Archaeobotanical Data for Research on the Introduction of Wheat into China¹

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Abstract: After being introduced into China from West Asia, wheat gradually replaced such varieties of millet as *Setaria italica* and *Panicum miliaceum* to become the main dry-land farming crop in northern China, forming China's current agricultural production pattern of rice in the south and wheat in the north. To date, there have been dozens of reported archaeological discoveries about early wheat remains. According to these newly unearthed findings, wheat was introduced into China through at least two routes between 4500 and 4000 years ago. One is the grassland route from West Asia, through Central Asia, the Bronze Age cultures of the Eurasian Steppe, the Northern Cultural Zone in northern China to the middle and lower reaches of the Yellow River. The other is the oasis route from West Asia, through Central Asia, Pamir's oases on both sides of the Tarim Basin, the Hexi Corridor, to the Loess Plateau of northern China.

Keywords: archaeobotany, wheat, wheat introduction to China, wheat diffusion, Eurasian Steppe, flotation technique

1 Introduction

West Asia, China, northern Africa and Mesoamerica/South America are four centers for the origin of agriculture in the world. Wheat has its origin in the Fertile Crescent in West Asia, which basically includes Israel, Palestine, Lebanon, Jordan, Syria, northeastern Iraq, and southeastern Turkey. Remains of the earliest wheat have been excavated from the archaeological sites of the EPPNB period (Early Pre-Pottery Neolithic B), which is dated to 10500–9500 BP (Weiss and Zohary 2011, 237–254). *Triticum monococcum* and *T. turgidum* are two varieties of the earliest domesticated wheat. About 8000 years ago, *T. turgidum* was introduced into the river

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valley between the northern Iranian plateau and southeastern Caspian Sea, and hybridized with local *Aegilops tauschii*, which gave birth to a new cultivated variety that is widely planted and used today – *T. aestivum*, which is also called common wheat or bread wheat (Zohary and Hopf 2000).

Wheat gradually spread to become the main crop in the regions of the major ancient civilizations, including Mesopotamian civilization in the Euphrates and Tigris valleys, ancient Egyptian civilization in the Nile Valley, ancient Indian civilization in the Indus Valley, and the ancient Greek and Roman civilizations, which were all established on the basis of agricultural production with wheat as the main crop.

In Central Asia, the eastward spread of wheat was very slow. According to archaeological findings, wheat had already spread into the south-western areas of Central Asia, such as the northern slopes of Kopet-Dagh in Turkmenistan, as early as 7000 years ago (Harris 2010), but only moved eastward to eastern Asia thousands of years later. There were many reasons for this hindrance of the eastward spread of wheat, among which the different climates of western and eastern Asia should be the main factor. As the birthplace to wheat, West Asia enjoys a Mediterranean climate with hot, dry summers, and cold, damp winters, with frequent rainfall in winter and spring. However, East Asia, including China, the Korean Peninsula, and Japanese archipelago, enjoys an East Asian monsoon climate with hot, wet summers, cold, dry winters, and frequent rainfall in summer. The difference in rainy seasons had a great impact on the growth of wheat. As a summer crop, wheat is sowed in winter and harvested in summer. Water is needed in spring, the growing season for wheat, but rain is scarce in East Asia at this time. For example, in the vast areas of northern China, it is said that rain in spring is as precious as oil. The lack of water is not conducive to the jointing and filling of wheat in the growing season, while the frequent rain in summer also affects its maturation and harvest. Under these conditions, East Asia is actually not suitable for growing wheat unless irrigation is used. Therefore, climate differences in western and eastern Asia are the main reason for the very gradual eastward spread of wheat.

According to historical documents, however, wheat continued to spread eastward, reaching the middle and lower reaches of the Yellow River, which was the core area of ancient Chinese civilization. Gradually replacing such local crops as foxtail millet (*Setaria italica*) and broomcorn millet (*Panicum miliaceum*), wheat became the major crop of dry-land farming in northern China, leading to China's current agricultural production pattern of rice in the south and wheat in the north. Thus, it follows that in spite of the fact that wheat did not originate in China, the time when it was introduced into China, the route it took to enter China, the method of its spread in China and its impact on ancient Chinese civilization are all important issues deserving serious attention.

In this paper, archaeological remains of ancient wheat are studied using the methods of archaeobotany so as to explore the time and routes of the introduction of

wheat into China. Specifically, the credibility and reliability of the dates of unearthed remains of early wheat are assessed, thereby determining the time of its introduction into China. This will involve integrating archaeological materials concerning wheat found in different regions, and synthesizing the environmental characteristics and cultural traditions in ancient China. The means and routes of wheat's transmission into China will be explored, especially to the core region of Chinese civilization, namely, the middle and lower reaches of the Yellow River.

2 Background for the study of the introduction of wheat

As for the time when wheat spread into China, some clues can be found in historical documents. For example, an ancient historical text, in the chapter "Duke Cheng of Lu (590–573 BC)" in *Zuo zhuan* 左传 (Zuo Qiuming's commentary on *Spring and Autumn Annals*), compiled in the early fourth century BC, records that "周子有兄而無慧，不能辨菽麥，故不可立 (the brother of Zhou Zi is not qualified to be a king, because he is not intelligent enough to distinguish soybean and wheat)." It is clear from this that wheat was widely grown in northern China during the Eastern Zhou period (770–256 BC). In addition, Chinese characters relating to wheat have been identified in China's earliest written artifacts, the so-called oracle bone inscriptions (inscriptions on bones or tortoise shells) dating from the period of the late Shang dynasty, roughly 1200–1050 BC. For example, though the two characters *lai* 來 and *mai* 麥 have been explained as triticeae crops, the former is regarded as denoting wheat and the latter barley (Song 2002). The character 來 referred to wheat originally, but later was used as a word meaning "come." Some scholars thus believe that this indicated that wheat came (來) from regions outside China (Ho 1985), though other scholars hold different views (Luo 1990). At all events, the Chinese character 來 in the oracle bone inscriptions clearly confirms that wheat had already entered China no later than the Shang period (about 3300 years ago).

These are the earliest historical records about wheat. To trace any further into the past requires archaeological findings that precede these historical documents, that is, archaeological materials dated to before 3000 years ago. This is the chronological demarcation line for the discussion of the present study.

The most direct archaeological evidence for when the introduction of wheat occurred should come from the remains of ancient wheat found on site. The fact is, though, that only in rare cases is wheat preserved in cultural deposits, because the plant as an organic material tends to rot away. Unlike other archaeological remnants, wheat grains are too small to be observed by the naked eye, with the result that it is very difficult to find any wheat remains by means of the usual methods employed in archaeological excavation. Despite this, there were still some reports of wheat remains in archaeological excavations

in the previous century. Archaeological sites where remains of early wheat from 3000 years ago were discovered include the Donghuishan site in Minle County in Gansu Province (Gansu Provincial Institute of Cultural Relics and Archaeology and Northern Archaeology Laboratory of Jilin University 1998), the Zhaojialai site in Wugong County in Shaanxi Province (Institute of Archaeology, Chinese Academy of Social Sciences 1988), the Diaoyutai site in Bo County in Anhui Province (Anhui Museum 1957), the Haimenkou site in Jianchuan County in Yunnan Province (Preparatory Office of Yunnan Museum 1958), the Changguogou site in Shannan in Tibet (Fu 2001), the Gumugou site in Lop Nor (Wang 1983), the Lanzhouwanzi site in Balikun County (Wang et al. 1985, 255–256) and the Wubao Tomb in Hami in Xinjiang Uygur Autonomous Region (Xinjiang Institute of Cultural Relics and Archaeology 1992) (Table 1).

