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MEASURING TIME ALONG THE SILK ROAD AT THE TIME OF MARCO POLO

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Abstract

The Silk Road is a metaphorical term for the network of roads extending from Southern Europe to East Asia. In the Middle Ages, this vast area included the Eastern Mediterranean, Byzantium, the Muslim Middle East, India and China. Expensive commodities were supplied through this network and various cultural and scientific achievements were exchanged. Thus, astronomical knowledge, hour systems and clocks were exchanged too. In this paper, their study is based primarily on the works of al-Biruni. Travelling over several thousand kilometers at the time of Marco Polo, the Silk Road travellers used to come across different timing systems: temporal and equinoctial. The first was a formal system according to which synchronization of social activities was performed, while the other was used only by scientists. Therefore, there were various sundial constructions of ancient Greek origin for the temporal system, while, as far as is known, equinoctial sundials existed only in ancient China at the time. Besides, during the Middle Ages, as products of naive gnomonics, semicircular sundials became widespread across Europe. They did not belong to any of the previously mentioned systems, and, paradoxically, they dictated a separate time system of their own – one showing unequal hours.

Key Words: *Silk Road, Middle Ages, hour system, gnomonics, sundial*

INTRODUCTION

The Silk Road stretched across the southern part of the north temperate zone, from South Europe to East Asia, from Venice to Chang'an. Not taking into account the connecting routes, land and maritime, it spread for almost a hundred degrees longitudinally and twelve degrees in latitude (with the central parallel at 37° N). It covered various Euro-Asian regions, thus forming a belt in which the ancient civilizations that indebted the entire humanity with their achievements developed.

By exchanging goods and developing commerce, merchants became familiar with diverse customs, religions and philosophical systems, and also different perceptions of time and various ways of timekeeping among ordinary people, clergy and courtiers. To illustrate this, Gurevich (1984, p. 128) cites an example of Europeans who brought a European invention to the Chinese court in the Middle Ages – a mechanical clock, which the distrustful Chinese accepted not as a practical timekeeping device but as a toy.

The time of medieval people was local, unsynchronized with the time of other places on the Silk Road. The pace of their lives and everyday activities was conditioned by natural rhythms and the time did not have its today's value (they did not equate time with money as we do today), so they did not have the need to keep time in today's sense, not to mention the need to conceive smaller time units (Markovic, 2007). "Main time categories of the Middle Ages were year, season, month and day, not hour and minute. Time in the Middle Ages was long, lengthy, slow, epic" (Gurevich, 1971, p. 171). Medieval people, at the time of Marco Polo, did not care about time systems. This "nonsense" was left to scientists who had developed two formal time systems in the ancient times – temporal for daily time orientation, and equinoctial that had more theoretical than practical value.

Invaluable data on division of a day into smaller time units in the Middle Ages in Byzantium, the Near and the Middle East and India were collected by the encyclopedist al-Biruni (973–1048), one of the most versatile scientists of all time. Al-Biruni spoke several languages and used diverse scientific sources, critically and objectively, which can be illustrated by the first paragraph of the chapter on the determination of climates ecumene from *Geodesy*:

> The Romans [Byzantines] and Indians are masters of this skill [determining climates] better than all other nations. However, the Indians have not reached such heights as the Greeks, and they themselves acknowledge the precedence of the Greeks. We also adhere to the views of the Greeks and give them precedence (1025/1966, V, p. 9).

By interpreting the original data from capital al-Biruni's works known under the abbreviated titles as *India, Geodesy, The Mas'udi Canon*, *The Science of the Stars* and *Gnomonics*, published in Russian as selected works (Vol. 2, 3, 5, 6, and 7) on the occasion of the thousandth anniversary of al-Biruni's birth, we will try to explain the astronomical time systems that existed in the Middle Ages along the Silk Road at the time of Marco Polo, their interrelation and describe the timekeeping devices that were used, simultaneously indicating their parallels in the Balkans.

HOUR SYSTEMS IN THE MIDDLE AGES

Unlike the annual, the daily rhythm of the medieval man was quite simple and in everyday life there was no need for the exact, formal division of a day into shorter intervals. The key moments in all informal divisions of a day were the four final positions of the sun in its apparent daily motion over the horizon: sunrise, upper culmination, sunset, and lower culmination. From the heliocentric point of view, these are the four final positions of a certain place on its rotational path: the moment when it passes through the Earth's terminator that separates the night side from the day side, the moment when the meridian of that place is normal to the Earth's terminator, the moment when it passes again through the Earth's terminator (when it moves from the day side to the night side), and the moment at night when its meridian is again normal to the Earth's terminator. The time intervals were established in accordance with these key moments – morning, forenoon, afternoon and evening, which were further divided according to the amount of natural light (dawn, daybreak, twilight, total darkness), usual activities, meals (small lunch, big lunch, etc.), religious services, audio or visual signs in the environment (the first, second and third crow of a rooster) and the like. All peoples have similar, picturesque, informal divisions of a day, sometimes very detailed ones.

