Gnomons in Ancient China

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Contents

Abstract

Gnomon shadow measurement was one of the most fundamental astronomical observations in ancient China. It was crucial for calendar making, which constituted an important aspect of imperial governance. A painted stick discovered from a prehistoric (2300 BC) astronomical site of Taosi (see ▶ Chap. 201, "Taosi Observatory") is the oldest gnomon known of China. From second century BC onward, gnomon shadow measurements have been essential part of calendrical practice. Various historical measurements are discussed in this chapter.

Introduction

The gnomon was widely used in ancient China in order to determine the seasons, orientation, and even geographical latitude. Gnomon shadow measurements are mentioned in several ancient texts. For example, according to the *Book of Songs* (*Shi jing* 诗经), one of the remote ancestors of King Wen of the Zhou dynasty used to measure gnomon shadow lengths to determine the orientation around the fourteenth century BC. The *Commentary on Spring and Autumn Annals by Master Zuo*

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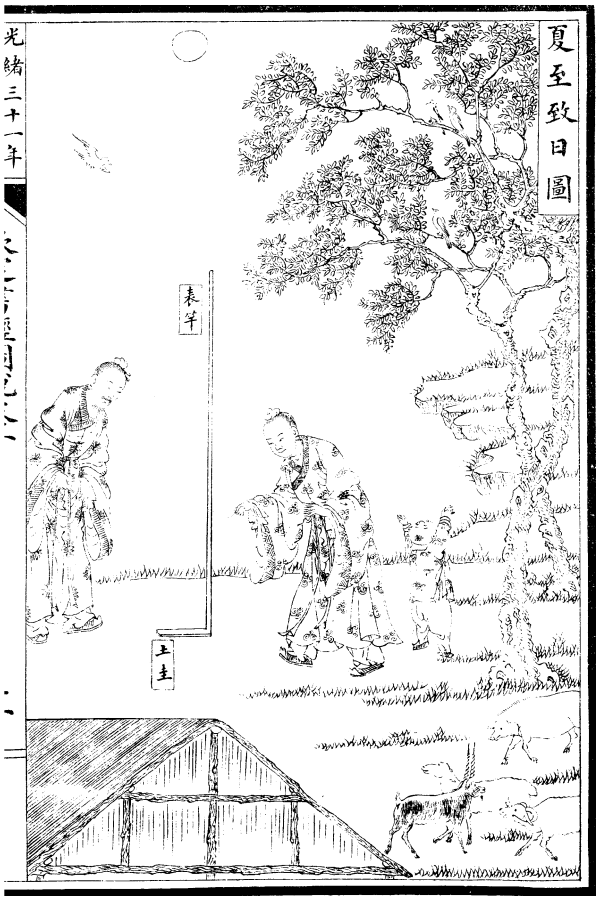

Fig. 200.1 An illustration from the eighteenth-century *Authentic Pictorial Illustrations of the Book of History* (*Qin ding shu jing tu shuo* 钦定书经图说) represented the scene of Chinese ancestors measuring the gnomon shadow lengths

(***Lü*** *shi chun jiu Zuo zhuan* 吕氏春秋左传) mentioned that the principal of the Kingdom Lu 鲁 had witnessed the gnomon shadow measurement on winter solstice of the year 654 BC. Measuring the gnomon shadow had acquired a sort of ritual meaning in ancient China because of its association with calendar making (Fig. 200.1).

A traditional Chinese gnomon consisted of a vertical stick of 8 *chi* long and a template for measuring its shadow lengths at noon during the year. The earliest records of ancient Chinese gnomon shadow measurements are found in the Rituals of the Zhou Dynasty (*Zhou li* 周礼) and the *Arithmetical Classic of the Gnomon and Circular Paths* (*Zhou bi suan jing* 周髀算经). Records of later measurements can be found in astronomical or calendrical treatises of the official dynastic histories (see Table 200.1). According to studies by Qian (1929), Gao (1937), and Bo (1989), the gnomon shadow lengths as given in the *Zhou bi suan jing* should be the results of measurements made no later than sixth century BC.