Table 1 Early wheat remnants in twentieth-century archaeological discoveries

Sites	Findings	Relative date	Absolute age BP	Dating material/ Method	References
Donghuishan site, Minle County, Gansu Province (甘肃民乐东灰山)	charred wheat grains	Siba culture	5000±159	soil samples/ conventional	Li Fan 李璠 et al. 1989
Donghuishan site, Minle County, Gansu Province	charred wheat grains	Siba culture	3770±145	charcoal/ conventional	Gansu Provincial Institute of Cultural Relics and Archaeology and Northern Archaeology Laboratory of Jilin University 1998
Donghuishan site, Minle County, Gansu Province	charred wheat grains	Siba culture	4230±250	wheat grains/ conventional	
Zhaojialai site, Wugong County, Shaanxi Province (陕西武功赵家来)	wheat straw impressions	Keshengzhuang culture	circa 4400–4000	—	Huang Shilin 黄石林 1991
Zaojiaoshu site, Luoyang City, Henan Province (河南洛阳皂角树)	wheat grains	Erlitou culture	3660±150	charcoal/ conventional	Cultural Relics Team of Luoyang 2002
Haimenkou site, Jianchuan County, Yunnan Province (云南剑川海门口)	ears of wheat	Late Neolithic Age	—	—	Preparatory Office of Yunnan Museum 1958
Changguogou site, Shannan, Tibet (西藏山南昌果沟)	wheat grains	Neolithic Age	3370	charcoal/ conventional	Fu Daxiong 傅大雄 2001
Gumugou site, Lop Nor, Xinjiang Uygur Autonomous Region (新疆罗布泊古墓沟)	wheat grains	—	3925–3765	coffin, sheepskin and blanket/ conventional	Wang Binghua 王炳华 1983

Table continued ...

Sites	Findings	Relative date	Absolute Age BP	Dating material/ Method	References
Lanzhouwanzi site, Balikun County, Xinjiang Uygur Autonomous Region (新疆巴里坤兰州湾子)	charred wheat grains	—	3285	wood and fur/conventional	Wang Binghua et al. 1985
Wubao Tomb, Hami, Xinjiang Uygur Autonomous Region (哈密五堡墓地)	wheat grains	—	3260–2960	charcoal and so on/conventional	Wang Binghua 1983

It should be noted that most of these wheat remains were discovered by accident, and there is a fair margin of doubt about the period and species that they belong to, provoking some debate. For example, the ceramic pot in which the remains of wheat were found unearthed at the Diaoyutai site in Bo County was initially considered to date to the Neolithic Age, but subsequently identified as a relic of the Western Zhou period (Yang 1963). Another example is that although there is an agreement on the age of the remains of wheat found at the Zhaojialai site in Wugong County (Longshan period), the determination of their species requires further research. It was reported that the wheat remains from this site were actually found in the traces of some plant stems present in the mud used to daub a wall (Huang 1991). However, it is difficult enough to identify the species of fresh stems of most crops based on appearance, let alone the impressions of stems left in such material.

The most influential and controversial of such wheat remnants discovered in the previous century are those unearthed at the Donghuishan site in Minle County. Li Fan was the first to research these wheat remains. Based on the wheat grains he collected at the site in 1985 and 1986, he identified *Triticum aestivum* and *T. compactum*, and determined that the wheat dated to 5000 years ago based on radiocarbon dating results of bulk samples (black carbon soil) from the site carried out by the Radiocarbon Laboratory of the Institute of Geography, Chinese Academy of Sciences (Li et al. 1989). Since Li Fan is a well-known agronomist rather than archaeologist, his identification of the wheat species is credible, but the methods he used to collect the samples of plant remains and to assess their date require further confirmation by professional archaeologists.

In 1987, a combined archaeologist team from the Gansu Institute of Archaeology and Archaeology Department of Jilin University officially began the excavation of the Donghuishan site. The results obtained by the team show that the site belongs to Siba culture (Gansu Provincial Institute of Cultural Relics and Archaeology and Northern

Archaeology Laboratory of Jilin University 1998, 131–132), an early Bronze Age culture in the Hexi corridor dated from 3900 to 3400 BP. Therefore, the date of the Donghuishan site determined by archaeologists based on excavation was over 1000 years later than that of the wheat remains at the site identified by Li Fan. Even more complicated are the two radiocarbon dating results published in the appendix of the official archaeological report. The calibrated result of the radiocarbon age of charcoal samples with clear acquisition layer (87MDTG②) was 3770 ± 145 cal. BP, determined by the Institute of Antiquities Preservation Sciences and Techniques, State Administration of Cultural Heritage, which was precisely in the period of Siba culture. However, the conventional radiocarbon age of charred wheat collected from the Siba cultural layer was 4230 ± 250 BP (Gansu Provincial Institute of Cultural Relics and Archaeology and Northern Archaeology Laboratory of Jilin University 1998, 190), obtained by the Radiocarbon Laboratory of Peking University, which seemed to be closer to Li Pan's assessment. These contradictory radiocarbon dating results added to the confusion over the age of the wheat remains found at the Donghuishan site, leading to further academic debate (Li and Mo 2004).

In 2005, a joint team consisting of Chinese and American archaeologists made a special trip to the Donghuishan site. Using the flotation technique, more remains of wheat and barley were discovered. Based on over 10 series of charred wheat samples selected through flotation, the age of this newly unearthed wheat was directly dated using accelerator mass spectrometry dating technique by the Radiocarbon Laboratory of Peking University (Flad et al. 2010). The results indicated that most wheat samples were from 3600–3400 BP. In recent years, new sampling and dating (Dodson et al. 2013) by Chinese and Australian scholars have determined that the calibrated results of radiocarbon dating age was 3829–3488 cal. BP.² These new data irrefutably prove that the cultural deposits and remains of wheat from the Donghuishan site are from the period of Siba culture, and their absolute age was about 3600 BP. As a result, this archaeological problem, which had been confusing academic circles for years, was finally solved.