A day, a week, a month, and a year as time units were imposed by the celestial bodies and their movements, whereas the division into smaller time units had to be conceived by man. The oldest formal divisions of a day were designed to regulate arrangement of a ruler's court activities, priests' services in ancient temples and monks' activities in monasteries. The earliest divisions at 12 and 60 time intervals were created by the ancient civilizations of China, Babylon and Egypt, which, according to al-Biruni in *The Mas'udi Canon* (1037/1973, Vol. I, ch. 7), were modelled upon the division of a year:

> The number 360 is in the middle between them [between the lunar and solar year] and exceeds their arithmetic mean in only 1/10 days. That is why 360 started to denote the number of degrees in a circle and consequently the number of days in a year. Accordingly, 30 became the number of degrees of one zodiac sign and the number of days in a month (p. 104).

Further division by 60 interrupted this link and there are several explanations of its significance. According to the earliest, the Babylonians knew that the circle is divided by its radius into six sectors of 60 degrees, and since they always applied geometry when conceptualizing reality, this harmony was decisive in choosing 60 as the basic unit. In addition, 60 is the smallest natural number divided by 2, 3, 4, 5, and 6, which proved to be of great advantage in the simple computation technique at that time. The Babylonian sexagesimal numeral system spread further with the help of the Alexandrian scientists through the ancient and medieval periods, and has remained until today for measuring angles and time intervals shorter than one hour.

The ancient Egyptians based their division on the observations of the night sky. Egyptian priests distinguished 36 constellations that they called *decans*. Time interval between the appearance of one of these constellations before sunrise and the appearance of the next one at the same time of the day was ten days, so they divided a year into 36 ten-day weeks. During the night, from the end of the evening twilight to dawn, 12 *decans* appear in a row, and accordingly, the night was divided into 12 intervals, while day and night together into 24 intervals. The ancient Egyptians gave each of these intervals a special name. This division spread through the Greco-Roman influence across Europe.

In *The Mas'udi Canon* (1037/1973, Vol. I, ch.7) al-Biruni describes two types of hours, temporal and equinoctial (Tab. 1).

Table 1

Types of hours in ancient and medieval periods

Type of hours	**Other names**	**Explanation of a name**
Temporal		Their length changes over the course of a year
	Unequal	Day and night hours are not equal
	Measurable	Scales of measuring devices were cut for them
Equinoctial		On equinoxes real and temporal hours are the same
	Justified/Equal	They are equal
	Proportionate	They equal half the sum of a real and a temporal hour
	Equatorial	There are no other hours at the equator

TEMPORAL HOUR SYSTEM IN THE MIDDLE AGES

A temporal hour is the basic unit in the temporal system: a day hour is one twelfth of a daytime, and a night hour is one twelfth of a night (Figure. 1, left). Their length and mutual relations change over the course of a year (Figure 2): in Nevşehir (36,7° N), for example, expressed in modern time units, on summer solstice, the longest day hour is 74 min and the shortest night hour 46 min, whereas on winter solstice the situation is reversed, with the same length proportion. Sunrise – the first hour of a day; apparent noon – the sixth hour of a day; sunset is the end of the twelfth hour of a day and the beginning of the first night hour; midnight – the sixth night hour, and sunrise is the end of the twelfth night hour.

The temporal hour system was a formal system throughout the ancient and medieval periods in Europe and in the Middle Ages in the Arab world, until the invention and perfecting of mechanical timekeeping devices. According to al-Biruni, this system was also known in India (*India*, 1030/1963) but only among astrologers: “Hour is called *hora*, which indicates that they [astrologers] use hours of varying size. The point is that they also call half of the zodiac signs [...] *hora*” (p. 305).

Key elements in the temporal hour system are sunrise and sunset, upper & lower culmination of the sun, noon and midnight, mid morning (3rd day hour), mid afternoon (9th day hour), and 3rd and 9th night hour. These eight moments divide daytime and night to quarters forming an informal, reduced temporal system (Figure. 1, right) that was used more often in the ancient times and the Middle Ages than the formal time system. According to al-Biruni (*India*, 1030/1963), the same divisions were also used in India: “Ordinary people in India accepted the division of a day into eight *praharhg*, that is, the *guard watches*” (p. 301).

