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Agricultural Diversification Evidenced by Crop Remains during the Late Neolithic in the Upper Ying River, Central China

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ABSTRACT

Analysis of crop remains has the potential to provide direct evidence of agricultural conditions and paleo-environment. This paper is to assess the relationship between the cereals cultivated in the Late Neolithic age and within the area of the upper Ying River, and their environmental settings. The various charred grains of cereal species represented in the archaeobotanical assemblages from the Wangchenggang site, especially in the proportion of millet, glutinous millet and wheat. The cereal assemblages were discussed regarding site altitude, weather conditions, soil sand soil productivity. The most important environmental variable influencing the choice of a particular crop seemed to be altitude which is correlated with other variables such as the length of growing season, mean annual temperature, soil quality etc. Although the ecological requirements of cereals cultivated in the late Neolithic ages are not known, they presumably thrived under similar conditions to present-day species/varieties, and the strategy of past crop husbandry was based on similar principles as today, e.g. flexible adaptation to local environmental conditions, in an effort to achieve optimal yields and maintain social sustainability.

Key words: charred grains; environmental change; diversification of ancient agriculture; the upper Ying River

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INTRODUCTION

Carbonized plant remains from archaeological sites are usually used for rebuilding paleoecology, ancient land-use and crop-cultivated process (Miller and Marston, 2012). Carbon-nitrogen isotopic analysis for charred grains, compared with $\delta^{13}C$, $\delta^{15}N$ values of animal bones, facilitates ancient agriculture and diet studies (Bogaard *et al.*, 2007). By similar methods, Amesbury et al.(2008) revealed the decline of the settlements at Dartmoor in southwestern Britain in the Bronze (Amesbury *et al.*, 2008), and Dreslerová *et al.*(2013) researched the ancient farming environment within Moravia area, east Czech. Some proposed that $\delta^{15}N$ contents of charred grains are closely related to corresponding carbonized settings so as to discover the life styles of ancients. Kanstrup et al. measured $\delta^{15}N$ changes of emmer wheat and barley after 2h's heating at 100~400 degree Celsius (Kanstrup *et al.*, 2012). Further, Dungait *et al*.(2008) developed a way to discern plant volatiles (e.g. acyl-lipids) in the heating process, which makes it possible to understand effects of carbonized process on $\delta^{13}C$, $\delta^{15}N$ contents. Also, some works (Giles and Brown, 2008; Fernández *et al.*, 2013) extracted gene sequence of partly-charred seeds by silicon-based method to broaden the road for ancient agriculture and archaeobotany.

Charred grains are also good materials for paleo-agroecology. In China, Li *et al*.(2007) discussed characteristics of Holocene crop assemblages in the east of Gansu Province. Zhao *et al.*(2009) recovered some early agricultural landscapes by millet morphology method in northeastern area. Yang *et al*.(2009) presented a novel method for discerning charred seeds that represented ancient agriculture. Current millet and glutinous millet grains were probed deeply into sub-microstructure to better understand formative backgrounds of the archaeological remains (Yang *et al.*, 2011; Zhou *et al.*, 2011). Theoretically, Wang *et al.*(2015) found out suitable temperature range for grains to be carbonized according to experimental data. Above works have put great efforts on charred plant research and made significant advances on both theoretical and technological levels.

This work focuses on crop properties of rainfed farming in the upper Ying River, one of cradles of Chinese civilization in central China. Millets (*Setaria italica*) and glutinous millets (*Panicum miliaceum*) are treated as cultural marks and indicators of environmental change as well as staple food for the ancients. We dedicated ourselves to identification of charred grains and its paleo-environment at the Wangchenggang archaeological site, especially paid attention to diversification of late Holocene crops which was rarely discussed by existing studies. Besides, we attempted to investigate interrelated mechanism of culture evolution and agricultural development, even the range of ancient agriculture and its population carrying capacity are expected.

STUDY SITE AND METHODS

2.1 Site description

The Wangchenggang Site(34°24′N，113°08′E), one of the Longshan Cultural sites, sits between the Ying River and the Songshan Mountain(Fig. 1). Deposits of the site were mainly formed in the late Longshan period and included layers in the Erlitou, Erligang and early Spring-Autumn periods (Archaeology and Museology of PKU and Henan Provincial Institute of Archaeology, 2007). The site sits on the second terrace of the Ying River and its terrain slopes gently from northwest to southeast. This area is temperate continental climate with mean annual rainfall at 640mm and mean annual temperature at 13.4℃.

