk astronomy, *Tuḥfat al-rāghib wa-turfat al-ṭālib fī taysīr al-nayyirayn*

FIG. 9.4. EXTRACT FROM THE SHORTER TREATISE ON THE QIBLA BY AL-DIMYĀṬĪ. This diagram shows eight parts of the world arranged in the cardinal and solstitial directions about the Kaʿba, crudely represented by a circle. No geographical regions are mentioned; rather, each part of the world is associated with a wind. The qibla was found in each region by means of the Pole Star.
Size of the original: not known. By permission of Dār al-Kutub, Damascus (Ẓāhirīyah 38, fol. 14r).

wa-ḥarakāt al-kawākib (The sun, the moon, and the movements of the fixed stars made easy as a gift to the desirous and a luxury for the seeker) (fig. 9.6). But in the same century, the well-known geographer Yāqūt (575–626/1179–1229) also reproduced a twelve-sector scheme, without the instructions for finding the qibla, in his *Kitāb muʿjam al-buldān* (Dictionary of countries) (fig. 9.7). Are we to assume that in this case the diagram and its annotations would speak for itself? The same scheme was copied by al-Qazwīnī in his celebrated cosmography *ʿAjāʾib al-makhlūqāt* (Wonders of creation).[12]

Qibla charts centered on the Kaʿba had a long tradition. In surviving manuscripts, they begin to appear in the twelfth century; they were still found, as we will see, in

12. Zakariyāʾ ibn Muḥammad al-Qazwīnī, *Kitāb ʿajāʾib al-makhlūqāt wa-gharāʾib al-mawjūdāt* (Marvels of things created and miraculous aspects of things existing), in *Zakarija ben Muhammed ben Mahmud el-Cazwini's Kosmographie*, 2 vols., ed. Ferdinand Wüstenfeld (Göttingen: Dieterichsche Buchhandlung, 1848–49; facsimile reprint Wiesbaden: Martin Sändig, 1967), 1:83.

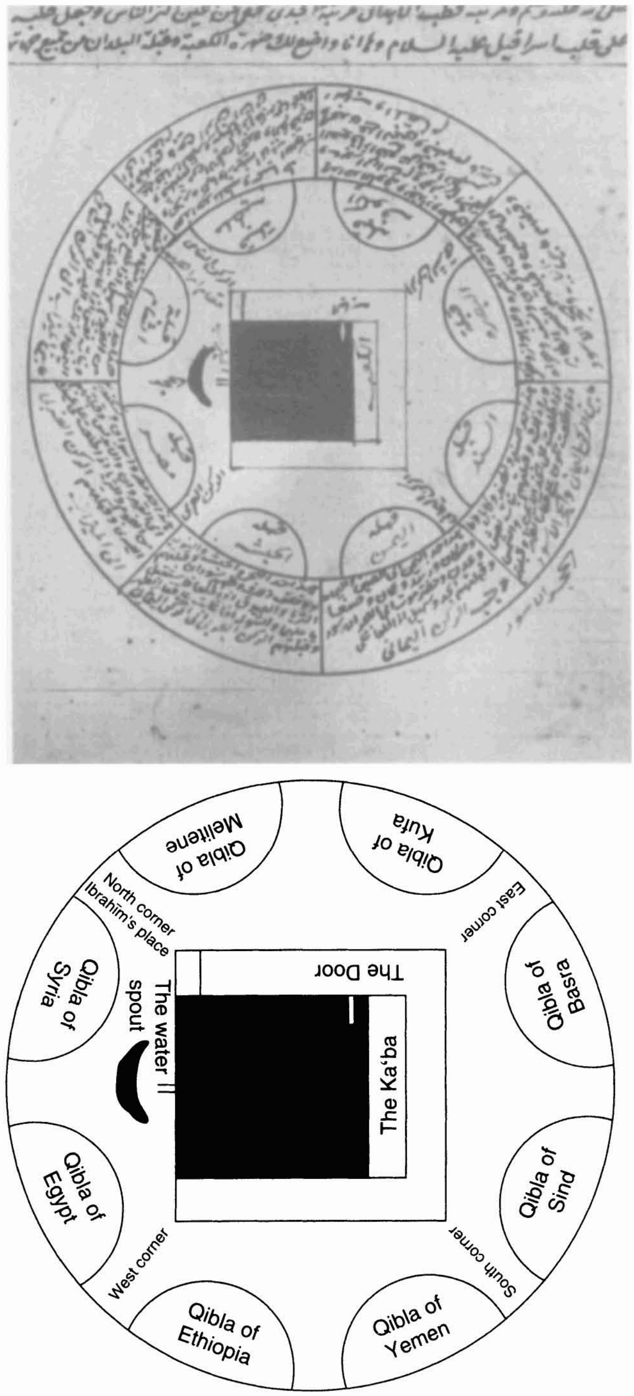


FIG. 9.5. EIGHT DIVISIONS OF THE WORLD ABOUT THE KAʿBA. According to an anonymous Ottoman treatise dating from the eighteenth century. The loops pointing toward the Kaʿba in the center contain the names of the regions or cities for which the qibla is defined (see the translation of this central part of the figure). Outside these are descriptions of the astronomical directions to be faced in the qibla for these regions and the parts of the perimeter of the Kaʿba associated with them. For each division the qibla is defined in terms of stellar risings and settings.
Size of the original: 18 × 13 cm. By permission of the Dār al-Kutub, Cairo (Ṭalʿat *majāmīʿ* 811, fol. 60v).