3 New archaeobotanical data

Flotation is currently the most effective way to obtain ancient plant remains from archaeological excavations. Since the beginning of this century, flotation has been vigorously promoted and popularized, making it much easier to find ancient plant remains in the process of excavation. It has now been used at hundreds of archaeological sites, resulting in the discovery of a large number of charred plant

² It is given as 1897–1538 cal. BC in the original report, and converted to the BP (Before Present) format, with BP as the 1950s. For the sake of consistency, all the BC (Before Christ) years in this paper (including tables) are converted to the BP format using this method.

remains of great value to Chinese archaeological research (Zhao 2014, 49–55). These plant remains also include ancient wheat, providing new evidence with which the introduction of wheat into China can be explored (Zhao 2009).

According to incomplete statistics, there have been dozens of cases of discoveries of early wheat remains reported or formally published this century. In contrast to the findings from the previous century, the remains of wheat discovered in this century have three distinctive characteristics. Firstly, instead of being found by accident, they have been mostly acquired deliberately through flotation or filtering soil samples collected during archaeological excavations or field investigations. Secondly, many geologists and biologists have participated in this process, and in research on these early wheat remains. Finally, with increasingly advanced radiocarbon dating technology, especially improvements in the AMS dating technique, a single grain of wheat now qualifies as a dating sample. In addition, thanks to China's growing economy, adequate research funds have meant that such samples can be tested by radiocarbon laboratories at home and abroad, resulting in a stream of relatively accurate dating data.

These early wheat remains have been acquired in two different ways. On the one hand, some have been discovered in deposits at archaeological sites through standard excavation. These remains usually corresponded to specific cultural layers, though highly specific dating of them is absent in most cases. The relative age of the wheat is basically calculated based on the cultural features of the site or on the dating of other samples excavated from the same layers, such as charcoal, animal bones, fur and even bulk samples. On the other hand, some have been acquired from profile sediments or cultural deposits through environmental observation or archaeological investigation. Although these remains may not be clearly located in archaeologically attested cultural contexts, they mostly have reliable dating data gained from direct AMS dating.

According to the statistics in Table 2, with the exception of those found at Xishanping in Tianshui, early wheat remains with only relative dating were all obtained through standard archaeological excavation. Based on their relative age determined by cultural periodization, the earliest date from the Longshan period about 4600 to 4000 years ago, while some belong to the Erlitou culture from about 4000 to 3500 years ago. According to the statistics in Table 3, those early wheat remains with direct dating data were obtained through both archaeological excavation and profile sampling during investigation (Chen et al. 2015). With the exception of those from Zhaojiazhuang in Jiaozhou, the samples tested by AMS dating all come from no earlier than 4000 years ago. Among these two sets of statistics, Xishanping and Zhaojiazhuang are special cases and deserve further analysis.

Table 2 Early wheat remnants only with relative age

Sites	Acquisition methods of wheat remains	Relative age	Presumed absolute age BP	Basis for the presumed age	References
Liangchengzhen site, Rizhao City, Shandong Province (山东日照两城镇)	archaeological excavation	Longshan culture	ca. 4600–4000	cultural features of the site	Crawford et al. 2004
Jiaochangpu site, Liaocheng City, Shandong Province (山东聊城校场铺)	archaeological excavation	Longshan culture	ca. 4600–4000	cultural features of the site	Zhao Zhijun 赵志军 2003
Zhaogezhuang site, Yantai City, Shandong Province (山东烟台照格庄)	archaeological excavation	Yueshi culture	ca. 3839–3627	cultural features of the site and dating results of other materials	Jin Guiyun 靳桂云 et al. 2010
Ma'an site, Zhangqiu City, Shandong Province (山东章丘马安)	archaeological excavation	Yueshi culture	ca. 3900–3600	cultural features of the site	Chen Xuexiang 陈雪香 and Guo Junfeng 郭俊峰 2009
Daxinzhuan site, Jinan City, Shandong Province (山东济南大辛庄)	archaeological excavation	Shang dynasty	ca. 3500–3000	cultural features of the site	Chen Xuexiang et al. 2008
Yuhuicun site, Bengbu City, Anhui Province (安徽蚌埠禹会村)	archaeological excavation	Longshan culture	ca. 4300–4140	cultural features of the site and dating results of other materials	Yin Da 尹达 2013
Xijincheng site, Bo'ai County, Henan Province (河南博爱西金城)	archaeological excavation	Longshan culture	ca. 4500–4000	cultural features of the site and dating results of other materials	Chen Xuexiang et al. 2010
Wangchenggang site, Dengfeng City, Henan Province (河南登封王城岗)	archaeological excavation	Late Erlitou culture	ca. 3640–3520	cultural features of the site and dating results of other materials	Zhao Zhijun and Fang Yanming 方燕明 2007
Wadian site, Yuzhou City, Henan Province (河南禹州瓦店)	archaeological excavation	Longshan culture	ca. 4260–4150	cultural features of the site and dating results of other materials	Liu Chang 刘昶 and Fang Yanming 2010
Baligang site, Dengzhou City, Henan Province (河南邓州八里岗)	archaeological excavation	Late Longshan culture	ca. 4000	cultural features of the site	Deng Zhenhua 邓振华 and Gao Yu 高玉 2012

Table continued ...

Sites	Acquisition methods of wheat remains	Relative age	Presumed absolute age BP	Basis for the presumed age	References
Xinzhai site, Xinmi City, Henan Province (河南新密新砦)	archaeological excavation	Xizhai phase of Erlitou culture	ca.3910–3830	cultural features of the site and dating results of other materials	Zhao Zhijun 2011
Erlitou site, Yanshi City, Henan Province (河南偃师二里头)	archaeological excavation	Phase IV of Erlitou culture	ca.3510–3480	cultural features of the site and dating results of other materials	Zhao Zhijun 2015
Zhouyuan site, Fufeng County, Shaanxi Province (陕西扶风周原)	archaeological excavation	Pre-Zhou period	ca.3080–2870	cultural features of the site and dating results of other materials	Zhao Zhijun and Xu Lianggao 徐良高 2004
Xishanping site, Tianshui City, Gansu Province (甘肃天水西山坪)	profile sampling in environmental survey	—	ca. 4650	presumption of deposition rate of sediments of profile	Li Xiaoqiang 李小明 et al. 2007
Fengtai site, Huzhu County, Qinghai Province (青海互助丰台)	archaeological excavation	Kayue culture	ca. 3200–2800	cultural features of the site and dating results of other materials	Zhao Zhijun 2004

Table 3 Early wheat remnants with direct dating data

Sites	Acquisition methods of wheat remains	Calibrated result of C14 dates (cal. BP)	Dating materials	Laboratory /Method	References
Zhaojiazhuang site, Jiaozhou City, Shandong Province (山东胶州赵家庄)	archaeological excavation	4500–4270	wheat grains	Peking University/AMS	Jin Guiyun et al. 2011
Huoshiliang site, Jinta County, Gansu Province (甘肃金塔火石梁)	profile sampling on cultural layer	4085–3845	wheat grains	Oxford/AMS	Dodson et al. 2013
Ganggangwa site, Jinta County, Gansu Province (甘肃金塔缸缸瓦)	profile sampling on cultural layer	3976–3709	wheat grains	Oxford/AMS	Dong Huanghui 董光辉 et al. 2014
Donghuishan site, Minle County, Gansu Province (甘肃民乐东灰山)	profile sampling on cultural layer	3829–3488	wheat grains	Oxford/AMS	Dodson et al. 2013
Donghuishan site, Minle County, Gansu Province	profile sampling on cultural layer	3573–3402	wheat grains	Peking University/AMS	Flad et al. 2010

Table continued ...

