AMS RADIOCARBON DATING OF TIANMA-QUCUN SITE IN SHANXI, CHINA

Zhiyu Guo[1,2,3] • Kexin Liu[1] • Xiangyang Lu[1] • Hongji Ma[1] • Kun Li[1]• Jinglin Yuan[1] • Sixun Yuan[2]
Xiaohong Wu[2] • Xu Liu[2]

ABSTRACT. Tianma-Qucun is the biggest site of Western Zhou Dynasty discovered in Shanxi Province, China. It has been recognized as the early capital of Jin, a vassal state of Western Zhou. The territories were granted to the first Marquis of Jin with the title in the early days of Western Zhou. Bone sample series from the site were radiocarbon-dated by accelerator mass spectrometry (AMS) and calibrated with the Oxford calibration program OxCal 3.5. Bayesian analysis of the calibrated ages shows that the earliest residents of the Western Zhou came to Tianma-Qucun area in 1020–940 BC and the lower boundary of the Western Zhou is 796–754 BC, which corresponds well to the historical record 770 BC.

INTRODUCTION

The ancient Chinese chronology was not well established for a long time. The most reliable book about ancient Chinese history is *Shi Ji* written by Sima Qian in about 90 BC. According to the book, the first dynasty in Chinese history is Xia, followed by Shang, Zhou, Qin, and Han. The Zhou Dynasty was divided into two parts, Western Zhou and Eastern Zhou, following a shift of the capital. *Shi Ji* recorded the king's genealogy of all the dynasties since the Xia Dynasty, but the complete chronological list exists only after 841 BC in late Western Zhou. There is considerable disagreement about the chronology of ancient China. The Project of Xia-Shang-Zhou Chronology has been recently conducted to establish a chronological frame for the dynasties Xia, Shang and Zhou (Guo et al. 2000).

The Western Zhou Dynasty put the system of enfeoffment into effect. Many nobles were vested with titles, territories, and slaves so there were lots of vassal states in the Western Zhou Dynasty. One of the important vassal states was Jin, of which the first prince was the younger brother of King Cheng, the second King of the Western Zhou. The State of Jin was located in the south of Shanxi Province and the Tianma-Qucun site was an early capital of Jin State. As a part of the Xia-Shang-Zhou Chronology Project, a number of new radiocarbon analyses have been carried out to investigate the age of Tianma-Qucun site, which has a close connection with the year of establishment of the Western Zhou.

SITE DESCRIPTION

The Tianma-Qucun site is located on the north fringe of the Quwo Basin in the south of Shanxi Province, China. The site area is distributed mainly between the villages Tianma and Qucun with a total area about 9 km^2 (Figure 1). The Fuhe River flows from east to west along the south side of the site and joins with the Fenhe River, one of the main tributaries of the Yellow River. The site was discovered in the early 1960s and the remains were mainly associated with the Jin. Since the 1980s many remains of ancient residents and more than 500 tombs of the Zhou Dynasty have been unearthed from the site (Zou et al. 1992). In the 1990s, the cemetery of the Marquises of Jin was excavated in the central area of the site, proving that the site was the early capital of Jin State. It is the biggest Western Zhou Dynasty site discovered in Shanxi Province so far.

[1]Institute of Heavy Ion Physics, Peking University and Key Laboratory of Heavy Ion Physics, Ministry of Education, Beijing 100871, China
[2]Department of Archaeology, Peking University, Beijing 100871, China
[3]Corresponding author. Email: zhyguo@pku.edu.cn

RADIOCARBON, Vol 43, Nr 2B, 2001, p 1109–1114
Proceedings of the 17th International ^{14}C Conference, edited by I Carmi and E Boaretto