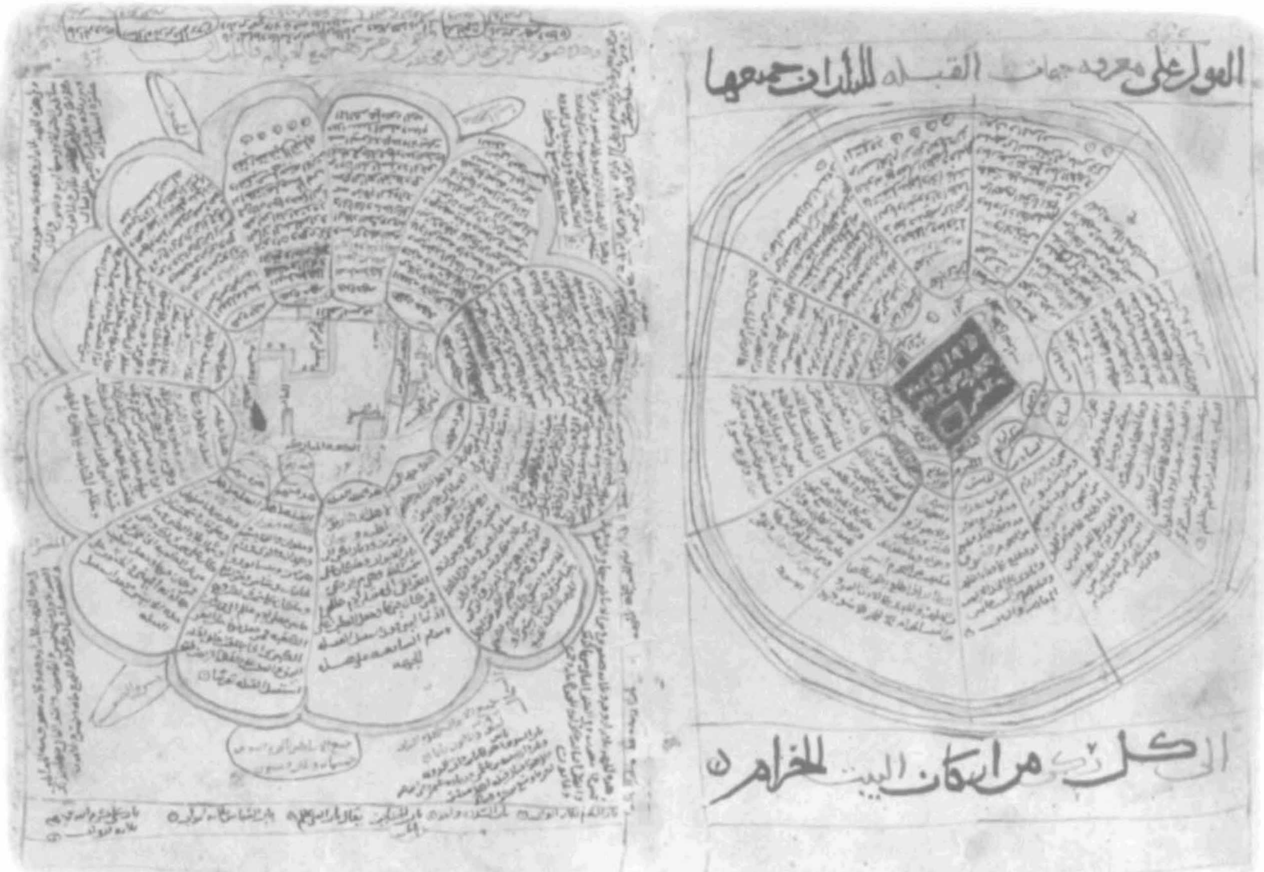


FIG. 9.6. TWO PAGES FROM A TREATISE ON FOLK ASTRONOMY. This work is by Muḥammad ibn Abī Bakr al-Fārisī, a scholar active in Aden in the thirteenth century. The two diagrams display two different schemes of the world arranged in twelve sectors about the Kaʿba. For each sector there is a statement regarding the corresponding segment of the perimeter of the Kaʿba as well as the appropriate astronomical directions that enabled the user to face that particular segment. Size of the original: not known. By permission of the Biblioteca Ambrosiana, Milan (Suppl. 73, fols. 36v–37r).

manuscripts of the later Ottoman period. The Ottoman examples show substantial development over the earlier charts, but they also contain fanciful elements. As in some earlier Arabic schemes, for instance, the orientation of the Kaʿba with respect to the cardinal directions, or with respect to localities around it, is often in error. At the same time, they also reflect particular Ottoman interests. Thus, some late schemes include Ottoman provincial cities in the Balkans as well as various European ports.

One of the main manuscripts to be illustrated was the cosmography, *Kharīdat al-ʿajāʾib wa-farīdat al-gharāʾib* (The unbored pearl of wonders and the precious gem of marvels) of Ibn al-Wardī, which was translated into Turkish several times. In one version there are eleven sectors, with instructions for finding the qibla in Turkish (fig. 9.8). In another version, prepared in 570/1562 by Maḥmūd el-Ḫaṭīb er-Rūmī, there is a chart with seventy-two sectors about the Kaʿba (fig. 9.9); this is independent of the five-, six-, and thirty-four-sector schemes attested in various Arabic copies of this work. These variations are further elaborated in other works. Two schemes of sacred geography are found in an Ottoman copy of a sixteenth-century Syrian astronomical handbook (*zīj*) among some notes at the end of the work. One of these shows twenty-four sectors, and the other has seventy-two. The latter is related to the scheme previously referred to as associated with Maḥmūd el-Ḫaṭīb er-Rūmī (fig. 9.10). A third is found in an Egyptian text. The Hanafī qadi ʿAbd al-Bāsiṭ ibn Khalīl al-Malaṭī (A.D. 1440–1514) wrote a short treatise on the qibla in which a simple twenty-sector scheme is presented (fig. 9.11). This example is unknown from any other source.

The most elaborate and visually spectacular scheme of Islamic sacred geography occurs in the navigational atlas of the sixteenth-century Tunisian chartmaker ʿAlī ibn Aḥmad ibn Muḥammad al-Sharafī al-Ṣifāqsī (plate 13) (see also pp. 285ff.). It is distinguished from all other schemes by the forty *miḥrāb*s centered on the Kaʿba, here represented by a cardinally oriented square. The scheme is superimposed upon a thirty-two-division wind rose, a

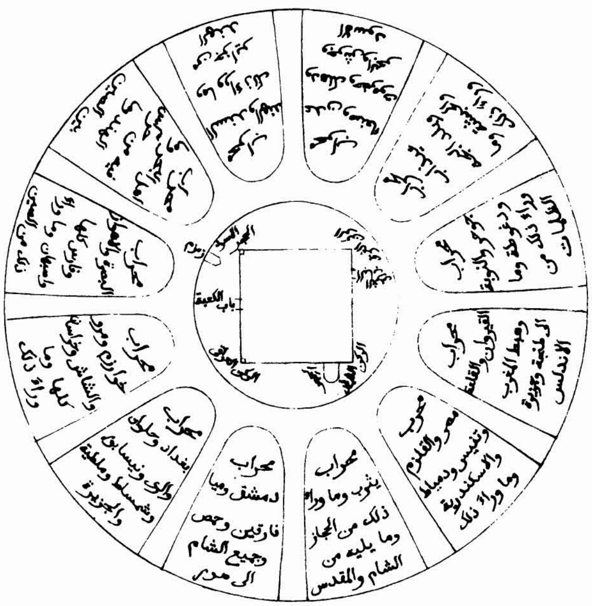


FIG. 9.7. SIMPLIFIED TWELVE-SECTOR SCHEME OF SACRED GEOGRAPHY. Taken from the published text of Yāqūt's geographical work, *Muʿjam al-buldān*.
Diameter of the original: 10.7 cm. From *Jacut's geographisches Wörterbuch*, 6 vols., ed. Ferdinand Wüstenfeld (Leipzig: F. A. Brockhaus, 1866–73), 1:36, by permission of F. A. Brockhaus.

FIG. 9.8. INSTRUCTIONS ON AN ELEVEN-SECTOR DIAGRAM OF SACRED GEOGRAPHY. Found in a Turkish translation of Ibn al-Wardī's *Kharīdat al-ʿajāʾib*. One of the sectors in the original twelve-sector scheme had already been dropped in an earlier Arabic version.
Size of the original: not known. By permission of the Topkapı Sarayı Müzesi Kütüphanesi, Istanbul (R. 1088, fol. 94r).

device Arab sailors used to find directions by the risings and settings of the stars. The two known copies of this diagram have different arrangements of the localities about the Kaʿba.

By the eighteenth century, however, the notion of an Islamic sacred geography was seriously weakened by Ottoman scholars increasingly familiar with European geography. For example, Kātib Çelebī's *Cihānnümā* (World mirror), an influential work on geography printed in Istanbul in the early eighteenth century, omitted any mention of the concept of the world centered on the Kaʿba.[13] In most regions of the Islamic world traditional qibla directions, used over the centuries, were now being abandoned for a new direction computed for the locality in question from modern geographical coordinates. Nevertheless, diagrams of the kind described above were still being copied as late as the nineteenth century, if only as illustrations to Ibn al-Wardī's *Kharīdat al-ʿajāʾib*. Written instructions for finding the qibla also continued to be transmitted in one form or another. A mid-nineteenth-century anonymous Ottoman navigational compendium, recently discovered in Cairo, presents extensive instructions for finding the qibla in different localities. In fact, the information is a garbled version of one of Ibn Surāqah's schemes, taken verbatim from a treatise on folk astronomy by a fourteenth-century legal scholar working in the Hejaz. The existence of this text proves not only that such material was still available to Ottoman writers in the nineteenth century, but also that it was still considered worth copying.