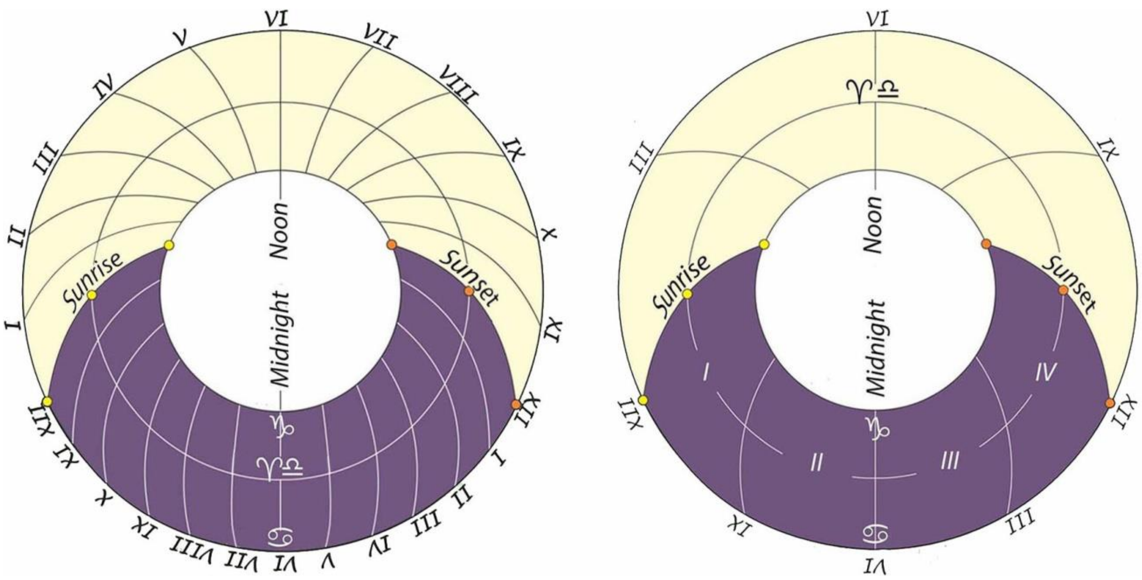

Figure 1. Graphic representation of the temporal hour system: complete (left) and reduced variant with four “guard watches”

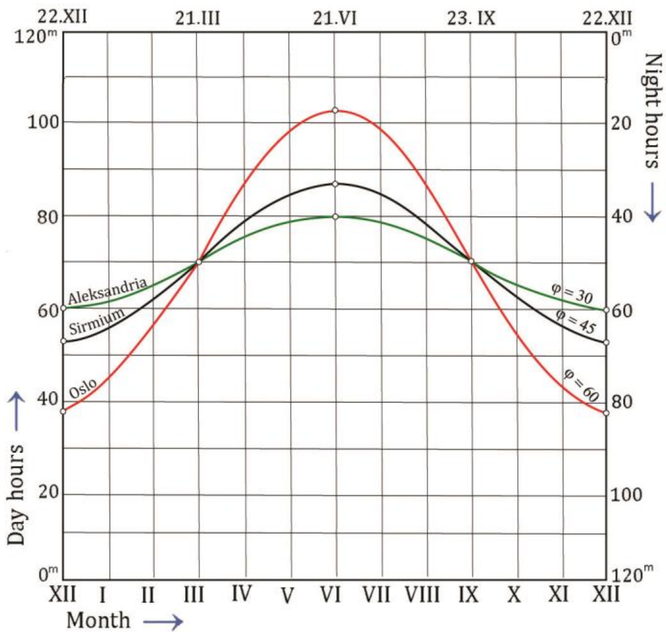

Figure 2. The proportion of day and night hour at different latitudes

In the ancient and medieval periods, noon was most often determined with a gnomon – a "stick of wood or other material conically sharpened at one end, similar to a pole, which was in normal position to the base" (al-Biruni, 1029/1975, p. 107) – as a moment when its shadow falls along the previously defined meridian line. The very midday line was also determined with a gnomon in eight different ways explained in detail by al-Biruni in *The Mas'udi Canon* (1037/1973, Vol. IV, ch.15). In the Middle Ages, in the Arab world, a gnomon was also used to determine the times of the midday and afternoon Muslim prayers, *Zuhr* and *Asr*. Considering this topic, al-Biruni in *Gnomonics* (1025–1030/1987) notes that muezzins usually apply experiential ways: "They use their [own] body as a gnomon, thus becoming natural pillars, and put them in relation to the shadows they have recorded (p. 157).

Time orientation within a day based on the length of one's own shadow was applied throughout the ancient and medieval periods. Astronomers determined geometrically shadow lengths in feet for each temporal hour of a day, using analemmas, assuming that the average height of a man is 6½ or 7 feet. A review of shadow schemes in the Arab world during the Middle Ages was provided by King (1990, pp. 205–206), including the shadow schemes from al-Biruni's *Gnomonics* and *India*. These shadow schemes could have been used by merchants on the Silk Road at the time of Marco Polo, just as they could come across gnomon-pillars erected in town squares or in courtyards of temples.

Figure 3. A Roman sundial for temporal hour system (The Side Archaeological Museum, Turkey (left) and a sundial, 2nd century AD carried on the shoulders by Atlant, Hercules and Zeus, in natural size ,The Srem Museum in Sremska Mitrovica, Serbia (right))

In ancient Greece and Rome there were water clocks (*clepsydra)*, but temporal hours were most often measured by sundials that were built in public places, very often as real works of art (Arnaldi, 1996; Tadić & Prnjat, 2016) (Figure 3, right). In essence, they represented a reversed model of the night celestial hemisphere (Figure 3). The basis of the hour network consisted of the projections of the tropics and the equator divided into 12 arcs through which the hour lines passed. Gnomons were not aligned with the celestial axis, because this position is only useful for the equinoctial hour system. Therefore, time was read according to the end of the shadow of the gnomon and not according to its direction as it is on contemporary sundials. The concave basis was designed to “catch” the ends of all shadows during a day, so it is obvious that the gnomon of the sundial shown in Fig. 3 (left) does not match the dial – the original gnomon must have been shorter (its shadow must not exceed the edge of the hour network).

