

# THE XIANGFEN, TAOSI SITE: A CHINESE NEOLITHIC ‘OBSERVATORY’?

DAVID W. PANKENIER, CIYUAN Y. LIU, SALVO DE MEIS

## Abstract

The Taosi late Neolithic site is located in Shanxi Province in north-central China. Three decades of excavation have unearthed storage pits, dwellings, and many artifacts, identified as the Taosi culture type (4300 to 3900 BP). Recent excavations led to the discovery of the tombs of chiefs of the Early Taosi period, and the largest walled-town in prehistoric China. A semi-circular foundation built in about 4100 BP along the southern wall was also discovered. The design of the raised terrace within it would have permitted observations of sunrise at specific dates along the eastern horizon. Here we report on what has been learned about this fascinating site, and analyze its astronomical features and function.

Key words: China, Neolithic, Taosi culture, solstice observation, archaocastrology, horizon calendar.

## Introduction

The Xiangfen, Taosi site (N 35° 52' 55.9" E 111° 29' 54" in Shanxi Province is located some 5.5 km from the Fen River to the west and barely 10 km from Ta'er Mountain to the east. According to historical accounts and local tradition, this area was the heartland of the first dynastic polity in Chinese history, the Xia, which ruled the north central China plains area along the Yellow River from ca 2100 to ca 1600 BCE. Taosi lies only 20 km from Pingyang, which is identified in ancient sources as the location of the capital of “Emperor” Yao, the semi-legendary hero whose sagely governance supposedly played a crucial role in the formative period of Chinese civilization.

The Taosi site contains the ruins of at least four walled cities which were successively occupied for some four-hundred years during the late Neolithic. Abutting the southeast wall of the large Middle Period city (ca 2100 BCE) is a smaller walled enclosure with a raised platform which has excited great interest. The arc of this foundation approximates the range in azimuth of sunrise along the eastern horizon at the latitude of Taosi. Observations from the center of the platform suggest that features on the foundation are oriented toward points on the mountain ridge to the east/southeast where the sun rose on certain dates. Below we report on the design and purpose of the site and evaluate the hypothesis that the Taosi site is a solar ‘observatory’.

## Archaeological and astronomical features of the Taosi site

### Archaeological characteristics

Excavations at Taosi from the late 1970s through the 1990s uncovered dwellings of commoners and an elite cemetery at the site, resulting in the identification of the Taosi culture type (ca 4300 to 3900 BP). Subsequent excavations led to the discovery of over 1 300 elite tombs, including those of the chiefs of the Early Taosi period, pointing to the emergence of a pre-dynastic kingdom. The <sup>14</sup>C dating and the location are both consistent with a transition to the early dynastic period which followed.

From 1999 to 2001, archaeologists excavated a huge pounded-earth enclosure from the Middle Taosi period (4100 to 4000 BP). Rectangular in shape with an inner area of 280 ha, it makes the Taosi site the largest walled town in prehistoric China. In addition to numerous building foundations, burials, storage sites, etc., the archaeological finds include a bronze bell, fine jades, painted pottery, and evidence of extreme social stratification. In addition, the discovery of a mark written with a brush and paint and reminiscent of the Shang dynasty oracle-bone script half a millennium later has led to speculation about the possible contemporaneous use of writing.

