Paper presented in the International seminar on the 'First Farmers in Global Perspective', Lucknow, India, 18-20 January, 2006

Primitive Cultivation of Rice at the Long-Qiu-Zhuang Site, Gao-You County, China

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ABSTRACT

During 1993-1994, archaeologists from the Nanjing Museum conducted an excavation at the Long-Qiu-Zhuang Site, Gao-You County. By rinsing with water, 4000 rice grains were found from four of five Neolithic layers of Unit T3830. This research was an analysis of the morphological features of these carbonized rice grains and rice plant opal in the soil samples from Unit 3929. Based on the output of the analysis, a preliminary interpretation about the primitive cultivation of rice at this site has been put forward.

The conclusions are: 1). During the initial stage of rice cultivation, the alternation of grain dimensions accelerated over time; 2). The evolution of rice varieties was slow in the early Neolithic Period, until a dramatic change took place between 6300BP and 5500BP, which was caused by intentional selection of rice varieties; 3). From the analysis of plant opal dimensions, we infer that the carbonized rice found at this site is japonica type.

Keywords : japonica type, Origin of rice, Carbonized rice

Introduction

Between 1993 and 1994, a team consisting of the workers from the Nanjing Museum and some other institutes carried out an archaeological excavation at the Long-Qiu-Zhuang Site, Gao-You County. The results reveal that the deposit at this site falls into eight layers. The layers between the fourth and the eighth layers are correlated to the Neolithic Period. Estimated by radiocarbon dating technique, the dates of the eighth and seventh layers are between 7000-6300 BP, and the dates of the sixth, fifth and fourth layer between 6300-5500 BP. Carbonized rice was unearthed from the fourth, sixth, seventh and eighth layers. This is the first time that carbonized rice of 6000-7000 year's old is found in the Jiang-Huai Area, which is an important discovery for the research of the primitive cultivation of rice in the Low Reaches of the Yangtze River.

At each of the sites yielding carbonized rice in the past, the rice usually came from only one layer. It has been held that the whole layer was characterized by rice cultivation. Actually, the carbonized rice is often the remains of a particular year instead of the whole period correlated to this layer. In contrast, the

Received : 18 April, 2006; Revised : 23 January 2007.

carbonized rice found at the Long-Qiu-Zhuang Site came from fourth layers, ranging from the early phase to the late phase of the Neolithic Period. Based on the findings, the research focused on the morphological features of carbonized rice from a diachronic perspective would shed some light on the understanding about the appearance and initial development of rice cultivation in the Neolithic Period.

Our research includes an analysis of the alternation of grain dimensions of carbonized rice and an analysis of the types of rice plant opal in the soil samples from the Long-Qiu-Zhuang Site, Gao-You County. The goal was to explore the origins and initial development of rice cultivation in the Neolithic Period.

Materials and Methods

1. Examination of plant opal found from the soil of the Long-Qiu-Zhuang Site

The analysis of rice phytolith was conduced on the samples from Unit T3929 of the Long-Qiu-Zhuang Site (Fig. 1), which was collected by the Archaeology

Fig. 1. Geographical distribution of observation site.

Institute of the Nanjing Museum. Supersonic wave was utilized to clean up the soil colloid staining on the surfaces of plant opal. After rinsed by water, the samples were dried and made into thin pieces. Under an optical microscope, plant opal was measured by four parameters: length of upper portion (A), length of lower portion (B), width (C), and thickness (D). Rice phytolith from every layer were defined as *indica* type or *japonica* type according to their discriminating values:

Z=0.49 x (A+B)-0.30 x C+0.14 x D-0.3.82 x B/A-8.96

2. Examination of phytolith of motor cell from rice leaves

Two modern varieties of rice, Hua-gu (*indica* type) and Huang-shan-shi (*japonica* type), were selected for the purpose of comparison. Samples were taken from flag leaf after heading. Dried in the air, the samples were then fired at 550^0 for six hours in an electric stove. After ash of the burned samples was cleared away by supersonic wave, an optical microscope was used to measure the profiles of the phytolith in the motor cell from rice leaves.

