Notes on new advancements and revelations in the agricultural archaeology of early rice domestication in the Dongting Lake region

The Liyang plain, located in the northwest of Hunan province, is part of the plain on the north of Dongting Lake. It is situated at longitude 111°22′30″E to 111°51′30″E, and latitude 29°35′31″N to 29°47′30″N. It is made up of the Li River, its tributaries and the alluvial plain, and occupies about 600 sq. km in area (Figure 1).

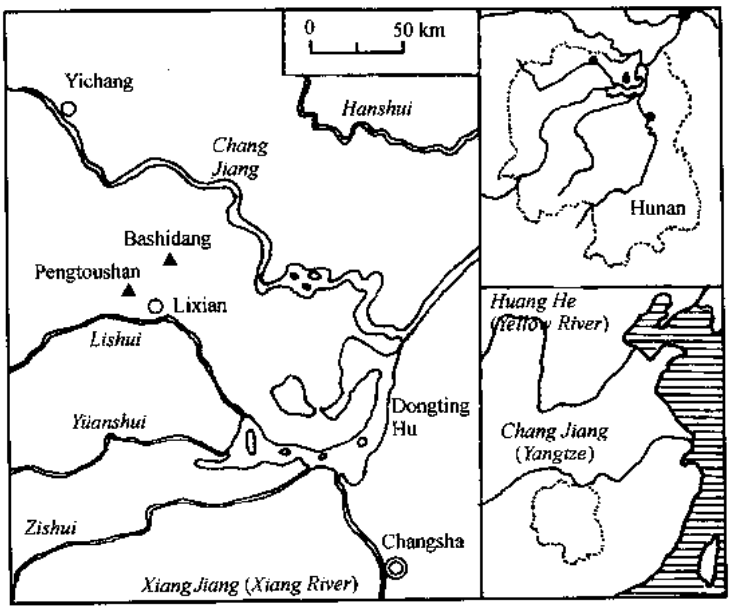

Figure 1 Location of Bashidang site, Pengtoushan, Lixian, Hunan Province, China

The plain is saucer-shaped and surrounded by small hills on three sides, joined at the eastern part to the plain north of Dongting Lake. The area is a classic 'plate-basin' structure. Inside its boundaries, the land is broad and flat, with small streams winding in different directions, and lakes and ponds dotting the landscape. It is 32 ~ 45 m above sea level, with an incline of 2°to 3°.

The climate of the plain is a mid-to northern subtropical monsoon climate, with obvious

continental characteristics. It has abundant rainfall, plenty of sunshine, warmth, and humidity. The average annual temperature is over16. 5° centigrade. The spring, summer, and autumn together last longer than eight months. The average annual amount of sunshine is 1770 hours, and the annual precipitation is 1100 ~ 1300 mm (Figure 2) .

Figure 2 Outlook of Bashidang site—summer in the Liyang Plain

Archaeological studies in the region indicate unusually favourable geographical and environmental conditions for human life over a long period, and high levels of cultural activity.

In 1988, the archaeological site at Pengtoushan in Lixian (prefecture) in the Liyang plain was discovered, dating from about 9000 years ago. At the time of discovery the site contained the earliest indications of rice domestication in the world, arousing great interest and attention from world archaeologists and agricultural scientists.

Since then, another site has been excavated in Bashidang, Lixian, which has also yielded important finds towards our understanding of the origins of rice culture and its development in the Dongting Lake region.

This site has two stratigraphic layers representing two time periods: early and later. The upper site is dated from about 8000 years ago and covers an area of over 30,000 sq. m. It is like the Pengtoushan site only 20 km distant, and also belongs to the 'Pengtoushan culture' (Figure 1) .

Six more excavations in Bashidang between 1993 and 1997 have revealed the earliest evidence of the Neolithic in China, including village defence ditches and walled fortresses. An unexpected discovery, dating from the same period, was mud from the edge of an ancient riverbed containing samples of organic matter that were very rich and complete (Figure 3), including rice kernels with and without the husk (Figures 4 ~ 6) and many animal and plant remains.