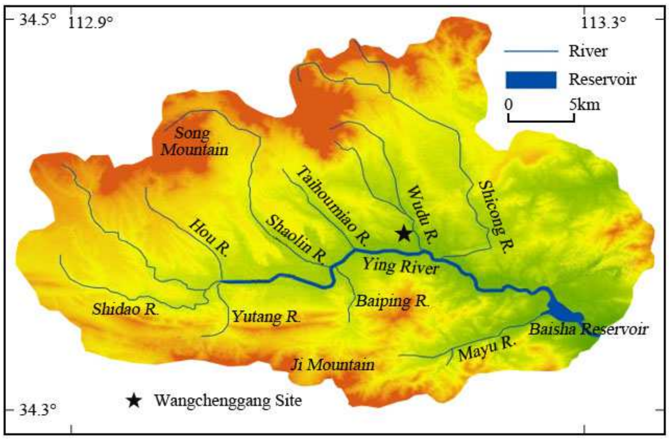

Fig. 1 Location of the study site

The studied stratigraphic profile was 235 centimeters in depth. Associated with research of archaeological chronology, the profile was divided into 5 epochs, i.e. (1) Chunqiu Period, this layer, 125~150cm, was light-brown, loose with high sand content and occasional pottery pieces. (2) Yin Dynasty (150~158cm), the sediments were whitey-brown sandy soil with pottery or burnt-soil shreds. (3) Erligang Cultural Period(158~175cm), the sediments in this layer were hard with accidental calcareous nodules and high carbon bits content; (4) Erlitou Cultural Period(175~192cm), this stratum was hard loess sediments with sparse carbon bits and pottery shards; and (5) Late Longshan Cultural Period (192~235cm), the sediments were dark-brown with large amount of pottery pieces, burnt-clay and carbon bits. Additionally, the studied profile covered from 4.1 ka BP. to 3.6kaBP according to previous ^{14}C dating results (Fang, 2006; Henan Provincial Institute of Archaeology, 1983; Chronology Team of Chinese Prehistoric Research, 2000).

EXPERIMENTAL SECTION

Total 22 soil samples were obtained for seed and pollen floating tests. Firstly, the samples were pretreated in acid-alkali method, then plant seeds and pollens were achieved through heavy fluid separation method. These plant remains were identified phyto-morphologically under microscope, and the detailed test process referred to the work of Li *et al*.(2012) .

Magnetic susceptibility of samples was measured with the Bartington MS2B kappameter. Samples were firstly dried at room temperature and then ground to powder in 200-mesh using an agate mortar. These powders were loaded in plastic beakers for determining. All samples were measured three times at low (0.47Hz) and high frequency (4.7Hz) and took mean values by given formula.

RESULTS

This study totally identified 2387 plant seeds (of which 590 were unknown species). They were classified to 15 families or genuses. Meanwhile, fourteen samples were conducted for pollen identification, and 2019 pollens of 53 families were completed.

3.1 Seed-floating

The floated charred grains were mainly millet, glutinous millet, wheat, soya and rice. Additionally, they included Gramineae, Leguminosae, Chenopodiaceae, Polygonaceae, Amaranthaceae, Compositae, etc. Besides, wild grapes, perilla and jujubes were found. The grain distribution are shown in Fig. 2.

Fig. 2 shows that the millet grains are the most at 879, which are distributed in late Longshan Period and Erligang Period (84.6%). The second most seeds are glutinous millet and wheat, and the number reaches 76 and 79 respectively. They also were clustered in the late Longshan Period and Erligang Period (93.1%). There is one noteworthy exception, and that wheat had not appeared by the Erligang Period. The soybean seeds were clustered in late Longshan Period, but it was almost missed in other layers.