Those schemes divided into thirty-six or seventy-two sectors lent themselves to representation on a horizontal disk fitted with a magnetic compass. Several examples of such qibla indicators survive,[14] but the organization of cities around the Kaʿba at the center is not based on calculation and so often departs drastically from geographical reality. Such qibla indicators were fitted to otherwise serious astronomical instruments; the motive

13. Muṣṭafā ibn ʿAbdallāh Kātib Çelebī (1017–67/1609–57) began work on a second version of the *Cihānnümā* in 1065/1654 after consulting Western sources, such as Gerardus Mercator's *Atlas Major*. It was printed in 1145/1732.

14. All such instruments are surveyed in David A. King, "Some Medieval Qibla Maps: Examples of Tradition and Innovation in Islamic Science," Johann Wolfgang Goethe Universität, Institut für Geschichte der Naturwissenschaften, Preprint Series, no. 11, 1989.

FIG. 9.9. SEVENTY-TWO-SECTOR SCHEME OF SACRED GEOGRAPHY. From a Turkish translation of Ibn al-Wardī's *Kharīdat al-ʿajāʾib* dated 1092/1681.
Size of the original: not known. By permission of the Topkapı Sarayı Müzesi Kütüphanesi, Istanbul (B. 179, fol. 52r).

for including them was both aesthetic and an attempt to provide a universal solution to the qibla problem. Illustrating the mathematically computed qibla directions of specific cities would have produced unhappy clusterings and asymmetries unpleasing to the eye.

Qibla Maps Based on Coordinates

In the corpus of qibla representations as a whole, there are far fewer extant examples in the category of qibla maps based on coordinates. Nevertheless, several qibla maps have been discovered in which the positions of towns are determined by their longitudes and latitudes. A minority display a coordinate grid or at least longitudinal and latitudinal axes. A distinction may be drawn between those maps with a prime meridian at the Canary Islands, as in Ptolemy's *Geography* (defined here as type A) and those with a prime meridian on the Atlantic coast of Africa (defined as type B).

Underlying these maps is the understanding that the qibla of a locality can be found from its position relative to Mecca.[15] Ideally, said the Muslim scientists, the qibla may be defined as the direction of the great circle joining the two. But how to represent this on a map? As readers will see from appendix 9.1, Muslim scientists were in full possession of the techniques necessary to calculate the qibla. In this section we shall consider only cartographic solutions to the qibla problem. Nevertheless we shall find it convenient to use the following mathematical notation:

L	terrestrial longitude
L_M	longitude of Mecca
ΔL	longitude difference from Mecca ($L \sim L_M$)
φ	terrestrial latitude
φ_M	latitude of Mecca
$\Delta\varphi$	latitude difference from Mecca ($\varphi \sim \varphi_M$)
q	qibla (measured as an angle to the local meridian)

The first surviving example (fig. 9.12, with simplified translation), is taken from a treatise on folk astronomy by an early thirteenth-century Egyptian author. Apart from his name, Sirāj al-Dunyā wa-al-Dīn, we know nothing about him. The horizontal axis of the map, designed to measure longitudes on the equator, is divided into 170 equal parts (the last five degrees at each end have not been marked). The vertical axis, serving to measure latitudes, is divided into 80 equal parts north of the equator (the last ten degrees are likewise excluded), though in reality the vertical diameter measures not ninety degrees of longitude, but eighty-five degrees. On the map, the towns are usually located by means of two perpendicular coordinate lines. To find the qibla, one draws a line from one's locality to Mecca and investigates where this line cuts the base circle; the corresponding direction of sunrise or sunset defines the qibla. The influence of folk-astronomical methods upon the compilation makes the procedure less accurate than it might otherwise have been. It is interesting to note here that the coordinates are of type B, in the tradition of al-Bīrūnī's *al-Qānūn al-Masʿūdī*, a work that was generally unknown in medieval Egypt.

15. David A. King, "Ḳibla: Astronomical Aspects" and "Makka: As the Centre of the World," in *Encyclopaedia of Islam*, new ed., 5:83–88 and 6:180–87; idem, "The Earliest Islamic Mathematical Methods and Tables for Finding the Direction of Mecca," *Zeitschrift für Geschichte der Arabisch-Islamischen Wissenschaften* 3 (1986): 82–149; and idem, "Al-Bazdawī on the Qibla in Early Islamic Transoxania," *Journal for the History of Arabic Science* 7 (1983): 3–38. For information on qibla values at Córdoba, Spain, see David A. King, "Three Sundials from Islamic Andalusia," *Journal for the History of Arabic Science* 2 (1978): 358–92; reprinted as item XV in his *Islamic Astronomical Instruments* (London: Variorum Reprints, 1987).

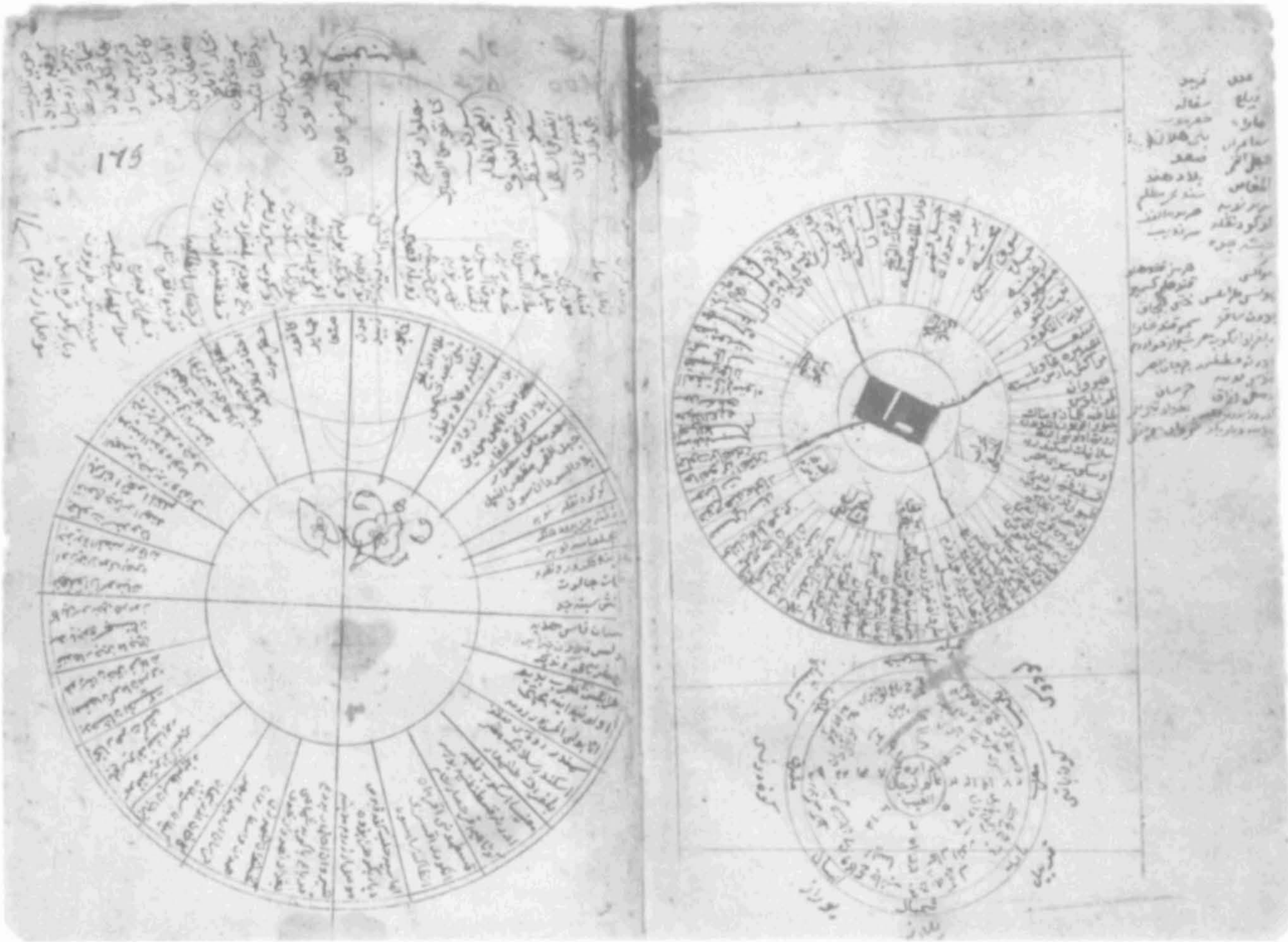


FIG. 9.10. VARIOUS SCHEMES OF SACRED GEOGRAPHY. These are appended to an Ottoman copy of a Syrian text dealing with mathematical astronomy.
Size of the original: 18.5 × 25 cm. By permission of the Bibliothèque Nationale, Paris (MS. Arabe 2520, fols. 174v–75r).