3. Measurement of the profiles of carbonized rice

The samples for this purpose were collected from the eighth, seventh, sixth, and fourth layers of Unit T3830 of the Long-Qiu-Zhuang Site (Fig. 2). Length, width, and thickness of carbonized rice grains were measured. During the process of washing, the surfaces of some grains of carbonized rice were worn. So measurement was only conducted on the grains with intact surfaces and plump shapes. As unpolished rice, these grains selected must have clear surface grooves.

Comparative samples were selected from five modern local varieties. Unpolished rice grains were obtained by threshing. Length, width and thickness were measured by the same method.

According to the values of length/width, square root of length x width, and cube root of length x width x thickness, the indexes of grain profile, size, and weight were estimated.

Results and Conclusions

1. Remains profiles of the carbonized rice

Most carbonized rice grains remain unpolished rice. The surfaces of some grains even retain husks. Only a few grains were polished, and the central section of several grains is dented (Fig. 2). A number of carbonized rice grains from the fourth layer have intact husks, which have no aristae. In addition, there are two rice grains connected each other by a stem (Fig. 2D).

The fact that paddy, unpolished rice and polished rice were found together suggests that all the grains might have originally been paddy. Carbonized rice husk is too fragile to survive washing process after unearthed. Most husks might have dropped off due to the flush of water, and the friction among rice grains as well as between grains and the soil. As a result, the paddy became unpolished rice. On the other hand, a part was turned into polished rice, while only a little remains unchanged.

2. Morphological features of carbonized rice from different layers

The average length of rice grains from the fourth layer is 5.80 mm; the ones of other three layers are 4.58 mm, 4.72 mm and 4.84 mm respectively Table 1. Comparing the four layers, we found that the average length of carbonized rice from the fourth layer is highly significantly longer than those

A B C D

Fig. 2. Remains profiles of carbonized rice from different layers of Unit T3830 of the Long-Qiu-Zhuang Site. A, carbonized rice from eighth layers; B, carbonized rice from seventh layers; C, carbonized rice from sixth layers; D, carbonized rice from fourth layers.

from other three layers. Also, the variation of grain lengths of carbonized rice from the fourth layer is the widest among all four layers, ranging between 4 mm - 7.5 mm. Those from the sixth and seventh layers are in the second place, with 97% ranging between 3.5 mm - 6 mm. 80% carbonized rice grains from the eighth layer fall into the range of 4.5 mm -5.5 mm. As to standard deviation, the

Table 1 : Mean values, Standard deviation and Coefficient of grain dimensions of Carbonized rice at the Long-Qiu-Zhuang site in Gao-You County

	Layer	4	6	7	8
	No. of sample	118	48	65	14
Length	mean(mm)	5.80	4.58	4.72	4.84
	S.D.	0.69	0.51	0.56	0.47
	C.V.%	11.87	11.13	11.90	9.65
Width	mean(mm)	2.57	2.28	2.31	2.24
	S.D.	0.45	0.30	0.31	0.23
	C.V.%	17.86	13.09	13.61	10.17
Thick	mean(mm)	1.78	1.65	1.69	1.65
	S.D.	0.41	0.29	0.23	0.21
	C.V.%	17.86	13.09	13.61	10.17

carbonized rice from the fourth layer has the largest value, followed by that from the sixth and seventh layers. The carbonized rice from the eighth layer has the smallest standard deviation.

The situation of grain width is similar to that of grain length. The average width of rice grains from the fourth layer is, at 1% level, obviously different from those from other three layers. The coefficient variation (C.V.) of grain width shows a clear increase from the early phase (the eighth layer) to the late phase (the fourth layer). Similarly, the coefficient variation and standard deviation of grain length increase from the eighth layer to the fourth layer. However, the peak values of the distribution of grain thicknesses of the four layers are close each other, without any obvious change.