Figure 3　Excavation of the Bashidang site showing black mud palaeochannels

Figure 4　Excavated grain from Bashidang site, Mengxi, Lixian, Hunan, 1996

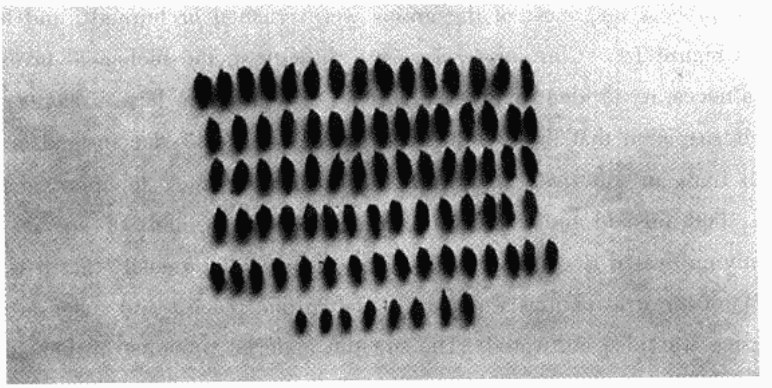

Figure 5 Excavated rice from Bashidang site, Hunan, Lixian county, 1996. 1

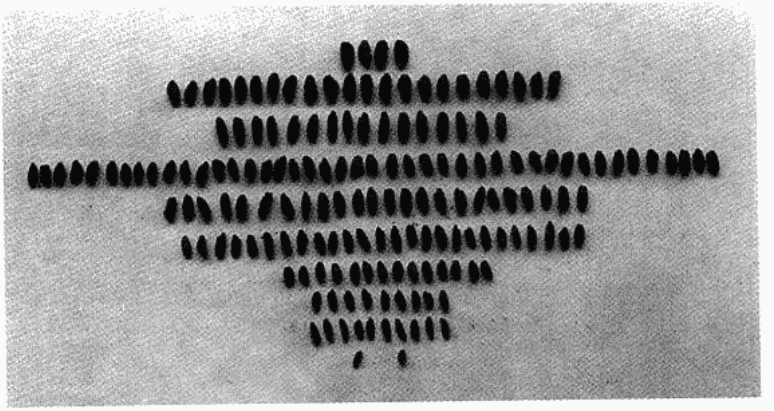

Figure 6 Excavated rice from Bashidang site, Hunan, Lixian county, 1996. 1

Since the late 1970s excavations at the site of Hemudu in Zhejiang (dated from 7000 BP) have yielded evidence for rice domestication, and the academic world has had to revise its views of rice domestication in China. The current theories claim that the centre of rice domestication was in the lower reaches of the Yangtze River. However, the discovery made at the Pengtoushan site called this into question. First, it proved that the origin of rice domestication and its practice are two different phenomena. Whilst the Hemudu and Pengtoushan sites showed signs that the practice and development of rice domestication was already developed, this did not necessarily prove that the practice originated in there. Second, it raises the possibility of independent rice domestication and the likelihood that there may have been multiple places of origin. Importantly, the new sites show that the middle reaches of the Yangtze also constituted a centre for rice domestication. At Pengtoushan one contentious source of rice grains and husks is fired clay used to make pottery. Organic matter was mixed with clay in or-

der to make it stronger and more permeable, but it had to be kneaded and fired at a high temperature in the process and most of the grains were crushed or burned, and fused together with the clay (Figure 7). Clay impressions are difficult in the biological investigations and measurements necessary to identify the rice grains. Scholars from Japan, Korea, and Australia voiced their suspicion that the rice in these vessels was wild rice instead of domesticated rice. Organic finds in the river mud from Bashidang amounted to approximately 15,000 grains of rice, both husked and wholegrain, in an area of less than 100 sq. m. These grains were apparently cultivated rice (wild rice breaks off the stalk so easily that it is unlikely that so many grains of the wild verities would be found in one place) and suggests that the early Pengtoushan rice was also cultivated. The organic material provides further support for the theory that the middle reaches of the Yangtze River constitute one of the earliest rice domestication centres in China, and probably the world.

Figure 7 Carbonized rice on the pottery of Pengtoushan site

Good preservation of organic rice grains is rare, due to post-depositional damage and the acidity of the Yangtze soil. The poor evidence led to sweeping conclusions, and results were neither reliable nor scientific. Bashidang has produced not only the most primitive cultivated rice, but also the largest sample, and its importance permits greater accuracy in the determination of the characteristics of early primitive cultivated rice.

Recently I invited Prof. Zhang Wenxu of the Chinese Agricultural University to do a preliminary assessment and study of Bashidang domesticated rice.