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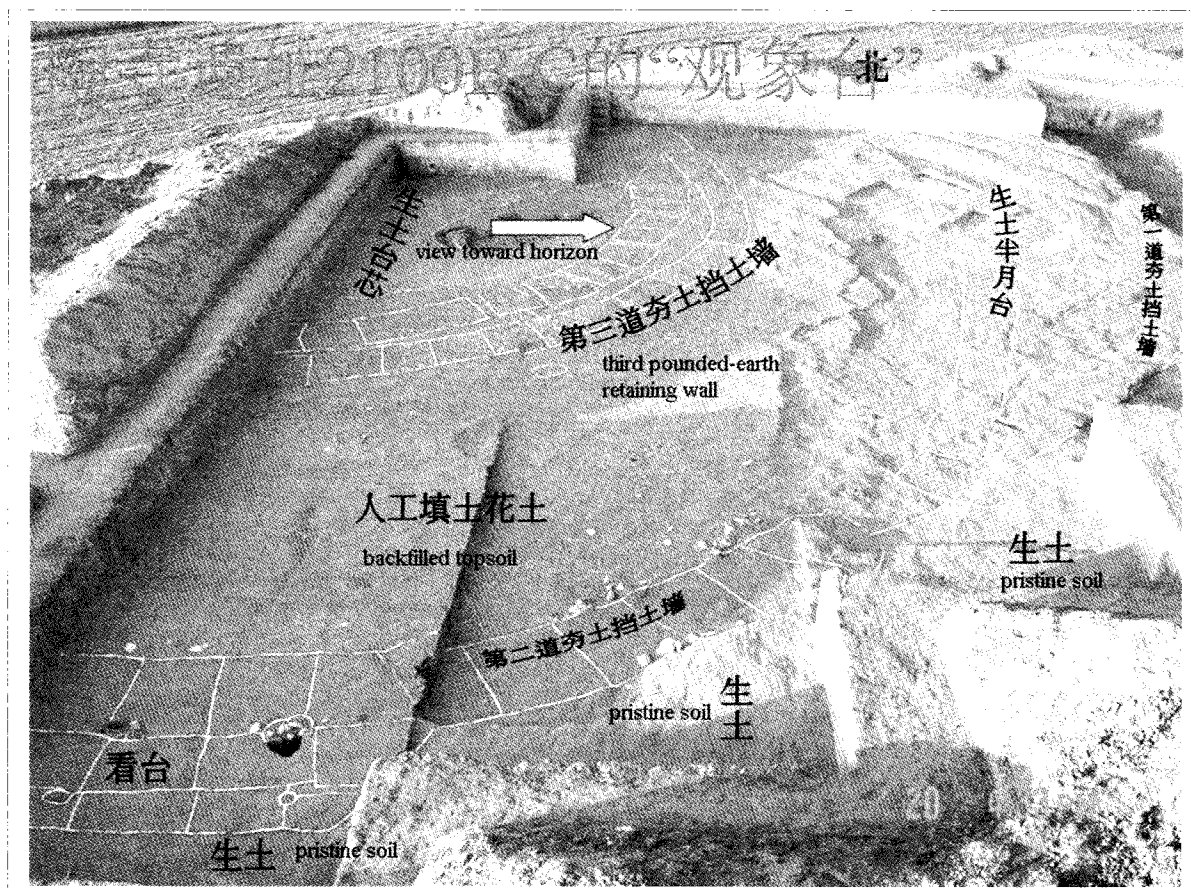


Fig. 1. Taosi observation terrace.

Excavations during 2003-04 unearthed a semi-circular enclosure along the southern perimeter of the Middle Taosi period city wall (Fig. 1).

The enclosure consists of an outer ring-shaped path and a pounded-earth platform with a diameter of about 60 m and an area of nearly 1,740 m<sup>2</sup>. It can be reconstructed as a three-level altar. The third level, the top of the altar complex, is a semi-circular platform. On it a curved pounded-earth foundation faces east-southeast, its upper surface scored by twelve regularly spaced grooves, each about 1.4 m apart, an average of about 25 cm wide, and 4 to 17 cm deep. Analysis of the grooves indicates that the raised portions of pounded-earth between them are the remains of more or less uniformly shaped earthen pillars, rectangular or trapezoidal in cross-section, erected at regular intervals to create narrow apertures. The arc of the semi-circular foundation approximates the range in azimuth of sunrise along the eastern horizon at the latitude of Taosi. Standing at the center of the platform and observing through the reconstructed apertures, it was found that most are oriented toward the mountain ridge to the east-southeast. The range in azimuth defined by apertures E2 to E12 precisely matches the arc defined by the sun's azimuth at sunrise between the solstices. These features of the

site immediately suggested to archaeologists the possibility that the site had been used to observe the rising sun throughout the year and that the apertures served as backsights.

