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Case Study 10.1: The Maragheh Observatory, Iran

Presentation and analysis of the site

Geographical position: Maragha, North-west Iran

Location: Latitude 37º 23´ 46˝ N, longitude 46º 12´ 33˝ E. Elevation 1560m above mean sea level.

General description: The Maragha Observatory has a unique place in the history of medieval astronomy. It represents a new wave of scientific activities in the Islamic world in the mid 13th century, it had a key role in the development of some sophisticated pre-Copernican non-Ptolemaic systems for explaining the planetary motions, and it was the model for several observatories that were built in Persia, Transoxiana, and Asia Minor up to the 17th century. As an influential institution that was not devoted solely to astronomy, the Maragha Observatory revived advanced scientific studies during what is normally considered the period when science declined in Islam. Ideas initiating from the Maragha School impacted well beyond the Islamic territories and influenced the astronomical revolution of the 16th century.

*Inventory of the remains***:** The central structure, which is assumed to be the main building of the observatory, is circular. Its diameter is 22m and the base of its enclosing wall is 80 cm thick. A 1.5m-wide entrance opens into a 3.1m-wide corridor that marks the meridian line and contains the remains of the mural quadrant, of which 5.5m has survived. On each side of the central corridor are 6 rooms, the pair at each end being smaller than the rest. Outside the main building towards the south, south-east and north-east are five circular constructions. These were the places where the smaller observational instruments were once mounted. There is also a separate building, with an area of 330m^2, which is assumed to be the library of the observatory. In addition, archaeologists have discovered a unit where the metal parts of the instruments were cast and assembled.

History of the site: The construction of the Maragha Observatory commenced in 1259 under the patronage of Genghis Khan's grandson Hūlāgū. Its director was Nasīr al-Dīn Tūsī (1201–1274), an eminent Persian mathematician, astronomer and philosopher whose reputation spread as far as China and whom Hūlāgū had appointed as one of his advisors. The observatory was in fact a scientific institute, with a main building for the observational equipment, some

Fig. 10.1.1. An aerial view of the observatory site. After Parviz Vardjavand, *Kavosh-e Rasadkhaneh-e Maragha.* Tehran: Amirkabir Publications, 1987.

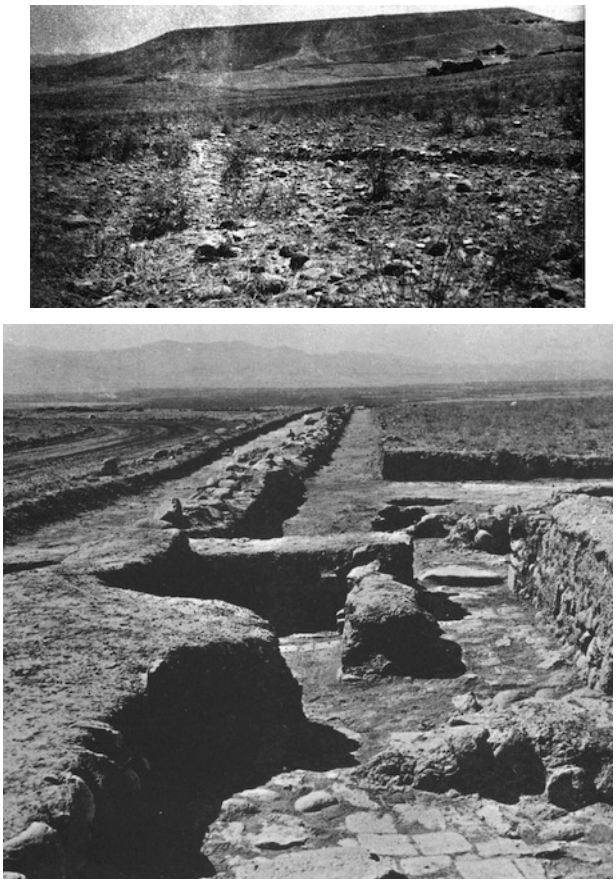

Fig. 10.1.2. The observatory site before excavation (top) and after the first stage of excavation. After Parviz Vardjavand, *Kavosh-e Rasadkhaneh-e Maragha.* Tehran: Amirkabir Publications, 1987.

auxiliary buildings, and accommodation quarters. In the observatory, there was a library which is said to have contained about 400,000 volumes. A team of astronomers, most of whom were invited from different parts of the Islamic world, were responsible for the design and construction of the astronomical instruments, as well as for conducting observations and performing calculations.

