

AMS RADIOCARBON DATING OF THE FENGXI SITE IN SHAANXI, CHINA

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ABSTRACT. The Fengxi site is near the Feng River in Shaanxi Province, China. Feng City was the capital of the vassal state of Zhou, and the Zhou people lived in this area until the end of the Western Zhou. Serial samples of charcoal, bone, and charred millet were collected from the site and dated by accelerator mass spectrometry (AMS). A sequence model with 6 phases of the Western Zhou dynasty was constructed and the ¹⁴C ages were calibrated with OxCal v 3.9. The results showed that the site was used from 1170–1070 BC until 825–755 BC, and the Conquest of Shang by King Wu most probably occurred during 1060–1000 BC.

INTRODUCTION

Xia, Shang, and Zhou are the 3 earliest dynasties in Chinese history. (Zhou is often designated as Chou in Western literature.) An important objective of studies on the Xia-Shang-Zhou chronology is to determine the date of the Conquest of Shang by King Wu of Zhou, signaling the end of the Shang dynasty and the beginning of the Zhou dynasty. Fengxi is one of the key sites for such a study, since Feng City was the capital of the Zhou dynasty. It is an archaeological site in central Shaanxi Province, near the present-day town of Mawang, about 20 km west of Xi'an.

Zhou originally was a vassal state in Zhouyuan in western Shaanxi Province during the Shang dynasty. (This time period is usually termed the Pre-Zhou.) Zhou became powerful during the reign of King Wen, King Wu's father. In the late period of King Wen's reign, Zhou wiped out the vassal state Chong in the Feng River basin and set up the new capital of Feng on the Feng River's western bank, which is the present-day Fengxi site. A few years later, King Wu built the new capital of Hao on the eastern side of the Feng River, thus establishing the Zhou dynasty. The Feng-Hao area was inhabited by the Zhou people until 770 BC, when King Ping moved the capital of Zhou to Luoyang, Henan Province. The Zhou dynasty is divided into 2 periods according to that event: the earlier period is called the Western Zhou, and the later period is the Eastern Zhou.

The Conquest of Shang by King Wu is an important event in Chinese history, but there is no definite record about its date in ancient Chinese literature. The reliable chronicle of Chinese history started in 841 BC during the late Western Zhou. Many researchers tried to deduce the date of the conquest by using various means and methods during the past 2000 yr, but the results vary from 1130 BC to 1018 BC. ¹⁴C dating of key related sites with phased serial samples could provide a reasonable estimate to the date of the conquest.

SITE DESCRIPTION

The Feng-Hao site location is shown in Figure 1a. The site has been excavated several times since 1951 and pottery sequences were established based on the remains unearthed from tombs and living sites by different archaeologists (Zhang 1980; Lu and Jiang 1987; Jiang 1992; Xu 1994). Although the particular phases given by different archaeologists were slightly different, the frame of the sequences was quite similar, which included the Pre-Zhou, the early Western Zhou, the middle Western Zhou, and the late Western Zhou. However, there were only a few remains associated with the Pre-Zhou until the Xia-Shang-Zhou Chronology Project launched in 1996. A new excavation at

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Fengxi was completed by the project in 1997 (Xu 2000) and furnished abundant remains with good stratigraphic sequences. Samples were collected and both the LS and AMS methods were used for ¹⁴C dating. Results of the LS measurements have been reported elsewhere (Qiu and Cai 2001). The AMS results are presented in this paper.