Greco-Roman sundials did not have dials. They were appropriate for the temporal hour system, because the end of the shadow constantly moved along the front edge of a sundial next to which a dial could be engraved. In contrast to them, in modern sundials, equinoctial hours are read according to the direction of the shadow cast by a sufficiently long gnomon (polos) aligned with the celestial axis.

Apart from various concave sundials with indented dials for the temporal hour system, the ancient Greeks constructed sundials of different orientations – on a flat surface, horizontal and vertical ones. Probably the best example is the octagonal “Tower of the Winds” with six sundials on its stone walls that were constructed in the first century BC by the astronomer Andronicus of Cyrrhus. Greek gnomonists constructed portable sundials as well, and one such (“ham shaped”), found in the ruins of Herculaneum, is exhibited today in the National Archaeological Museum of Naples (Pipunyrov, 1982,

p. 52). Portable sundials were also known in the Middle Ages (Kren, 1977) and it is quite likely that they were used by the Silk Road merchants at the time of Marco Polo. Besides portable sundials, for determining temporal hours, including night hours, ancient astrolabes were used, whose application for this purpose is explained by al-Biruni in *The Science of the Stars* (1029/1975, Ch. 7).

EQUINOCTIAL HOUR SYSTEM IN THE MIDDLE AGES

Daytime and night hours are equal on the equinox. An hour, the 24th part of a day is called the equinoctial hour, and the system – the equinoctial hour system (Figure 4). The hours were counted as today, from midnight. This system was used in the ancient and medieval periods by astronomers, astrologers and geographers, from Eratosthenes, Hipparchus and Ptolemy to al-Khwarizmi, al-Biruni and many others. At that time, the latitude of a place (climat) was determined by duration of the longest daytime period and it could not be expressed in temporal hours (each daytime lasts 12 temporal hours). Thus, for example, Nevşehir would be placed in the IV climate, determining its position by duration of the longest daytime period – 14¾ hours (equinoctial hours).

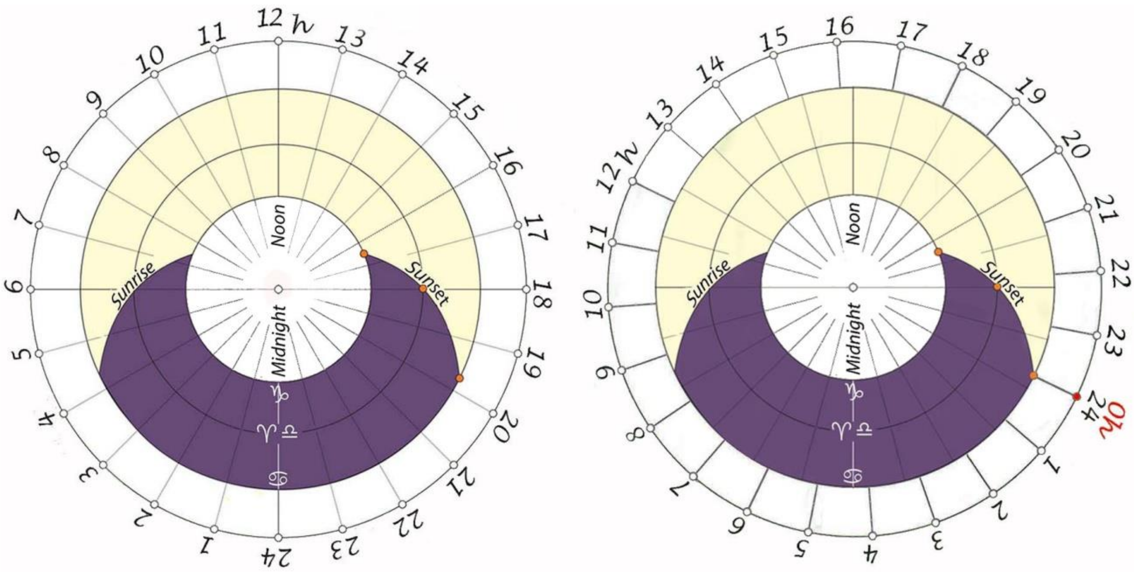

Figure 4. Graphic representation of the equinoctial time system (left) and Byzantine ("alla turca") variant (right)

Since in Byzantium and in the Arab world, a new day began at sunset, a variant of the equinoctial system was used, in which the sunset was the zero moment from which hours were counted from 0 to 24 h or from 0 to 12 h twice. The choice of sunset as a zero moment is explained by the lunar calendar: 1) a new month of the lunar calendar begins with the first appearance of the young moon; 2) the young moon becomes visible shortly before sunset; 3) this means that sunset represents the beginning of a new day, that is, the beginning of hour countdown. In Europe, this variant of equinoctial system is known as “ab accasu”, “Byzantine”, “old Italian” and “old Czech” variant. The variant with the “dual reading“ from 1 to 12 hours that was applied in the Islamic world, was known in Europe as “alla turca”. In the Ottoman Empire, this system was used since the 15th century and was the official time system in Turkey until 1926. In contemporary Europe, the Byzantine variant of the equinoctial system is used only on the “Holy Mountain” (Mount Athos), with the exception of the Greek (once Georgian) Monastery of Iviron, in which the equinoctial hours are counted in a Babylonian way, from sunrise (“ab ortu”) (Tadić, 2014).