Preliminary analysis, based on calculation as well as on-site observations in 2003-04, suggested that the apertures were originally intended to permit observation of the rising sun at certain times, especially the solstices. In other words, the complex is thought to have been a sacrificial site and solar 'observatory' whose design would have permitted the establishment of a horizontal calendar. The discovery would be unprecedented in China and would lend support to early historical accounts of the use of such observational methods at this time.

#### Astronomical study

The archaeological team led by He Nu which excavated the semi-circular platform in 2003-04 (He 2004) recognized that the length of the pounded-earth foundation suggested a possible use in connection with sunrise observations and sacrifices. Preliminary measurements were made with transit and compass from the presumed center of the arc, followed by simulated

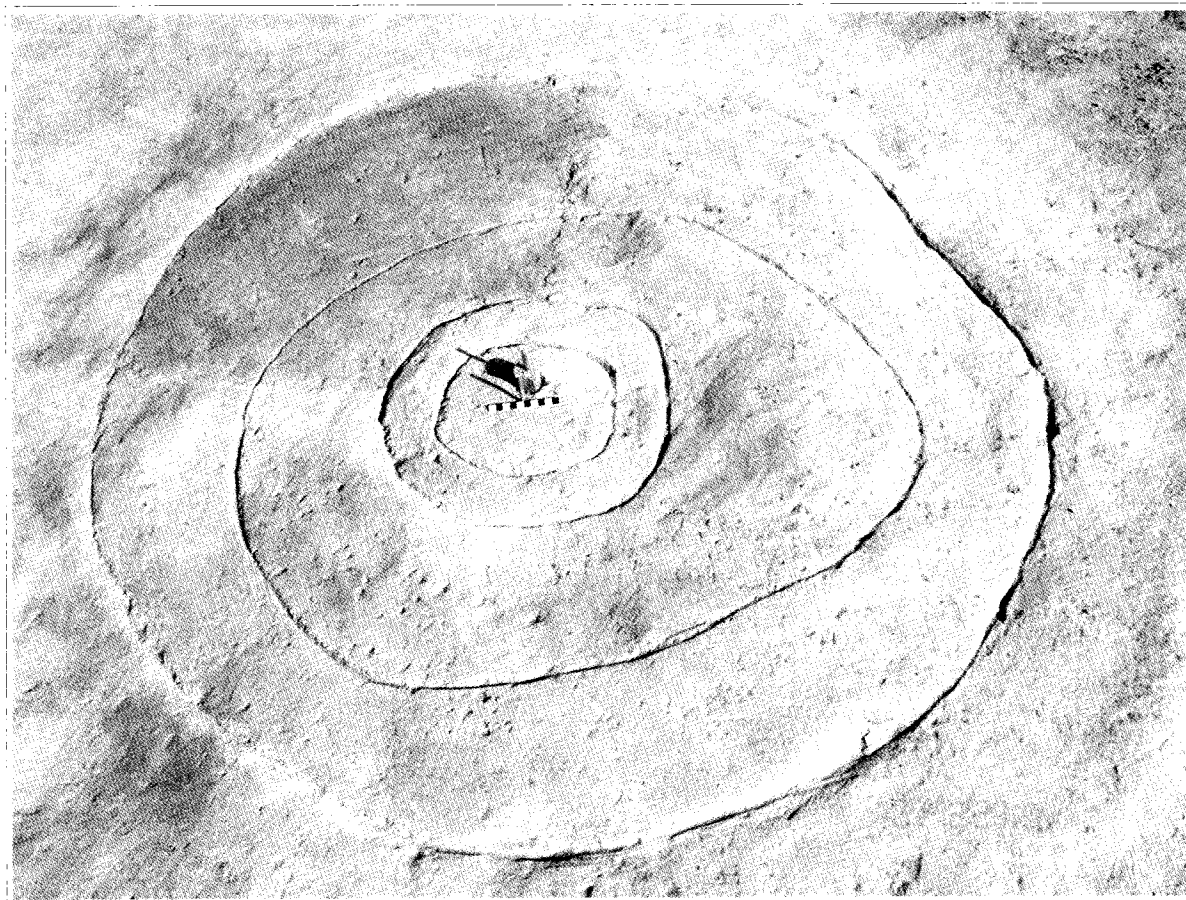


Fig. 2. Central observation point.

sunrise observations in 2004-05. The observations were accomplished by fabricating an iron frame with the same dimension as the viewing apertures, and then erecting the frame on one slot after the other to determine whether the sun rose in the framed space. It was only after these measurements and observations had been completed that a circular pounded-earth platform was discovered under a previously unexcavated column of earth (Fig. 2). At the very center of this small circular platform was a pounded-earth core 25 cm in diameter, which apparently marked the precise point from which the original observations were made.

