Remains of Ancient Rice Unearthed from the Shangshan Site and Their Significance

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Key words: Shangshan Site (Zhejiang Province) Rice-China-History

The Shangshan Site is so far the earliest dated Neolithic site in the Lower Reach of the Changjiang (Yangtze) River, ^{14}C dated to 9,000–11,000 BP on pottery sherd samples. The pottery assemblage is represented by large-sized thick-wall *pen*-basins with red-coating and charcoal-tempered paste. The implement assemblage mainly includes millstones, pestles and bolas, along with chipped stone tools. The site contains a number of features like storage pits present in high numbers. The two excavation sessions yield important evidences not only enable us to understand Neolithic development in the Lower Changjiang Valley, but also allow us to explore the origins of rice domestication in the region based on the finding of rice remains at the site (Jiang 2004).

Rice Remains and Agricultural Tools

The charcoal used as tempers for pottery pastes at the Shangshan site was identified in fact to be rice husk remains (Figure 1). Applying plants to paste-mixtures in pottery making was a common practice in the Early to Middle Neolithic cultures of the Lower Changjiang Valley. The objective of plant-tempered paste application is to ensure that the utilization of non-clay earth in making pottery will not cause the cracks while drying and firing. The petrologic analysis of pottery sherds reveals that the fan-shaped phytoliths are from motor cells (or bulliform cells) of rice leaves (Figure 2).

The discovery of rice-husk in paste-tempers at Shangshan does not only provide us with new evidence for understanding the pottery-making technology in the region, but also new information on the socio-economic life of the people at the site. First, the rice consume must have been very high, becoming a primary diet resource at the time. Second, there must have been effective means of drying, storage, and process. Third, steaming must be the primary cooking method for rice. In addition,

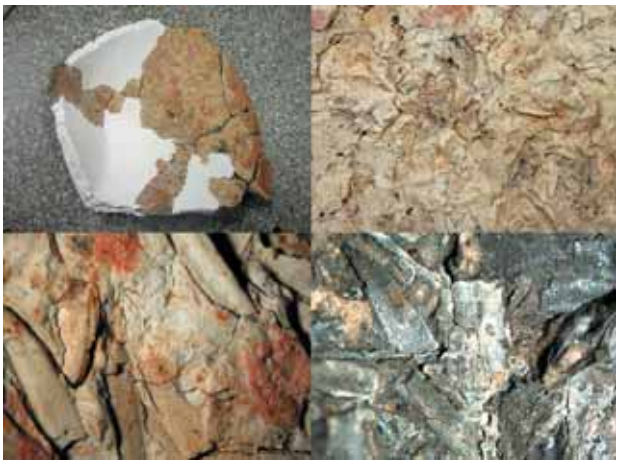

Figure 1. Potsherd Unearthed from Shangshan Site (Pit H383) and the Rice Husk Impressions on It

Figure 2. The Rice Phytoliths Recovered from Paste-tempers of Potsherd (T2 ⑥) at Shangshan Site

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based on the discovery of the motor cell phytoliths from the rice leaves, it suggested that the pottery paste-tempers might not just the husks, probably also included rice leaves. If it is so, this evidence also indicates that tempered husks might not be of wild rice collected from the field, instead should be of domesticated products.

Stone sickles and knives are functional-designated tools for agriculture. The knives and sickles are for harvesting, primarily working towards cutting off the stems of rice. The presence of these tools is suggestive of rice cultivation.

Biological Features of Archaic Rice Remains

From our observations on those samples recovered from paste-tempers, it is notable that the length of some rice grains under study is shorter than that of wild rice, while the width of Shangshan archaic rice is broader than that of wild rice. The difference in morphology likely point to an evolutionary process in early domesticate rice. However, this observation is subjective and the evidence is not sufficient. To prove the Shangshan archaic rice to be of domesticated pieces, it needs more investigations.

1. Morphology

Although a large number of rice husks were recovered from paste-tempers of pottery vessels and sherds, careful screening reveal very few complete rice grains. After extensive search in pottery sherds, we finally identify one complete grain that is suitable for measures (Figure 3). The grain is 7.73 mm in length, and 2.86 mm in width, with an L/W ratio at 2.70. In general the difference in L/W ratio exists between modern domesticated rice and wild rice. The ratio is smaller in the former than the latter. If one uses the L/W ratio at 3.50 to be the criteria to differentiate domesticated and wild rice, then Shangshan rice should fall into the range of domestication.

2. Features of Rachillae

The features of rachillae are critical not only to distinguish domesticated rice from the wild (Crawford and Shen 1998), but also to identify the two sub-species of domesticated rice. After detailed examinations on large quantity of rice husks, we identify some rachillae with wild rice features, as well as husks with domesticated *japonica* rice features (Figure 4). Our examination does not reveal any yet of rice grain with *indica* rice featured rachillae. Therefore, the Shangshan archaic rice is characterized by the mixture features of domesticated and wild rice, suggesting a transitional type of the early form of domesticate *japonica* rice.

3. Morphological Features of Phytoliths of Motor Cells

The morphology of phytoliths of motor cells is in fan-shape, with turtle-shell pattern on the base. One or two ridges are apparent on two sides. The cell features are clear and significant for the purpose of classification.