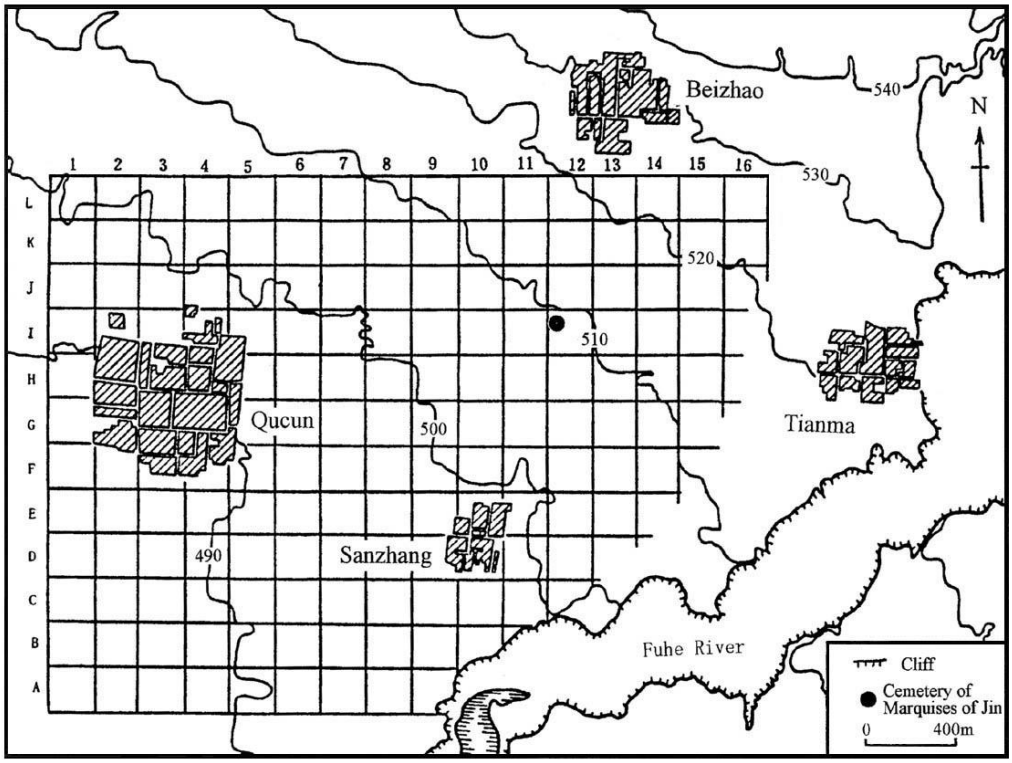

Figure 1 Map of Tianma-Qucun site. The check shows the sub-areas of excavation and its code.

Because the site covers a wide area, the archaeologists divided it into sub-areas. In early 1980s the sub-areas were labeled with I, II, III, etc. But later, more remains were unearthed from different places so a description in terms of two-dimensional coordinates has been adopted since 1986 (Figure 1). The cemetery of the Marquises of Jin was excavated in I11–I12 and many small and medium-sized tombs were unearthed from I2–J4. The area J6–J7 might be an area of handicraft industry, where a large amount of semi-manufactured bone objects and materials were unearthed (Liu and Luo 1998). Several pottery kilns were also discovered there. Tubular tiles of the Western Zhou period have been unearthed in the site, so large-scale buildings should have existed at that time, although their foundations have not been found so far.

The cultural remains discovered in Tianma-Qucun site can be divided into five phases. The first three phases correspond to the early, middle, and late parts of the Western Zhou, and the later two phases correspond to the early and middle parts of the Spring and Autumn Period (770–476 BC), which is the first half of the Eastern Zhou Dynasty. Each phase can be further divided into two sub-phases. The Chinese archaeologists usually numbered the sub-phases sequentially, for example, the sub-phase 3 and 4 belong to the "Middle of Western Zhou" phase.

METHODS

Sample Collection

The measured bone samples were collected from two areas: small and medium-sized tombs in I2–J4 and living quarters J6–J7. There were abundant samples in those areas and it has been proved that

https://doi.org/10.1017/S0033822200041758 Published online by Cambridge University Press

well-preserved bone can give reliable dating result if gelatin is extracted as the dating material (Hedges and van Klinken 1992; Wu et al. 2000). Well preserved bones of human and animals, including livestock, were selected. Another principle of sample selection was that all the samples should constitute a series that could continuously cover all the archaeological phases that we are interested in. At the moment our interest is concentrated on the Western Zhou Dynasty, so the samples come from the sub-phases 1–6.