On sundial scales of this variant of the equinoctial system, projections of the celestial sphere with tropics cover the field through which the hour lines without a common pole cross. The gnomon casts a shadow that cuts the hour lines and with its end shows the day hours: on Figure 5 (left) the end of the shadow of the gnomon shows 5 h 45 min (17 h 45 min). Vertical sundials of this type were mounted for a long time in the Islamic world on the walls of mosques (Selin, 1997, pp. 922–923) (Figure 5, left). On them the end of the shadow of the gnomon showed, besides day hours, solstices and equinoxes, beginnings of the midday and afternoon Muslim prayers, *Zuhr* and *Asr* (Selin, 1997, p. 88). The only sundial of this system on the territory of the former Yugoslavia is preserved at Hadji Ali-Bey’s mosque in Travnik (Figure 5, right) (Tadić, 1991a; 1991b).

Figure 5. A vertical sundial at Fatih Mosque (Istanbul), late 16th century (left) and a sundial at Hadji Ali-Bey’s mosque (Travnik, B&H) that was constructed when the mosque itself, in 1856.

Sundials built on the walls of mosques have a standardized graphic solution – simple and beautiful (Figure 5). The hour network is framed by a right triangle. The vertical leg is the gnomonic projection of the local meridian arc (and also the line for the midday prayer time – Arabic, *zuhr*, Turkish, *öğle*), while the horizontal leg is the projection of the evening arc of the horizon and the starting point of the hour line. The hypotenuse of the triangle connects the endpoints of the gnomonic projection – the Tropic of Cancer and the Tropic of Capricorn by a hyperbola arc that covers the field of the sundial within which the end of the shadow of the gnomon moves during a year. The field is divided by the projection of the celestial equator along which the end of the shadow of the gnomon moves on the equinox.

On the sundial from Travnik (Fig. 5, right), the projections of the tropics are connected by a slightly curved line that indicates afternoon prayer time (Arabic *asr*; Turkish, *ikindi*). Hour lines are directions without a common pole. They are drawn between the projections of the tropics indicating every 15 minutes on the hour scale; only lines indicating full hours reach the hypotenuse. There is a dial engraved along the hypotenuse in the Eastern Arabic figures. The dial range is 5–12 "alla turca" hours. On the sundial of the Fatih Mosque in Istanbul, on the right of the hypotenuse of the basic triangle, there is a special gnomon with a ten-line scale for the afternoon prayer time (Figure 5, left).

This graphic solution of the hour scale of a vertical wall sundial that Çam (1990, p. 193) names as "triangular sundials" has proved to be the most suitable for southwestern walls, that is, for mosques in the southeastern Qibla area, such as the Balkans and Turkey.

HOUR SYSTEMS IN THE MIDDLE AGES – DIFFERENT FROM TEMPORAL AND EQUINOCIAL

The division of a day (day and night together) into 24 equal hours, and the division of an hour into 60 minutes was not the only division into equal intervals in the Middle Ages. In *India* (1030/1963, Vol. XXXIV) al-Biruni writes that the Indians divide a day into 60 minutes that they call *ghati*, which are further divided into 60 seconds, called *casaka* or *vighatika*. They consist of six parts called *prana* and are defined as a medium breathing of a sleeping person who is in two equilibria, spirit and body, that is,

> ...as a breathing of a sleeping person with normal sleep, a person that is healthy and does not abstain from physical needs, a person that is neither hungry nor overeaten, a person who is not burdened with worry or sorrow. [...] or [without] any cause that disturbs the most beautiful spiritual mood and brings various changes into the breathing of a sleeping person (p. 299).

After *prana* al-Biruni lists even smaller time units such as, for example, *nimesha* – a blink of an eye (3/4 seconds), and *truta* – a cracking of fingers (3/256 seconds) (Tab. 2), adding that the Indians are improving their time system in vain by conceiving smaller time units and that "it is impossible to read in two different books or to hear from two different persons two equal sets of time units" (al-Biruni, 1030/1963, Vol. XXXIV p. 299).

Table 2

The proportion of time units in the Old Indian division of a day

Time unit	Number of times it is present in a higher-level unit	Number of times itis present in a day
Ghati, nadi	60	60
Ksana	4	240
Casaka, vighatika, kala	15	3600
Prana	6	21600
Nimesha	8	172800
Lava	8	1 382 400
Truta	8	11059 200
Anu	8	88 473 600

Note. Taken from (al-Biruni, 1030/1963, p. 301).

In medieval Europe, there were similar attempts to make abstract “cuts” of a day. Thus, Honorius of Autun (1080–1154) divides an hour into five smaller parts, from a minute (one tenth of an hour) to an atom (22560th part of an hour), acknowledging that an hour is the limit for time keeping devices of that time: “Hora is the end of anything whatsoever […] And it is called this from horologium, that is, it is the definite boundary of time on the clock” (as cited in Spence, 1996, p. 21).