This central observation point lay only 4 cm from the center of the platform computed by the archaeologists, lending strong support to their presumption about the platform's observational function. Preliminary calculation of the sun's rising points on the solstices at Taosi in 2100 BCE by Wu Jiabi and He Nu (2005) confirmed the presumption that the structure was used for that purpose. Further consultation with astronomers then led the archaeologists to conclude that the preliminary measurements and observations initially based on the computed center of the platform had to be repeated, this time using the actual central observation point as well as higher precision equipment. This was accomplished in 2004-05.

### Structural features

Several things are immediately apparent from the design of the structure. First, the sun could never have risen in the southernmost aperture (E1) because this backsight is oriented toward a point on the horizon several degrees south of winter solstice sunrise. This has given rise to speculation that alignment E1 may have been intended to mark the moon's major standstill limit. Second, for the backsights E2-E12 to have served the intended purpose, the pillars (or posts) which originally defined them would have to have been 3-4 m tall in order to bracket the sun's rising point on the mountain ridge some 10 km distant. Third, the two backsights E11 and E12 at the northern end of the arc are significantly offset from the curve of the main foundation and also deviate somewhat in their dimensions, suggesting the possibility of a different purpose or, perhaps, construction at a different time. Subsequent detailed analysis of the physical features of the structure (Wu et al. 2007) indicates that in general it was crudely built, in that the pounded-earth foundation conforms poorly to the arc of a circle. As a result, several of the backsights (E1, E6, E9) do not actually point toward the original observation point. (Fig. 3) This has the effect of drastically narrowing the apparent size of the aperture in some cases from the perspective of the



