High Precision Radiocarbon Dating of the Western Zhou Tombs in the Liulihe Site

Zhang Xuelian Qiu Shihua Cai Lianzhen

Keywords: high precision radiocarbon dating Western Zhou period tombs Liulihe site

I. Introduction

China has one of the longest uninterrupted writing traditions of the world; yet, the exact date in the received text began in 841 BC. The earlier historical dates, for example, the date of King Wu conquest of the Shang, one of the most defining moments in Chinese history, had been debated for over 2000 years without a general agreement. Regardless of the effort of numerous scholars from the Han Dynasty to the modern times, the attempt to fix an exact date for this historical event remains inconclusive. Consequently, the exact chronology of the Xia, Shang, and the Western Zhou has become an intellectual puzzle in Chinese studies.

After the Second World War, Libby, an American scientist, developed the technology of radiocarbon (^{14}C) dating that can extrapolate absolute dates from carbonized archaeological material, thus opening a new avenue for dating in archaeology. However, scientists soon found that the absolute dates resulted from ^{14}C dating systematically deviated from the tested materials of known dates. It is because the ^{14}C dates are extrapolated from a standard derived from the modern ratio of carbon isotopes in the atmosphere; however, this ratio is not constant and fluctuating through time. As a result, the ^{14}C dates must be calibrated with curves derived from dendro-chronology in order to obtain more realistic calendar dates. The resulting calibrated dates, in general, have error terms of over 100 years. Calendar dates with error terms of this magnitude are unacceptable in the study of the chronology of the Xia, Shang, and Zhou Dynasties. The time from the Xia to the first year of Gonghe (841 BC) accumulates to about 1200 years. An absolute date with a range of error of 200 plus years could cover the reigns of a dozen or so sage kings. The slightest utility of radiocarbon dating in the study of the chronology of early Chinese civilization must involve the effective reduction of the error terms. This paper is going to discuss how radiocarbon scientists in China live up with this challenge.

The reduction of error terms during the calibration procedure can be achieved through a program of extraction of radiocarbon dates from sequential samples and fits these ordered ^{14}C dates onto the calibration curve of high precision. This method, known as high precision wiggle-matching, is a new calibration program that was made possible after the establishment of the high precision ^{14}C-dendro-chronology calibrating curve since 1986. The program starts with the extraction of high precision ^{14}C data from well-stratified samples that their sequence of succession or the exact age gaps between samples are known. Based on Bayesian statistics, the ^{14}C dates are wiggle-matched against the high precision ^{14}C-dendro-chronology calibrating curve to obtain the calendar dates and the error terms. This method significantly reduces the error terms of the calibrated dates because it incorporates the archaeological information–information other than the ^{14}C dates–in the calibration processes.

The Xia–Shang–Zhou Chronology Project used the high precision wiggle-matching method in such a scale and systematic fashion that has no precedent in the international radiocarbon dating community. It involves base-line studies in many areas, for example, the reliability of bone samples in ^{14}C dating. This paper reports the dating of some key sites of the Xia–Shang–Zhou Chronology Project.

II. Samples and Results

Carbon samples taken from the Liulihe 琉璃河 site in Fangshan 房山, Beijing 北京, include samples from the outer coffin wood of M1193 and human and animal bones from the tombs of three periods or six phases.

The ^{14}C dates and calibrated results of the wood log

recovered from M1193 and the human bones from the three periods or six phases of the tombs of Liulihe are shown in Tables 1 and 2. The calibrated results are also shown in Figs. 1–4.

Table 1 Radiocarbon dating and wiggle-matched calibrated results of the outer coffin wood of M1193, Liulihe

Labo No. (ZK)	Tree Ring	^{14}C Date (5568, 1950)	Calibrated Date by Wiggle-matching (BC)
5834B	47–56 ring	2921±37	1082–1042
5833B	37–46 ring	2870±37	1072–1032
5832B	27–36 ring	2888±32	1062–1022
5831B	17–26 ring	2870±33	1052–1012
5830B	7–16 ring	2857±35	1042–1002
5829B	1–6 ring	2864±33	1032–992

Table 2 Radiocarbon dating and wiggle-matched results of the human bones from Liulihe tombs