Sites	Acquisition methods of wheat remains	Calibrated result of C14 dates (cal. BP)	Dating materials	Laboratory /method	References
Jinchankou site, Datong County, Qinghai Province (青海大通金蝉口)	archaeological excavation	3980–3720	wheat grains	Beta/AMS	Dong Huanghui et al. 2014
Aiqingya site, Gangcha County, Qinghai Province (青海刚察爱情崖)	profile sampling on cultural layer	3406±49	wheat grains	Beta/AMS	Chen et al. 2015
Xiaeryamakebu site in Dulan County, Qinghai Province (青海都兰夏尔雅马可布)	profile sampling on cultural layer	3316±69	wheat grains	Peking University/AMS	Chen et al. 2015
Shuangerdongping site, Ledu County, Qinghai Province (青海乐都双东坪)	profile sampling on cultural layer	3251±88	wheat grains	Peking University/AMS	Chen et al. 2015
Xiaohe Tomb Complex, Lop Nor, Xinjiang Uygur Autonomous Region (新疆罗布泊小河墓地)	archaeological excavation	3640–3370	wheat/millet /tips of animals' ears	Peking University/AMS	Xinjiang Institute of Cultural Relics and Archaeology 2007
Xintala site, Heshuo County, Xinjiang Uygur Autonomous Region (新疆和硕新塔拉)	profile sampling in environmental survey	3830–3677	wheat grains	Oxford/AMS	Zhao Kelaing 赵克良 et al. 2012

Although the wheat remains from Xishanping in Tianshui were gained from sediment profiles through environmental observation, the age of the wheat was based on speculation due to the lack of direct AMS dating of the grains unearthed. According to the original report:

Twenty samples with the thickness of 10–15 cm and weighing approximately 80 kg were acquired from a 650-cm-thick sedimentary section. Various archaeological remains were then extracted through filtration and flotation. Wheat was detected in the top profile of the eight samples, with an earliest date of 4650 cal. a BP. (Li et al. 2007)

After being published, the report immediately attracted wide attention due to the relatively early dating, and has been cited as data relating to the earliest wheat in China in many relevant papers.

However, the question remains concerning how the date 4650 cal. a BP was obtained, and how accurate and reliable it is. Tables in the original report offered eight radiocarbon dating results in which the data 4650 cal. a BP was not included. The eight dated samples

mainly consisted of charcoal (in six samples), and rice and millet grains (*Setaria italica*) (one sample each), but these samples contained no wheat grains. Clearly, no AMS dating was carried out on any unearthed wheat in this research, and thus, the date of the wheat found at Xishanping must have been calculated based on the age of the layer from which it was excavated. Which layer, then, was the wheat actually found in? What was the basis of the determination of the layer's age? The eight sets of age data in the report all corresponded to the layer depth of the sedimentary sections, yet, other than recording that wheat was discovered in the top eight samples. The report does not refer to the layer depth in which it was found, making it impossible to identify the age.

The only information of reference value in the report is the relative dates in the pollen spectrum, which was calculated based on deposition rate. The period between the two relative dates of 4600 and 4500 corresponded to the layer depth of 200 cm, which was roughly the position where the "top eight samples" with wheat were unearthed. Thus, the date of the wheat remains unearthed at Xishanping was calculated based on the depth of the sedimentary section, the dates of which were determined by the deposition rate of the corresponding section. Clearly, due to this lack of credibility, the relative dating obtained through this method could only serve as a reference rather than as firm data for the earliest wheat in China.

In contrast, the wheat remains unearthed at Zhaojiazhuang in Jiaozhou were acquired from archaeological excavation, and have provided data based on direct age dating. According to the original report (Jin et al. 2008), Zhaojiazhuang contained sites that included cultural deposits from the Dawenkou, Longshan and Eastern Zhou periods. By means of the application of flotation during the archaeological excavation in 2005, rich charred plant remains were obtained that include wheat. After analysis using the AMS dating method at the Radiocarbon Laboratory of Peking University, the conventional radiocarbon age of the wheat from site H339 of the Longshan period was determined to be 3905 ± 50 BP, and the calibrated result was 2500–2270 BC, that is, 4450–4220 BP. Therefore, combining both the clear archaeological cultural background and accurate dating data, the wheat remains from Zhaojiazhuang are highly credible and of great research value.

In summary, based on the analysis of the ages of early wheat remains unearthed from over 30 archaeological sites listed in Table 1 to Table 3, wheat had already been introduced into China no later than 4000 years ago, and was widely planted in northern and southwestern China. According to the dates of the wheat remains from Zhaojiazhuang, it is likely that wheat entered China 4500 years ago. With just this single piece of evidence available for such a judgment for this date, final identification will require more archaeological materials.

4 Potential routes for the introduction of wheat

As stated above, there are more than 30 archaeological sites in China that contain wheat remains of an early period, that is, over 3000 years ago. These sites are mainly distributed along a belt of terrain stretching for several thousand kilometers, from the east of Mount Tianshan in the west to the Shandong Peninsula in the east. This belt is located at approximately 34 to 46 degrees north latitude (Figure 1). According to the features of its ecological environment and the archaeological division of cultural regions, it included three regions, that is, from east to west, the Haidai Region, Central China Region and Northwest Region.

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Figure 1: The potential routes for the spread of wheat into China:
1) Northern Cultural Zone; 2) The middle and lower reaches of the Yellow River.
The dashed line indicates the Steppe Route and the dotted line indicates the Oasis Route.

The Haidai Region refers to the areas where the Dawenkou and Haidai-Longshan cultures of the Neolithic Age and the Yueshi culture of the Bronze Age flourished. It basically embraces today's Shandong Province and northern parts of Anhui Province and Jiangsu Province (Luan 1997). Archaeological sites with early wheat remains in the

Haidai Region include: Zhaojiazhuang in Jiaozhou, Liangchengzhen in Rizhao (Crawford 2004), Jiaochangpu in Liaocheng (Zhao 2004, 210–224), Zhaogezhuang in Yantai (Jin et al. 2010, 331–343), Ma'an in Zhangqiu (Chen and Guo 2009, 368–371), Daxinzhuang in Jinan, Shandong Province (Chen and Fang 2008, 47–68) and Yuhuicun in Bengbu, Anhui Province (Yin 2013, 250–268). The importance of the wheat remains found at Zhaojiazhuang has already been stated. The findings from Liangchengzhen, Jiaochangpu and Yuhuicun also deserve proper attention because traces of charred wheat have been found at all three sites although no direct dating data has been published.