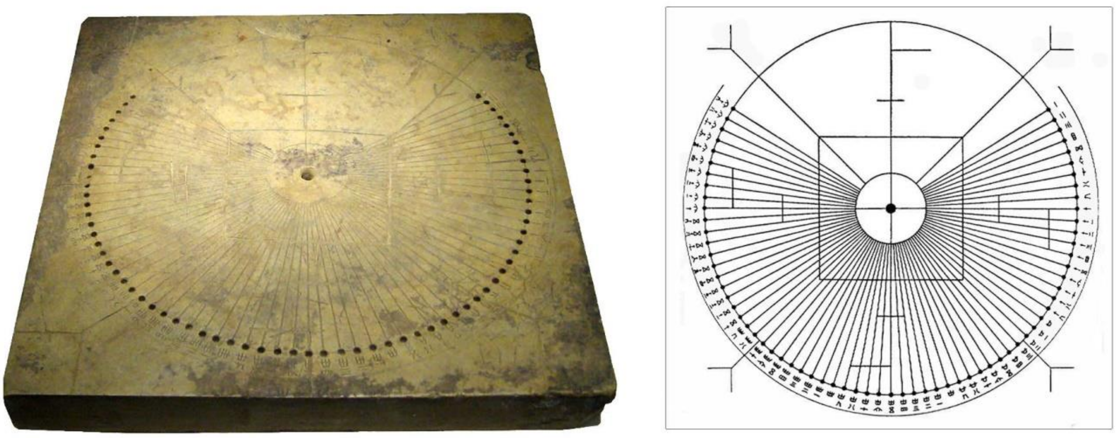

Figure 6. An ancient Chinese sundial (The National Museum of China, Beijing) (left) and an outline of its scale that consists of 69 equal segments (69/100 segments of a complete circle). Adapted from *The Science News-Letter*, Vol. 34, No. 14 (Oct. 1, 1938), p. 211. Copyright by Society for Science & the Public Stable.

In addition to the division of 24 (2 x 12) and 60 intervals, derived from the division of a year (from the number of days in a year and the number of degrees in one zodiac sign), there was also a division of a day into 100 parts in ancient China alongside a division into 12 parts (6 + 6) (James, 1909). This is evident on a sundial, of which this is a line drawing, made about 2300 years ago, at the time of the Han dynasty (206 BC–AD 220) (Figure 6).

It is the base of an equatorial sundial that the Chinese had made for centuries (Needham, 1974, p. 69; Selin, 1997, pp. 920–921). The base is placed in the plane of the celestial equator so that the direction of the shadow of the gnomon that is inserted at a right angle through the centre of the base and aligned with the celestial axis shows day hours. The scale of 69% of a full circle corresponds to a solstice daytime of 16 h 34 min, that is, the latitude of 51° 49’ N (further to the north than the old capital of China Chang’an – 34° 16’ N), which indicates that this device was not only a sundial.

In *Geodesy* (1025/1966), for example, in the section “On determining the latitude of a city and the Sun’s declination by their interrelated calculation” (p.151), al-Biruni describes determination of the latitude of a place by means of a simple device that consists of a square plate in whose centre a gnomon of the v height is fixed. A circle whose radius is calculated by the formula $r = v\ ctg$□□□is drawn from the centre of the plate, whereas □□ is the declination of the sun at the moment of measurement. The plate is placed on a horizontal surface so that the centre of the lower edge lies on a previously specified meridian line. Without moving the lower edge, the plate is tilted slowly until the end of the shadow of the gnomon falls on the drawn circle. The angle which the surface of the plate forms at that moment with the horizontal base equals the inclination of the equator towards the horizon, and its complementary angle represents the latitude of that place. In this way, al-Biruni positioned the plane of the plate in alignment with the plane of the celestial equator, and the gnomon with the celestial axis, so that circle drawn on the plate becomes a gnomonic projection of the Sun’s apparent path on that day (that is, the projection of the corresponding celestial parallels). Therefore, al-Biruni describes the determination of the latitude of a place (climat) with the help of a simple device that, when its circle is divided into identical sectors, becomes an equatorial sundial such as the aforementioned Chinese sundial. (Tadić, 2002a, p. 22-23). Obviously, al-Biruni knew very well the principle of constructing equatorial sundials, which can be seen in the following sentence from his *Gnomonics* (1025–1030/1987, Ch. XXVI):

> There are many different forms of basic sundials. Among them all, apart from the horizontal ones, sundials laid in the level of the meridians and also those laid at the level of the beginning of the azimuth circles [in the prime vertical plane] and the celestial equator plane can be distinguished (p. 238).

Time orientation is inseparable from spatial orientation. In the ancient Chinese division of a day into equal parts, the key moments were midnight and noon, which corresponded to the meridian spatial orientation: north is the equivalent of midnight (reflection of the "celestial" orientation), while south is the equivalent of noon (reflection of the "earthly" orientation) (Podosinov, 1999, p. 87). In this regard, ancient Chinese temples are oriented in the south–north direction (entrance in the south, the altar section in the north) while Christian temples are oriented in the west–east direction (entrance in the west, the altar section in the east), which is in accordance with the temporal hour system. At the very beginning, even in the Islamic world, the orientation of the temples had a solar meaning that was not completely lost even after moving to the orientations towards Mecca. It was preserved indirectly through one of the ways of determining Qibla, which can be done in the following way: dates and moments of local time in a place are determined when the sun is found in the zenith of Mecca/Kaaba, that is, when the shadows of the gnomon fall along the local Qibla.