Table 200.1 The gnomon shadow lengths for the solstices, as recorded in ancient Chinese literature

Literature	Era	Winter solstice	Summer solstice
Zhou bi suan jing	Not clear	135.0	16.0
Zhou li	Sixth century BC	130.0	15.0
Shang shu	Third century BC	130.0	15.0
Hong fan zhuan by Liu Xiang	First century BC	131.4	15.8
Huai nan zi	First century AD	130.0	15.0
Yi wei	First century AD	130.0	14.8
Si fen calendar	First century AD	130.0	15.0
Jing chu calendar	Third century AD	130.0	15.0
Yuan jia calendar	Fifth century AD	130.0	15.0
Da ming calendar	Fifth century AD	130.0	15.0
Lin de calendar	Seventh century AD	127.5	14.9
Da yan calendar	Eighth century AD	127.1	14.7

UNIT: Chinese *cun*

Fig. 200.2 The remains of the IIM22:43 painted stick, imbedded in the original block of soil

As one can see in the table, the gnomon shadow lengths recorded in literature from 200 BC to 900 AD show different traditions:

(1) The *Zhou bi suan jing* tradition, which perhaps corresponded to a prehistoric situation in about 2000 BC. The shadow lengths for the summer solstice and winter solstice were 16.0 and 135.0 *cun* respectively.
(2) The *Zhou li* tradition, with the shadow lengths for the two solstices being 15.0 and 130.0 *cun* respectively. These were based on observations from the first century BC to the fifth century AD.
(3) Data based on actual observations since the seventh century AD. These data correspond more accurately to modern astronomical calculations.

A Gnomon Discovered at the Prehistoric Taosi Site

In 2002, a painted stick with calibrated scales was excavated from a tomb at the prehistoric Taosi site in Xiangfen 襄汾, Shanxi Province. The Taosi site belongs to the Taosi Culture Type dated from 2300 BC to 1900 BC. The size of this tomb and its contents (labeled IIM22) indicate that the person buried must be a member of the royal family. The painted stick (labeled IIM22:43) was originally made from wood. Its main body had been decomposed. But fortunately, from the colored remains imbedded in soil, we can still restore the shape of the stick (Fig. 200.2).