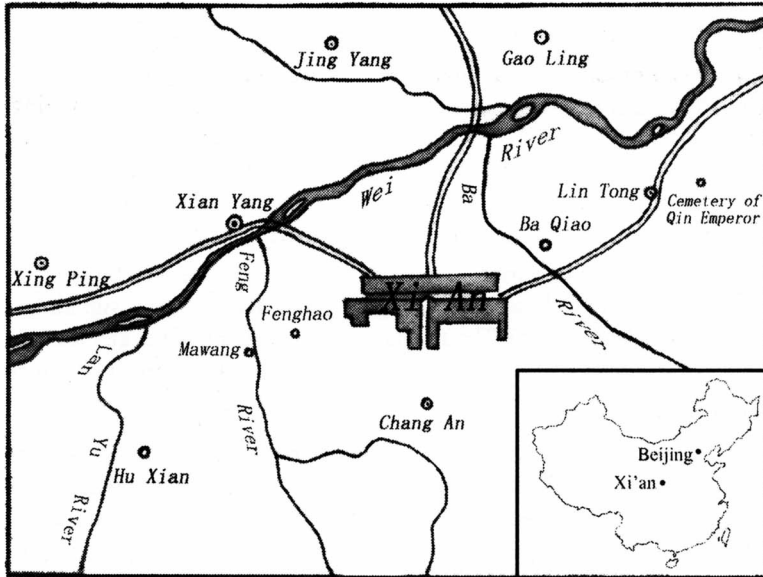


Figure 1a Map of the Fengxi site and location of the Feng-Hao site. The Fengxi site is near the town of Mawang, and the original capital, Hao, is near Fenghao Village.

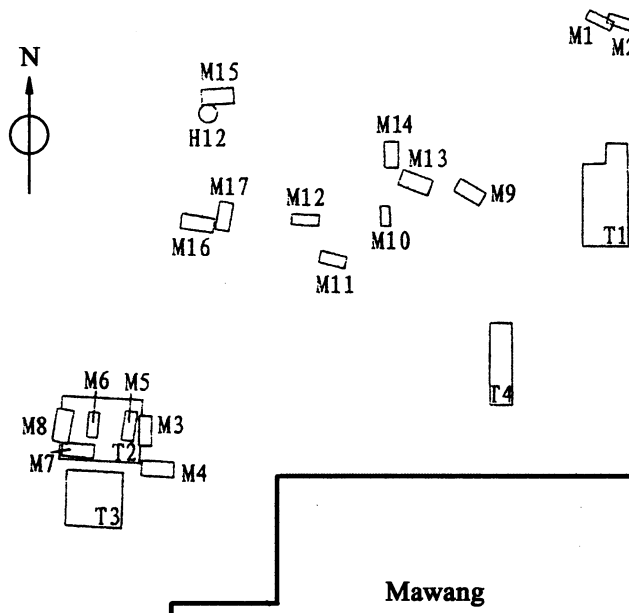


Figure 1b Map of the Fengxi site. Square trenches (T) and tombs (M) were excavated in the spring of 1997. Dating materials were collected from T1 and T2.

The excavation was carried out near the Fengxi wool mill, in the town of Mawang, in the spring of 1997. Four square trenches (97SCM T1–T4) and 17 tombs were excavated as shown in Figure 1b. More than 10,000 pottery fragments were unearthed and many complete pottery wares were recovered. Those pottery wares can be divided into 6 phases according to their configuration and the units from which they came. Figure 2 shows some typical examples. It was agreed that Phase 1 corresponded to the Pre-Zhou, phases 2 and 3 to the early Western Zhou, phases 4 and 5 to the middle Western Zhou, and Phase 6 to the late Western Zhou (Xu 2000). The square trench 97SCM T1 (Figures 3 and 4) contained a group of serial strata and ash pits. According to their sequential relation and the characteristics of the excavated pottery, their time sequence and corresponding phases could be decided as shown in Figure 5. Ash pit H18 is especially important. There were more than 5000 pottery fragments unearthed from H18 and the pottery ware style is similar to the other wares excavated from the tombs of the late Shang and Pre-Zhou; thus, H18 should belong to Phase 1. Some charred millet was found in H18, which will provide a reliable date because of its short lifetime.

	鬲 (Li)	簋 (Gui)	豆 (Dou)	罐 (Guan)	盂 (Yu)	甗 (Tan)
1	1, 2, 3	4		5, 6	7	8, 9, 10
2	11, 12, 13	14, 15		16, 17, 18		
3	19, 20, 21	22, 23	24	25, 26	27	28
4	29, 30	31	32	33	34	
5	35, 36, 37	38	39	40	41	42
6	43, 44, 45		46, 47	48	49	