VISUAL-TEMPORAL HOUR SYSTEM

Apart from the precisely constructed sundials, in ancient time and the Middle Ages, there were simple wall-mounted sundials as products of naive gnomonics: a semicircle divided into 12 equal sectors with a horizontal gnomon in the centre (Figure 7, left). Some of the best preserved sundials of this type have been found in Anatolia, Turkey – among the nearly 150 Anatolian sundials, there are 14 of this type (Özdemir, 2013, p. 15).

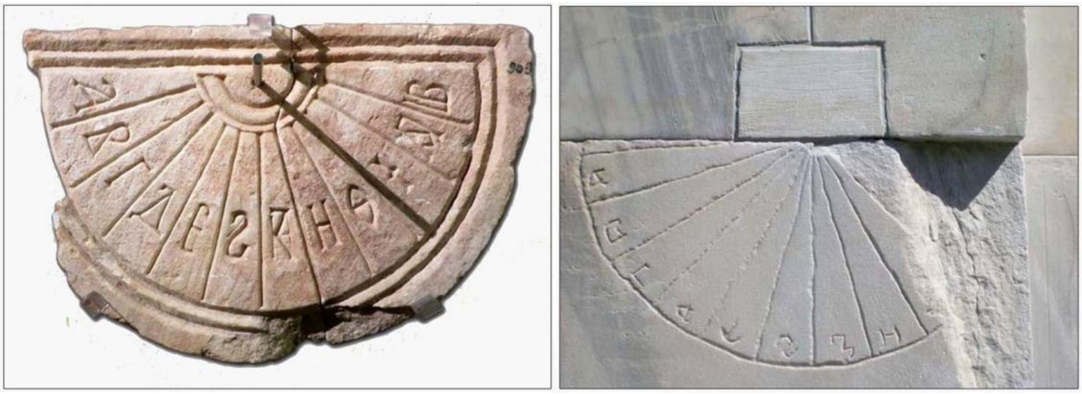

Figure 7. A Byzantine sundial from Nicomedia, 9th or 10th century (The Archaeological Museum, Istanbul) – the horizontal gnomon is not original (left) and a sundial from the Studenica Monastery, 12th/13th century (Serbia)

Armenian sundials are also among the best preserved. Some of them are "authorized" (Weis, 1988, p. 92) and as such they are unique in two ways: they are stylized in the form of a palmette, carved or embossed, and for the first time (7th century) there are dials (only later in the 9th century the Byzantine sundials would have dials) with the letters of the Greek alphabet in the role of numbers (Weis, 1988; Lush, 2011). The first hour of a day is indicated by the first letter of the Greek alphabet

A, denoting number 1, the second letter B denotes number 2, etc. (Fig. 7, left). The oldest sundial in the Serbian lands belongs to this type of sundials. It was mounted on the Studenica Monastery, on the southern portal of the Church of the Holy Virgin (Tadić, 2011) (Figure 7, right).

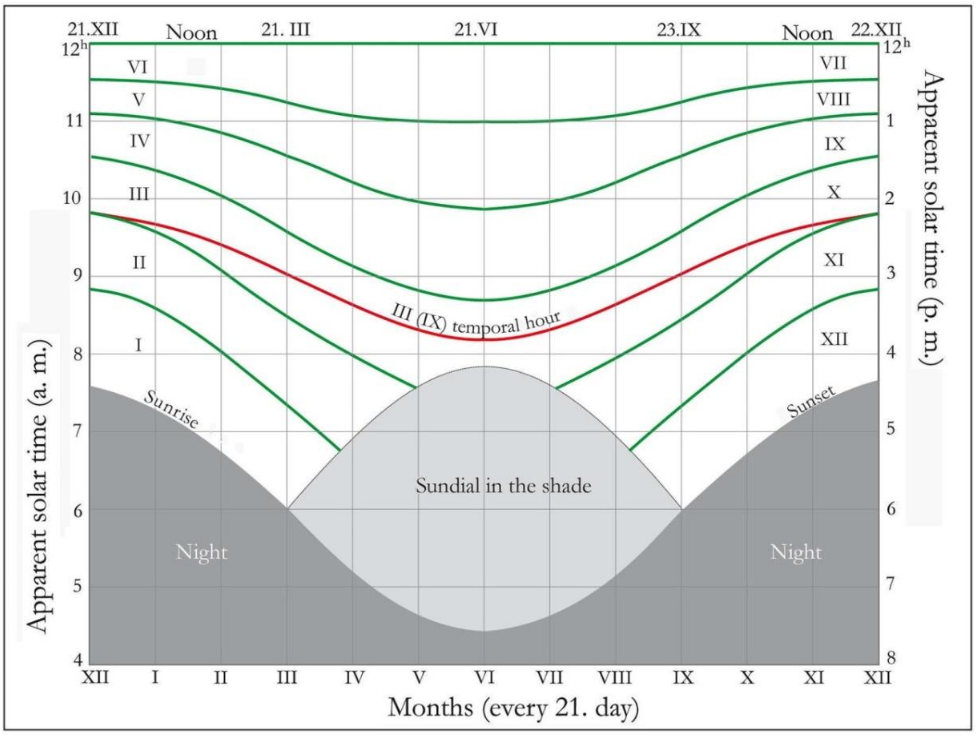

Figure 8. Parallel description of the annual circle of time intervals indicated by the shadow on the sundial on a latitude of 43° 30’ N, and hours of the temporal hour system