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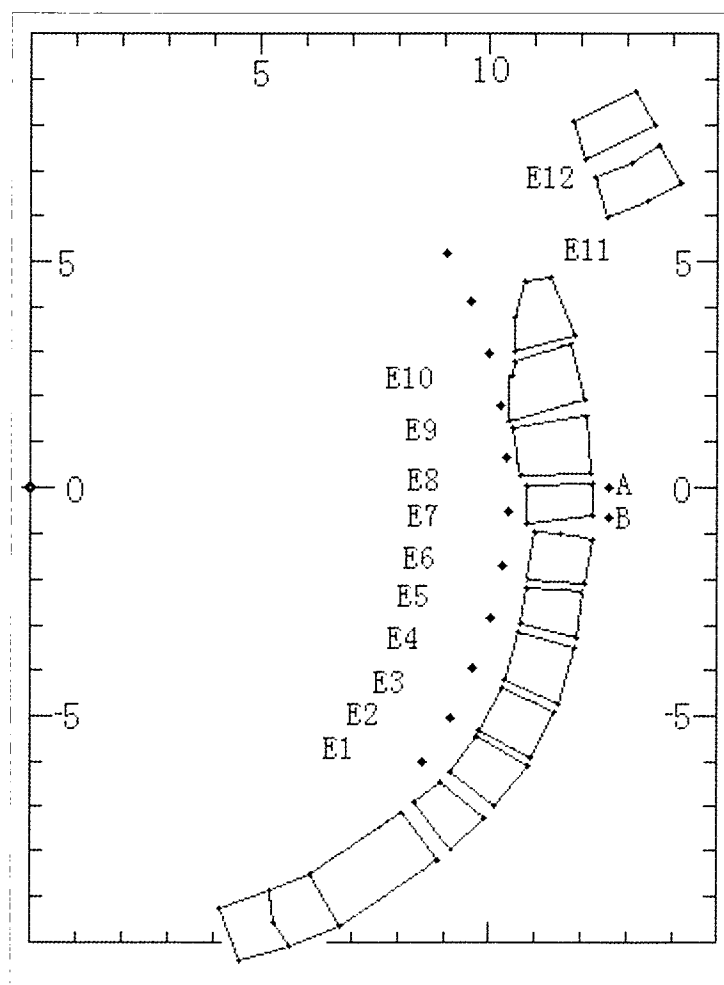


Fig. 3. Theoretical layout (in gray) superimposed on a precision drawing of the actual structure (after Wu et al. 2007).

central point (marked by the dot at zero meters on the lefthand scale). It is also curious that the backsights number exactly twelve and were regularly spaced, since the sun moves much faster along the horizon around the equinox by comparison to the weeks near the solstices. This means that the intervals defined by the 12 backsights, rather than demarcating fortnightly periods, would have varied greatly in length. In this the Taosi structure resembles the towers of Chankillo in Peru from two thousand years later which appear to have served a similar purpose (Ghezzi et al. 2007).

### Astronomical Analysis

Shown here in Table 1 are the characteristics of the Taosi site derived from the latest survey data (IACASS 2007). The first six columns on the left reproduce the physical features of the twelve backsights E1-E12. Column four shows the approximately  $5^{\circ}$ - $6^{\circ}$  difference in azimuth between backsight midlines, which is a reflection of the more or less regular size of the slots and the pillars separating them. As noted above, this regu-

larity is not reflected in the apparent slot width in those cases where the backsight does not accurately point toward the central observation point. The misalignment has the effect of drastically compromising the aperture's usefulness, for example in the case of backsight E6, whose apparent width is only  $0.09^{\circ}$ . Deviation from the norm is also apparent in the case of backsights E10 and E11 marking the transition between the main curve of the foundation and the significantly offset pillars that define backsights E11-E12 on the north end of the array. This deviation also has the effect of drastically altering the structural symmetry in terms of the number of days intervening between the sun's appearance in successive backsights near the solstices (column 10, " $\Delta n$  days", in Table 1). For example, before and after winter solstice up to five weeks intervened between the sun's appearances in backsights E2-E3, while near the summer solstice it took about half that time to move between E11 and E12.

Table 1 shows the conversion to declination of the midline azimuth of each backsight (column 6) based on the survey data shown in columns 2-4. Column 7 shows the sun's declination within the slot (upper limb tangent) at date between 6 January -1999 and 11 July -2000 (*Starry Night Pro* simulation), followed by the local time of sunrise in three cases: E2, E7, E12. Columns 8-9 give the Julian Day Number and the number of days since the summer solstice. Column 11 shows those "best fit" Julian calendar dates (Gregorian in parentheses) when the sun could have been observed to rise in each of the backsights. Highlighted in the table are the pertinent data for the backsights of particular interest: E2 and E12 associated with the solstices; E7, the only potential candidate for equinoctial association; and E1 for which a lunar association has been proposed. Computed dates for the solstices and equinoxes using the complete VSOP theory for -2000 and -1999 are as follows:

WS Jan 6, 22h26m, TD JDN 990563.4347 (-2000)  
VE Apr 7, 17h48m, 990655.2417  
SS Jul 11, 0h40m, 990749.5278  
AE Oct 9, 18h59m, 990840.2910  
WS Jan 6, 4h26m, 990928.6847 (-1999)  
VE-WS 91.8070 days, SS-VE 94.2861 days, AE-SS  
90.7632 days, WS-AE 88.3937 days; year = 365.2500

Table 1. Dimensions and alignments of the twelve backsights and circumstances of the sun's appearance in each

Backsight number	Midline azimuth	Horizon altitude	App. slot width	$\Delta$ Az	Midline $\delta$ (GETDEC)	Sun's $\delta$ -2000	JDN	Day (ss+n)	$\Delta$ n days	Julian date in 2000 BCE (~Gregorian)
E1	131.07°	5.56°	0.36°	---	-28° 20' 06" -28.33	---		---	---	---
E2	125.06	5.81	1.23	6.02°	-23 53 51 23.90°	-23.93 8:30LT	990928	179		6 Jan -1999 (~20 Dec)
E7	94.46	4.27	0.76	6.17	-1 12 44 -1.21	-1.51 6:27LT -1.36 6:39LT	990842 991016	93 267	10 12	12 Oct -2000 (~25 Sep) 4 Apr -1999 (~18 Mar)
E12	60.35	1.27	1.42	5.73	24 12 04 24.20	23.92 5:19LT	990749			11 Jul -2000 (~24 Jun)

From Table 1 it is apparent that backsights E2 ( $\delta$  -23.46 to -24.50) and E12 ( $\delta$  23.65 to 24.75) precisely bracket winter and summer solstice sunrise, respectively. In contrast, the sun would have risen in backsight E7 ( $\delta$  -0.91 to -1.52) three days after the autumnal equinox and three days before the vernal equinox. Backsight E1, whose northern edge was nearly 5° south of the sun's southernmost declination, could not have been used to observe sunrise. Therefore, the suggestion has been made that E1 could have been used to observe the moon's major standstill limit. Below are the data for the major standstill closest to the epoch of Table 1, with declination as indicated by backsight E1 ( $\delta$  -28.21 to -28.46):

Moonrise: -1995.07.11 at 20:44LT  
age 14.8d (100%)  
az 132.85 alt 5.56 =  $\delta$  -29.56  
(geocentric lunar  $\delta$  -28.86)

This moonrise occurred at summer solstice on 11 July -1995, when the full moon rose at least two lunar diameters south of backsight E1. Hence, although the moon could have been observed to rise within backsight E1 some time earlier, strictly speaking, backsight E1 does not mark the southern lunistice.

## Discussion

Although summer solstice sunrise cannot be observed in backsight E12 today, when the change in obliquity of the ecliptic since -2100 is taken into account, it is evident that solstitial sunrises could have been observed through backsights E2 and E12 to an accuracy of a few minutes of arc. The alignment in -2100 was better than at present, whether one defines sunrise as upper limb tangent or sun's center on the horizon. Thus, the potential use of the complex to observe and conduct sacrificial rituals at sunrise on the solstices is confirmed by the astronomical analysis.

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The situation is more ambiguous with regard to backsight E7 and its possible association with the equinoxes, as well as the possible association of backsight E1 with the southern lunistice. In neither case is the degree of accuracy of alignment close to that achieved on the solstices. In the absence of persuasive evidence of ritual or calendrical focus on those particular dates, especially given the extreme difficulty of accurate prediction, the argument that the two backsights were intentionally designed for the purpose is problematic. The earliest textual evidence from China of interest in the midpoint of the seasons does not appear until over a millennium later in the canonical *Yao dian*, though that text's astronomical content clearly refers to a time centuries earlier. Still, it is not clear that direct solar observation was involved in determining when the "day is of medium length" rather than simple calendrical calculation. In the case of the lunar maxima and minima, evidence is lacking of an interest in marking the event, although the co-occurrence with summer solstice may have been recognized later. Apart from Taosi's proximity to the traditionally accepted location of Yao's capital, as suggestive as that is, there is no other evidence of a direct connection with that semi-legendary figure.