According to a text written by Mu'ayyad al- Dīn al-'Urdī (d. 1266), one of the chief astronomers and instrument designers of the observatory, its astronomical equipment included a mural quadrant with a radius of about 40m, a solstitial armilla, an azimuth ring, a parallactic ruler (triquetrum), and an armillary sphere with a radius of about 160cm.

After the death of Nasīr al-Dīn Tūsī in 1274, the Maragha observatory was supervised by his son and remained active until the end of the 13th century. However, following the death of Hūlāgū in 1265 and his son Abāqā in 1282, it lost its powerful patrons and had become inactive by the beginning of the 14th century. Despite this, we have reports that Ghāzān Khān, who reigned from 1295 to 1304, visited the Maragha Observatory several times, probably using it as a model for his own observatory in Tabriz (which has not survived).

Cultural and symbolic dimension: Maragha observatory is the place where Tūsī, with the cooperation of a number of renowned astronomers, mathematicians, and instrument makers, compiled one of the most important Islamic astronomical tables, the *Īlkhānī Zīj*, completing this work in 1272. The astronomers at Maragha also carried out complicated programmes in observational and computational astronomy to update the Ptolemaic parameters.

In addition, the Maragha Observatory represents a turning point in the development of alternatives to Ptolemy's planetary models that were compatible with Aristotelian cosmological principles. These elaborate models, together with further innovations developed at the Samarqand

Observatory and later at Damascus, found their way to Europe and formed a critical part of the mathematical tools that enabled Copernicus to create the heliocentric model of the universe.

Authenticity and integrity: The location of the observatory is essentially an archaeological site with visible material remains and ruins of ancient constructions.

Present site management

Present use: Apart from a few star parties and occasional visits to the site by scholars, there is little activity at the site.

Protection: Since the Islamic Revolution in Iran (1978), the nearby Tabriz University has been responsible for the management and protection of the Maragha site.

State of conservation: In recent years a dome-shaped shelter has been constructed above the remnants to preserve them from further destruction.

Context and environment: The observatory is located at the top of a hill to the west of Maragha.

Archaeological / historical / heritage research: The site of the observatory was excavated in the 1970s by an Iranian archaeological team supervised by P. Vardjavand. They recovered the remnants of 16 original constructional units: some are located at the central observatory building, while others are assumed to be auxiliary structures. There have not been any further investigations since this time.

Management, interpretation & outreach: There is no indication of a general plan for the future of the site.

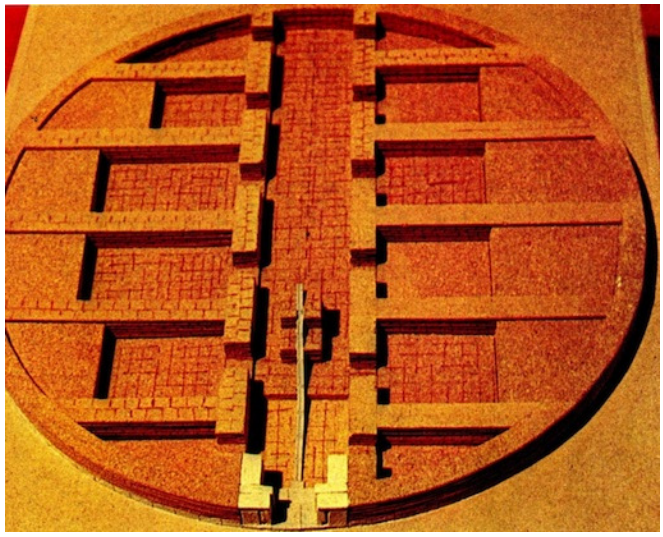

Fig. 10.1.3. Model replica of the observatory site. After Parviz Vardjavand, *Kavosh-e Rasadkhaneh-e Maragha.* Tehran: Amirkabir Publications, 1987**.**