Sample Preparation and Measurement

The samples were crushed and washed by ultrasonic cleaning. They were then decalcified in 0.5M HCl at 4 °C. After centrifugation, the bone was rinsed with distilled water, washed with 0.5M NaOH, and rinsed with distilled water again. The collagen was hydrolyzed in HCl with pH 3 at 90 °C. Solid residue was discarded after centrifugation and gelatin was obtained after lyophilizing. Bone gelatin was combusted in a Vario Elemental Analyzer and the gaseous products were separated with different columns. Pure CO_2 was collected and split into two parts. A small part of CO_2 was sealed in a tube for $\delta^{13}C$ analysis and the remaining CO_2 was reduced to graphite on Fe powder by hydrogen gas. All the samples were measured by the Peking University AMS facility (PKUAMS). The $\delta^{13}C$ values were measured by a VG Sira-24 mass spectrometer for fractionation correction.

CALIBRATION

The Bayesian method was introduced into the calibration of ^{14}C ages of the serial samples in 1990s if the sequence of the samples or the sequence of the samples' phases is known (Buck et al. 1991). By the Bayesian method known time relations of the samples, called prior conditions, give a restriction to the calibrated ranges of the samples that is corresponding to posterior distribution converted from ^{14}C ages with calibration curve, so the calibrated ranges can be reduced remarkably comparing to the results obtained by simple calibration. An available program that can be used for calibration with the Bayesian method is OxCal developed in Oxford (Bronk Ramsey 1995; 1999). The version OxCal 3.5 with the calibration curve INTCAL98 (Stuiver et al. 1998) was used for the calibration of dating results of the Tianma-Qucun site. The samples were organized into a sequence of phases with an upper boundary at the beginning and a lower boundary at the end. The boundary, as an event in the series, was calculated together with sample ages and its probability distribution could be given, too. Generally, the calibrated ages with 1-σ confidence level can be used to estimate the phases' ages good enough if the serial samples are well organized. It is obvious that the prior conditions have important influence to the final results. OxCal gives a parameter with the calibration results called overall agreement, which is a measure whether the dating results accord well with the prior conditions. If the overall agreement is less than 60%, then either the prior conditions are not rational, or some ^{14}C ages are wrong.

RESULTS

Table 1 shows the measured ^{14}C ages and $\delta^{13}C$ values, as well as the calibrated ages obtained with the Bayesian method. The upper and lower boundaries calculated by OxCal are also given. The upper boundary 1020–940 BC gives the date that the earliest residents of the Western Zhou came to Tianma-Qucun area. The lower boundary 796–754 BC corresponds with the replacement of the Western Zhou by the Eastern Zhou, which occurred in 770 BC. The overall agreement of the calibration is 117.3%. But the boundaries of early to middle Western Zhou and middle to late Western Zhou are somewhat later than the archaeologists expected.

https://doi.org/10.1017/S0033822200041758 Published online by Cambridge University Press

Table 1 ^{14}C dates from Tianma-Qucun site

Phase[a]		Field nr[b]	Material	Lab nr	^{14}C age (BP)	$\delta^{13}C$ ‰	Calibrated age Cal BC, 1σ
Upper boundary							1020 BC (68.2%) 940 BC
Early	1	88QJ7 T1327 H147	Animal bone	SA98014	2870 ± 50	−12.2	995BC (68.2%) 915 BC
W.Z.		86QJ4 M6266	Human bone	SA98006	2775 ± 50	−6.3	980BC (68.2%) 915 BC
		86QJ4 M6081	Dog bone	SA98007	2765 ± 50	−9.6	980BC (68.2%) 915 BC
	2	86QJ4 M6306	Human bone	SA98008	2860 ± 50	−7.3	948BC (68.2%) 900 BC
		86QJ7 T35 H78	Animal bone	SA98017	2745 ± 35	−13.1	930BC (68.2%) 880 BC
		80QI T115 H109	Animal bone	SA98016	2710 ± 75	−12.2	935BC (68.2%) 875 BC
Middle W.Z.	3	86QJ4 M6411	Human bone	SA98009	2795 ± 50	−6.9	910BC (10.3%) 895 BC 885BC (57.9%) 840 BC
		84QJ7 T17 H23	Sheep bone	SA98019	2790 ± 60	−9.2	905BC (8.0%) 890 BC 885BC (60.2%) 840 BC
		82QIV T411 H410	Human bone	SA98018	2760 ± 35	−9.3	905BC (8.1%) 890 BC 885BC (60.1%) 840 BC
	4	82QIV T401 H402:1	Deer bone	SA98021	2745 ± 60	−19.0	855BC (68.2%) 819 BC
		82QIV T401 H402	Sheep bone	SA98020	2710 ± 45	−16.1	851BC (68.2%) 815 BC
Late W.Z.	5	86QI2 M5215	Human bone	SA98010	2605 ± 50	−7.0	819BC (68.2%) 792 BC
		82QIII T322 H326	Pig bone	SA98022	2575 ± 50	−7.1	815BC (68.2%) 786 BC
	6	86QI2 M5217	Human bone	SA98011	2600 ± 50	−6.8	801BC (68.2%) 772 BC
Lower boundary							796BC (68.2%) 754 BC

[a]W.Z. = West Zhou Dynasty.