Figure 2 Pottery sequence of Fengxi site excavated in 1997

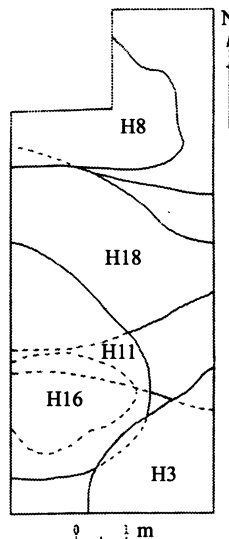


Figure 3 Plan of square trench 97SCM T1

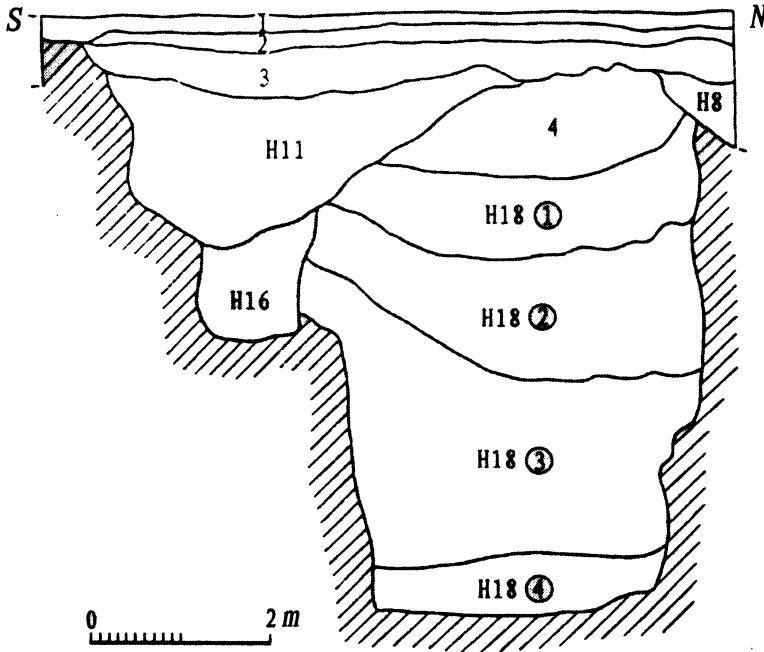


Figure 4 Profile of the west wall of square trench 97SCM T1

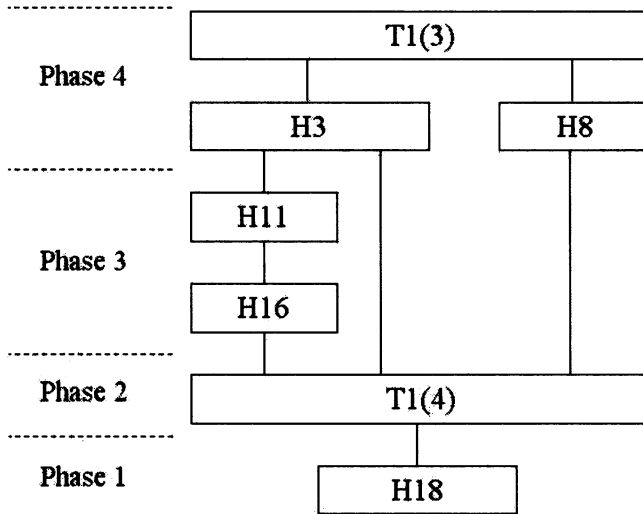


Figure 5 Configuration of the units in square trench 97SCM T1 and their corresponding phases.

METHODS

Serial samples of charcoal, bone, and charred millet were collected from the square trenches 97SCM T1 and T2. The field number of a sample was defined as SiteCode + TrenchCode + UnitCode + SerialNumber. In Table 1, we omitted the serial number and simply use the number 1 or 2 when there are 2 samples from the same unit.

Table 1 ¹⁴C ages and calibrated dates of the samples excavated from the Fengxi site in 1997.