Period	Phase	Tomb No.	Lab. No. (ZK)	^{14}C Date (5568, 1950)	Calibrated Date by Wiggle-matching (BC)
Early	I	M509	5802	2890±35	1039–1007
		M503	5800	2878±33	1039–1006
	II	M1082	5807	2851±31	1015–972
		M1026	5806	2850±32	1015–971
		M1115	5808	2844±20	1012–972
		M513	5804	2830±31	1010 (66.1%) 965 955 (2.1%) 950
Middle	III	M512	5809	2840±32	959–922
		M1022	5812	2832±44	960–915
	IV	M1088	5817	2830±80	935 (48.1%) 885 880 (20.1%) 855
		M516	5805	2766±31	925 (39.3%) 890 880 (28.9%) 850
		M1003	5811	2751±35	920–850
Late	V	M1045	5822	2713±37	852–808
		M1140	5826	2626±32	819–795
	VI	M403	5803	2540±31	800 (28.8%) 750 690 (10.8%) 660 630 (21.4%) 590 580 (7.2%) 560

1. High precision ^{14}C dating

The relevance of ^{14}C in the discussion of Xia–Shang–Zhou chronology hinges on the precision of ^{14}C dating in the first place. In this regards, we took several procedures, which included reducing the background, improving the sample-preparing, and measuring.

2. Wiggle-matching and other related questions

The key difference between the ^{14}C dating of the Xia–Shang–Zhou Chronology Project and that in the past is on the calibration procedures. There are three essential factors in the reduction of the error terms in the calendar dates. First, the project used sequential samples with archaeologically established relative chronological order or known between-sample intervals. Second, it necessitates a high precision ^{14}C-dendro-chronology calibrating curve. Third, the calibration is derived from Bayesian statistics. Moreover, many other particular factors should also be considered.

3. Results of wiggle-matching

(1) The results of wiggle-matching and its significance

The outer coffin wood from M1193 in the Liulihe site

The specimen is well-preserved, and about 80 countable rings are observable. The result of wiggle-matching is 1032–992 BC, which is slightly later than the date of King Wu conquest of the Shang (determined by the sequence of H18 of Fengxi 沣西), 1050–1020 BC. According to the archaeologists, M1193 is the tomb of Marquis Yan 燕, and its relative date should be brack-