The phytolithic analysis on the sherd samples from Shangshan site suggested that some types of cells belong to that of rice leaves. In order to further understand the biological feature of the Shangshan archaic rice, we need to study rice phytoliths in detail. The phytolith grains are 41.77μm in average length, and 33.85μm in average width, and 33.99μm in average thickness. And

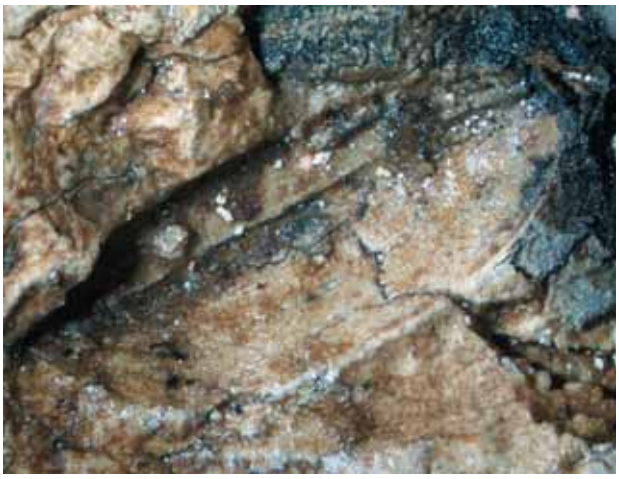

Figure 3. Rice Husks Recovered from Paste-tempers of Potsherd (Pit H383) at the Shangshan Site

Figure 4. Rice Rachillae Recovered from Paste-tempers of Ptsherd (T6 ⑦) at the Shangshan Site (Top. Wild Rice; Bottom. Japonica)

the shape coefficient is about 0.76, indicative of large, thick, and pointed features. In general, the phytoliths of *indica* rice has index features of small, thin, and rounded, while that of *japonica* rice has index features of large, thick, and pointed; between tropical *japonica* rice and sub-tropical *japonica* rice, the difference in size and shape of the phytolith grains appears that the former is of large, thick, and pointed, while the latter is of relatively small, thin, and rounded. According to the present data, we arrive at the average index at 3.27 to judge the Shangshan rice to be of *japonica* rice, while the average coefficient of estrangement is 1, suggestive of being in the range of tropical *japonica* rice. Therefore, it can be determined that the Shangshan archaic rice has been a primitive cultivated rice and mixed with some features of modern domesticated *japonica* rice, or particularly, tropical *japonica* rice.

The Significance of the Shangshan Archaic Rice and the Origin of Rice Domestication

The Shangshan archaic rice is one of the most important discoveries in the study on the origins of rice domestication. There are two aspects in the study of the origins of rice domestications: One is on the scenario of culture, which concerns when and where human began to domesticate rice; the other is on that of agronomy and biology, which involves how the wild rice was evolved biologically into domesticated rice and to which strain it developed. The discovery and research on the Shangshan archaic rice has provided us with much new information in this field.

1. Over 10,000 Years' History of Domesticated Rice in the Lower Changjiang Valley

The discovery of the Shangshan archaic rice had pushed the history of rice domestication back to more than 10,000 years ago in the Lower Changjiang Valley, where the process of rice domestication began as early as that in the Middle Changjiang Valley. Furthermore, the Shangshan site is not the only location where the archaic rice remains are identified in the Early Neolithic sites in the region. The Xiaohuangshan site in Shengzhou, Zhejiang Province (Zhang *et al.* 2005), one of the top ten archaeological discoveries in 2005, yielded remains of archaic rice in form of, just like the Shangshan site, carbonized husk grains in paste-tempers of pottery sherds (Figure 5) as well as phytoliths of rice motor cells.

The discovery of the rice remains in Shangshan site along with cultivated rice suggests the Lower Changjiang Valley is one of the origin regions for rice domestication. This argument further suggests that the origin of domestication in China can be studied in terms of the central origins and non-central origins. It means, within a given region of the origin in the Lower and Middle Changjiang Valleys, there are many centers of origins, where variability of evolutionary process in accordance with local ecological system could be observed.

2. *Japonica* Rice as the Transitional Type to Domestication

Our analysis suggests that the features of the rachillae from Shangshan archaic rice remains have two types: one wild rice and the other *japonica* domesticated rice. There is no existence of *indica rice*. The phytolithic analysis also suggests that morphology of the Shangshan archaic rice is close to that of modern *japonica* rice. This evidence indicates that wild rice was evolved directly into *japonica* rice in the beginning of domestication. The

Figure 5. Rice Rachillae Recovered from Paste-tempers of Potsherd at Xiaohuangshan Site (Top. Japonica; Bottom. Wild Rice)

coefficient of estrangement of the rice phytolith infers further that the Shangshan archaic rice could belong to tropic *japonica* rice, evidenced by the morphological features of the grains similar to the latter.