The Central China Region, referring to the area of Neolithic Longshan culture and Bronze Age Erlitou culture in Central China, is the core area for the formation of Chinese civilization. This region generally covers today's Henan Province and the southern parts of Shanxi Province and Hebei Province. Archaeological sites in the region where early wheat remains have been unearthed using flotation in recent years include: Wangchenggang in Dengfeng (Zhao and Fang 2007), Xijincheng in Bo'ai County (Chen et al. 2010), Wadian in Yuzhou (Liu and Fang 2010), Baligang in Dengzhou (Deng and Gao 2012), Xinzhai in Xinmi (Zhao 2011, 1295–1313) and Erlitou in Yanshi, Henan Province (Zhao 2015) and others (Zhao 2007, 1–11). The most noteworthy of these are the Xijincheng, Wadian and Baligang sites because the remains of charred wheat belonging to the Longshan culture have been excavated at these three sites. The wheat remains found at the Wadian site were delivered to a radiocarbon dating laboratory for dating, yet without satisfactory results. The tests indicated that the date of the wheat was evidently later than the Longshan period, and further analysis and verification are required.

The Northwest Region covers a vast territory of complex geographical units, involving the upper region of the Yellow River, the Hexi Corridor and most of Xinjiang. Wheat remains from an early period found in this region have been obtained mainly through environmental and archaeological investigation, and most of them have direct dating data. Sites in which these wheat remains have been unearthed are mainly distributed across three areas, that is, the eastern part of Qinghai Province, the Hexi Corridor in Gansu Province and the eastern part of Xinjiang; their chronology falls between 4000 to 3500 years ago. Important sites here include Jinchankou in Datong County, Qinghai Province (Dong et al. 2014), Huoshiliang (Dodson et al. 2013) and Ganggangwa (Cultural Relics Team of Luoyang 2002) in Jinta County, Gansu Province. The direct dating data for the charred wheat remains found at these three sites reaches or approaches 4000 BP, the earliest absolute chronological data obtained so far, besides Zhaojiazhuang in Shandong Province.

Wheat was introduced to China from West Asia through Central Asia. Therefore, the Northwest Region seems to be most closely related to the route along which wheat came to China. Correspondingly, in historical times, especially after the Qin and Han

dynasties, the major channel of cultural exchanges between East and West was the so-called Silk Road, the Hexi Corridor being a key section of this route. In addition, the Northwest Region is where early wheat remains have been most commonly found, which easily leads to the conclusion that wheat was brought to China by that route. Thus, wheat spread from Central Asia, crossed the oasis routes along the northern and southern sides of Tarim Basin in Xinjiang, passed down the Hexi Corridor and Guanzhong Plain to the Central China Region, and finally arrived in the Haidai Region.

However, the distribution of archaeological sites in which early wheat remains around 4000 years old have been unearthed does not show a west-to-east spreading pattern, since they have been found in all the three regions—the Northwest Region, Central China Region and the Haidai Region. Moreover, the earliest wheat remains of highest reliability found so far were unearthed at the Zhaojiazhuang site, Shandong Province, right at the eastern end of this belt of terrain, the Shandong Peninsula. Therefore, whether wheat simply followed the route of the Silk Road to China from the west requires rethinking.

In fact, the Silk Road was not the only channel for exchanges between the cultures of the East and West in ancient times. There were other routes, at different times, such as the Maritime Silk Road, the Southern Silk Road and the Eurasian Steppe Route. This last is an ancient route that stretches along the Eurasian Steppe, linking East and West. The channel extends from the western part of the Greater Khingan Mountains in Northeast Asia to the Carpathian Mountains in Central Europe, passing through the Mongolian Plateau, South Siberia, Central Asia and the northern part of Western Asia to Central Europe. This Eurasian Steppe Route, the main part of which is vast, flat prairie presenting no difficulties in overcoming natural barriers, serves as a natural corridor linking the cultures of East and West.

As mentioned earlier, wheat reached Central Asia about 7000 years ago and continued spreading eastwards to East Asia, including China. Therefore, the starting point for this propagation of wheat should be Central Asia. The region that connects to Central Asia is the eastern part of the Eurasian Steppe, including South Siberia, the Sayan-Altai-Tianshan Region and the Mongolian Plateau. Archaeological discoveries have verified that by 5600 to 3400 years ago, several early cultures of the Bronze Age were widely distributed across the eastern part of Eurasian Steppe, such as the Afanasevo, Okunev, Chemurchek, Seima-Turbino and Andronovo cultures (Lin 2014, 14–49). These Bronze Age cultures scattered over the vast steppes may not have been successive, yet they share common cultural features, such as bronze accessories with animal designs and bronze daggers, and a mixed type of economic production and lifestyle combining animal husbandry and farming. This shows that these early bronze cultures interacted closely, making possible cultural exchanges on the Eurasian Steppe and ensuring smooth communication between cultures of East and West.

Table 4 List of archaeological cultures in the Central Asian Steppe

South Siberia	Sayan-Altai	Altai-Tianshan
Afanasevo culture, c. 3600–2500 BC	Afanasevo culture, c. 3600–2500 BC	Afanasevo culture, c. 3600–2500 BC
Okunev culture, c. 2100–1800 BC	Chemurchek culture, c. 2500–2100 BC	Chemurchek culture, c. 2500–2100 BC
Seima-Turbino culture, c. 1800–1700 BC	Seima-Turbino culture, c. 2200–1700 BC	Okunev culture, c. 2100–1800 BC
		Seima-Turbino culture, c. 1800–1700 BC
Andronovo culture, c. 1600–1400 BC	Andronovo culture, c. 1600–1400 BC	Andronovo culture, c. 1600–1400 BC

During about the same period, namely 5000 to 3000 years ago, in northern China to the south and north of the Yanshan Mountains, archaeology has revealed a special complex of cultures (Su and Yin 1981) known as the Northern Cultural Zone (Yang 2004) or Northern Zone (Watson 1971). The scope of this zone varies at different times, but basically it is a strip from northeast to southwest around the route where the Great Wall now runs, including the south and north of the Yanshan Mountains, the north of Shanxi Province, the southern part of Inner Mongolia, the north of Shaanxi Province and the Hetao area. What is noteworthy is that the Northern Cultural Zone falls exactly at the ecologically sensitive zone, called ecotone, of the transition from the semi-arid zone to arid zone in northern China. This zone is suitable for both agriculture and animal husbandry. In other words, the Northern Cultural Zone in archaeology coincides with the ecotone between agriculture and animal husbandry.

The Northern Cultural Zone is sandwiched in between the Bronze Age cultures on the steppes and the agricultural civilization around the middle and lower reaches of the Yellow River. Thus, the zone, apart from the cultural features peculiar to it, such as large earthen pots with snake design (west) and pottery with decorative patterns of the Chinese character “zhi” (之) (east), also possessed characteristics of early Bronze Age cultures on the steppes, such as bronze daggers, bronze accessories with animal designs and horn-shaped eared cups, as well as features of ancient cultures around the middle and lower reaches of the Yellow River, such as painted and corded pottery.