Careful study of Fig. 3 gives an indication how the complex may have been built. First, the fact that the arc of the main pounded-earth foundation extends well south of the winter solstice position, and yet falls short of the summer solstice position, suggests that the builders did not have a good grasp of the requisite range in azimuth that needed to be covered. Second, the fact that the backsights (E2-E5) nearest the winter solstice conform most closely to the theoretical ideal (shown by the black dots on their centerlines in Fig. 3) suggests that the winter solstice alignment was probably fundamental. Rather than being intentionally placed to observe sunrise on particular days, the remaining slots were laid out sequentially at regular intervals (one yard?) northward, with the result that by the time the halfway point was reached at slot E6 the cumulative measurement error had already produced a serious misalignment vis à vis the central observation point. Third, when it was realized, six months later, that the structure failed to capture summer solstice sunrise in the northeast, an extension was added to create backsights E11-E12, but because of site constraints that extension had to be built as an outlier several meters farther from the central observation point, its idiosyncratic dimensions therefore resulting from its construction at a different time from the rest. Fourth, the design of the complex, with twelve uniformly spaced backsights, displays either a lack of understanding or a lack of concern with the variability in the sun's daily progress along the horizon during the course of the seasons. Its curvature

may reflect the emergence of the concept of a circular heaven. Fifth, apart from fixing the solstices and the length of the tropical year, given the irregularities built into the structure it is difficult to imagine what sort of functional calendar the Taosi alignments might have generated. The trial-and-error approach and relative lack of sophistication displayed by the structure seems technologically "age appropriate" with respect to the late Neolithic cultural level of Taosi.

In general, the design and placement of the structure is highly suggestive of the monopolization of ritualized sunrise observation by the Taosi elite who were buried close by, no doubt for reasons of control and prestige. The observation platform was built adjacent to the city wall at a point near where elite dwellings were located. Exclusive access to the walled enclosure was afforded by a passageway through the city wall. Although no trace remains of a roof, it is possible that originally, like most sacred spaces in ancient China, the platform was not open to the sky, and that the shafts of sunlight shining through the apertures into a darkened inner sanctum may have heightened the effect and figured importantly in the observation ritual. The high prestige and sacral function may explain why, when it fell out of use, the site was razed to the ground rather than being simply abandoned.

The comparative crudeness of the construction, the misalignments, as well as the irregular and unsymmetrical sectioning of the seasons produced by the spacing of the backsights, all point to an early stage in the ritualized use of sunrise observations to determine the seasons. Nevertheless, the Taosi site is unprecedented in providing evidence of a rudimentary horizontal calendar and accurate determination of the length of a solar year centuries earlier than expected. Although the Chinese term *guanxiangtai* (lit. "[celestial] observation platform") is frequently applied to the Taosi site, the English translation "observatory" is best avoided because, unlike the Chinese, it connotes a modern facility for dispassionate scientific study of the heavens.

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gratefully acknowledged. The present authors assume sole responsibility for the opinions expressed in the present analysis.

## Abbreviations

IACASS – Institute of Archaeology, Chinese Academy of Social Sciences  
IASP – Institute of Archaeology of Shanxi Province  
CRBLC – Cultural Relics Bureau of Linfen City

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# TAOSI ARCHEOLOGINĖ GYVENVIETĖ – KINŲ NEOLITINĖ „OBSERVATORIJA“?