The wild rice (*O. perennis*), which is generally regarded as the ancestry of domesticated rice, is distributed mostly in the wetlands like glens, marshes and ponds of plains and hilly areas. The Shangshan site is located in the Upper Valley of the Puyangjiang River at 40-50 meters above see level. The landscape has a typical basin valley filled with ponds and wetland. Surveys reveal that there was an ancient riverbed at the west side of the site. This environment is suitable for the domestication of rice.

In summary, the process of rice domestication at Shangshan can be reconstructed as follows: Around 10, 000 years ago, wild rice was well grown in the wetlands at the valley around the site. The Shangshan people collected the wild rice as a part of their subsistence resources. With increased demand for food, in particular their knowledge of the rice growing, storage and process, the Shangshan people started to domesticate rice. Because there was not suitable large paddy field in the surrounding of the site, people had to cultivate rice on the upper lands where the water sources were not sufficient so that the dry-land rice became the primary diet supplements at the site. Through the cultivation, the biological nature of the rice had changed, appearing with features of dry-land rice or tropical *japonica* rice. The study of Shangshan archaic rice provides new archaeological evidence to suggest that *japonica* rice evolved from wild rice in the wetlands in lower altitudes and then was domesticated in the upper lands with dry conditions.

3. The Development of Rice-Cultivating Agricultures in the Lower Changjiang Valley

A number of important Neolithic sites in the Lower Changjiang Valley, including Shangshan, Xiaohuangshan, Kuahuqiao, Hemudu, Luojiajiao, Tianluoshan, are dated between 10,000–7,000 BP. These sites established a continuous chronological framework in time and space of the region, and present unique cultural phenomena. For examples, At the Shangshan site dated to 10,000 BP there are depositional sequences between the Shangshan Culture and the Kuahuqiao Culture. Cultural remains at the 9,000 BP Xiaohuangshan site yield the Kuahuqiao cultural elements, while the 8,000 BP Kuahuqiao site produced material cultures with features of Hemudu Culture. Rice became one of the common cultural presentations related to human activities during this period of 10,000–7,000 BP.

The Shangshan site is located in the small basin of the Upper Puyangjiang Valley. Given the ecological condition of the site and biological features of the rice, we believe that possibility of Shangshan people adapted the mode of dry-land rice or tropical *japonica* rice cultivation highly. Furthermore, we examined the rice phytoliths recovered from the Xiaohuangshan site in the Upper Puyangjiang Valley. The morphology of Xiaohuangshan phytolith is in average size of 41.22μm in length, 34.54μm in width, 32.58μm in thickness, and shape coefficient is 0.84, coefficient of estrangement is 1, suggesting that the Xiaohuangshan archaic rice also falls in range of features for dry-land rice or tropical *japonica* rice. The biological features of both Shangshan and Xiaohuangshan archaic rice suggest that dry-land rice should be the primary type of early domesticated rice in the Lower Changjiang Valley.

Over the Siming Mt and Kuaiji Mt from the Shangshan site is the Hangzhou-Jiaxing-Huzhou Plain where Kuahuqiao and Majiabang sites were located and the Ningbo-Shaoxing Plain where the Hemudu site was located. Both plains are the affluent regions during the Middle Neolithic and afterwards. Of course, rice cultivation was also an important mode of production in the regions. Sato (1996) applied the DNA method to the analysis of carbonized rice samples from the Hemudu site and suggested that the Hemudu rice belonged to *japonica* rice, and probably belonged to the tropical type. The phytoliths of rice motor cells from Hemudu also reveal some characteristics of tropical *japonica* rice. In addition, the morphology of rice phytolith from the Kuahuqiao site is in average 40.95μm in length, 34.15μm in width, 31.11μm in thickness, and shape coefficient is 0.90. And the coefficient of estrangement is 2, which falls into the range of coefficient of estrangement for tropical *japonica* rice (Zheng *et al.* 2004).

Both Hemudu and Kuahuqiao are located in the Ningbo-Shaoxing and Hangzhou-Jiaxing-Huzhou Plains, where water source is sufficient and wetlands are plenty. Hypothetically, the domestication in this region should begin with paddy-field rice given such rich environment. However, the phytolith data suggest dry-land or tropical *japonica* rice at archaeological sites. The contradictions have puzzled archaeologists working in the region for a long time; and now with the discoveries of Shangshan and Xiaohuangshan archaic rice, answer

seems coming to light. About 8,000 year ago, Shangshan (or Xiaohuangshan) people who lived in the small basins at the upper reaches of the rivers brought with themselves semi-domesticated rice to joint zones of plains and mountainous areas or hilly plains where sites like Kuahuqiao are located. During the beginning of the Holocene when the change of sea coastline occurred, rice cultivations became one aspect of cultural phenomena in such extended floodplains. Although in both Kuahuqiao and Hemudu periods the ecological condition for rice domestication had changed since, some characteristics of dry-land rice or tropical *japonica* rice still remained in the archaic rice remains recovered from the abovementioned sites.

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Postscript: the original paper, with five illustrations and three tables, was published in *Kaogu* 考古 (Archaeology) 2007. 9: 19–25. The authors of the original paper are Zheng Yunfei 郑云飞 and Jiang Leping 蒋乐平; the abridged version is prepared by Zheng Yunfei and translated into English by Chen Shen 沈辰.