Lin Yun notes that many typical bronze wares of the early Bronze Age cultures on the Eurasian Steppe first arrived in the Northern Cultural Zone in China, and then spread to Central China. For example, bronze daggers, tube-holed axes and bow-shaped tools, artifacts typical of the northern Bronze Age cultures, unearthed from Shang dynasty sites, can be traced back to the Bronze Age cultures on the Eurasian Steppe (Lin 1987). Hence, it can be seen that the Northern Cultural Zone played an important role as a medium for cultural communications between the early Bronze Age cultures on the Eurasian Steppe and ancient cultures in the region of the middle and

lower reaches of the Yellow River.

In summary, the most likely way that wheat spread to China is the Eurasian Steppe route: about 7000 years ago, wheat was brought to Central Asia from West Asia and spread gradually eastwards, becoming the staple crop of early agricultural production in river valleys in Central Asia. Around 5000 years ago, wheat cultivation was adopted by the early Bronze Age cultures in the east of the Eurasian Steppe, which were characterized by a mixed production pattern of animal husbandry and farming, with wheat as one of the crop varieties. Due to frequent contact between these early cultures on the steppe, wheat quickly spread eastwards, through the Sayan-Altai-Tianshan Region to the Mongolian Plateau, where it was adopted by the Northern Cultural Zone in the south of the plateau. Since the connection between the Northern Cultural Zone and ancient cultures around the middle and lower reaches of the Yellow River is longitudinal, the direction of the spread of wheat took a turn south, and reached the middle and lower reaches of the Yellow River along multiple river valleys, such as those of the Luan River, Sanggan River/Yongding River and Yellow River on both sides of the Hetao area. It is significant to note that this route is driven by cultural factors rather than population migration.

Early cultures of the East and West communicated in a variety of ways, and the routes along which wheat travelled to China were not limited to the Eurasian Steppe Route. As mentioned early, wheat remains around 4000 years old were found at several sites near the Hexi Corridor, Gansu Province, such as the Huoshiliang site and Ganggangwa site in Jinta County, which means early wheat appeared in the Northwest Region at the same time as it did in the middle and lower reaches of the Yellow River. This leads to another possibility, that wheat followed different routes to the Northwest Region and the middle and lower reaches of the Yellow River. Early wheat could have reached the Northwest Region through the Oasis Route: it left Central Asia, crossed Pamir to the Tarim Basin, followed the oasis routes on the northern and southern extremes of the Taklimakan Desert, and passed down the Hexi Corridor to the Loess Plateau. This Oasis Route is basically the same as the famous Silk Road of later history.

5 Conclusion

Since the beginning of this century, with the application of the flotation technique, extremely rich ancient plant remains, including substantial samples of wheat, have been found in China. According to statistics, there are over 30 archaeological sites where early wheat remains dating from more than 3000 years ago have been discovered. The application of AMS dating on such unearthed wheat grains has provided relatively reliable data to explore the time when wheat entered China.

Following comprehensive analysis of excavated early wheat remains, the conclusion is that wheat had already been introduced into China no later than 4000 years ago.

Wheat entered China by more than one route. Analysis of the distribution of archaeological sites where early wheat remains have been found indicates that early wheat in the middle and lower reaches of the Yellow River and in Northwest Region may have been introduced by two different routes: the Eurasia Steppe Route and Oasis Route. As for the former, from Central Asia, wheat entered the early Bronze Age Cultural Zone in the eastern Eurasia Steppe. With the close connection among Bronze Age cultures on the grassland, early wheat moved eastward and was adopted in the Northern Cultural Zone in China after being introduced into the Mongolian Plateau. Finally, wheat was spread into the middle and lower reaches of the Yellow River along river valleys. As for the Oasis Route, from Central Asia, wheat crossed the Pamir Mountains and entered the Tarim Basin. From there it passed along the oases on the northern and southern extremes of the Taklimakan Desert, finally reaching the Loess Plateau through the Hexi Corridor.

These spreading routes and means are only hypothetical, as archaeological materials are still insufficient to be absolutely conclusive. Early wheat remains have not yet been discovered in the Northern Cultural Zone in China or the eastern foot of the Pamir Mountains, something that requires further great efforts in archaeology, especially in archaeobotany.

References

- Anhui Museum 安徽省博物館. 1957. "Anhui xinshiqi shidai yizhi de diaocha" 安徽新石器時代遺址的調查 (Investigation of Neolithic Age sites in Anhui). *Kaogu xuebao* 考古學報 (Acta Archaeologica Sinica) (1):21-30.
- Chen, F. H., Dong G. H., Zhang D. J., Liu X. Y., Jia X., An C. B., Ma M. M., Xie Y. W., L. Barton, Ren X. Y., Zhao Z. J., Wu X. H. and M. K. Jones. 2015. "Agriculture facilitated permanent human occupation of the Tibetan Plateau after 3600 BP." *Science* 347(6219):248-250.
- Chen, Xuexiang 陈雪香 and Fang Hui 方辉. 2008. "Cong Jinan Daxinzhuang yizhi fuxuan jieguo kan Shangdai nongye jingji" 从济南大辛庄遗址浮选结果看商代农业经济 (The agricultural economy in the Shang dynasty: As seen from flotation results from the Daxinzhuang site in Jinan). *Dongfang kaogu: disiji* 东方考古: 第4集 (East Asia Archaeology, vol. 4): 47-68. Beijing: Science Press.
- Chen, Xuexiang and Guo Junfeng 郭俊峰. 2009. "Shandong Zhangqiu Ma'an yizhi 2008 nian fuxuan zhiwu yicun fenxi" 山东章丘马安遗址 2008 年浮选植物遗存分析 (An analysis of plant remains through flotation from the Ma'an site [2008], Zhangqiu, Shandong). *Dongfang kaogu: diwuji* 东方考古: 第5集 (East Asia Archaeology, vol. 5): 368-371. Beijing: Science Press.
- Chen, Xuexiang, Wang Liangzhi 王良智 and Wang Qing 王青. 2010. "Henan Bo'aixian Xijincheng yizhi 2006-2007 nian fuxuan jieguo fenxi" 河南博爱县西金城遗址 2006-2007 年浮选