3. Grain dimensions of carbonized rice from each layer

The grain dimensions of carbonized rice from the sixth, seventh, and eighth layers are only slightly larger than that of modern local varieties, but the grain dimensions of carbonized rice from the fourth layer are much larger than modern local varieties (Table 2). However, the indexes of the dimensions

Table 2 : Grain dimensions of carbonized rice and local varieties

		Length/Width	L x W$^{1/2â}$	L x W x T$^{1/3â}$
Carbonized rice	4th layer	2.31	3.85	2.97
	6th layer	2.03	3.22	2.57
	7th layer	2.07	3.29	2.64
	8th layer	2.19	3.28	2.61
Local varieties	Ai huang zhong	1.94	3.96	3.00
	Chang jing gu	1.82	3.78	3.01
	Hei zhong	1.78	3.91	3.06
	Ma que qing	2.07	3.91	2.88
	Huang zhong	1.96	3.88	2.98

L : Length; W : Width; T : Thick

of grain size and weight of carbonized rice from the fourth layer are close to that of modern local varieties, while those of carbonized rice from other three layers are smaller. Therefore, we found that the rice grains of ancient varieties are somewhat longer and slender compared with modern local varieties. With regard to grain size and weight, the rice from the fourth layer is similar to modern local varieties. On the other hand, the carbonized rice from other three layers show transitional features from wild rice to domesticated rice.

4. Analyses of rice phytolith in the soil samples from the Neolithic layers

Among the six layers analyzed, no rice phytolith was found from the eighth and ninth layers. Since the ninth layer has not been disturbed by human activity, it is not strange that no trace of cultivation was found. Nevertheless, the fact that the eighth layer has not yielded rice phytolith does not imply that no rice grew in this phase. As a matter of fact, carbonized rice was unearthed from the eighth layer of Unit T3830, which location is opposite to that of Unit T3829.

Rice phytolith has been found from the fourth, fifth, sixth and seventh layers. The morphological values, including length, width, thickness and aristae length of phytolith from the flexible cells of rice leaves, are presented as Table 3. The samples included the rice phytolith from the four layers, modern local *japonica* type (Huang-shan-shi), and modern local *indica* type (Hua-gu).

From Table 3 we found that the average value of B/A of Hua-gu type is larger than 1, belonging to 'a' type; the average value of B/A of Huang-shan-shi is smaller than 1, belonging to 'b' type. Such a classification is in accordance with the model established by Udatsu and Fujiwra[1] who suggests defining the phytolith of *indica* rice as 'a' type, and that of *japonica* rice as 'b' type. Since the mean values of B/A of rice phytolith from the fourth, fifth, sixth, and seventh layers are smaller than 1, they should be regarded as 'b' type; The values of the thicknesses of rice phytolith from all the four layers are close to that of the phytolith of *japonica* rice; By calculating, the *indica-japonica* discriminating values (Z) of the rice phytolith are 1.2081, 0.8733, 0.7688, and 1.0803 from the four layers, respectively. All of them are above the critical value. This indicates that all the rice varieties from the fourth, fifth, sixth and seventh layers are *japonica* type. Although no rice phytolith found in the eighth layer, the grain

Table 3 : Plant opal dimensions at a vestige site and *indica-japonica* discriminating values

	Length	Width	Thick	B/A	Z
4th layer	41.26	34.05	27.55	0.90	1.21
5th layer	41.06	33.45	25.86	0.91	0.87
6th layer	39.52	34.16	27.63	0.87	0.77
7th layer	39.97	32.00	26.57	0.88	1.08
Hua gu	40.73	35.59	17.66	1.10	-1.74
Huan shang shi	42.23	40.38	28.11	0.96	0.24

dimensions of carbonized rice from the eighth layer of Unit 3830 are identical to that from the sixth and seventh layers, which suggests that the rice from this layer is also *japonica* type.