According to the observations and measurements of the external appearance of the rice kernels made using a stereo microscope, and the observations of the structure of bi-peak tubercles of lemma of rice made with an S-450 scanning electro-microscope, we have now identified three characteristics of the Bashidang rice (Figures 8 ~ 13, Tables 1 ~ 4):

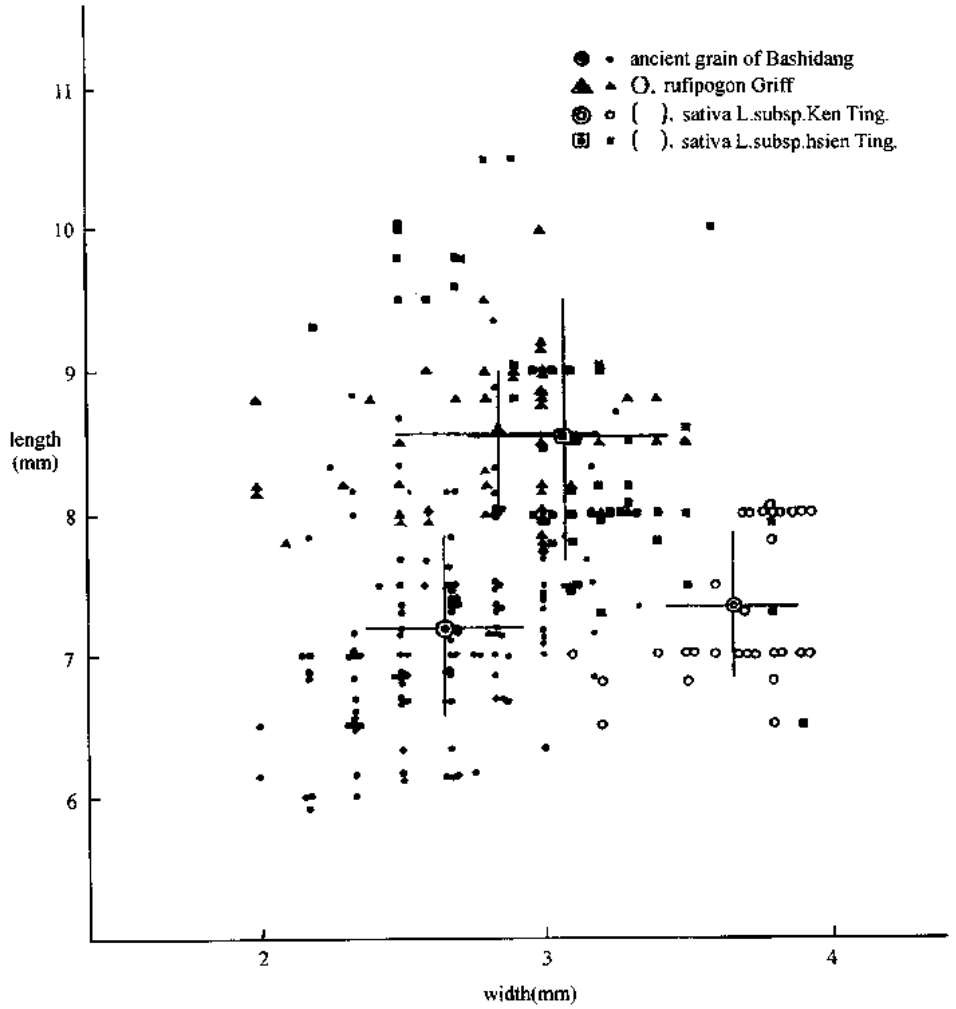

Figure 8 The scatter of grain length and width in ancient rice of Bashidang, hsien, keng and O. rufipogon

1 Length-width is smaller than modern indica and japonica and relates to small-grain rice.

2 Shared characteristics between indica, japonica and common wild rice suggested that indica and japonica differentiated later on.

3 Ratio of length to width (range of change in characteristics of the bi-peak tubercle) shows a tendency to differentiate to indica types.

The early cultivated rice from Bashidang represents the small-grain ancient rice at a precise stage in the history of its evolution. We suggest it is called 'Bashidang ancient cultivated rice'.