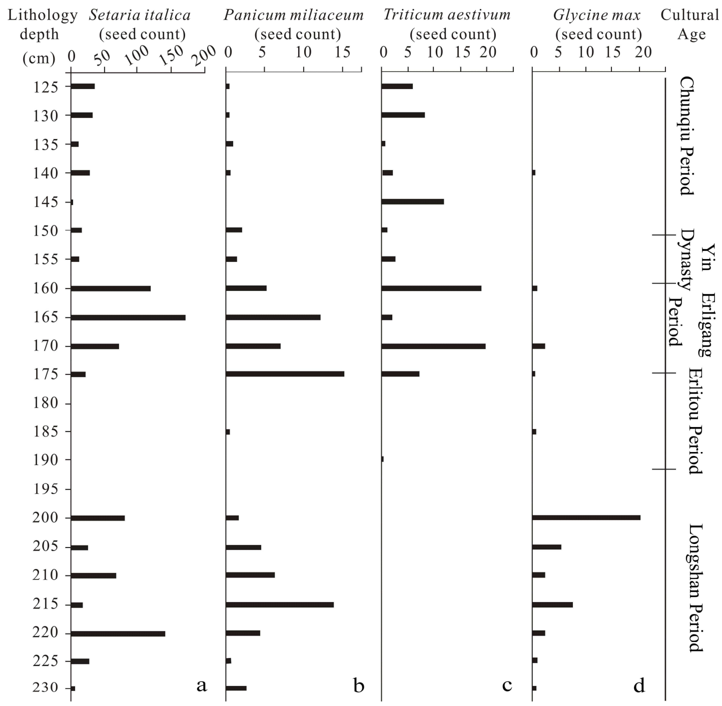

Fig. 2 Seed distribution at the Wangchenggang Profile (a. millet; b. glutinous millet; c. wheat; d. soya)

Ancient rain-fed farming of North China was characterized by seed distribution in the Wangchenggang Site. From Fig. 1, the late Longshan Period and Erligang Period are boom time of ancient agriculture. The crop components of the late Longshan Period are millet, glutinous millet and soybean, by contrast, it is glutinous millet, millet and wheat in the Erligang Period. A noticeable feature is that soybean grains have been weak since the late Erlitou Period.

3.2 Palynological diagram

Pollen distribution of the Wangchenggang profile was presented in Fig. 3, and what the study focuses is four key cultural periods, i.e., late Longshan Period (Z1), Erlitou Period(Z2), Erligang Period (Z3) and the Yin Dynasty (Z4). Therefore, the following is unrolled in that order.

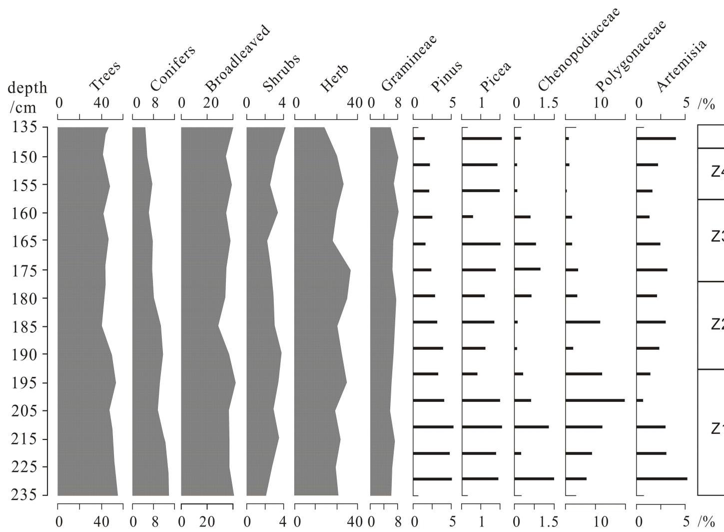

Fig. 3 Percentage diagram of pollen separated from layers of the Wangchenggang Profile

Late Longshan Period (Z1). In this period the percentage of arbor species is high at 54.8%. In which the temperate broad-leaved plants account for 32.2% with *Betula*, *Quercus*, *Carpinus*, *Ulms*, etc. Needle-leaved plants account for 12.7% and major types are *Pinus* and *Tsuga*. Shrub vegetation merely takes up 2.2%, e.g. Rosaceae and Oleaceae etc. Herbaceous plants takes up 43.5% and major is Cyperaceae. This pollen combination reflects warm dry climate.