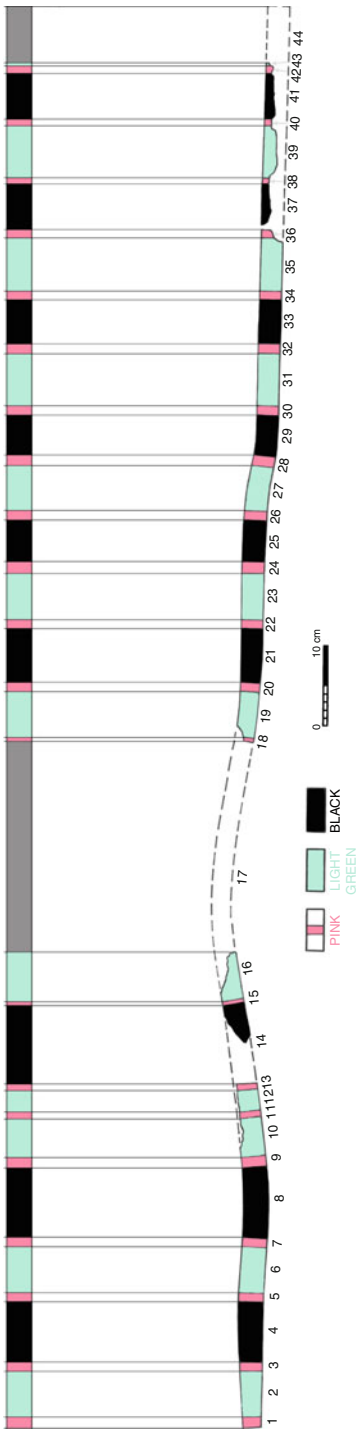

Fig. 200.3 A restoration of the IIM22:43 painted stick

Table 200.2 Dimensional features of the IIM22:43 painted stick

No. of markings	Length of the colored markings (cm)	Thickness (cm)	Distance to the end (cm)	Color	Remarks
1	1.5	2.18	1.5	Pink	
2	5.75	2.6	7.25	Light green	
3	1.05	2.5	8.3	Pink	
4	7.65	3.3	15.95	Black	
5	1.2	3.3	17.15	Pink	
6	5.85	3.2	23	Light green	
7	1.3	3.2	24.3	Pink	
8	8.6	3	32.9	Black	
9	1.4	3.05	34.3	Pink	
10	4.7	3.32	39	Light green	Horizontal defect
11	0.9	2.55	39.9	Pink	Horizontal defect
12	2.6	3.4	42.5	Light green	Horizontal defect
13	0.9	2.85	43.4	Pink	Horizontal defect
14	9.9		53.3	Black	Vertical defect
15	0.7		54	Pink	
16	5.5	2.35	59.5	Light green	Vertical defect
17	26.4		85.9		Broken
18	0.5	1.5	86.4	Pink	Horizontal defect
19	5.7	2.5	92.1	Light green	
20	1.2	2.5	93.3	Pink	
21	6.7	2.25	100	Black	
22	1.2	2.6	101.2	Pink	
23	5.7	2.6	106.9	Light green	
24	1.5	2.65	108.4	Pink	
25	5.3	2.75	113.7	Black	
26	1.3	2.75	115	Pink	
27	5.6	2.75	120.6	Light green	
28	1.5	2.75	122.1	Pink	
29	5	2.6	127.1	Black	
30	1.3	2.6	128.4	Pink	
31	6.5	3.1	134.9	Light green	
32	1.3	2.9	136.2	Pink	
33	5.4	2.7	141.6	Black	
34	1.2	2.7	142.8	Pink	

(*continued*)

Table 200.2 (continued)

No. of markings	Length of the colored markings (cm)	Thickness (cm)	Distance to the end (cm)	Color	Remarks
35	6.7	2.63	149.5	Light green	
36	1.2	1.2	150.7	Pink	Horizontal defect
37	5.6	2	156.3	Black	Horizontal defect
38	1.1	2	157.4	Pink	Horizontal defect
39	6.5	1.9	163.9	Light green	Horizontal defect
40	0.9	0.75	164.8	Pink	Horizontal defect
41	5.7	1.1	170.5	Black	Horizontal defect
42	1	1.2	171.5	Pink	Horizontal defect
43	0.3	0.3	171.8	Light green	Both horizontal and vertical defect
44	6.2		178		Broken

Table 200.3 The yearly dates produced with the painted stick, compared to the yearly dates corresponding to the 12 slots of the Taosi observatory

No.	Color	Gnomon dates	Slots in Taosi structure	Horizontal dates	Solar terms
40	Pink	Mar. 8th	E6	Mar. 8th	Excited insects
34	Pink	Mar. 18th	E7	Mar. 18th	
32	Pink	Mar. 21st			Vernal equinox
28	Pink	Mar. 28th	E8	Mar. 28th	
24	Pink	Apr. 5th			Clear and bright
22	Pink	Apr. 9th	E9	Apr. 10th	
18	Pink	Apr. 18–19th			Seed-corn
16	Pink	Apr. 23–24th	E10	Apr. 26th	
13	Pink	May 23–25th	E11	May 20th	Grain fills
11	Pink	Jun. 19–23rd	E12	Jun. 21st	Summer solstice
13	Pink	Jul. 18–20th	E11	Jul. 23rd	The great heat
16	Pink	Aug. 19–20th	E10	Aug. 14th	
18	Pink	Aug. 24–25th			The limit of heat
22	Pink	Sep. 3rd	E9	Sep. 2nd	
24	Pink	Sep. 7th			The white dew
28	Pink	Sep. 14th	E8	Sep. 14th	
32	Pink	Sep. 22nd			Autumnal equinox
34	Pink	Sep. 25th	E7	Sep. 25th	
40	Pink	Oct. 5th	E6	Oct. 4th	