- 结果分析 (An analysis of flotation results from the Xijincheng site [2006–2007], Bo'ai County, Henan). *Huaxia kaogu* 华夏考古 (Huaxia Archaeology) (3):67–76.
- Crawford, Kelly et al. 2004. "Liangchengzhen yizhi chutu Longshan wenhua zhiwu yicun de chubu fenxi" 两城镇遗址出土龙山文化植物遗存的初步分析 (Initial analysis of Longshan culture plant remains from the Liangchengzhen site). *Kaogu* 考古 (Archaeology) (9):73–80, 2.
- Cultural Relics Team of Luoyang 洛阳文物工作队. 2002. *Luoyang Zaojiaoshu* 洛阳皂角树 (Zaojiaoshu remains in Luoyang). Beijing: Science Press.
- Deng, Zhenhua 邓振华 and Gao Yu 高玉. 2012. "Henan Dengzhou Baligang yizhi chutu zhiwu yicun fenxi" 河南邓州八里岗遗址出土植物遗存分析 (An analysis of plant remains from the Baligang site, Dengzhou, Henan). *Nanfang wenwu* 南方文物 (Cultural Relics in Southern China) (1):156–163.
- Dodson, J., Li X., Zhou X., Zhao K., Sun N. and P. Atahan. 2013. "Origins and spread of wheat in China." *Quaternary Science Reviews* 72:108–111.
- Dong, Guanghui 董广辉, Yang Ying 杨颖, Ren Xiaoyan 任晓燕 and Wang Zhongxin 王忠信. July 4, 2014. "Jinchankou Qijia wenhua yizhi faxian Qinghaisheng zaoqi damai, xiaomai yicun" 金禅口齐家文化遗址发现青海省早期大麦, 小麦遗存 (Remains of early barley and wheat in Qinghai discovered at the Qijia culture site in Jinchankou). *Zhongguo wenwubao* 中国文物报 (China Cultural Relics News): 7.
- Flad, R., Li S. C., Wu X. H. and Zhao Z. J. 2010. "Early wheat in China: Results from new studies at Donghuishan in the Hexi Corridor." *The Holocene* 20(6):955–965.
- Fu, Daxiong 傅大雄. 2001. "Xizang Changguogou yizhi xinshiqi shidai nongzuowu yizhi de faxian, jian ding yu yan jiu" 西藏昌果沟遗址新石器时代农作物遗址的发现、鉴定与研究 (Neolithic Crops site at Changguogou in Tibet: Discoveries, identification and research). *Kaogu* 考古 (Archaeology) (3):66–74.
- Gansu Provincial Institute of Cultural Relics and Archaeology 甘肃省文物考古研究所 and Northern Archaeology Laboratory of Jilin University 吉林大学北方考古研究室. 1998. *Minle Donghuishan kaogu* 民乐东灰山考古 (Archaeology of the Donghuishan site, Minle): 131–132, 190. Beijing: Science Press.
- Harris, David. 2010. *Origins of Agriculture in Western Central Asia*. Philadelphia: University of Pennsylvania Museum.
- Ho, Ping-ti 何炳棣. 1985. "Zhongguo nongye de benshang qiyuan (xu)" 中国农业的本土起源 (续) (The origin of Chinese agriculture [continued]). *Nongye kaogu* 农业考古 (Agricultural Archaeology) (2):43–51.
- Huang, Shilin 黄石林. 1991. "Shaanxi Longshan wenhua yizhi chutu xiaomai (gan)" 陕西龙山文化遗址出土小麦 (秆) (Wheat unearthed at a Longshan culture site in Shaanxi [wheat stem]). *Nongye kaogu* 农业考古 (Agricultural Archaeology) (1):118.
- Institute of Archaeology, Chinese Academy of Social Sciences. 1988. *Wugong fajue baogao* 武功发掘报告 (Wugong excavation report). Beijing: Cultural Relics Press.
- Jin, Guiyun 靳桂云, Yan Dongsheng 燕东升 and Liu Changjiang 刘长江. Feb. 22, 2008. "Shandong Jiaozhou Zhaojiazhuang yizhi faxian Longshan wenhua xiaomai yicun" 山东胶州赵家庄遗址发现龙山文化小麦遗存 (Longshan culture wheat remains from Zhaojiazhuang, Jiaozhou, Shandong). *Zhongguo wenwubao* 中国文物报 (China Cultural Relics News): 7.

- Jin, Guiyun 靳桂云, Zhao Min 赵敏, Wang Chuanming 王传明, Wang Fuqiang 王富强 and Jiang Guojun 姜国均. 2010. "Shandong Yantai Zhaogezhuang Yueshi wenhua yizhi tanhua zhiwu yicun yanjiu" 山东烟台照格庄岳石文化遗址炭化植物遗存研究 (Research on charred plant remains from the Yueshi cultural site in Zhaogezhuang, Yantai, Shandong). *Dongfang kaogu: diliuji* 东方考古: 第6集 (East Asia Archaeology, vol. 6): 331-343. Beijing: Science Press.
- Li, Fan 李璠, Li Jingyi 李敬仪, Lu Ye 卢晔, Bai Pin 白品 and Cheng Huafang 程华芳. 1989. "Gansusheng Minlexian Donghuishan xinshiqi yizhi gunongye yicun xinfaxin" 甘肃省民乐县东灰山新石器遗址古农业遗存新发现 (New discoveries of ancient agricultural remains at the Neolithic Donghuishan site, Minle County, Gansu Province). *Nongye kaogu* 农业考古 (Agricultural Archaeology) (1):56-69.
- Li, Shuicheng 李水城 and Mo Duowen 莫多闻. 2004. "Donghuishan yizhi tanhua xiaomai niandai kao" 东灰山遗址炭化小麦年代考 (On the date of the charred wheat from the Donghuishan site). *Kaogu yu wenwu* 考古与文物 (Archaeology and Cultural Relics) (6):51-60.
- Li, Xiaoqiang 李小强, Zhou Xinying 周新郢, Zhang Hongbing 张宏宾, Zhou Jie 周杰, Shang Xue 尚雪 and John Dodson. 2007. "Kaogu shengwu zhizhen jilu de zhongguo xibei diqu 5000 a BP shuidao yicun" 考古生物指针记录的中国西北地区 5000 a BP 水稻遗存 (Rice remains from 5000 a BP in Northwestern China: A record of biological indicators in archaeology). *Kexue tongbao* 科学通报 (Chinese Science Bulletin) 52(6):673-678.
- Lin, Meicun 林梅村. 2014. "Changji gudai wenming de bianqian" 昌吉古代文明的变迁 (Changes of ancient civilization in Changji). In *Sichouzhilu Tianshan langdao* 丝绸之路天山廊道 (Tianshan Corridor of the Silk Road), edited by the Bureau of Cultural Relics in Changji Hui Autonomous Prefecture, Xinjiang Uyghur Autonomous Region, 14-49. Beijing: Cultural Relics Press.
- Lin, Yun 林沄. 1987. "Shang wenhua qingtongqi yu beifang diqu qingtongqi guanxi zhi zaiyanjiu" 商文化青铜器与北方地区青铜器关系之再研究 (Revisiting the relation between bronze wares in Shang culture and Northern China). In *Kaogu wenhua lunji (yi)* 考古学文化论集 (一) (Anthology of archaeological studies [One]). Beijing: Cultural Relics Press.
- Liu, Chang 刘昶 and Fang Yanming 方燕明. 2010. "Henan Yuzhou Wadian yizhi chutu zhiwu yicun fenxi" 河南禹州瓦店遗址出土植物遗存分析 (An analysis of plant remains from the Wadian site, Yuzhou, Henan). *Nanfang wenwu* 南方文物 (Cultural Relics in Southern China) (4):55-64.
- Luan, Fengshi 栾丰实. 1997. "Haidai Longshan wenhua de fenqi he leixing" 海岱龙山文化的分期和类型 (Periodization and types of Longshan culture in the Haidai area). In *Haidai diqu kaogu yanjiu* 海岱地区考古研究 (Archaeology in Haidai): 229-282. Jinan: Shandong University Press.
- Luo, Kun 罗琨. 1990. "Jiaguwen lai zi bianxi" 甲骨文来字辨析 (On the character "lai 来" in oracle bone inscriptions). *Zhongyuan wenwu* 中原文物 (Cultural Relics of Central China) (3):24-31.
- Preparatory Office of Yunnan Museum 雲南省博物館籌備處. 1958. "Jianchuan Haimenkou guwenhua yizhi qingli jianbao" 劍川海門口古文化遺址清理簡報 (A brief report on an ancient cultural site in Jianchuan, Haimenkou). *Kaogu tongxun* 考古通訊 (Archaeology) (6):5-12.
- Song, Zhenhao 宋镇豪. 2002. "Wugu, liugu yu jiugu tantan jiaguwen zhong de gulei zuowu" 五谷、六谷与九谷——谈谈甲骨文中的谷类作物 (On cereal crops in oracle bone inscriptions: Five