Erlitou Period (Z2). Percentage of arbor species is 47.3% of all. Coniferous plants drop to 10.5%, and they are *Pinus* (7.0%), *Tsuga* (1.2%) and *Picea* (0.9%). Broadleaved plants accounts for 35.3%, and most of them are deciduous genuses, e.g., *Quercus deciduous*, *Juglans*, *Betula*, *Carpinus*, *Ulms*, *Corylus* and *Morus* etc. In this period the percentage of evergreen oaks decreases at 3.6%, and mixing with Meliaceae, Sapindaceae and Rutaceae etc. on occasion. Shrubs take up 2.9%, and mainly are Rosaceae and Spiraea etc. Herbs accounts for 47.7%, which are mesoxerophytes (18.8%), e.g., Poaceae, Euphorbiaceae, Chenopodiaceae, *Artemisia*, *Humulus*, *Rubia* etc. The vegetation assemblage makes up a mixed landscape of broadleaf-conifer forest, reflecting dry cold climate.

Erligang Period (Z3). Arbor pollen percentage decreases to 41.7% compared with Erlitou Period. In which the coniferous percentage drops significantly(6.6%), and the deciduous plants are *Corylus*, *Quercus*, *Ulms*, *Juglans* and *Carpinus* etc. Herbs, however, increase to 55.2%, including Poaceae, *Artemisia*, *Humulus*, and *Conandron* etc. Besides, some species, e.g. Compositae, Chenopodiaceae and Sanguisorba increase to the extent. It represents significantly dry cold landscapes.

Yin Dynasty (Z4). Tree pollen percentage in the stage increases to 46.4%, in which the coniferous pollens, e.g. *Pinus* and *Picea*, account for 8.1%. Broadleaved trees accounts for 40.2%, including *Quercus deciduous*, *Ulms*, *Juglans* and *Betulas*. Shrubs make up for 2.9%, mainly being Rosaceae, *Spiraea*, Elaeagnaceae, etc. The hygrophilous herbaceous pollens rises to 32.7%, mainly consisting Cyperaceae, Gramineae, Brassicaceae, Euphorbiaceae, Typhaceae and *Artemisia*. This plant assemblage indicates a relatively a wetter period.

Chunqiu Period (130-135mm). Percentage of arbor pollens accounts for 45.1%, and amount of broadleaved plants increases a little. Herbaceous types decrease to 26.7%. Percentage of ferns, however, rises to 23.8%. They are mainly Polypodiaceae and monolete spores etc., reflecting humid environment.

DISCUSSION

4.1 Agricultural characteristics of the upper Ying River in the late Neolithic

Pollen percentage diagram in Fig. 3 describes that the arbor pollen proportion has been dropping from the late Longshan Period (54.8%) to the Erligang Period (41.7%). Correspondingly, the herbaceous percentage is rising from 43.5% to 55.2%, indicating a dry-cold climatic trend. Apparently, drought became a limited factor for ancient agriculture. Though there appeared a wetter turn between the Yin Dynasty and Chunqiu Period, rain-fed farming with millets, according to seed-floating results, had been acting a leading role. Oxygen isotope ($\delta^{18}O$) curve in stalagmite of Sanbao Cave (Dong *et al.*, 2010) showed that precipitation dropped notably since approx. 4ka BP.. This result consists with pollen percentage in Fig. 3 and seed distribution in Fig. 2.

To investigate the interaction between ancient agriculture and environment, we introduced normalized index (NI = seed number of a layer / maximum of the profile) to compare with magnetic susceptibilities which could reflect paleo-environment properties by quantity of ferromagnetic minerals. Generally, high values of magnetic susceptibility match active weathering stage under warm-wet environment, and vice versa. The magnetic susceptibility curve (Chen *et al*., 2015) shown in Fig. 4e represents weathering intensity in the middle Holocene. According to the NI changes, the peaks of millets (Fig. 4a, b) and soybean (Fig. 4d) echo to high values of magnetic susceptibility, especially in the late Longshan Period and Erligang Period. It indicates that a high correlation stands between ancient agriculture and paleo-environment.

