MUHAMMAD IBN MUSA AL-KHWARIZMI'S كِتَابُ صَنْعَةِ الأَسْطُرْلابِ "SAN'AT AL-ASTURLAB" ("THE CONSTRUCTION OF THE ASTROLABE") AND ITS BERLIN MANUSCRIPT AS AN IMPORTANT SOURCE

Ibadulloyev Nurollo Abdulla og'li – 11th-grade student of the 1st Specialized Boarding School, Khiva

Scientific Supervisor: Gularam Masharipova

Professor at Alfraganus University,

Doctor of Philological Sciences

Abstract. This article provides a scholarly and analytical study of the 9th-century encyclopedic scholar Muhammad ibn Musa al-Khwarizmi's treatise كِتَابُ صَنْعَةِ الأَسْطُرْلابِ "San'at al-Asturlab" ("The Construction of the Astrolabe") and its manuscript copy preserved in Berlin. The work explains the structure of the astrolabe, the methods of its construction, its application in astronomical calculations, and the procedures for determining geographical coordinates. The Berlin manuscript represents an important source from textual, source-critical, and codicological perspectives. It holds particular significance for elucidating the development of astronomy and applied mathematics within Islamic civilization. Through this treatise, the high level of scientific advancement in 9th-century Central Asia and the scholarly traditions of the Khwarazm school of science are clearly manifested. The Berlin copy provides an opportunity for international research on the scientific heritage, for conducting comparative source analysis, and for further clarifying al-Khwarizmi's contribution to astronomy.

Keywords: Muhammad ibn Musa al-Khwarizmi, San'at al-Asturlab, astrolabe, Berlin manuscript, handwritten source, astronomy, 9th-century science, Islamic civilization, source studies, codicology.

In the 9th century, the schools of astronomy and mathematics that developed within the scientific milieu of Central Asia played a crucial role in the progress of world civilization. One of the leading representatives of this period, Muhammad ibn Musa al-Khwarizmi, was not only the founder of algebra but also a scholar who left a significant legacy in astronomy and geodesy. His treatise "San'at al-Asturlab" is valued as a scientific work illuminating the traditions of astronomical instrument-making in the medieval Islamic East.

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The astrolabe was a universal astronomical instrument used to determine the altitude of celestial bodies, calculate time, identify the qibla direction, and compute geographical coordinates. The treatise explains both the theoretical foundations of this instrument and the practical process of its construction.

The following issues are addressed in كِتَابُ صَنْعَةِ الأَسْطُرْلابِ “San‘at al-Asturlab”:

The structure of the astrolabe (mater, plate, rete, alidade).

Methods of its construction based on geometric and trigonometric calculations.

Projection of the celestial sphere and the coordinate system.

Rules for determining time and the qibla using the instrument.

The work harmonizes the astronomical traditions of Claudius Ptolemy with the methodological approaches of the Islamic scientific school, thereby demonstrating the continuity of scientific heritage.

Several manuscript copies of al-Khwarizmi’s works are preserved in various European libraries. Among them, an important copy of “San‘at al-Asturlab” is housed in the Berlin State Library (Staatsbibliothek zu Berlin).

The distinctive features of the Berlin manuscript include:

The manuscript is written in Arabic in naskh script.

It contains astronomical diagrams and geometric drawings.

Marginal notes added by later scribes appear on certain pages.

Paleographic analysis indicates that the copy dates to the 12th–13th centuries.

This manuscript serves as one of the principal sources for textual criticism and scholarly reconstruction. It enables the restoration of the complete text of the treatise and the identification of differences among various manuscript copies.

Muhammad ibn Musa al-Khwarizmi was one of the most prominent astronomers of the 9th century. Unfortunately, many of his works have not survived. His algebraic and arithmetic treatises, astronomical tables (zij), and geographical works have been preserved only in rare Arabic manuscripts or Latin translations.

According to available data, more than ten works are attributed to him. His treatise “Kitab al-‘Amal bi-l-Asturlabat” (“The Book on the Use of the Astrolabes”) is included within an anonymous manuscript collection preserved under number 5093 in the former Prussian Library in Berlin.