According to Prof. He Nu who excavated the tomb, the IIM22:43 painted stick was discovered in a vertical position at the southeast corner of the tomb chamber. A small top part of the stick was damaged during the excavation. The residual length is 171.8 cm. He estimated that the damaged part of the stick is less than 10cm long. The stick is painted in colored belts, pink, light green, pink, and black,

Fig. 200.4 Simulative observations with the reconstructed 8 *chi* high gnomon and the IIM22:43 painted stick, performed on June 21, 2009, at the Taosi site

alternately. Figure 200.3 shows our reconstruction of the painted stick, and Table 200.2 shows the lengths indicated by the colored markings.

In 2009, Prof. Sun Xiaochun suggested that this painted stick could have been the template of the gnomon. Based on this hypothesis, He (2009) and Li and Sun (2010) undertook a computational analysis and made simulative measurements with the painted stick. Given that the height of the gnomon was 8 *chi* (approximately 2 m), the pink markings on the painted template would indicate lengths of the gnomon on specific days, producing a series of yearly dates.

On June 21, 2009, summer solstice, we performed a simulative observation with the reconstructed template at the Taosi site (Fig. 200.4). One pink belt is quite special. It lies between light green segments. Our simulative measurement showed that the gnomon shadow at noon extended exactly to this pink belt (No. 11 in Table 200.2). So this pink belt must correspond to summer solstice. The painted stick is not long enough for gnomon shadow at winter solstice, because its length would be 344.4 cm at the Taosi site. Our immediate thought was that the stick could be flipped over for measuring longer gnomon shadows, the first pink belt indicating the longest shadow for winter solstice. From this assumption, we also deduce that the length of the original template was 172. 2 cm.

Table 200.3 shows the yearly dates corresponding to the pink markings of the painted template. Some of these "gnomon dates" fit quite well with the "horizon calendar" derived from the Taosi structure, which we suggest was a prehistoric observatory (see ► Chap. 201, "Taosi Observatory").