		Phase	Field nr ^a	Material	Lab nr	¹⁴ C age (BP)	Calibrated date (cal BC, 1 σ) 68.2%	Agreement ^b
Older Boundary								
Pre-Zhou	1	97SCM T2 H7	Animal bone	SA97022	2935 ± 35	1130–1040	101.2%	
		97SCM T1 H18(3)	Charred millet	SA97029	2850 ± 50	1115–1025	91.8%	
		97SCM T1 H18(2):1	Charred millet	SA97030	2900 ± 50	1120–1035	123.4%	
		97SCM T1 H18(2):2	Charcoal	SA97002	2905 ± 50	1120–1035	123.0%	
		97SCM T1 H18(1)	Charcoal	SA97003	2895 ± 50	1115–1030	123.4%	
Conquest of Shang								
Early Western Zhou	2	97SCM T1(4)L:1	Charcoal	SA97004	2855 ± 55	1035–975	130.4%	
		97SCM T1(4)L:2	Charcoal	SA97009	2840 ± 55	1030–975	128.4%	
Middle Western Zhou	3	97SCM T1 H16	Animal bone	SA97010	2810 ± 45	998–952	125.7%	
		97SCM T1 H11	Charcoal	SA97011	2845 ± 45	1005–945	129.3%	
		97SCM T1 H8:1	Charcoal	SA97012	2890 ± 40	958–922	34.0%	
Late Western Zhou	4	97SCM T1 H8:2	Charcoal	SA97013	2860 ± 35	959–920	77.1%	
		97SCM T1 H3B	Charcoal	SA97015	2695 ± 50	915–840	94.5%	
		97SCM T1 H3	Charcoal	SA97014	2685 ± 45	905–825	86.2%	
		97SCM T1(3)	Charcoal	SA97023	2730 ± 45	920–845	103.0%	
Younger Boundary	6	97SCM T2 M8	Human bone	SA97025	2620 ± 55	832–785	127.7%	
						860–800	825–755	

^aT = square trench, H = ash pit, M = tomb, L = lower part, B = bottom.^bThe overall agreement is 107.6%.

The sample pretreatment and preparation methods are the same as we described in previous literature (Wu et al. 2000; Yuan et al. 2000a, 2000b; Guo et al. 2001). The samples were washed by ultrasonic cleaning and 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. The samples and bone gelatin was combusted in a Vario Elemental Analyzer™ and the gaseous products were separated with different columns. Pure CO₂ was collected and reduced to graphite on Fe powder by hydrogen gas. The samples were measured by the Peking University AMS facility (PKUAMS) (Liu et al. 2000).

¹⁴C dates of serial samples were calibrated with the OxCal v 3.9 program and the IntCal98 calibration curve. OxCal is a calibration program based on the Bayesian statistical method, which takes the knowledge of samples' relation as a prior, so the calibrated age intervals (posterior) can be reduced (Bronk Ramsey 1994, 1995, 1998, 2001). OxCal provided several important commands which we used for our calibration. The command Sequence allows the information—that one event precedes another—to be incorporated into the resulting probability distributions. The command Phase is used to group events between which there are no known relationships but which may all share some relationship. The command Event (which in this paper we term Event Conquest) is used to determine the distribution of an event which is constrained in some way by the model but which has no direct dating information. OxCal also provided the command Boundary, which must always be used in conjunction with a sequence when the events in a model are from well-defined periods.

OxCal gives an agreement index to each posterior distribution after calibration. It indicates the extent to which the final (posterior) distribution overlaps with the original distribution. An unaltered distribution will have an index of 100%, but it is possible for the value to rise above this if the final distribution only overlaps with the very highest part of the prior distribution. If this value for any individual sample is below 60%, it may be worth questioning its position in the sequence. For the whole sample series, OxCal gives an overall agreement index which should also be greater than 60%; otherwise the supposed prior might be wrong.

Samples collected from the Fengxi site were organized into a sequence of 6 phases with an older boundary at the beginning and a younger boundary at the end (see Table 1). According to the archaeological periodization, the date of the Conquest of Shang by King Wu should be between phases 1 and 2 (Xu 2000), so an assumed Event Conquest was inserted there to evaluate its date. There was no measured sample in Phase 5, so an undated event was inserted in that phase. In the calibration results, the 1- σ interval was taken as the range of calibrated calendar dates, and the real confidence level is higher than 68.2% due to the wiggles in the calibration curve (Guo et al., forthcoming).