I. Frank published a partial German translation of the text [1]. Together with E. Wiedemann, he published translations of two sections of the treatise [2, pp. 122–125]. The treatise was also studied by K. Schoy [3, p. 143]. A Russian description of the work was published by B. A. Rosenfeld and N. D. Sergeeva [4, pp. 201–218].

In the manuscript preserved under number 5093 in the former Prussian Library in Berlin, the name of the author of the treatise is not explicitly mentioned. However, the fifth section of the manuscript begins with the phrase: "Muhammad ibn Musa al-Khwarizmi said…". Since the manuscript follows immediately after Ahmad ibn Kathir al-Farghani's "Kitab 'Amal al-Asturlab" ("The Book on the Construction of the Astrolabe"), and both texts are written in the same hand, researchers until relatively recent times considered this work to be by al-Farghani as well. According to information provided by Sezgin, however, it has been proven that the manuscript in fact belongs to al-Khwarizmi [2, p. 143].

The Berlin manuscript consists of two parts. Its first part is entitled "San'at al-Asturlab" ("The Construction of the Astrolabe"). According to Rosenfeld and Sergeeva, this section represents a revised version of al-Khwarizmi's treatise. It consists of four chapters: the definition of the radii of parallels, tables, the construction of almucantars, the construction of shadows on the astrolabe's surface.

The second part of the manuscript is entitled "Kitab al-'Amal bi-l-Asturlabat" ("The Book on the Use of the Astrolabes") and consists of 48 chapters.

Chapter 1 explains the method of determining the altitude of celestial bodies using the astrolabe. Chapters 2–3 describe how to determine the ascendant (ṭāliʿ) and the time during the night or day. To determine the ascendant according to the Sun's altitude, al-Khwarizmi locates the Sun's position on the rete of the astrolabe using the diopter and rotates the rete until this position corresponds to the almucantar appropriate to the observed altitude. The degree of the ecliptic that intersects the eastern horizon represents the sought ascendant. The angle through which the rete has been turned indicates the elapsed portion of the day. The elapsed portion of the night is determined by placing the corresponding degree of the ecliptic opposite the Sun's position.

In Chapter 4, al-Khwarizmi compares the result obtained by means of the astrolabe with the result calculated from tables, thereby verifying the instrument's accuracy.

Chapters 5–7 discuss the determination of the arcs of day and night. To determine the daytime arc, the Sun's degree is placed on the eastern horizon and the corresponding point indicated in the cell (scale) is marked. Then the Sun's degree is placed on the western horizon and the corresponding point is marked again. The difference between these two degrees represents the daytime arc, while the difference between 360° and the daytime arc gives the nighttime arc.

Chapters 8–9 deal with the ascensions of the zodiacal signs at the terrestrial equator and at various latitudes. To determine the ascension (maṭāliʿ) of a zodiacal sign at the terrestrial equator, al-Khwarizmi places the beginning of the sign on the celestial meridian; the degrees indicated on the scale correspond to the degrees of ascension. To determine the ascension of a sign at an arbitrary location, he places the beginning of the sign on the eastern almucantar, then aligns its end with the same almucantar; the degrees indicated on the scale represent the degrees of ascension.

Chapters 10–12 and 14–15 explain how to determine the ecliptic coordinates of celestial bodies. To determine the ecliptic latitude of a celestial body, al-Khwarizmi measures the altitude of the body and the altitude of its corresponding degree; the difference between the two altitudes equals the ecliptic latitude. To determine its longitude, he places the body's marker on the celestial meridian; the degree of the ecliptic corresponding to that meridian gives the longitude.

Chapters 13 and 19 describe the method for determining declination. To find the declination of a celestial body, al-Khwarizmi determines the altitude of the body's parallel and the altitude of the parallel of the sign of Aries (Ḥamal) at the celestial meridian; the difference between them equals the declination.

Chapters 16–18 are devoted to determining the degrees of rising (maṭlaʿ), setting (maghrib), and culmination of celestial bodies. To determine the degree of rising, the body's marker is placed on the eastern horizon and the position of the indicator on the scale is marked. Then the rete is rotated until the Sun's degree reaches the eastern horizon. The difference between the first and second positions of the indicator gives the degree of rising. The same procedure is applied for determining the degree of setting, except that the eastern horizon is replaced by the western horizon. To determine the degree of culmination, the body's marker is placed on the celestial meridian and its noon altitude—its greatest altitude at that locality—is determined. The corresponding degree of the ecliptic at that meridian represents the body's degree of culmination.