Also from Egypt is the more schematic diagram in figure 9.13. In the manuscript this appears opposite the Kaʿba-centered chart illustrated as figure 9.5. Again, the ordinates and abscissas are equally spaced, so that the configuration corresponds only roughly to geographical reality. In the coordinates (x,y), x is measured horizontally from the left and y vertically from the top. The meridians and parallels are marked with the labels listed in table 9.1. The Kaʿba is represented by a square at (1, 1) appropriately inclined to the local meridian. The names of the corners of the edifice are written in. Other localities are shown by means of circles, usually at the intersections of grid lines, sometimes with their longitudes and a letter representing 2, 3, or 4 to indicate the geographical climate in which they are situated. The longitudes are confused and do not correspond to geographical reality.

The next example, engraved on an astrolabe made in Lahore, is shown in figure 9.14. Here the positions of Mecca and various other localities are marked, and each place is connected to Mecca by a straight line representing the qibla. Both longitude and latitude scales are nonlinear, corresponding to an orthographic projection of the globe. The longitudes are of type A, for Mecca has coordinates approximately (77°, 22°). With the exception of the Atlantic coast of North Africa, which is close to (0°, 0°), Jazīr al-Zanj (?) in western Sudan, Jerusalem, and Medina, most of the localities marked are in Iran and Kashmir.

A more practical map is found on the qibla indicator displayed in figure 9.15. Mecca is shown at the center of the dial, and various places, mainly in Iran, are marked around it. Their positions are intended to be approximate, but they are nevertheless carefully arranged. For example, Jerusalem is shown about 45° west of north of Mecca (correct for medieval coordinates), and Baghdad is 10° east of north of Mecca. The other markings on the instrument south of the parallel of latitude for Mecca relate to an unusual variety of horizontal sundial for an

FIG. 9.11. SIMPLE TWENTY-SECTOR SCHEME OF SACRED GEOGRAPHY. From al-Malaṭī's short treatise on the qibla.
Size of the original: not known. By permission of the Topkapı Sarayı Müzesi Kütüphanesi, Istanbul (A. 527, fol. 93r).

unspecified latitude, the gnomon of which is at the bottom of the instrument.

In 1989 a remarkable qibla indicator was sold at Sotheby's of London (fig. 9.16). The calligraphy and various ornamental features reveal the provenance: Isfahan, about A.D. 1700. It is circular with a radius of 22.5 centimeters. The rim is marked in labeled ten-degree intervals each subdivided in half, and individual degrees are indicated by dots. The cardinal directions are identified by name, and the north-south and east-west lines are drawn in. Three pieces have been cut out of the perimeter; some other parts—now missing—were added to serve other (astronomical) functions.

The instrument bears a distinctive grid with two families of markings. The first are linear, parallel meridians for each two degrees of longitude up to 48° on either side of meridian 77° (see below). The second are nonrectilinear curves for each two degrees of latitude from 10° up to 50°. The meridians are produced below latitude 10° and are cut off by a straight line parallel to the east-west line and corresponding to a latitude of about 2° (there is no indication that this was supposed to represent the equator). An inscription on the alidade indicates that the point at the center of the disk is Mecca. A scale in *farsakhs* marked on one-half of this alidade is intended to measure distances from Mecca.

The longitude of Mecca is taken as 77°10′, that is, a nonintegral value, and this is a feature that caused the maker a lot of extra work. The longitudes corresponding to the meridians for odd longitudes are marked along a band above the curve for latitude 50°. The arguments corresponding to the latitude curves are marked in a band between the meridians for 51° and 53°. The seven climates are identified (in Persian) along this scale. Localities are indicated by inlaid studs, the names being engraved on neighboring "squares" of the grid. The size of the grid was chosen so that, for example, Beijing (Khānbāligh) would just fit on it.

The now-empty frame of a magnetic compass adorns the lower center of the disk, its radius being about one-third that of the disk. There is no indication that the compass might not point due north, but this fact was known to at least some Ottoman astronomers in the sixteenth century and presumably also thereafter.

The estimated coordinates of various localities are listed in table 9.2. These estimates are sufficient to identify the source as the astronomical handbook of Ulugh Beg, compiled in Samarkand in the early fifteenth century. Variations are all within acceptable limits. Also Sri Lanka (Sarandīb), with coordinates (10°, 130°) in the *zīj*, is indeed off the grid altogether; presumably the stud right on the perimeter of the plate at about 20° south of east was intended to mark it.

The problem of constructing a rect-azimuthal grid could have been easier for a Muslim astronomer than it was for a twentieth-century researcher like Schoy, who first investigated the mathematics of such a projection.[16] The former had access to tables displaying the qibla directions for all points on the kind of grid on our instrument (and more), whereas Schoy had to make his calculations himself. The medieval tables, of which several sets are known to us, display a function such as $q(\Delta L, \varphi)$ for a range of arguments. The table of Shams al-Dīn Abū ʿAbdallāh Muḥammad ibn Muḥammad al-Khalīlī of Damascus (fl. ca. A.D. 1365),[17] for example, displays this function for the domains:

$$\varphi = 10°, 11°, \dots 56°, \text{ and } \Delta L = 1°, 2°, \dots 60°.$$

16. For a discussion of this projection, see Carl Schoy, "Die Mekka- oder Qiblakarte," *Kartographische und Schulgeographische Zeitschrift* 6 (1917): 184–86, and idem, "Mittagslinie und Qibla: Notiz zur Geschichte der mathematischen Geographie," *Zeitschrift der Gesellschaft für Erdkunde zu Berlin* (1915): 558–76; both reprinted in *Beiträge zur Arabisch-Islamischen Mathematik und Astronomie*, 2 vols. (Frankfurt: Institut für Geschichte der Arabisch-Islamischen Wissenschaften, 1988), 1:157–59 and 1:132–50, respectively.

17. David A. King, "Al-Khalīlī's *Qibla* Table," *Journal of Near Eastern Studies* 34 (1975): 81–122; reprinted as item XIII in his *Islamic Mathematical Astronomy* (London: Variorum Reprints, 1987).