RESULTS AND DISCUSSIONS

Table 1 and Figure 6 show the measured ¹⁴C ages and the calibrated calendar ages obtained using OxCal and the Bayesian method. The calculated dates of the older and younger boundaries as well as the Event Conquest are also given. Also listed in Table 1 is the agreement index of every sample. The overall agreement of the calibration is 107.6%, which is a good indicator that the measuring results coincide with the prior quite well. Figure 6 also shows that the interval of the calibrated calendar age somewhat depends on the shape of the calibration curve, which is wider in the plateau section. Yet, the calibrated calendar age intervals with the Bayesian method are much narrower than the case of single sample calibration, as the prior introduces strong constraints to the intervals.

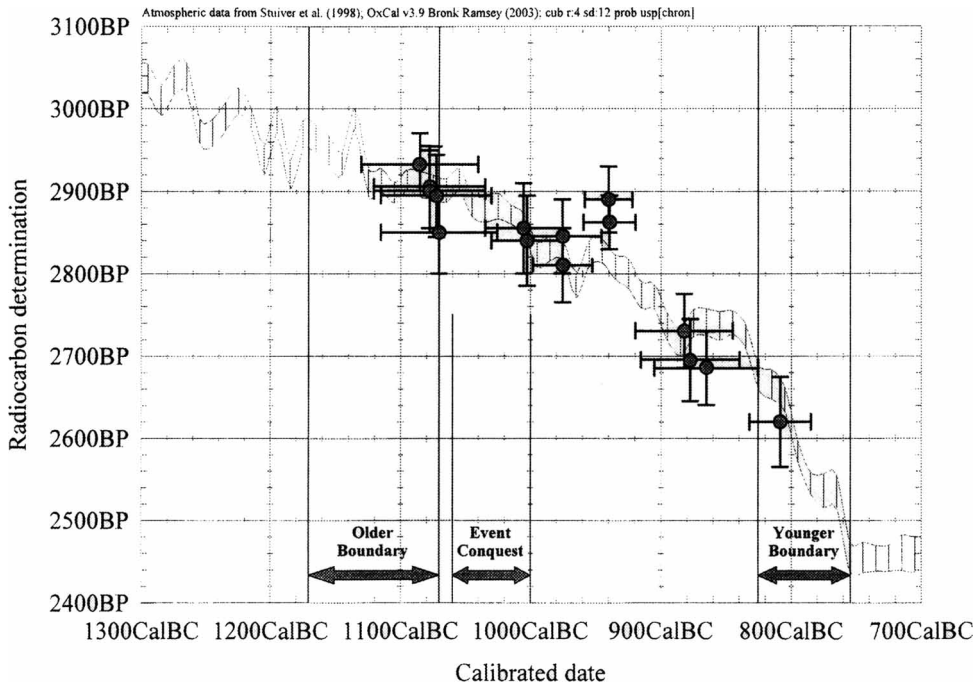


Figure 6 A section of the IntCal98 calibration curve that covers the period of the Fengxi site. The measured and calibrated results of the samples are plotted as circles with crossed bars. The circle and vertical bar indicate the measured ^{14}C age ($1\text{-}\sigma$ error), and the horizontal bar shows its calibrated calendar age ($1\text{-}\sigma$ interval). The $1\text{-}\sigma$ intervals of 2 boundaries and Event Conquest are also given.

The Age of Charcoal Samples

Sometimes a danger exists in dating charcoal samples because charcoal may give an older date when the sample comes from the central part of a log. In fact, sample SA97012 might be such a situation. In Figure 6, its point jumps above the calibration curve and its agreement index is a bit lower, which indicates the sample is a bit older than the expected prior. The single sample calibration of SA97012 gives a $1\text{-}\sigma$ interval of the calibrated calendar age as 1190–1000 BC, which is 50–200 yr older than the result using the Bayesian method, but the calibrated interval of SA97012 given in Table 1 is still within the $2\text{-}\sigma$ interval of its single sample calibration. There are also some other possible reasons that may bring about older data, such as a piece of old charcoal was introduced into the younger ash pit, or data may shift far away randomly due to the statistics. This example also shows another advantage of the serial sample calibration using the Bayesian method, i.e. an individual sample of questionable stratigraphy would not affect the age framework of whole series very much. The agreement index of SA97012 is not too low, so we kept it in the series. If a sample strays too far from the curve, however, it should be removed from the series.