Chapter 20 explains how to determine the arcs of day and night according to celestial bodies.

Chapter 21 describes the method of determining the gnomon's shadow (that is, the cotangent or tangent of the Sun's altitude) according to the "shadow quadrant" on the astrolabe's surface.

In Chapter 22, al-Khwarizmi explains the method for determining geographical latitude.

Chapters 23–24 and 26 describe the method of determining the altitude of a celestial body and the time according to the ascendant (ṭāliʿ). To determine the altitude of a celestial body based on the ascendant, al-Khwarizmi places the degree of the ascendant on the eastern almucantar, then identifies the almucantar corresponding to the Sun's degree; this indicates the altitude of the celestial body at the given time. To determine the elapsed portion of the day according to the ascendant, the degree of the ascendant is placed on the eastern almucantar, and the degree opposite the Sun's degree is examined to see how many hours it corresponds to—these represent the hours that have passed.

In Chapters 25 and 27–28, the altitude of a celestial body is determined according to time. For example, if the Sun's altitude is to be determined by a given hour, its degree is set to the corresponding hour mark; whichever almucantar the Sun's degree intersects in the east or west represents its altitude.

Chapters 29–30 explain the conversion of "equal hours" (1/24 of the full day and night) into "unequal hours" and vice versa.

Chapters 31–33 discuss the equalization of houses and other astrological procedures.

Chapters 34 and 40 compare the geographical coordinates of two locations.

Chapters 35–36 describe the determination of the times of the dawn (fajr), noon (zuhr), afternoon ('asr), and sunset (maghrib) prayers.

Chapter 37 explains how to determine the azimuth of a celestial body.

Chapter 38 discusses the determination of the Moon's rising time, and Chapter 39 explains how to determine the ascendant according to the Moon.

Chapters 41–42 describe a well-known compass (divider) used for determining prayer times. Chapters 43 and 45 are devoted to certain astrological problems.

Chapter 44 discusses various types of astrolabes constructed with 90/n almucantars: full, half, one-third, one-fifth, one-sixth, and others. In the full astrolabe, 90 almucantars are drawn from the horizon to the zenith at intervals of 1°. In the half astrolabe, 45 almucantars are drawn at intervals of 2°; in the one-third astrolabe, 30 almucantars at 3° intervals; in the one-fifth astrolabe, 18 almucantars at 5° intervals; and in the one-sixth astrolabe, 15 almucantars at 6° intervals.

Chapter 46 discusses the division of the inhabited part of the Earth into climatic zones (iqlīms).

Chapters 47–48 describe the method of constructing a quadrant. Chapter 47, in particular, explains the construction of the sine quadrant. The description of the sine quadrant in al-Khwarizmi's treatise represents the earliest known account of this instrument in the history of astronomy as a distinct scientific device.

Conclusion

In conclusion, the great Khwarazmian scholar Muhammad ibn Musa al-Khwarizmi left an enduring mark on world science and is rightfully regarded as the father of modern algebra. He introduced decimal numerals into mathematics and systematized the decimal positional numeral system based upon them. Moreover, his works laid the theoretical foundations for later developments that ultimately influenced the formation of computational science.

Based on the foregoing analysis, al-Khwarizmi emerges as one of the foremost scholars of medieval science across multiple disciplines, including as an inventor and constructor of scientific instruments.

The Berlin manuscript is significant for several reasons:

It demonstrates the development of astronomical instrument-making in the Islamic world.

It confirms al-Khwarizmi's practical engagement in astronomy.

It served as one of the sources that later contributed to the study of Eastern scientific heritage during the European Renaissance.

It contains important information for the history of geometry and trigonometry.

From this perspective, the manuscript is an important object of study not only for source criticism but also for the broader history of science.

Al-Khwarizmi's "San'at al-Asturlab" represents a crucial stage in the development of Islamic science. The manuscript preserved in Berlin constitutes an essential source for studying the textual tradition of the work, conducting in-depth analysis of its scientific content, and reconstructing al-Khwarizmi's astronomical legacy. Textual and source-critical research based on this manuscript will further clarify the role of Eastern scientific heritage in the development of world civilization.

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