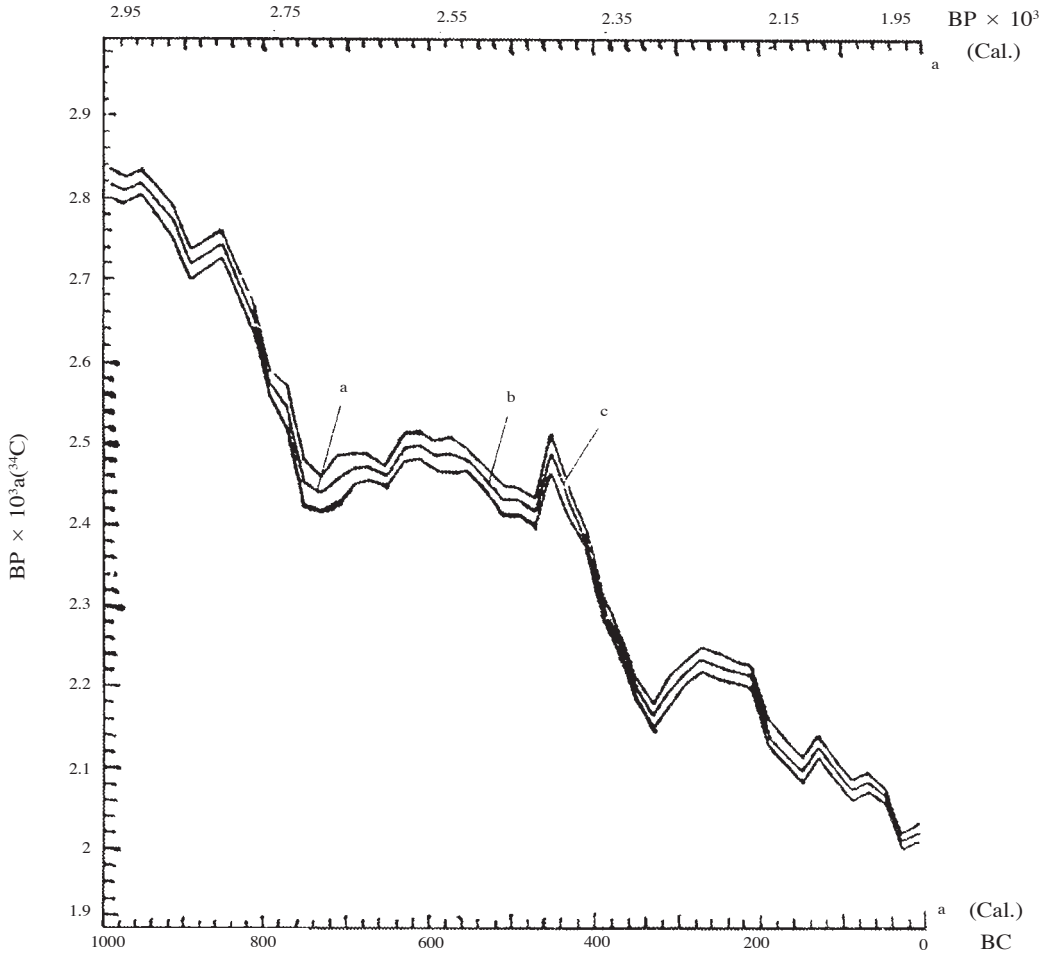

Fig. 1 ^{14}C-dendro-chronology calibrating curve

Atmospheric data from Stuiver et al. Radiocarbon 40 1041−1083(1998);
OxCal V3.3 Bronk Ramsey(1999); cubr:4 sd:12 Prob usp[chron]