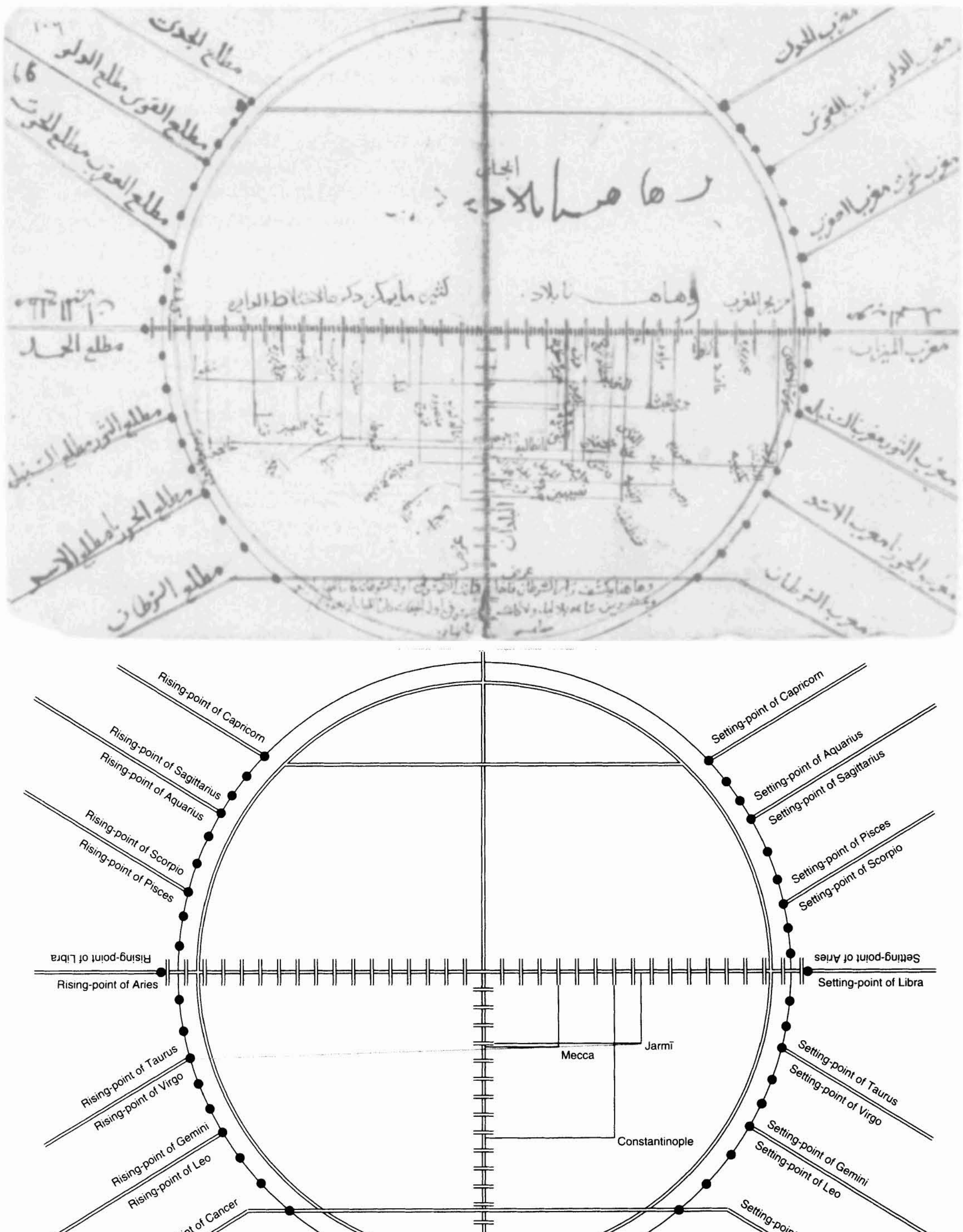


FIG. 9.12. QIBLA MAP CONTAINED IN A TREATISE ON FOLK ASTRONOMY. This is by an otherwise unknown early thirteenth-century Egyptian author named Sirāj al-Dunyā wa-al-Dīn. In the lower diagram, which illustrates his principle, only three of the localities are shown: Mecca, Constantinople, and Jarmī (Aksum) in Ethiopia. A line has been added joining Jarmī and Mecca that is extended to the circumference of the circle. According to the system of this map, the qibla of Jarmī would therefore be roughly the rising point of the sun when it is at the beginning of Taurus or Virgo.

Diameter of outermost circle: 18.5 cm. By permission of the Yahuda Collection of Arabic Manuscripts, Princeton University Library, Princeton (Yahuda Arabic manuscript no. 4657, fols. 65v–66r).

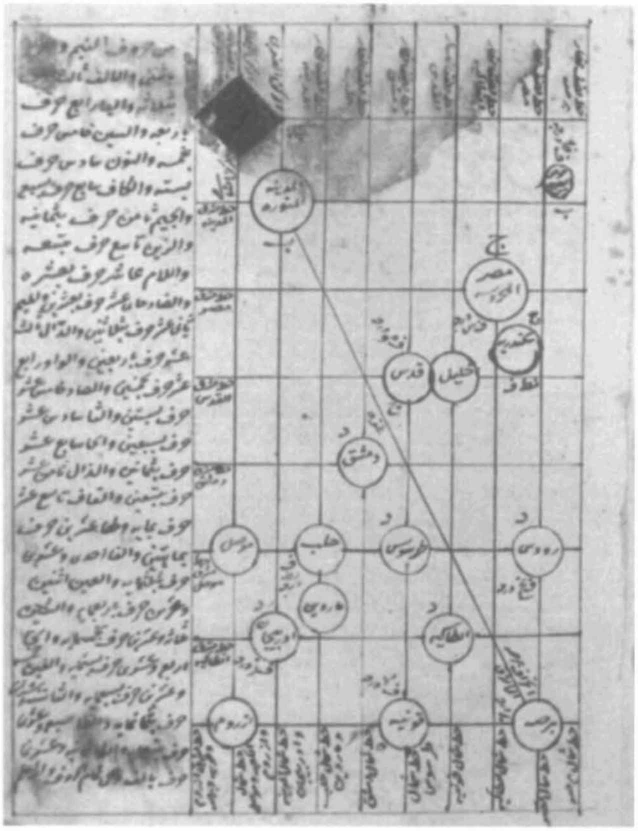


FIG. 9.13. QIBLA MAP BASED ON COORDINATES. Taken from an anonymous Ottoman treatise (see also figs. 9.2 and 9.5), this map shows the locations of various major cities with respect to the Kaʿba, the cities being shown on an orthogonal longitude-latitude grid.
Size of the original: 18 × 13 cm. By permission of the Dār al-Kutub, Cairo (Ṭalʿat *majāmīʿ* 811, fol. 61r).

TABLE 9.1 Labels for a Schematic Qibla Diagram (see figure 9.13)

MERIDIANS OF LONGITUDE

x	*Upper Frame*	*Lower Frame*
0	–	–
1	al-Kaʿba, Mosul, Erzurum	Mosul
2	Medina, Azerbaijan	–
3	Aleppo, Mardin	Medina
4	Damascus	Aleppo
5	Tarsus	Damascus
6	Konya	Jerusalem
7	Antioch	Antioch
8	Cairo	Cairo
9	Bursa	Bursa

PARALLELS OF LATITUDE

y	
0	–
1	(al-Kaʿba)
2	Medina
3	Cairo
4	Jerusalem
5	Damascus
6	Mosul
7	Antioch
8	Erzurum, Konya, Bursa

However, underlying this table is the parameter φ_M – 21°30′, and besides, our astronomer accepted 77°10′ for the longitude of Mecca (al-Khalīlī used 77°, so his tables serve all integral longitudes). This means that a table such as al-Khalīlī's would provide qibla values for integral latitudes, but for integral longitudes plus ten minutes. It is more likely that the astronomer computed a matrix of values $q(\Delta L, \varphi)$ for each degree of φ from 10° to 50° and a set of nonintegral values of ΔL (2° apart or perhaps 6° or 10°), which would yield the required values of q for the integral values of L used on his grid. In other words, he tabulated $q(L, \varphi)$. His values would no doubt have been for the parameter $\varphi_M = 21°40'$.