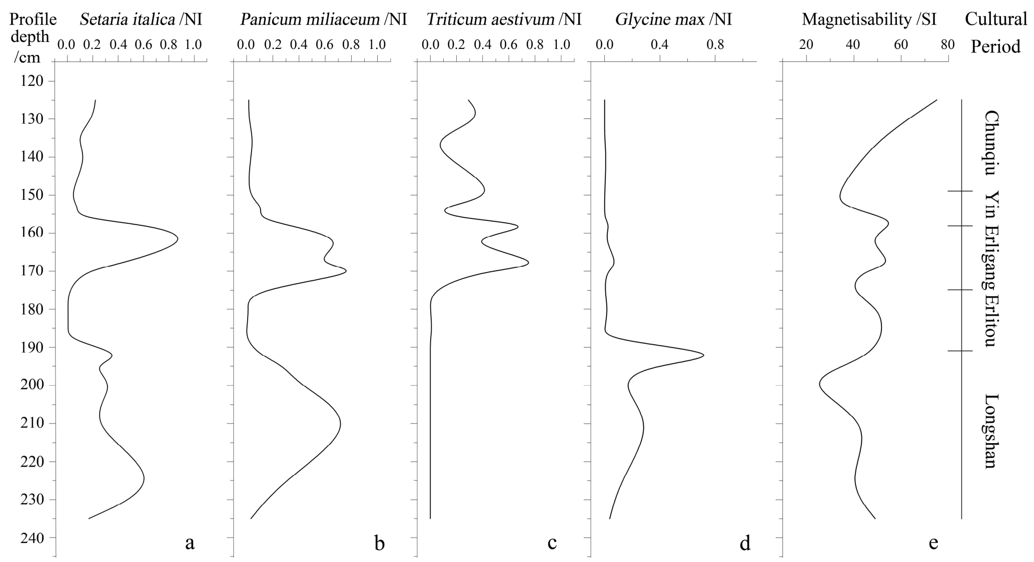

Fig. 4 Correlation between seed quantity changes and paleo-environment (magnetic susceptibility).

From Tab. 1 (Zhang *et al*., 2010), the ratio of millet/glutinous millet (G. millet) has been in a high place, indicating millets were dominant in ancient agriculture. Rice/millet ratio shows that rice proportion had been rising slowly. However, it is anomaly that the percentage of soybeans, a drought-tolerant crop, kept decreasing from the late Longshan to Eriligou Period. Drought herbs, comparatively, were continual increase showing a cold-dry tendency since 4ka in the area.

Tab. 1 Relative quantity of seeds in the upper Ying River

Site	Period	Rice/Millet	Millet/G. millet	Wet herbs/%	Drought herbs/%	soybean/%	Wild fruit/%
Wangchenggang	Longshan	0.0074	1.6575	0.0012	0.0104	0.0927	0
Chenyao	Longshan	0.7338	29.0003	0.0055	0.2680	0	0
Youfangtou	Longshan	0.0361	6.1018	0.0059	0.3642	0.0191	0.0029
Xifandian	Erlitou	0.0515	16.5107	0.0592	0.4007	0	0

4.2 Agricultural diversification of the late Longshan Period

Since the middle or late Yangshao Period (approx. 5.5kaBP.), the ancient agriculture had started its diversification, and cultural exchanges deepened the process after the Longshan Culture (Qin et al., 2010). It maintained wetter climate with some rice farming in the Yangshao Period, and accompanying jujube (*Ziziphus jujuba*), peach (*Amygdalus persica*) and hawthorn (*Crateaegus*) collecting (Kong *et al*., 2003). In the late Erlitou Period found the wheat seeds with 79 grains, approximately close to the amount of millets indicating the new phase of agricultural diversification. Study shows that the wheat root system is similar to the local millets with drought tolerant nature in root trunk, root length and root range (Yang *et al*., 2011). Clearly, the crop of wheat has better adaptability to natural environment of North China.

Rice seeds clustered in the Erligang Period (30 grains) and late Longshan Period (17 grains), with the same stage as millets, G. millets, Panicum L. and Leguminosae sp. etc. Table 2 displays two peak phases of rain-fed agriculture, i.e., the late Longshan Period and Erligang Period. Especially in the latter period, the ancient agriculture reached its maximum throughout the study period. In the Erlitou Period, however, met few seed remains, probably being affected by floods or settlement migration.

Tab. 2 Numbers and types of seeds separated from the Wangchenggang sediments

Cultural Period	*Oryza sativa*	Panicum L.	Leguminosae	Chenopodiaceae	Polygonaceae
Chunqiu	1	16	9	6	1
Yin Dynasty	1	11	10	0	0
Erligang	30	329	82	0	2
Erlitou	0	1	0	0	0
Late Longshan	17	252	21	10	0

Apart from millets, G. millets, wheat and soybeans, some crop seed remains e.g., Panicum L., Leguminosae, Chenopodiaceae and Polygonaceae represent diverse properties of ancient agriculture. Sorghum and barnyard millet, which belong to Panicum L., were secondary food and fodder respectively. Peas, cowpeas and green beans were subsidiary food of the ancients. Spinach and sasola (Chenopodiaceae) could be good vegetables. Meanwhile, oleaster and buckwheat (Polygonaceae) could be supplementary provisions. During the diversification process of agriculture, the introduction of wheat was a milestone event, which improved population carrying capacity and provided material base of cultural evolution.