[b]T = exploring square, H = ash pit, M = tomb.

DISCUSSION

$\delta^{13}C$ Values

It is noticeable that all human bones as well as dog and pig bones in Tianma-Qucun site give quite low $\delta^{13}C$ values, in the range of –6‰ to –10‰. This is because the main diet of the ancient Chinese was millet, which is a C_4 plant and has very low $\delta^{13}C$ values.

Comparing with the Data of the Cemetery of the Marquises of Jin

The cemetery of the Marquises of Jin has been discovered in Tianma-Qucun site, including the tombs of eight Marquises of Jin and their wives as well as sacrificial tombs. The samples associated with five Marquises of Jin have been collected and measured (Wu et al. 2000; Lu et al. 2000). The results coincide well with above results (Table 2). Marquis Cheng is the third generation Marquis of Jin, whose year of death is not reliably recorded but should be around the transition from early to middle Western Zhou.

Dating and Chronology

There are some difficulties associated with studying historical chronology by ^{14}C dating (Guo et al. 2000). The first difficulty is to find suitable samples that should have reliable connections with particular events. Secondly, there can be an age shift between the sample and the event we want to date. Thirdly, the measuring error may introduce a quite large uncertainty in the calendar age that might be too large to be accepted by historians. As a part of the Xia-Shang-Zhou Chronology Project, the dating of the Tianma-Qucun site and cemetery of the Marquises of Jin aims to examine the validity of the methods used. The results can also be used to establish the range of the year when King Wu

https://doi.org/10.1017/S0033822200041758 Published online by Cambridge University Press

Table 2 Comparison of calibrated age between Tianma-Qucun site and cemetery of marquises of Jin

Phase[a]	Sub-phase	Sample lab nr	Calibrated age Cal BC, 1σ	Name	Year of death[b] (BC)	Sample lab nr	Calibrated age Cal BC, 1σ
Early W.Z.	1	SA98014	995–915				
	2	SA98008	948–900	Marquis Wu	Unknown	SA98089	930–855
		SA98016	935–875			SA98090	
Middle W.Z.	3	SA98009	910–840	Marquis Cheng	Unknown	–	910–845
		SA98019	905–840	Marquis Li	859	SA98091	880–831
	4	SA98020	851–815	Marquis Jing	841	–	860–816
Late W.Z.	5	SA98010	819–792	Marquis Lii	823	–	834–804
		SA98022	815– 786	Marquis Xian	812	SA98155	814–794
						SA98092 SA98094	
	6	SA98011	801–772	Marquis Mu	785	SA98157	804–784
						SA99043 SA98095	
				Uncle Shang	781	SA98096[c]	789 – 768
Early E.Z.	7			Marquis Wen	746		

[a]W.Z. = West Zhou Dynasty, E.Z. = East Zhou Dynasty.
[b]Quoted from Sima Qian, Aristocratic Family of Jin, In: *Shi ji.*
[c]The tomb belongs to either Uncle Shang or Marquis Wen.

of Western Zhou overthrew the Shang Dynasty. The dating and calibration of the Tianma-Qucun site have given reasonable upper and lower boundaries and the dating results of the cemetery of the Marquises of Jin also coincide well with the historical records. It shows that the well-organized serial samples, suitable sample preparation procedure, reliable AMS measurement with necessary quality control, and the calibration by Bayesian method can give reliable results to archaeological phases in a site. But one still should be cautious in trying to derive the age of an event from such a result. For example, we can only say that the year that King Wu of Western Zhou overthrew the Shang Dynasty should be before the upper boundary of the Tianma-Qucun site, from the results presented above.