Our astronomer would then have proceeded as follows. First, he drew the meridians as equally spaced parallels. Actually, on the instrument the meridians are not all equally spaced: those on the outer edges are separated by about four-fifths of the distance between those closer to the center of the ensemble. This feature is still under investigation. Second, to construct the point on the meridian for longitude L corresponding to latitude φ, he simply read $q(L, \varphi)$ from the table and drew a line through the center inclined at angle q to the meridian there. That the meridians are parallel ensures that this angle is the qibla of the locality. The latitude curves on our instrument have been drawn with remarkable precision. Only in two places in the northeastern quadrant has the maker had to repeat a part of a curve that did not satisfy him.

This cartographic solution to the qibla problem is to be regarded as a brilliant achievement for an astronomer working in the medieval tradition. The basic idea is, of course, quite simple, but it required a spark of genius to realize just that. The instrument also merits mention as one of the numerous universal solutions to problems in spherical astronomy (the qibla problem is equivalent to one such) devised by Muslim astronomers and also as one of various graphical representations of two-argument functions they developed.

Methods of Qibla Determination with Spheres and Astrolabes

A direct mathematical method of finding the qibla was described by the little-known astronomer Naṣr ibn ʿAbdallāh. His dates are uncertain, but his procedure for finding the qibla is no later than A.D. 1162–63, the date

FIG. 9.14. QIBLA MAP INSCRIBED ON A SEVENTEENTH-CENTURY INDO-PERSIAN ASTROLABE.
Diameter of the original: 25 cm. By permission of the Trustees of the Science Museum, London. Photograph courtesy of Christie's of New York.

FIG. 9.15. MAP INSCRIBED ON A LATE PERSIAN QIBLA INDICATOR. Undated.
Diameter of the original: 7.5 cm. Museum of the History of Science, Oxford (ref. no. 57-84/44). By permission of the Bettman Archive, New York.

of the manuscript.[18] His method involved drawing a map on a sphere. It will be seen in figure 9.17 that the meridian line AEB and the east-west line GED are drawn on the curved surface of a hemisphere whose base represents the horizon. Then the north pole (Z) is marked on the zenith (ZB = φ, the latitude of the locality), and the equator circle GHD is drawn; a point T is marked, so that HT = ΔL (the difference in longitude); this point (T) and the pole (Z) are joined by an arc of great circle (KTMZ); from this arc TM is cut off equal to φ_M; and finally an arc of the great circle (EMN) is drawn through the end point of this arc and the zenith (E). The intersection (N) of this last arc with the horizon circle gives the azimuth of Mecca when the hemisphere is aligned with the meridian. Clearly, the instrument would have been simple enough to use where a suitable pair of compasses and a curved graduated ruler were available, though making an accurate hemisphere would be difficult. It does not, however, seem to have been well known.

Another type of instrument, the "solid sphere," called in Arabic *dhāt al-kursī* (the instrument with the frame) or, more simply, *al-kurah* (the sphere), was also sometimes used to determine the qibla directly. This consisted of a sphere—with equator and other celestial markings—that could be rotated about its poles. It was mounted in a fixed horizontal ring and (usually) a fixed meridian ring. ʿAbd al-Raḥmān al-Khāzinī (fl. early twelfth century) described an automatically rotating sphere of this sort and showed how the qibla was found with it.[19] First, Mecca is marked on the sphere according to its geographical coordinates, that is, as though its geographical longitude and latitude were the right ascension and de-

18. Damascus, Dār al-Kutub, Ẓāhirīyah 4871, fol. 83r. See Richard P. Lorch, "Naṣr b. ʿAbdallāh's Instrument for Finding the Qibla," *Journal for the History of Arabic Science* 6 (1982): 123–31.

19. Richard P. Lorch, "Al-Khazini's 'Sphere That Rotates by Itself,' " *Journal for the History of Arabic Science* 4 (1980): 287–329, and for more on al-Khāzinī, see idem, "The *Qibla*-Table Attributed to al-Khāzinī," *Journal for the History of Arabic Science* 4 (1980): 259–64.

FIG. 9.16. RECT-AZIMUTHAL QIBLA MAP. This was used for finding the qibla of any locality. Mecca is at the center, and numerous cities between Spain and China, Europe and the Yemen are marked on a cartographic grid. The rule attached at the center enables one to read off the qibla on the circular scale around the circumference of the instrument, and the scale on the rule gives the corresponding distance between the two localities. This instrument came to the attention of scholars only in 1988.
Diameter of the original: 22.5 cm. Photograph reproduced courtesy of the owner.

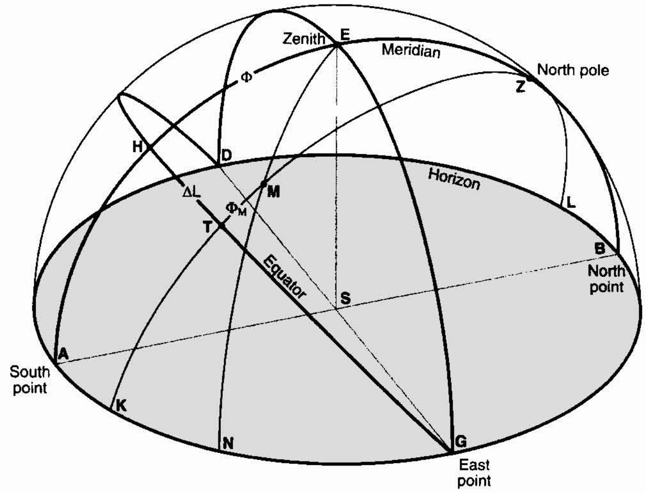


FIG. 9.17. DIRECT MATHEMATICAL METHOD FOR FINDING THE QIBLA. Naṣr ibn ʿAbdallāh (fl. before A.D. 1162–63) suggested finding the qibla by drawing a map on a hemisphere. If E and M are the zeniths of the chosen place and of Mecca, respectively, AN will be the azimuth of Mecca from this place.

TABLE 9.2 Estimated Coordinates of Localities on the Rect-azimuthal Qibla Indicator

Place	φ	L
Mecca	21°40′	77°10′
Aden	11° 0′	75°50′
Beijing	46° 0′	124° 0′
Cairo	30°20′	63°30′
Istanbul	45° 0′	60° 0′

clination of a star. Second, the place from which the qibla is to be determined is similarly marked on the sphere. The sphere is then rotated until the second mark coincides with the zenith. Then the spot marking Mecca is joined to the zenith by a curved ruler that fits the sphere, to give the point on the horizon that defines the qibla.

A much earlier treatise on the solid sphere was written by Qusṭā ibn Lūqā in the ninth century. This gives what appears to be a similar, but not identical, method. Nothing comparable, however, is included in a short account of the instrument by Ḥabash al-Ḥāsib (fl. 240/850),[20] or in the enormous treatise (157 chapters) by ʿAbd al-Raḥmān ibn ʿUmar al-Ṣūfī (d. 372/983), although the latter does give four chapters on finding the azimuth of the sun or of a star (for more information on these authors, see chapter 2).

A treatise describing the spherical astrolabe compiled for the *Libros del saber de astronomía* of King Alfonso X of Castile (r. 1252–84) gives a method for finding the azimuths of terrestrial locations. On the spherical astrolabe, a sphere carries the horizontal coordinates, that is, the lines of equal altitude and lines of equal azimuth (see pp. 41–42 and fig. 2.25). The rete (Arabic *ʿankabūt*), or net that fits over the sphere and could rotate round it about the celestial pole, carried the stars and the usual celestial circles such as the equator and ecliptic. A mark was made at that point on the rete that lies over the meridian and is distant from the equator by the latitude of the place (here Mecca) whose azimuth is required. The rete was then rotated through an angle equal to the difference of longitudes of the two places. The required azimuth could then be read off from the position of the mark among the azimuth circles. The astronomers of Alfonso's court probably took this use of the spherical astrolabe ultimately from Arabic sources, for although they found no Arabic treatise to work from, they must have found someone familiar with the instrument to be able to describe it all.