4.3 Influences of agricultural activities on landscapes

According to pollen percentage diagram (Fig. 3), the study area had been a mixed forest landscape with oak-domination since the late Longshan Period. Arbor pollen percentage shown in Fig. 3 decreases from bottom to top in which the mean percentage of the coniferous accounts for 8.5%. Furthermore, the deciduous trees (mean percentage, 7.7%) include *Quercus deciduous*, *Juglans*, *Ulmus*, *Corylus* etc.(Zheng *et al.*, 2008). Pollen percentage of Chenopodiaceae changes similarly to *Artemisia*, which met its maximum in the late Longshan and Erligang Period respectively. Mean percentage of herbs is 26.2%, and the two peaks of which appeared in Erligang and Chunqiu Period. Gramineous plant pollen percentage maintains at 6.8% and with increasing tend showing a warm-dry paleoenvironment.

Agricultural activities e.g. deforestation or land reclamation would change original landscapes. Study (Wang *et al.*, 2012) showed that the mixed forest of the area is composed of pine (27.3%), oak, birch, walnut, sumac tree and hazel etc. The mean percentage of pine in study profile is merely 3.8% far less than present. Identification results of carbon remains in cultural layers of the neighborhood found large amount of plant species e.g. *Quercus*, *Dendrocalamus*, *Ziziphus* and *Zelkova*. It indicates the agricultural activities since the late Longshan Period disturbed original landscape and its components. From the Fig. 3, pollen percentage peaks of Gramineae echoed to valley values of coniferous pollen percentages in stage Z2, Z3 and Z4, showing decreasing of primary vegetation while expanding of rain-fed farming.

4.4 Population carrying capacity of ancient agriculture

Seed separating results showed that millets, G. millets and wheat crops led primary position of ancient agriculture in the upper area of Ying River. Large amount of primitive stone tools were widely used e.g. stone shovels, stone knives, stone chisels, sharpening stones and bone arrowheads etc. (Archaeology and Museology of PKU and Henan Provincial Institute of Archaeology, 2006), reflecting an extensive production style and lower population capacity. Aleen (1972) suggested that crop yields of using stone tools are approximately 550 kilograms per hectare and with land bearing capacity of 12 persons per kilometers. Apart from small coastal plains and flat mounds, the upper area of Ying River is covered with loess hills between gullies and arable land is limited. Since the late Longshan Period the climate had turned cold-dry influencing crop production and fruit-collecting. Although wheat was introduced in the late of Erlitou Period, the growing population caused great pressure upon land carrying capacity.

Archaeological excavation (Wu and Wang, 2002) proved that the study site was a city site which owned inner city to protect private properties of patricians or to ward off invaders. This fact showed from the side that the population then had exceeded agricultural production. On the positive side, population pressure promoted process of agricultural production technology through improving production tools, introducing high-yielding crops or exploiting new food sources. Above all, environmental and population pressures pushed agricultural diversification forward so as to keep sustainable development of society.

CONCLUSION

Since the late Longshan Period the upper area of Ying River had started its process of agricultural diversification out of environmental forcing and population pressure. From the Erlitou Period to Erligang Period the Wangchenggang Profile evidenced that the millets, G. millets, wheat and rice acted a leading part, which was embodied in two aspects, plenty of crop types and numerous seed remains. Apart from the dominants, other seeds were found in the Wangchenggang Profile e.g. Panicum L., Leguminosae, Chenopodiaceae and Polygonaceae, reflecting the feature of diverse crops. On the other hand, original forests were deforested for arable land in terms of limited carrying capacity. Primitive landscape was deeply disturbed and main signs were low percentage of *Pinus* pollens and high proportion of plant charcoal remains e.g. *Quercus*, *Dendrocalamus* and *Zelkova*. Consequently, the agricultural diversification in the upper area of Ying River was mainly forced by both population and environmental degradation. Moreover, it was a milestone of wheat to be introduced in the late of Erlitou Period (approx. 3.7kaBP.) and laid the material foundation for the coming of civilized society.

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