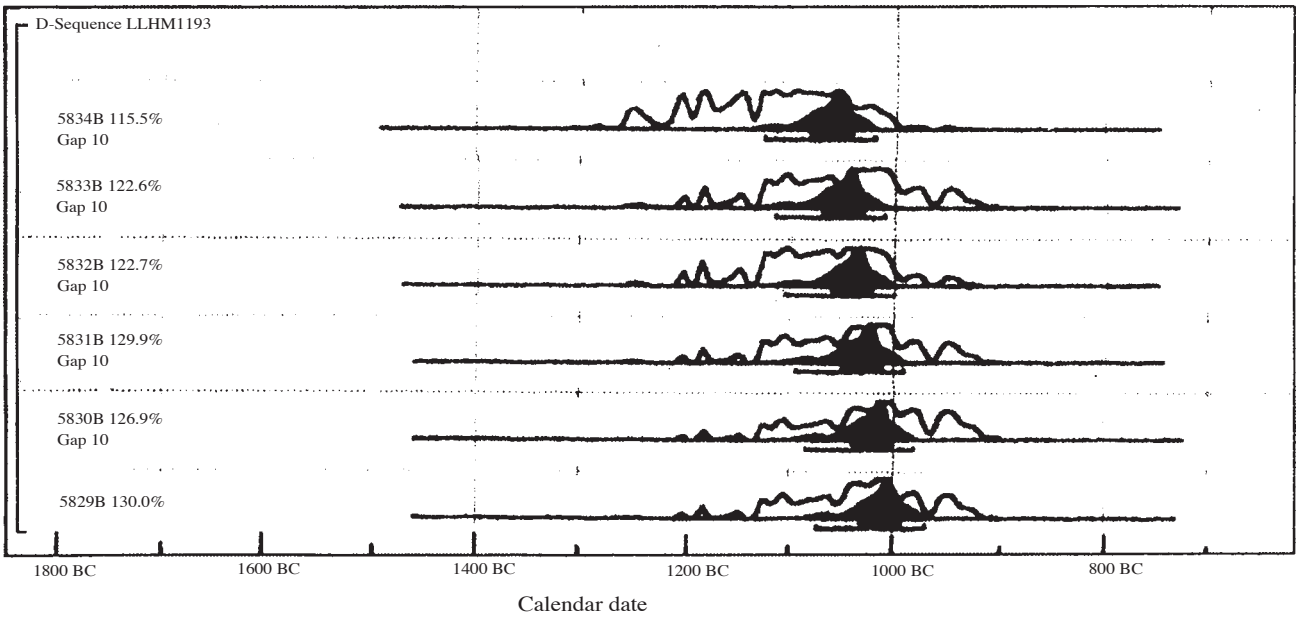

Fig. 2 Calibrating result of wood sequential samples from M1193

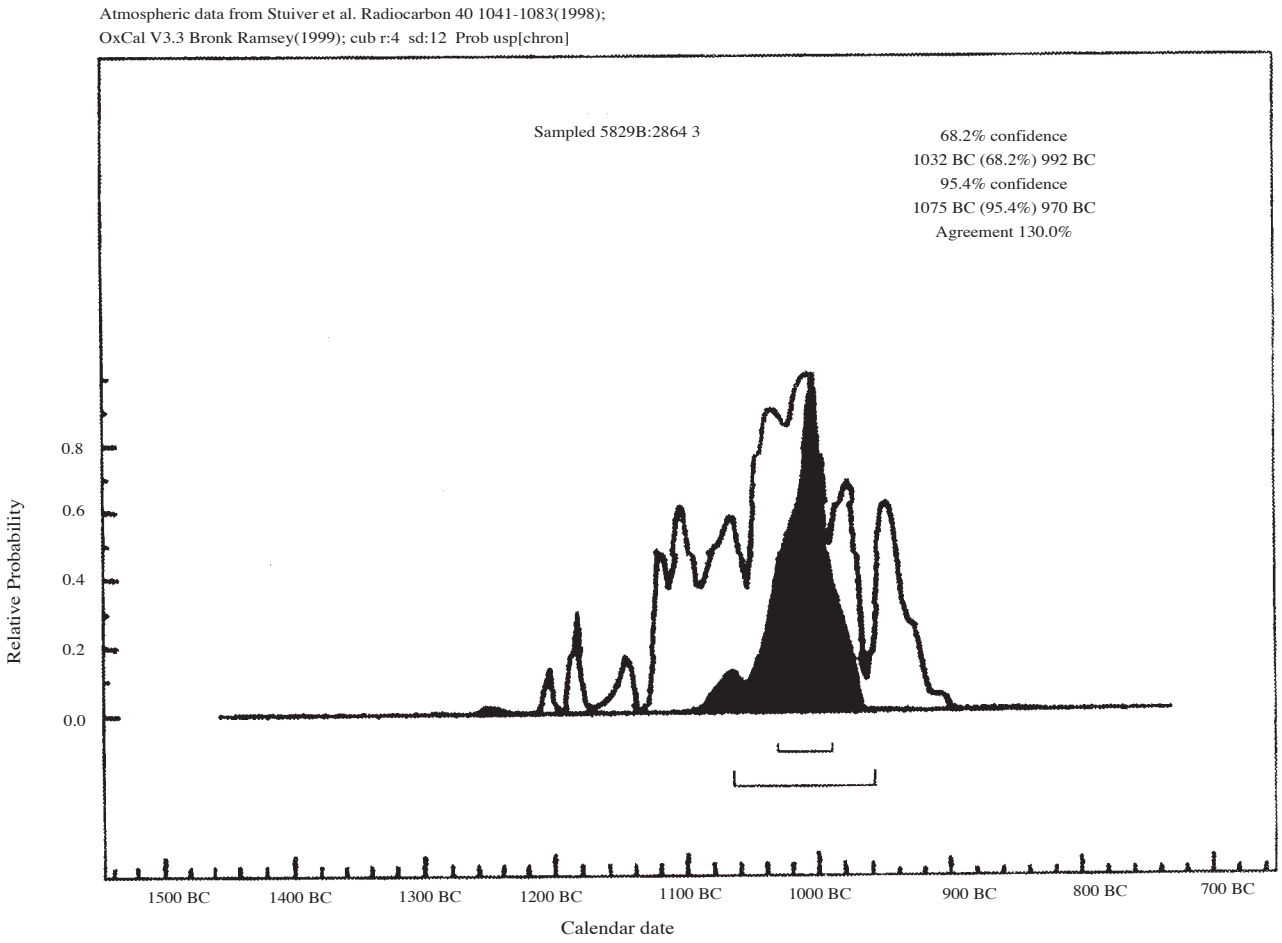

Fig. 3 Calibrating result of sample ZK-5829B of wood sequential samples from M1193

eted between the periods of King Cheng 成 and King Kang 康. The calibrated dates are consistence with the historical and archaeological information.