The plane astrolabe—mathematically the stereographic projection of the spherical astrolabe from the South Pole onto the equatorial plane—and the astrolabe quadrant—a quadrant made by folding the markings of an astrolabe

20. Richard P. Lorch and Paul Kunitzsch, "Ḥabash al-Ḥāsib's Book on the Sphere and Its Use," *Zeitschrift für Geschichte der Arabisch-Islamischen Wissenschaften* 2 (1985): 68–98.

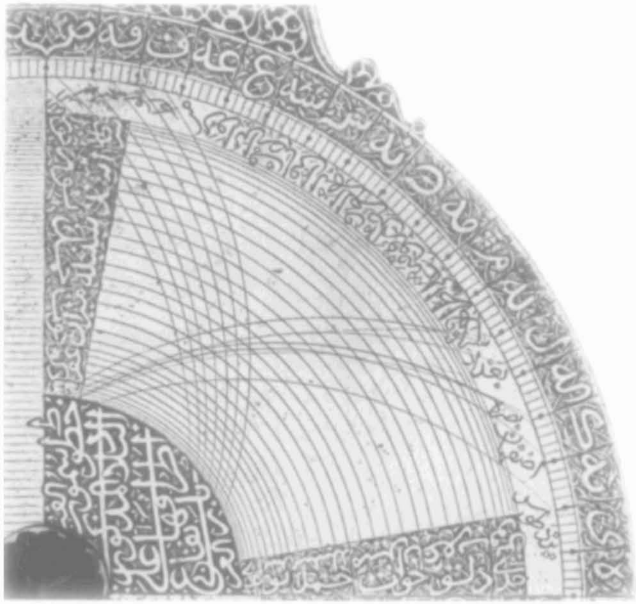


FIG. 9.18. DETAIL OF A QIBLA MAP INSCRIBED ON THE BACK OF AN ASTROLABE. Bears the signature Muḥammad Mahdī al-Khādim; undated (ca. A.D. 1650).
Size of the original: not known. Museum of the History of Science, Oxford (ref. no. 57-84/6). By permission of the Bettman Archive, New York.

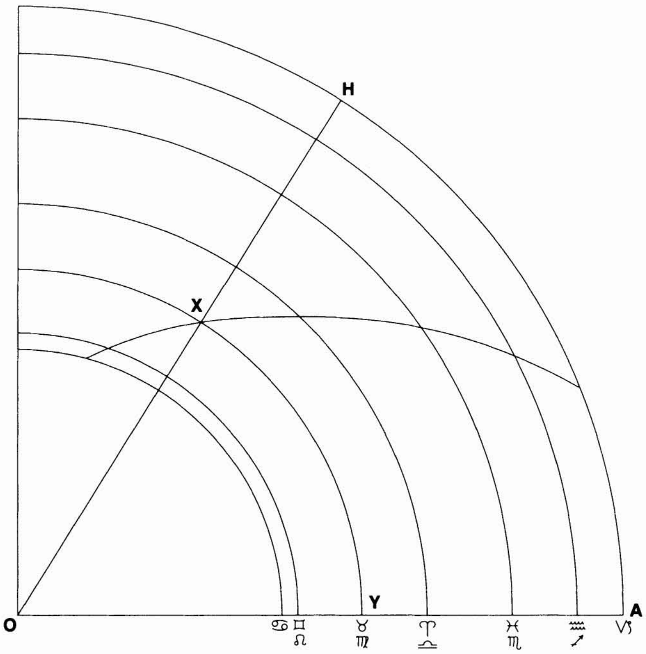


FIG. 9.19. EXPLANATORY DIAGRAM FOR FIGURE 9.18. The sun has the same azimuth as Mecca when it has the altitude (arc AH) indicated by the graph. The example taken here is the first point of Taurus or Virgo. The line OXH represents the alidade (or radial rule).

twice—were also adapted to the purpose of finding the qibla.[21] To be sure, some astrolabe treatises describe only how the instrument may be used to display a result already known or give a method by calculation. In this context it should be remembered that another type of quadrant (the sine quadrant) had the means of making trigonometric calculations and that the backs of astrolabes usually incorporated such quadrants in their markings.

A convenient means of finding the qibla using the sun is provided by the graphs on the backs of some astrolabes (fig. 9.18). These graphs (fig. 9.19) give the altitude of the sun when it has the same azimuth as Mecca—for any time of the year, which is specified on the base line OA by the position of the sun in the ecliptic. The angle AOH made with the base line by the join of the center O and the intersection X of the graph with the circle XY that corresponds to the point Y of the ecliptic occupied by the sun is the required solar altitude. The line OXH could be represented by the alidade of the astrolabe. One qibla curve is specific to one location. Several lines labeled with the names of cities were usually provided on these graphs.

The makers of such graphs must have known the qiblas in advance. The solar altitudes for these azimuths at various times of the year may be found empirically or determined by means of the astrolabe itself. Another possibility is that both the direction of the qibla and the various altitudes of the sun were read off directly from some instrument, such as the "solid sphere." Tables were also compiled for specific localities giving the altitude of the sun for the time of the year when it had the same azimuth as Mecca.

Whether or not the authors of these various instrumental determinations of the qibla were thinking in terms of a diagram or map, one factor is common to all methods: a precise notion of geographical direction, or azimuth. This is in contrast to the much vaguer and less consistent notions of folk astronomy and sacred geography. Both, however, serve the same purpose—to help one face the Kaʿba, a symbol of the presence of God.

21. Peter Schmalzl, *Zur Geschichte des Quadranten bei den Arabern* (Munich: Salesianische Offizin, 1929).

APPENDIX 9.1
METHODS TO CALCULATE THE QIBLA

An approximate method for finding the qibla was described by al-Battānī (d. 317/929) and al-Jaghmīnī (fl. thirteenth century). In essence, these authors described taking a horizontal graduated circle quartered by two diameters whose end points face north, south, east, and west (fig. 9.20*a*), and cutting off AB equal to ΔL (the difference in longitude between Mecca and the location concerned) and CD equal to $\Delta\varphi$ (the difference in latitude). Then BM was drawn perpendicular to OC and DM perpendicular to OA. The join of O and their intersection at M gave the approximate qibla. A comparison with figure 9.20*b* and perhaps figure 9.3 shows immediately the connection with cartographic procedures. Clearly, this simple procedure is equivalent to the modern formula:

$$q = \tan^{-1}\left\{\frac{\sin \Delta L}{\sin \Delta\varphi}\right\}.$$

Several other approximate formulas were known. A favorite method of displaying the results was a 20 × 20 table based on one or other of these formulas giving the azimuths of the qibla for values of ΔL and $\Delta\varphi$ going up by degrees from 1° to 20°.

Far more sophisticated were the "analemma" methods (the name coming from the title of a book by Ptolemy containing similar graphic procedures) for finding the qibla. The earliest known procedure of this kind—by Ḥabash al-Ḥāsib in the ninth century[1]—may be summarized by the following instructions (fig. 9.21*a*):

Draw the meridian ABGD, the vertical AG, and the horizon BD

$$\begin{aligned}
AZ &= \varphi;\ ZH = \varphi_M;\ ZT = \Delta L\\
HY &\parallel ZK;\ M \text{ is midpoint of } HY\\
ES &= HM\\
SO &\perp HY\\
OFQ &\parallel AG\\
OLN &\parallel DB\\
EF &= LN\\
&\text{FEG is the required angle.}
\end{aligned}$$

To justify the construction, we compare figure 9.21*a* with figure 9.21*b*, which carries lowercase letters corresponding where possible to the uppercase letters of figure 9.21*a*. Unfortunately, the correspondence cannot be consistent because the plane of the analemma represents different planes in the space of the diagram at various stages of the construction. At the beginning ABGD represents the meridian circle zp, with A as the zenith p. A circle HY may be imagined perpendicular to the plane of the paper with Mecca imagined on it at a point X, whose angular distance from H is equal to ΔL (X will be directly above O). Correspondingly, xo is perpendicular to the meridian plane bphz. Thus if l is the center of the circle parallel to the horizon and passing through x (the position of Mecca), then OL = ol. The required azimuth is ∠def, which is equal to ∠olx. Since xl = XL (the radius of the circle JN), this angle may be constructed by taking EF = LN. In the final result circle ABGD represents the horizon circle.