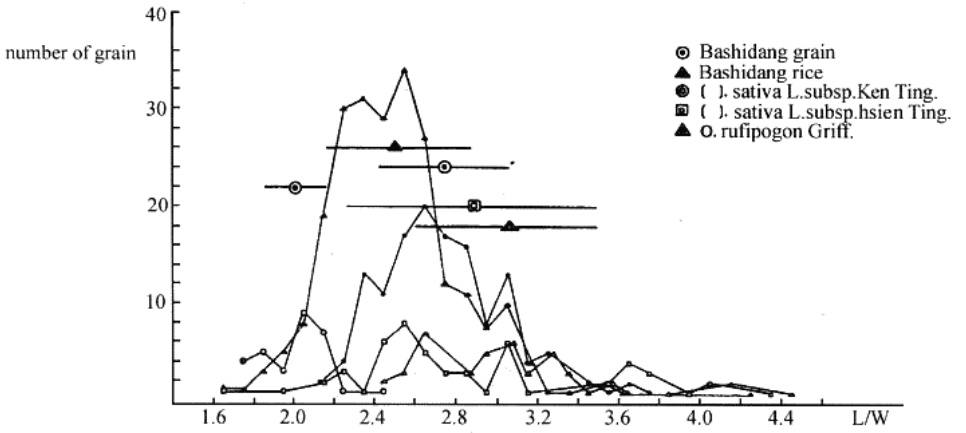

Figure 9　The scatter of grain length and width in Bashidang grain, rice, hsien, keng and O. rufipogon

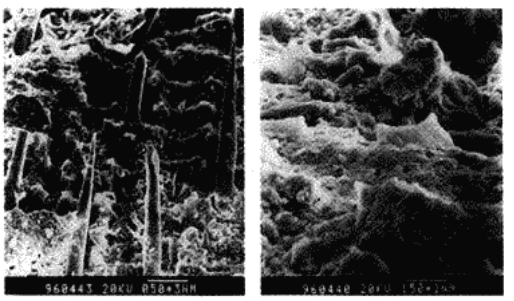

Figure 10　The bi-peak tubercle of Bashidang grain no. 1 (close to hsien type)

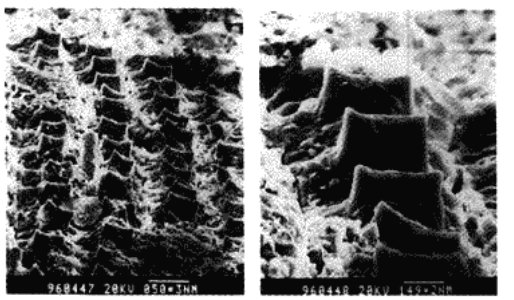

Figure 11　The bi-peak tubercle of Bashidang grain no. 2 (close to keng type)

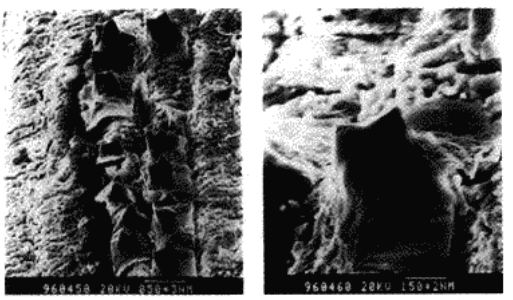

Figure 12　The bi-peak tubercle of Bashidang grain no. 4 (close to hsien type)

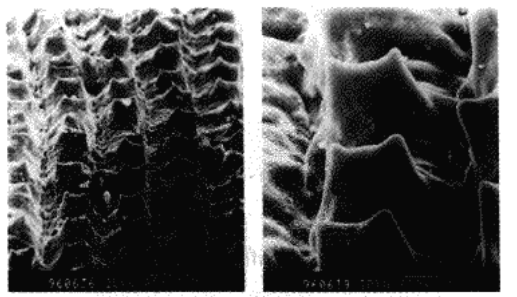

Figure 13　The bi-peak tubercle of Bashidang grain no. 9 (close to hsien type)

Research in early rice domestication and its economic role has lacked good evidence. It was not clear at what stage rice was exploited in the cultivation of plants. The 'Bashidang' ev-

idence provides support for the arguments that cultivation of other wetland plants, including walter caltrop and lotus root, had already taken place by that time.