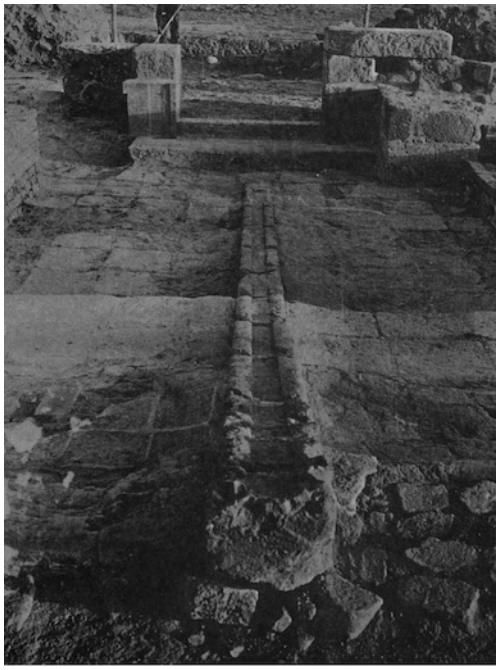

Fig. 10.1.4. Top: The remnants of the mural quadrant, the observatory's main instrument. **Bottom:** Auxiliary observational sites close to the main building of the observatory. After Parviz Vardjavand, *Kavosh-e Rasadkhaneh-e Maragha.* Tehran: Amirkabir Publications, 1987**.**

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Case Study 10.2: Ulugh Beg's Observatory, Uzbekistan

Presentation and analysis of the site

Geographical position: City of Samarkand, Uzbekistan.

Location: Latitude 39º 40´ 29˝ N, longitude 67º 0´ 20˝ E. Elevation 705m above mean sea level.

General description: The site comprises the remains of a meridian arc that originally formed part of the 15th-century observatory of Ulugh Beg. This colossal quadrant, its white marble slabs containing incised Arabic symbols and numerals, was constructing by cutting its lower part out of living rock while its upper part was supported by a brick structure 40m high.

History of the site: Ulugh Beg, the ruler of Transoxiana from 1409 to 1449, had been interested in astronomy from childhood and had visited the remains of Maragha Observatory in his younger years. In 1420 he established a school in his capital city Samarqand, where mathematical sciences were taught, and after four years he established his own observatory, one of the largest in the pre-modern era.

The observatory was a large round building with three stories, decorated with glazed tiles, majolica and mosaic. Its main instrument was a huge sextant with a radius of 40m, embedded in a trench about two metres wide, dug into a hill in the plane of the meridian. This method of construction made the instrument completely stable and reduced the errors arising from the minor displacements common in movable observational tools. At the same time, the enormous size of the sextant made its graduation very accurate. On the arc of the sextant, divisions of 70.2 cm represented one degree, while marks separated by 11.7 mm corresponded to one minute and marks only 1mm apart represented five seconds.

Following the demise of Ulugh Beg the observatory was reduced to ruins. Its remains, primarily the sextant, were discovered in 1908.

Cultural and symbolic dimension: The main purpose of the observatory was to produce a zīj, and the *Sultānī Zīj* or the *Zīj-i Ulugh Beg* was duly compiled in 1438–39. This became one of the most widespread zījs: it was copied more than a hundred times, translated into Arabic and Turkish, and parts of it were translated into Latin and published in Oxford and London in the mid 17th century.

An important aspect of the *Sultānī Zīj* is its updated values for astronomical parameters and new computational procedures. Samarqand astronomers attempted to calculate the trigonometric tables from scratch and derived new values for essential parameters. The basis of the trigonometric tables of the *Sultānī Zīj* is the very accurate calculation of the sine of 1°, which Ulugh Beg Ghiyāth al-Dīn Jamshid al-Kāshī, the senior astronomer of the observatory, calculated using new procedures to sixteen decimal places. His work the *Key to Arithmetic* is one of the best treatises written about arithmetic in the Middle Ages.