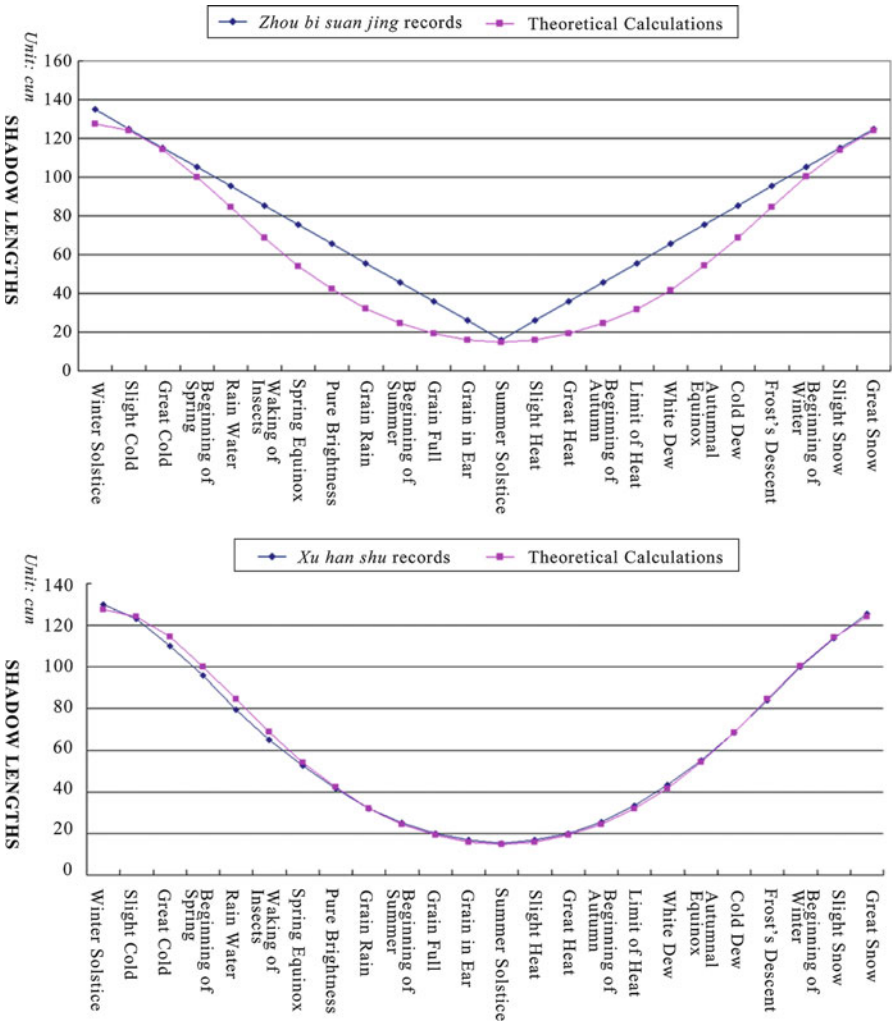

Fig. 200.5 The two diagrams show the different patterns of gnomon shadow lengths for the 24 solar terms. The upper graph shows that the data were fabricated according to the *gai tian* cosmology. The lower graph shows that data were based on actual measurements

Cosmological and Cultural Meanings of the Gnomon

The study of this prehistoric case of gnomon shadow measurement also gives us some clues about its cosmological and cultural meanings. The IIM22:43 painted stick was excavated in a royal tomb, implying that the gnomon must be a symbol of power.

A systematic analysis of gnomon shadow lengths for the 24 solar terms from the second century BC to eighth century AD also concludes that these data featured two

types (Li and Sun 2009). One type of data shows that they were not based on actual measurement, but were derived from the lengths for winter solstice and summer solstice by means of linear interpolation. The other type of data shows a curved increase and decrease that closely matches the actual values for the 24 solar terms. The first type of data appeared in the *Zhou bi suan jing* and the apocalyptic *Book of Changes*, while the second type of data appeared in astronomical treatises some time later. This change is remarkable, because it might reflect the transition in cosmological theory from *gai tian* 盖天 (covering sky) to *hun tian* 浑天 (celestial sphere) during the period from the first century BC to the second century AD (see Fig. 200.5).

Gnomon shadow measurement was a top priority for rulers wishing to establish imperial authority during the Zhou dynasty. As mentioned in the *Zhou li*, the capital should be constructed at the "center of land", where the gnomon shadow length on the summer solstice measured 1.5 *chi* (approximately 37.5 cm). The "center of land" symbolized where the imperial authority lied. The geographical location of the "center of land" changed through history (Guan 2000). Some of the earliest records of the "center of land" include Luoyi 洛邑 and Yangcheng 阳城, corresponding to different dynasties. The boundaries of territories of vassalage were also determined by the gnomon shadow length. This was based on the belief that "one shadow length *cun* corresponds with one thousand *li* on earth", which is actually wrong.

Calendar reforms supported by government promoted the techniques of gnomon shadow measurement. In the beginning of the Yuan dynasty, Guo Shoujing erected the 40-*chi*-high gnomon in order to improve accuracy. All these developments in the technique of gnomon shadow measurement were driven by the need to make precise astronomical calendars.

Cross-References

- ▶ Ancient Chinese Astronomy - An Overview
- ▶ Chinese Calendar and Mathematical Astronomy
- ▶ Dengfeng Large Gnomon
- ▶ Taosi Observatory

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