Table 1 Characteristics of grains of ancient rice in Bashidang.

material	no.	length	width	l/w ratio	note
excavated grain	133	7.20 ±0.66	2.65 ±0.28	2.74 ±0.31	awned grain 78.2%
excavated rice	240	4.94 ±0.59	1.98 ±0.27	2.52 ±0.35	
hsien (indica)	49	8.56 ±0.92	3.09 ±0.35	2.88 ±0.61	
keng (japonica)	30	7.35 ±0.53	3.66 ±0.23	2.10 ±0.15	
Oryza rufipogon	46	8.51 ±0.50	2.84 ±0.36	0.35 ±0.44	

(common wild rice)

Table 2 Comparison of ancient Bashidang grain with cultivated grain and Oryza rufipogon

material	length	significant	width	significant	l/w ratio	significant
excavated grain	7.20 ±0.66		2.65 ±0.28		2.74 ±0.31	
hsien (indica)	8.56 ±0.92	**	3.09 ±0.35	**	2.88 ±0.61	_
keng (japonica)	7.35 ±0.53	_ **	3.66 ±0.23	** **	2.01 ±0.15	** **
Oryza rufipogon	8.51 ±0.50	** _ **	2.84 ±0.36	* ***	0.35 ±0.44	** _ **

(common wild rice)

Table 3 Frequency of grain characteristics of Bashidang ancient rice compared with variant area of hsien, keng and Oryza rufipogon

species of	*hsien*		*keng*		*Oryza rufipogon*	
ancient rice	no. of grains	%	no. of grains	%	no. of grains	%
grain length	28	21.1	76	57.1	12	9.0
grain width	49	36.8	0	0	97	72.9
l/w	122	91.7	2	1.5	85	63.9

Table 4 Characteristics of bi-peak tubercle of Bashidang ancient rice

grain no.	grain length (mm)	grain width (mm)	l/w ratio	angle of glume shoulder	two peak distance (μm)	col depth (μm)	p. d. /c. d.	peak angle	col angle	width of tubercle seat
1	6.35	2.80	2.27	113	18.00	3.00	6.00	67.33 ±10.22	144.93	50.0
2	7.40	2.40	3.08	65	29.36 ±2.26	2.69 ±0.79	10.91	73.70 ±6.33	159.23	72.2
4	6.75	2.35	2.87	84	20.86 ±1.29	3.34 ±1.34	6.25	82.80 ±7.81	144.49	66.7
9	6.85	2.45	2.80	94	29.67 ±5.97	3.97 ±0.94	7.67	72.70 ±10.07	150.76	67.8

The water caltrop is an annual plant which can be eaten either raw or cooked. It will keep for over a year, and can be dried or fried. Not only is the fruit edible when ripe, but the tender leaves are also edible even before the fruit ripens. Its cultivation requirements are also simple. One need only throw the fruit into the water or marsh to cultivate the plant and yield a plentiful harvest. The empty fruit shells remain, and measurement of the shell allows estimation of the size of the fruit once contained therein, and estimate of the food provided by this plant.

The lotus is a perennial plant. At Bashidang, in addition to lotus seeds of the same period as Pengtoushan, large ceramic plates formed in the shape of lotus flowers were also found. This shows the extent to which the lotus plant was valued at the time. Cultivation of the lotus plant is also easy. One just buries the roots, or throws the lotus seeds into the water. There is also a lengthy time period of harvest and consumption of the lotus root. It can be picked and eaten 11 out of 12 months in the year, and the yield is high.

The cultivation of other food plants supplemented wet rice when food supplies were low and continued until rice became the main staple food.

Rice remains dating back to 10,000 BP have been found in limestone caves located in various sites in mountain basins, including Yuchan (Jade Toad) Rock in Dao County in the Nanling hinterland of southern Hunan, and the 'Wannian xianrendong' (10,000-year Immortal Cave) of the Qinling hills in northeastern Jiangxi, Diaotonghuan. However these discoveries definitely do not show the cultural influence of Pengtoushan and Bashidang. Instead they indicate that practices in the mountainous areas and the plains took a separate course of development. The sites in the basins within the mountainous areas, although continuously inhabited later on, did not manifest cultivation on the same scale as that indicated by discoveries in Pengtoushan and Bashidang, nor did they achieve the same level of cultural development or degree of social organization. There is a long and continuous sequence of occupation in the Liyang Plain, from early Palaeolithic until the Neolithic. The evidence from Pengtoushan and Bashidang shows that rice cultivation developed to a productive scale in an extremely short time.

There are three reasons for this scale of development. The first was population increase, which put pressure on subsistence agriculture and accelerated development. The second was the high productivity of the plains and their varied environments of lakes and marsh, allowing expansion of plant cultivation. The third is the cultural and environmental benefit offered by the plains, enabling the development of agricultural knowledge and complex social organization.

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