Past Environment

Geological investigations show that the Tianma-Qucun area was an alluvial plain in the late Pleistocene. There was a warm and humid period in the middle of the Holocene and the terrain is now more flat than in the past. Some remains belonging to Yangshao culture (about 7–5 ka BP) were unearthed close to Qucun. But later as the weather became cooler and dryer, the river valley and low-lying land silt up. As a result, the water level rose and human activity was reduced in this area due to the threat of flood. Since about 3 ka BP the Fuhe River started to cut down the land so the threat of flood was reduced. When the first Marquis of Jin was appointed, the area of Tianma-Qucun was habitable and suitable for agriculture. But several hundred years later, the Fuhe River cut down the land further and the river valley became deep so that the groundwater level dropped, which made getting water and traveling difficult. At the same time, the area around Houma County about 25 km in the downstream direction became more suitable for living. The most prosperous period of Tianma-Qucun area is the sub-phases 3–5 and it declined after the capital of Jin moved from Tianma-Qucun to Houma in the middle of the Spring and Autumn Period (Zou et al. 1992).

CONCLUSION

1. The dating and calibration results of Tianma-Qucun site show that the people of Zhou Dynasty came to this area in 1020–940 BC and the lower boundary of the Western Zhou is 796–754 BC.

https://doi.org/10.1017/S0033822200041758 Published online by Cambridge University Press

2. The determined age of the end of Western Zhou corresponds with the record in *Shi Ji* (700 BC). The results of Tianma-Qucun site also correspond with the results of the cemetery of the Marquises of Jin, some of those years of death are recorded in *Shi Ji*. So it is proved that the method used is reliable.
3. The boundaries of the early to middle Western Zhou and middle to late Western Zhou are later than archaeologists expected. They should be further studied.

ACKNOWLEDGMENTS

We gratefully acknowledge Prof Li Beqian for helpful discussions. Thanks are extended to Ms. Wang Junxia for assistance in the sample preparation. This work was supported by the National Natural Since Foundation of China (NSFC).

REFERENCES

Bronk Ramsey C. 1995. Radiocarbon calibration and analysis of stratigraphy: the OxCal program. *Radiocarbon* 37(2):425–30.

Bronk Ramsey C. 1999. An introduction to the use of Bayesian statistics in the interpretation of radiocarbon dates. In: *Proceedings of the International Workshop on Frontiers in Accelerator Mass Spectrometry, January 6–8, 1999*. Tsukuba and Sakura, Japan. p 151–60.

Buck CE, Litton CD, Kenworthy JB, Smith AFM. 1991. Combining archaeological and radiocarbon information: a Bayesian approach to calibration. *Antiquity* 65: 808–21.

Guo Z, Liu K, Lu X, Ma H, Li K, Yuan S, Wu X. 2000. The use of AMS radiocarbon dating for Xia-Shang-Zhou Chronology. Kutschera W, Golser R, Priller A, Strohmaier B, editors. Proceedings of the Eighth International Conference on Accelerator Mass Spectrometry. *Nuclear Instruments and Methods in Physics Research* B172:724–31.

Hedges REM, van Klinken GJ. 1992. A review of current approaches in the pretreatment of bone for radiocarbon dating by AMS. *Radiocarbon* 34(3):279–91.

Liu X, Luo X. 1998. Excavation of the Zhou Dynasty living quarters at the Tianma-Qucun site. *Cultural Relics* (11):29–36. In Chinese.

Lu X, Guo Z, Ma H, Yuan S, Wu X. 2001. Data analysis and calibration of the radiocarbon result of the cemetery of marquises of Jin. *Radiocarbon*. Forthcoming.

Stuiver M, Reimer PJ, Bard E, Beck JW, Burr GS, Hughen KA, Kromer B, McCormac G, van der Plicht J, Spurk M. 1998. INTCAL98 radiocarbon age calibration, 24,000–0 cal BP. *Radiocarbon* 40(3):1041–84.

Wu X, Yuan S, Wang J, Guo Z, Liu K, Lu X, Ma H, Li K, Yuan J, Cai L. 2000. AMS radiocarbon dating of cemetery of Jin marquises in China. Kutschera W, Golser R, Priller A, Strohmaier B, editors. Proceedings of the Eighth International Conference on Accelerator Mass Spectrometry. *Nuclear Instruments and Methods in Physics Research* B172:732–35.

Zou H, Li B, Xu W, Wu Z. 1992. Report of archaeological investigation in Yicheng and Quwo. In: Zou H, editor. *A collection of studies on archaeology (I)*. Beijing: Cultural Relics Publishing House. p 124–228. In Chinese.