Older and Younger Boundaries

From historical records, we know that King Wen died 2 yr after he moved to Feng. His son Wu then became the King of Zhou and the Conquest of Shang occurred in the 11th year of King Wu's reign. Thus, only 13 yr passed from the founding of Feng City to the Conquest of Shang. The calibration, though, gave an older boundary of the sequence, 1170–1070 BC at the $1\text{-}\sigma$ confidence level, which means that the earliest Zhou residents probably came to this area at some time during that interval.

The 1- σ interval of Phase 1 is about 100 yr, from 1130–1025 BC, which is too long compared with historical records. There are several possible reasons for the discrepancy. The 13 yr are too short compared with ^{14}C dating errors, and the shape of the calibration curve further extended the calendar year interval. There is a plateau at 1125–1050 BC followed by another plateau from 1045–1015 BC, with a shift just 30 ^{14}C yr (Figure 6). Thus, the extension of Phase 1 is quite normal. Jiang suggested that there might be some remains of the Chong people in this area (Jiang 2003), which may also extend Phase 1. The younger boundary of 825–755 BC corresponds with the replacement of the Western Zhou by the Eastern Zhou, which historical records state actually occurred in 770 BC.

Event Conquest

The calibration results give an interval of 1060–1000 BC for the Event Conquest, corresponding to the Conquest of Shang by King Wu. There is always some danger when one tries to connect a particular phase with particular kings unless writing evidence exists to provide a specific date. However, the boundary of the Shang and Zhou can be found in the pottery sequence at Fengxi. This is because some pottery wares of phases 2 and 3 excavated in Fengxi are quite similar to the early Western Zhou wares excavated in the Liulihe and Tianma-Qucun sites, which are the locations of the vassal states Yan and Jin, enfeoffed at the beginning of the Western Zhou. Furthermore, the pottery ware style of Phase 1 is similar to the wares excavated from the tombs of the late Shang and Pre-Zhou (Xu 2000). Thus, it is reasonable to conclude that the Conquest of Shang by King Wu (i.e. the replacement of Shang by Zhou) occurred between phases 1 and 2.

In general, it is quite difficult to determine a historical chronology by ^{14}C dating even though the margin of error can be reduced by using the Bayesian method (Guo et al. 2000). There are still some arguments among Chinese archaeologists on the connection of a particular phase with a particular king. However, many sites and tombs of the Shang, Pre-Zhou, and Western Zhou have been excavated so far in China; thus, the style and characteristics of pottery wares in each period are well known. For the Fengxi site, there is a good stratigraphic sequence that spans from Phase 1 to Phase 4 in square trench T1 (as shown in Figure 4). A combination of the pottery sequence and the stratigraphic sequence is more reliable than when only a pottery sequence is available (e.g. as with group of tombs).

Note that the interval of a phase, boundary, or event somewhat depends on the particular sample series. It may shift a bit (e.g. 5 yr) when a different subset of a sample series is used, but the results are usually stable enough if the sample sequence model is constructed well (Guo et al. 2002).

Comparison with Other Results

The Fengxi serial samples were also measured by the Institute of Archaeology, Chinese Academy of Social Sciences, and the College of Archaeology and Museology, Peking University, using the LS method. Some samples were measured with both the LS and AMS methods, and the results are consistent. The calibration based on the LS data gave a date interval of 1050–1010 BC for the Event Conquest (Cai 2003).

There are also some other sites related to the conquest. The Yinxu site in Henan Province was the capital of Shang for more than 200 yr until the conquest. The Liulihe site in Beijing was the capital of Yan, while the Tianma-Qucun site in Shanxi Province was the capital of Jin. Qiu and Cai (2001) have dated the Yinxu and Liulihe sites using the LS method, and they calibrated the 2 sites as 1 series. The results showed that the Conquest of Shang by Zhou occurred around 1040 BC (Qiu and Cai 2001). Tianma-Qucun site was dated by AMS and its older boundary was 1020–940 BC (Guo et al. 2001).

CONCLUSION

The Zhou people lived in the Fengxi area for more than 300 yr, from the Pre-Zhou until the end of the Western Zhou. AMS ¹⁴C dating and the calibration of serial samples show that the Conquest of Shang by King Wu most probably occurred during 1060–1000 BC, which is consistent with other measurement results. Some arguments remain regarding the details of archaeological periodization for the Fengxi site. The results presented here are based on the samples collected from the excavation in the spring of 1997 by Xu et al. Further research would be helpful in determining a more definite time frame.