Semicircular sundials originate from ancient Egypt (Schwarzinger, 1999) and although they have a rather simple construction when compared to precisely constructed sundials, they remained in use during the ancient time and the Middle Ages when they became extremely widespread across entire Europe, from the Byzantium and the Mediterranean all the way to the British Isles (Cowham, 2011) and Scandinavia. They appear in various forms, with different decorations, with 12, 8 or 4 sectors, equal or different, primarily on churches (sometimes with lines that highlight prayer time), but also on other public buildings and in public places, in Ireland, for example, even in cemeteries (Arnaldi, 1996; Arnaldi 2011).

These sundials were not constructed *lege artis* and they did not indicate hours of the formal temporal hour system (Figure 8). Nevertheless, their equal sectors (15°) that were covered by the shadow of the gnomon in different time intervals can be exactly determined (Tadić, 2002b). These time intervals are symmetrical near noon (1st and 12th, 2nd and 11th...) and are becoming shorter from sunrise to noon (from 1st to 6th hour) and at the same pace they are getting longer until sunset (from 7th to 12th hour). The same time interval is the shortest on winter solstice and the longest on summer solstice. These sundials were mounted on southern walls so they were “fully operational” only during winter.

Semicircular sundials (ecclesiastical, missionary, scratch, medieval) are one of the symbols of the Middle Ages and indicators of the perception of time of the people of that era. The answer to the question when the Middle Ages ceased to exist could be the following – when the semicircular sundials ceased to be built.

CONCLUSION

In the mind of a medieval man, at the time of Marco Polo, time did not occupy such an important place as it does in the mind of a modern man who has built the cult of time. Today, people are always busy, their days are rather hectic. In the Middle Ages, time was slow and lengthy and the only indication of passage of time was the shadow of the gnomon on a sundial. For the vast majority of inhabitants of medieval cities, the basic indicators of parts of a day were their own shadows and the sounds of the bells that called for prayer or signified the opening or closing of the city gates. As luxury items, timekeeping devices (sundials, water and sand clocks) were quite rare, mostly owned by courtiers, clergy or wealthy individuals.

In the Middle Ages, in the Arabic world and in Europe, there were two hour systems: temporal and equinoctial. The temporal hour system was a formal hour system throughout the ancient and medieval periods, and it was based on seasonally variable day and night hours, first defined as the twelfths of a day and the other as the twelfths of a night. The daytime hours were longer in summer and shorter in winter, which was in line with the way of life and everyday activities of people of that era.

The beginnings of religious services, shifts of guards, court debates, official manifestations were all scheduled according to the temporal hour system. Temporal hours were most often measured by one’s own shadow and the shadows of sundials mounted in public places. Such sundials or “shadow hunters” remained unrivalled by the ingenuousness of their structural solutions.

Unlike the temporal, the equinoctial hour system did not have practical value until the end of the Middle Ages. It was used only by scientists, astronomers and geographers to determine the position of celestial bodies and latitude of a place. Namely, throughout the ancient and medieval periods, latitude of a place was determined by duration of the longest day, so for Samarkand it can be said that its latitude is 39° 38’ N or that its longest daytime period is 14 h 48 min, in equinoctial hours. The only preserved timekeeping devices for the equinoctial hour system from the time before Marco Polo are the ancient Chinese equatorial sundials.

There was a tendency among the scientists of the Middle Ages to divide a day into smaller and smaller intervals (for example, Indian scientists), but this remained at the level of abstract gradations, since this kind of "atomization" was in evident contrast to the timekeeping devices of that time, which could not "follow" such short intervals – an hour remained the ultimate measurement unit of time during the Middle Ages.

Semicircular sundials that showed unequal hours, neither temporal nor equinoctial, different from each other day after day and also within a single day, were typical of the Middle Ages. The hour system did not dictate the construction of these sundials, on the contrary – it was the hour scale that dictated a particular division of a day. Taking into consideration their longevity of several centuries, it might be said that a third medieval time system existed: a visual-temporal hour system.

Thus, the Middle Ages at the time of Marco Polo, and even before him, are characterized by the simultaneous existence of a formal temporal time system and a twelve-hour semicircular sundials that did not rely on that system. Nevertheless, there were not any negative practical consequences of this discrepancy in the synchronization of daily activities. Ordinary people were not aware of that paradox because timekeeping devices that would give reliable information about the exact time did not exist until the 14th century, when the sophisticated mechanical clocks appeared and marked the end of a slow, "epic" time and the beginning of a new time announced by busy merchants of the Silk Road.

It can be said that medieval people, compared to modern, had an extremely negligent attitude towards time, but it can also be said that in a sense they were more realistic because they did not believe in a naïve idea that time can be measured.

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