Bone samples from Liulihe tombs

These bone samples, taken from the tombs of the Liulihe site, are seriated into three periods or six phases. The specimens were dated with high precision. They were then wiggle-matched along with the radiocarbon data of the Yinxu 殷墟 site. In order to maximize the results of wiggle-matching and minimize the error terms, it is necessary to have chronological strata on both the lower and the upper ends to provide the basis for the derivation of posterior probability. We used the radiocarbon data of the late Shang site Yinxu as an expedient to provide a lower bracket for the Liulihe sequence. It is a historical fact that the occupation of Yinxu terminated soon after the Zhou conquest of the Shang; therefore, the Yinxu data are justifiably used to provide an expedient lower bracket. Based on the established archaeological stratification, the wiggle-matching results give the early period phase I at Liulihe calendar dates of 1039–1007 BC. In contrast, we did not supply a proxy chronological upper bracket for the terminal occupation of Liulihe, that is the late period phase VI, the error terms of the calibrated dates of this phase have a much wider margin of error, which is determined no later than 800–560 BC. The combined information from the textual records and archaeological investigation indicate that the Liulihe site was first enfeoffed at the time right after the conquest of the Shang, during the early reign of King Cheng. The site was continuously occupied to approximately the end of the Western Zhou. The wiggle-matching results are consistent with these facts.

The coffin wood recovered from M1193 of Liulihe had previously been ^{14}C dated. Nevertheless, the wiggle-matching method had not been used, thus the margin of error was much wider. The date is bracketed in between 1045 BC and 900 BC, a span of 145 years. The present dating was based on high precision ^{14}C dating, and wiggle-matching of sequential samples. The result is