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## Santrauka

Remiantis istoriniais duomenimis ir vietos tradicija, Taosi buvo pirmosios kinų dinastijos – Sia – branduolys. Maždaug nuo 2000 iki 1600 m. pr. m. e. ši dinastija valdė Šiaurės vidurio Kinijos lygumas išilgai Geltonosios upės. Taosi vietovėje yra mažiausiai keturių dar ikidinastinių miestų, kuriuose buvo gyvenama apie keturis penkis šimtus metų vėlyvojo neolito laikotarpiu, liekanos. Prie pietrytinės vidurinio laikotarpio (apie 2100 m. pr. m. e.) miesto sienos mažesnėje aptvetoje teritorijoje yra aukštesnė terasa, kelianti ypatingą mūsų susidomėjimą. Šio statinio pamato skliautas panašus į rytų horizonto atkarpą, kurioje pateka Saulė. Šis faktas archeologams piršo mintį, kad šioje vietoje visus metus galėjo būti stebima tekanti Saulė.

Keli dalykai nagrinėjamoje struktūroje yra akivaizdūs. Pirmia, tekanti Saulė negali būti stebima per labiausiai į pietus nutolusią angą (E1), nes ji yra nukreipta į horizonto tašką, esantį keletu laipsnių toliau į pietus nuo saulėtekio per žiemos saulėgrįžą vietos. Todėl kilo tam tikra spekuliatyvi mintis, kad ašis E1 galėjo būti skirta Mėnulio didžiosios lunisticijos kryptčiai pažymėti. Antra, kad stebėjimo vietos E2–E12 galėtų atlikti savo paskirtį, kolonos, kurios kažkada tuos taškus žymėjo, turėjo būti 3–4 m aukščio – tam, kad sutaptų su Saulės tekėjimo tašku virš kalnų grandinės, esančios apie 10 km atstumu. Trečia, dvi stebėjimo vietos – E11 ir E12 – šiauriniame skliauto gale yra akivaizdžiai atskirtos nuo pagrindinio pamato linijos išlinkimo ir nuo kitų skiriasi savo matmenimis. Tai perša mintį apie kitokią jų paskirtį arba galbūt nevienalaikę statybą. Tolesnė detali fizinių šios apskritos konstrukcijos savybių analizė rodo, kad statinys buvo pastatytas primityviai ir nelabai atitiko apskritimo lanko formą. Dėl to keletas stebėjimo angų (E1, E6, E9) apskritai nebuvo orientuotos centrinio stebėjimo taško kryptimi (3 pav.). Tai ir galėjo lemti drastišką kai kurių stebėjimo angų susiaurinimą.

Šiandien saulėtekis vasaros saulėgrįžos metu negali būti stebimas E12 taške, tačiau įvertinus ekliptikos pasvirimą 2100 m. pr. m. e. tampa aišku, jog vasaros ir žiemos saulėgrįžų saulėtekis per taškus E2 ir E12

tuomet galėjo būti stebimas. Atlikta astronominė analizė patvirtino prielaidą, jog šis kompleksas galėjo būti naudojamas vasaros saulėgrįžos aukojimo ritualo laikui nustatyti pagal Saulės patekėjimo kryptį. Kur kas labiau neaiškus taško E7 interpretavimas, galimos jo sąsajos su lygiadieniais ir tašku E1 (pietinės lunisticijos vietoje). Abiem atvejais stebėjimo krypties tikslumas yra daug blogesnis negu solsticijų azimutų.

Palyginti grubi ištirtos struktūros konstrukcija, netikslus orientavimas, netaisyklingas ir asimetriškas sekcijų tarp stebėjimo angų išdėstymas – visa tai byloja apie ankstyvąjį stebėjimų laikotarpį, kai ritualiniais tikslais pagal saulėtekis buvo nustatoma metų laikų pradžia. Vis dėlto Taosi archeologinis paminklas yra beprecedentis liudytojas, rodantis egzistavus rudimentinį horizontalų kalendorių ir bandymus nustatyti Saulės metų trukmę keliais šimtmečiais anksčiau, negu buvo tikėtasi.

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