ACKNOWLEDGMENTS

This work was supported by grants from the National Natural Science Foundation of China and the Ministry of Science and Technology of the People's Republic of China. The authors gratefully acknowledge professors Heng Zou, Shihua Qiu, Boqian Li, Tiemei Chen, Lianzhen Cai, and Dr Zudi Jiang for helpful discussions.

REFERENCES

- Bronk Ramsey C. 1994. Analysis of chronological information and radiocarbon calibration: the program OxCal. *Archaeological Computing Newsletter* 41:11–6.
- Bronk Ramsey C. 1995. Radiocarbon calibration and the analysis of stratigraphy. *Radiocarbon* 37(2):425–30.
- Bronk Ramsey C. 1998. Probability and dating. *Radiocarbon* 40(1):461–74.
- Bronk Ramsey C. 2001. Development of the radiocarbon calibration program. *Radiocarbon* 43(2A):355–63.
- Cai Lianzhen. 2003. The whole story on distinguishing the age range by ¹⁴C dating of King Wu conquering Shang. *Science of Conservation and Archaeology* 15(1):1–5. In Chinese.
- 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. *Nuclear Instruments and Methods in Physics Research B* 172:724–31.
- Guo Z, Liu K, Lu X, Ma H, Li K, Yuan S, Wu X, Liu X. 2001. AMS radiocarbon dating of Tianma-Qucun site, Shanxi, China. *Radiocarbon* 43(2B):1109–14.
- Guo Z, Liu K, Bronk Ramsey C. 2002. Simulation study of ¹⁴C age calibration with archaeological phased samples. The Ninth International Conference on Accelerator Mass Spectrometry, Workshop II, Sakura, Japan, 7 September 2002.
- Jiang Zudi. 1992. On the chronology of pottery from the Fenghao site of the Zhou culture. In: Zou H, editor. *A Collection of Studies on Archaeology* (I). Beijing: Cultural Relics Publishing House. p 256–86. In Chinese.
- Jiang Zudi. 2003. Argument for query on the study of Western Zhou chronology. *Kaogu yu Wenwu* (Archaeology and Cultural Relics) 2:86–90. In Chinese.
- Liu K, Guo Z, Lu X, Ma H, Li B, Wang J, Zhou G, Yuan J, Ren X, Zhao Q, Zhang Z, Zhang G, Yuan S, Wu X, Li K, Chen C. 2000. Improvements of PKUAMS for precision ¹⁴C analysis of the Project of Xia-Shang-Zhou Chronology. *Nuclear Instruments and Methods in Physics Research B* 172:70–4.
- Lu Liancheng, Jiang Zudi. 1987. Excavation of the Western Zhou sites and tombs at Fengxi in 1984–1985. *Kaogu* (Archaeology) (1):15–32. In Chinese.
- Qiu Shihua, Cai Lianzhen. 2001. ¹⁴C chronological framework in the Xia-Shang-Zhou Chronology Project. *Kaogu* (Archaeology) (1):90–100. In Chinese.
- 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. *Nuclear Instruments and Methods in Physics Research B* 172:732–5.
- Xu Lianggao. 1994. A preliminary report on excavation at Fengxi in 1992. *Kaogu* (Archaeology) (11):974–85. In Chinese.
- Xu Lianggao. 2000. Excavations at Fengxi in 1997. *Acta Archaeologica Sinica* (2):199–256. In Chinese.
- Yuan S, Wu X, Gao S, Wang J, Cai L, Liu K, Li K, Ma H. 2000a. Comparison of different bone pretreatment methods for AMS ¹⁴C dating. *Nuclear Instruments and Methods in Physics Research B* 172:424–7.
- Yuan S, Wu X, Gao S, Wang J, Cai L, Guo Z, Lu X. 2000b. The CO₂ preparation system for AMS dating at Peking University. *Nuclear Instruments and Methods in Physics Research B* 172:458–61.
- Zhang Changshou. 1980. Excavation of the Western Zhou tombs at Zhangjiapo in Chang'an in 1967. *Acta Archaeologica Sinica* (4):457–502. In Chinese.