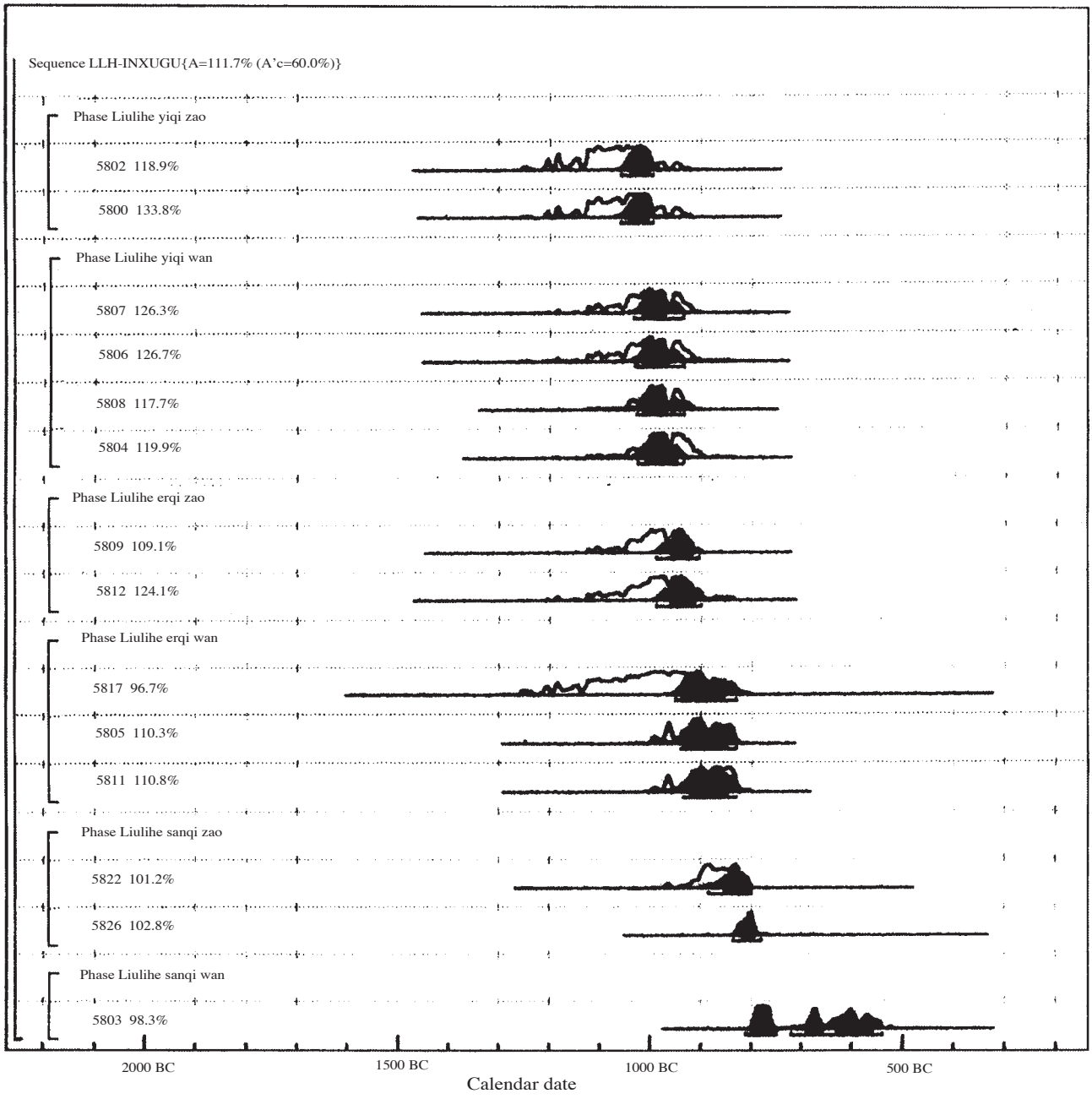

Fig. 4 Calibrating result of bone sequential samples of tombs from Liulihe site

1032–992 BC, a much reduced range of 40 years. Such a difference proves that wiggle-matching on high precision ^{14}C dating of sequential samples can significantly reduce the margin of error.

The result of dating with bone samples from the Liulihe site is equally encouraging. As shown above that bone samples are difficult for radiocarbon dating. During the experiment, we faced some complications. The various tests finally isolated the sources of instability. The results were satisfactory after we modified the procedures. The resulting calendar dates do not contradict with that of archaeology. From the calibrated results of the bone samples extracted from the three periods or six phases of the burials, we determine that the Liulihe site is primarily contemporary to the Western Zhou Dynasty, from early to late. Specific dates for each period are also given for the first time. The results from M1193 and the human bone remains are consistent with

the archaeological study. The archaeological seriation places M1193 to the early period phase II, a little later than the first phase. This discrepancy is reflected in the slightly latter date obtained from radiocarbon dating.

The date when King Wu conquered the Shang is a perennial debating issue among learned individuals. More than 40 dates–a span of over 100 years–had been proposed. The earliest date is 1130 BC, and the latest date is 1018 BC. Radiocarbon dating on the sequential strata of H18 at Fengxi provides important chronological data for the event. By wiggle-matching, the results are bracketed in between 1050 and 1020 BC. This has effectively reduced the range of over 100 years to 30 years and eliminates many of the propositions that fall beyond this range.

(2) Synthesize with other studies

How do the dating results of Liulihe integrate into a larger scheme of early Chinese chronology?

The Liulihe sequence has been proven to be consistent with other chronological sequences of the Xia–Shang–Zhou Chronology Project. First, the Liulihe sequence is compared with the dates obtained from the cemetery of Marquis Jin Cemetery, at the countryside Tianma 天马–Qucun 曲村, Quwo 曲沃, Shanxi 山西 Province. This site is a royal cemetery of the state of Jin of the Western Zhou Dynasty. In the center to the north of the cemetery there are 19 tombs partitioned into nine groups. These tombs have been identified to be that of the nine marquis and their spouses. Their dates span from the early phase of the Western Zhou Dynasty to the beginning of the Springs and Autumns Period. The detailed textual documentation can firmly cross-refer the reigns of the Jin marquis to that of the kings of the Western Zhou Dynasty. The archaeological study indicates that tomb M8 is the burial for Marquis Su of Jin. The calibrated ^{14}C dates pinpointed the tomb to 808 ± 8 BC, which is comparable to the written documentation. In the Annals of the Jin State chapter of the *Shi Ji* 史记 · 晋本纪 (Records of History), it is recorded that Marquis Su of Jin State died in the sixteenth year of King Xuan 宣 (i.e., 812 BC) of the Western Zhou Dynasty. This is a significant result for the study of the Western Zhou chronology.

Second, the date of M1193 can be compared to other absolute dates of the early Zhou Dynasty. Tomb M1193 is one of the few big tombs unearthed in the Liulihe site. According to the inscriptions on the bronze vessel recovered from M1193, some scholars argue that the tomb is that of Shaogong Shi 召公奭or his son. It has been established that Shaogong Shi or his son was enfeoffed in the early years of the Western Zhou Dynasty, which should be contemporary to that of the early stage of the Western Zhou Dynasty in Fengxi. The multi-strata feature of H18 at Fengxi provides an ideal stratified context for the procurement of sequential specimens for wiggle-matching. Archaeologists have established that the stratum T1④ belongs to the early stage of the Western Zhou Dynasty. The ^{14}C results bracket this stratum to 1040–980 BC. This result is consistent with that of M1193.

Third, the Liulihe sequence can be compared to the dating results of Yinxu, which should be earlier than the Liulihe site and H18 of Fengxi. Archaeological seriation partitions Yinxu Culture into four successive phases. The first and the second phases are the times of King Wuding 武丁, and the fourth phase is the terminal dates of the Shang Dynasty.