- cereals, six cereals and nine cereals). *Zhongguo lishi wenwu* 中国历史文物 (Journal of National Museum of China) (4):61–67.
- Su, Bingqi 苏秉琦 and Yin Weizhang 殷玮璋. 1981. “Guanyu kaoguxue wenhua de quxi leixing wenti” 关于考古学文化的区系类型问题 (Regional systems of cultures in archaeology). *Wenwu* 文物 (Cultural Relics) (5):10–17.
- Wang, Binghua 王炳华 et al. 1985. “Balikunxian Lanzhouwanzi sanqian nian qian shigou jianzhu yizhi” 巴里坤县兰州湾子三千年前石构建筑遗址 (A 3000-year-old stone building site at Lanzhouwanzi, Balikun County). In *Zhongguo kaoguxue nianjian 1985* 中国考古学年鉴 1985 (Chinese Archaeology Almanac [1985]): 255–256. Beijing: Cultural Relics Press.
- Wang, Binghua. 1983. “Kongquehe gumugou fajue jiqi chubu yanjiu” 孔雀河古墓沟发掘及其初步研究 (Excavation and primary research of ancient tomb ditches in the Kongque River region). *Xinjiang shehuikexue* 新疆社会科学 (Social Sciences in Xinjiang) (1):117–172.
- Watson, William. 1971. *Culture Frontiers in Ancient East Asian*. Edinburgh: Edinburgh University Press.
- Weiss, Ehud and Daniel Zohary. 2011. “The Neolithic southwest Asian founder crops – their biology and archaeobotany.” *Current Anthropology* 52(4):237–254.
- Xinjiang Institute of Cultural Relics and Archaeology 新疆文物考古研究所. 1992. “Hami Wubao mudi 151, 152 hao muzang” 哈密五堡墓地 151、152 号墓葬 (Hami Wubao cemetery: Tombs no. 151 and 152). *Xinjiang wenwu* 新疆文物 (Xinjiang Cultural Relics) (3):1–10.
- Yang, Jianfang 杨建芳. 1963. “Anhui Diaoyutai chutu xiaomai niandai shangque” 安徽钓鱼台出土小麦年代商榷 (On the age of the wheat unearthed at Diaoyutai, Anhui). *Kaogu* 考古 (Archaeology) (11):630–631.
- Yang, Jianhua 杨建华. 2004. *Chunqiu Zhanguo shiqi Zhongguo beifang wenhuadai de xingcheng* 春秋战国时期中国北方文化带的形成 (The formation of the cultural belt in Northern China in the Spring and Autumn and Warring States periods). Beijing: Cultural Relics Press.
- Yin, Da 尹达. 2013. “Yuhuicun yizhi fuxuan jeguo fenxi baogao” 禹会村遗址浮选结果分析报告 (Report of flotation results from the Yuhui Village site). In *Bengbu Yuhuicun* 蚌埠禹会村 (Yuhui Village in Bengbu), edited by Institute of Archaeology, CASS and Bengbu Museum, 250–268. Beijing: Science Press.
- Zhao, Zhijun 赵志军. 2004. “Liangchengzhen yu Jiaochangpu Longshan shidai nongye shengchan tedian de duibi fenxi” 两城镇与教场铺龙山时代农业生产特点的对比分析 (Comparative analysis of agricultural production features at Liangchengzhen and Jiaochangpu in the Longshan period). *Dongfang kaogu: diyiji* 东方考古: 第1集 (East Asia Archaeology, vol. 1): 210–224. Beijing: Science Press.
- Zhao, Zhijun. 2007. “Gongyuanqian 2500 nian gongyuanqian 1500 nian zhongyuan diqu nongye jingji yanjiu” 公元前 2500 年–公元前 1500 年中原地区农业经济研究 (On the agricultural economy of Central China: 2500–1500 BC). *Keji kaogu: dierji* 科技考古: 第二辑 (Science for Archaeology, vol. 2): 1–11. Beijing: Science Press.
- Zhao, Zhijun. 2009. “Eastward spread of wheat into China: New data and new issues.” *Chinese Archaeology* 9(1):1–9.
- Zhao, Zhijun. 2011. “Zhonghua wenming xingcheng shiqi de nongye jingji fazhan tedian” 中华文明形成时期的农业经济发展特点 (Features of the development of the agricultural economy in

- the formation of Chinese civilization). *Guojia bowuguan guankan* 国家博物馆馆刊 (Journal of National Museum of China) (1):19-31.
- Zhao, Zhijun. 2014. "Zhongguo zhiwu kaoguxue de xueke fazhan licheng" 中国植物考古学的学科发展历程 (The development of archaeobotany in China). In *Zhongguo zhexue shehuikexue fazhan licheng huiyi* 中国哲学社会科学发展历程回忆 (Review of the development of Chinese philosophy and social sciences), edited by Chinese Academy of Social Sciences, 49-55. Beijing: China Social Sciences Press.
- Zhao, Zhijun. 2015. "Erlitou yizhi fuxuan jieguo" 二里头遗址浮选结果 (Flotation results from the Erlitou site). In *Erlitou: 1999-2006* 二里头 (1999-2006), edited by Institute of Archaeology, CASS, 1295-1313. Beijing: Cultural Relics Press.
- Zhao, Zhijun and Fang Yanming. 2007. "Dengfeng Wangchenggang yizhi fuxuan jieguo ji fenxi" 登封王城岗遗址浮选结果及分析 (An analysis of flotation results from the Wangchenggang site in Dengfeng). *Huaxia kaogu* 华夏考古 (Huaxia Archaeology) (2):78-89.
- Zohary, Daniel and Maria Hopf. 2000. *Domestication of old world plants: The origin and spread of cultivated plants in West Asia*. Oxford: Oxford University Press.