Discussions

1. Increase of grain size of carbonized rice

Based on the researches of the origins and differentiations of cereals, some students, such as Harlan,[2] pointed out that the initial stage of domestication might have involved an automatic selection which was unconscious by the earliest cultivators. During such a process, the grain shattering decreased, whereas fertility increased. Meantime, the number of spikelets and grain size increased. The samples analyzed in this research came from four layers dated to different phases of the Neolithic period. From the eighth layer to the sixth layer, the coefficient variations of the length, width, and thickness of rice grain increased over time, but, in general, the change was not obvious. However, the increase of coefficient variation of rice grain indicates that the differentiation of wild rice already happened through human unintentional selection. During the period correlated to the fourth layer, a sharp change appeared due to such a differentiation. In short, it could be held that during the process of rice domestication, the varieties with larger grain sizes sprouted and grew more quickly than other ones because of the change of ecological circumstance. Strong sprouting ability brought the varieties of larger grain sizes with selective advantages in the competition with other varieties. As a result, during the process of rice domestication, the grain size of cultivated rice increased over time.

2. The appearance of domesticated rice

Some rice grains in the fourth layer do not have aristae, which indicate that they are not wild rice already, because wild rice usually has such aristae. It hence infers that the carbonized rice from this layer is domesticated cultigens which were bred by human's cultivation in a long period. This conclusion is also supported by the fact that some rice grains from the fourth layer are connected by stems, which suggests that the dropping trait of grain of this rice may have become degenerated. During the period of gathering subsistence, when a part of gathered plants were selected to be cultivated, the varieties without grain shattering decreased might have been preferred by the cultivator[3]. So that we found that the feature of long aristae gradually disappeared during the process of rice domestication. Wild rice with long aristae could easily propagate whereas the varieties without aristae could be easily harvested; Dropping trait was an indispensable characteristic for wild rice to reproduce, whereas attaching trait was wanted by the gatherer; Low yield is another characteristic of wild rice because of their smaller grain sizes, whereas cultivated rice usually have much higher productivity because of their larger grain sizes. All the characteristics of domesticated rice, including non-aristae, attaching trait and large grain size have been observed on the carbonized rice from the fourth layer. We conclude that the carbonized rice from the sixth and lower layers had not been fully domesticated, but those from the fourth layer, which is correlated to the late phase of the Neolithic Period, are real domesticated cultigens. In this phase, the domesticating process of rice had completed.

3. Types of the primitively domesticated rice

As to the appearances of cultivated *indica* and *japonica* rice, dispute exists among the workers who study the origins of domesticated rice. The school which held that domesticated rice originated in Southern China argued that *indica* type is closer to wild rice than *japonia* type not only on morphological aspect, but also on the aspect of hereditary mutation[4]. So the workers of this school claimed that the process of rice domestication is: from wild rice to *indica* type; then from *indica* type to *japonica* type. The school that suggested the domesticated rice originated in the Yun-Gui Plateau believed that the domestications of *indica* and *japonica* types were parallel. They took place in different environments. Zhou Shi-lu, the founder of the school arguing that rice domestication originally appeared in the Low Yangtze Valley, suggested that the Lu-dao(weed rice) found in Lian-yun-gang, Jiangsu Province, and the float rice found in Chao-hu, Anhui Province, were wild Japonica rice[5]. He hence argued Chinese *japonica* rice directly originated from wild rice. However, based on the analyses of the dimensions (profiles) of rice grains found from the He-my-du Site and other Neolithic sites, many experts found that both *indica* and *japonica* types were unearthed from most of these sites. In our examination of the phytolith of flexible cell of rice leaves remained in soil, morphological analysis demonstrated that the cultivated rice from the fifth, sixth and seventh layers were all *japonica* type. Between these samples and modern local *japonica* varieties, similarities have been observed on grain morphology and various ratios. Although the ratio of length/width of some carbonized rice samples were more than 3, we could not regard this site contained both *indica* and *japonica* rice. The conclusion reached in this research would be a supporting evidences to the viewpoint that *japonica* type directly originated from wild rice.

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