Archaeological investigation indicates that the pottery assemblage unearthed from H18 is diagnostic to the terminal stage of the pre-dynastic Zhou, and the cultural layer above H18 belongs to the Western Zhou Dynasty. The date of the latest stage of the pre-dynastic Zhou is contemporary with phase IV of Yinxu, and is prior to the Western Zhou Dynasty. The wiggle-matched results bracket Yinxu phase IV in between 1087 BC and 1036 BC, and the date of the pre-dynastic Zhou stratum is about 1050 BC. The date of the earliest tombs at Liulihe, which was built after the downfall of Shang, is slightly younger as expected.

Finally, the Liulihe dates can be compared with the astronomical study of the King Wu conquest of the Shang Dynasty. The textual documentation of the celestial events during the times when King Wu conquered the Shang indicates that the conquest was most likely completed in 1046 BC. This date is also consistent with the Liulihe sequence.

As a whole, the determination of the dates of Liulihe plays an important role for establishing the absolute dates of the Xia–Shang–Zhou chronology framework, and provides a time base for studying the history of the Western Zhou Dynasty and its chronology.

III. Conclusions

1. The relevance of ^{14}C dating in the discussion of the Xia–Shang–Zhou chronology hinges on the precision of the radiocarbon procedures in the first place. High precision is mainly dependent to a stable system, scrupulous sample-preparing, as well as measuring with low level and repeatability.

2. Sample-preparing for bone specimens is difficult

because bone samples have complex composition. Our experiment suggests that the use of well-preserved bone material for the preparation of gelatin may produce result that is more satisfactory.

3. Increase of the precision in radiocarbon dating can also be achieved through the wiggle-matching on sequential samples. The reduction of error terms in calendar dates is contingent with the successful procurement of sequential samples in well-stratified archaeological context, the availability of high precision ^{14}C-dendro-chronology calibrating curve, and the use of Bayesian statistics.

4. The radiocarbon scientists must closely collaborate with the archaeologists to develop the best carbon sample collecting strategies. Accurate archaeological information is crucial for the wiggle-matching of sequential samples.

5. Different archaeological sample is of characteristic itself in age.

6. By using the wiggle-matching calibration method on sequential samples, we have obtained high precision calendar dates with small error terms for the Liulihe site. The precision level is significantly higher than that of the previous effort.

7. The determination of the dates of the Liulihe site of the Western Zhou Dynasty plays an indispensable role for building the chronological framework of the Xia–Shang–Zhou Chronology Project, and provides a time base for studying the history of the Yan State during the Western Zhou Dynasty.

References

1. Qiu Shihua 仇士华, Chen Tiemei 陈铁梅, and Cai Lianzhen 蔡莲珍(1990). *Zhongguo ^{14}C Niandaixue Yanjiu* 中国^{14}C年代学研究. Beijing: Kexue Chubanshe 科学出版社.

2. Qiu Shihua and Cai Lianzhen (1998). "Jiejue Shangzhou jinian wenti de yixian xiwang 解决商周纪年问题的一线希望". *Zhongguo Shang Wenhua Guoji Xueshu Taolunhui Lunwenji* 中国商文化国际学术讨论会论文集. Beijing: Zhongguo Dabaike Quanshu Chubanshe 中国大百科全书出版社.

3. Yin Weizhang 殷玮璋 and Cao Shuqin 曹淑琴 (1991). "Zhouchu taibaoqi zonghe yanjiu 周初太保器综合研究". *Kaogu Xuebao* 考古学报 1991.1: 1–22.

4. Zhongguo Shehui Kexueyuan Kaogu Yanjiusuo 中国社会科学院考古研究所 and Beijing Shi Wenwu Gongzuodui Liulihe Kaogu Gongzuodui 北京市文物工作队琉璃河考古工作队(1984). "1981–1983 nian Liulihe xizhou yanguo mudi fajue jianbao 1981–1983 年琉璃河西周燕国墓地发掘简报". *Kaogu* 考古1984. 5: 405–416.

Note: The original paper was published in *Kaogu Xuebao* 2003.1: 137–160, written by Zhang Xuelian 张雪莲, Qiu Shihua, and Cai Lianzhen with 6 figures and 4 tables. The present version, an abridgment from the original, is prepared and English-translated by the first author and revised by Lee Yun-Kuen 李润权.