Such procedures gave rise to several sets of verbal instructions equivalent to correct trigonometrical formulas.[2] These are mathematically equivalent to the modern formula:

$$q = \cot^{-1}\left\{\frac{\sin\varphi\cos\Delta L - \cos\varphi\tan\varphi_M}{\sin\Delta L}\right\}$$

Qibla tables based on exact procedures are of considerable interest to the history of mathematics. Particularly impressive is the table of Shams al-Dīn al-Khalīlī (fl. Damascus, ca. 1365), in which $q(\varphi, \Delta L)$ was tabulated with remarkable accuracy for each degree of φ from 10° to 56° and each degree of ΔL from 1° to 60°.

Finally, there were several methods of finding the qibla based on the fact that the direction of Mecca is the azimuth of the sun when it is standing above the city. The day when this occurs is the day (toward the end of May or about the middle of July) when the declination of the sun is equal to φ_M, the latitude of Mecca. Since on this day the sun will stand above Mecca at noon, the difference in longitude (ΔL) was converted at the rate of four minutes per degree to find when this occurred according to local time—before or after noon according to one's location west or east of Mecca. The time of day would have been determined from the solar altitude. Graphs of the type shown in figure 9.18 may be considered an extension of this method.

1. Edward S. Kennedy and Yusuf ʿId, "A Letter of al-Bīrūnī: Ḥabash al-Ḥāsib's Analemma for the Qibla," *Historia Mathematica* 1 (1974): 3–11; reprinted in *Studies in the Islamic Exact Sciences by E. S. Kennedy, Colleagues and Former Students*, ed. David A. King and Mary Helen Kennedy (Beirut: American University of Beirut, 1983), 621–29; J. L. Berggren, "A Comparison of Four Analemmas for Determining the Azimuth of the Qibla," *Journal for the History of Arabic Science* 4 (1980): 69–80.

2. David A. King, "The Earliest Islamic Mathematical Methods and Tables for Finding the Direction of Mecca," *Zeitschrift für Geschichte der Arabisch-Islamischen Wissenschaften* 3 (1986): 82–149.

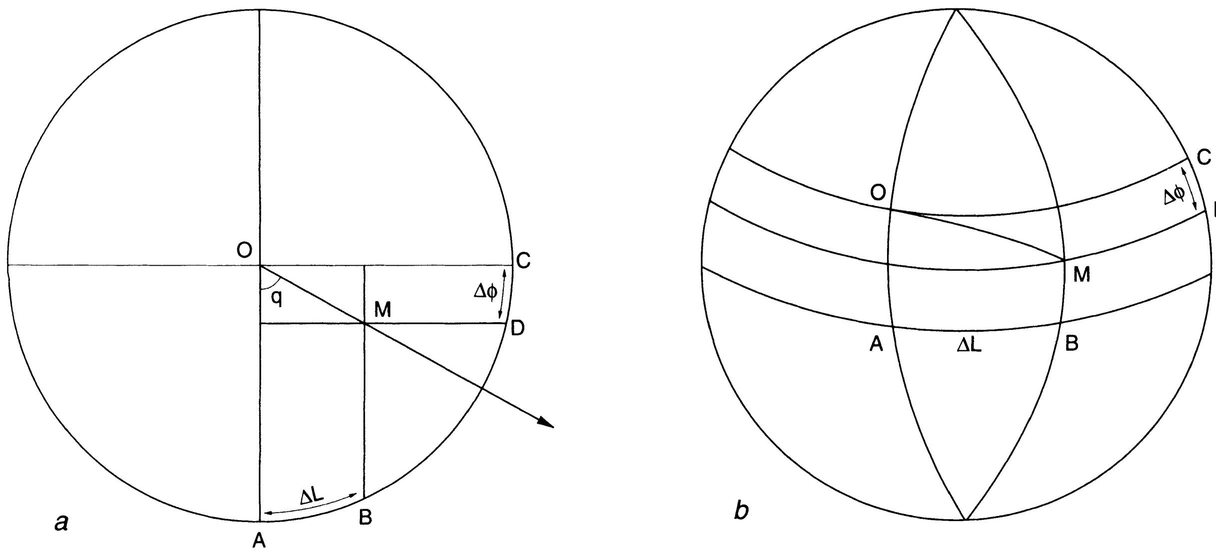


FIG. 9.20. APPROXIMATE METHOD FOR FINDING THE QIBLA DESCRIBED BY AL-BATTĀNĪ AND AL-JAGHMĪNĪ.

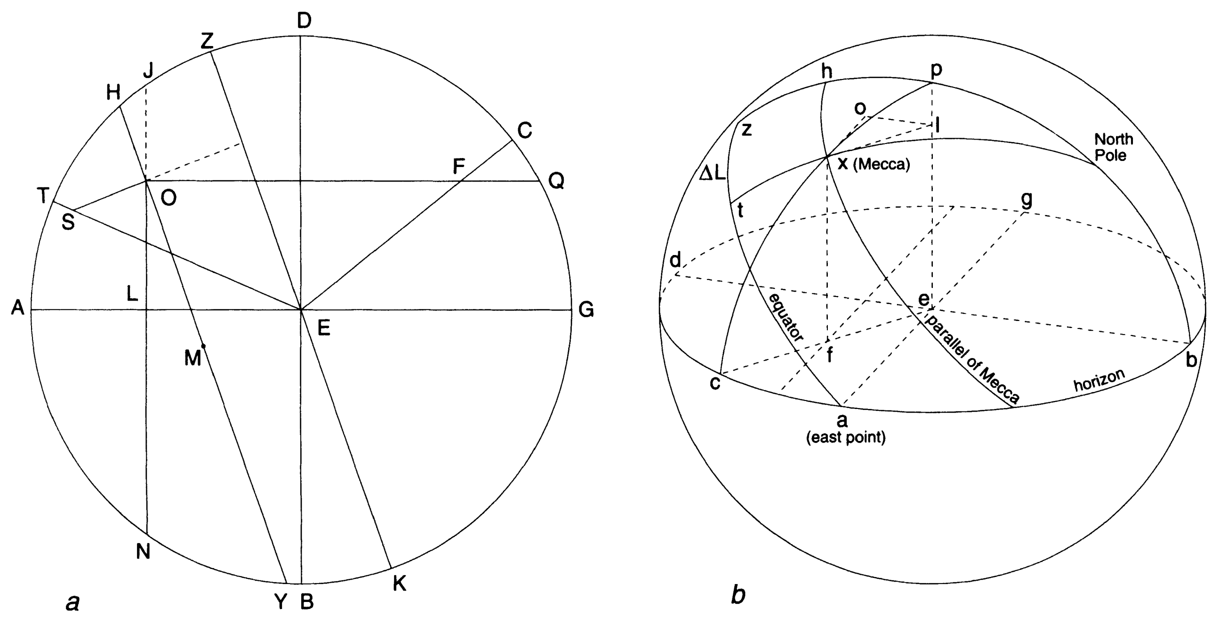


FIG. 9.21. ANALEMMA METHOD FOR FINDING THE QIBLA DESCRIBED BY ḤABASH AL-ḤĀSIB.