

THE ORIGIN AND SPREAD OF RICE CULTIVATION WITHIN THE YANGTZE  
RIVER VALLEY, SOUTHERN CHINA

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## Abstract

The purpose of this paper is to provide a description of the origin and spread of rice cultivation within the Yangtze River Valley. The region of eastern China, particularly the Yangtze River is thought to be the point of origin for rice cultivation and domestication, among many other theories. The data came from assemblages from various sites in Southeastern and central China. The oldest dates are associated with rice husks and grains being used as pottery temper, dated to  $9500 \pm 500$  years B.P. According to one theory *Oryza rufipogon* evolved into *O. sativa japonica* and *O. sativa indica*. However research on the genetics from *O. sativa indica* indicated that this subspecies could be the result of hybridization between wild rice and *O. s. japonica*.

## Introduction

Asian cultivated rice (*Oryza sativa* L.) is one of the most commonly grown crops in South, Southeast and East Asia. It has become one of the most important staple food crops, feeding more than 30% of the world population (Higham and Lu 1998). As both wild (*O. rufipogon*) and cultivated rice (*O. sativa*) are aquatic plants, requiring inundated condition to grow, one of the most accepted theories on the origin of cultivated rice is along the middle of the Yangtze River Valley. The research on this topic has been conducted for more than 50 years (Wang et al., nd), but there are still many unanswered questions. It is without question that China is the site of origin for cultivated rice but the exact location is still unknown, which led to the numerous theories regarding this subject. Within China, there are two types of cultivated rice *indica* and *japonica*, each requiring different environments. However, the origin of *indica* is under question, some (Londo et al., 2006) have suggest India as the source, while others suggest that it is the result of hybridization between *japonica* and wild rice in China. Sato (nd) suggests that *indica* is thought to have originated in S and SE Asia; however the evidence for this is much later (pre-date 2000 B.C.) than evidence from China.

The research process also reveals several difficulties in tracing the source of origin of cultivated rice. Where do you separate wild and cultivated strains? What defining characteristics would be indicative of cultivated rice? I will be answering these questions in the latter part of this paper. However, the appearance of rice being used as pottery temper can be an indication that local inhabitants had begun to cultivate rice in order to increase yield.

## Theories

There are several different theories concerning the place of origin for rice cultivation in Asia. Some have been refuted through either lack of evidence or dates from other sites. These theories range from a single location to those covering whole regions of China and Eastern Asia.

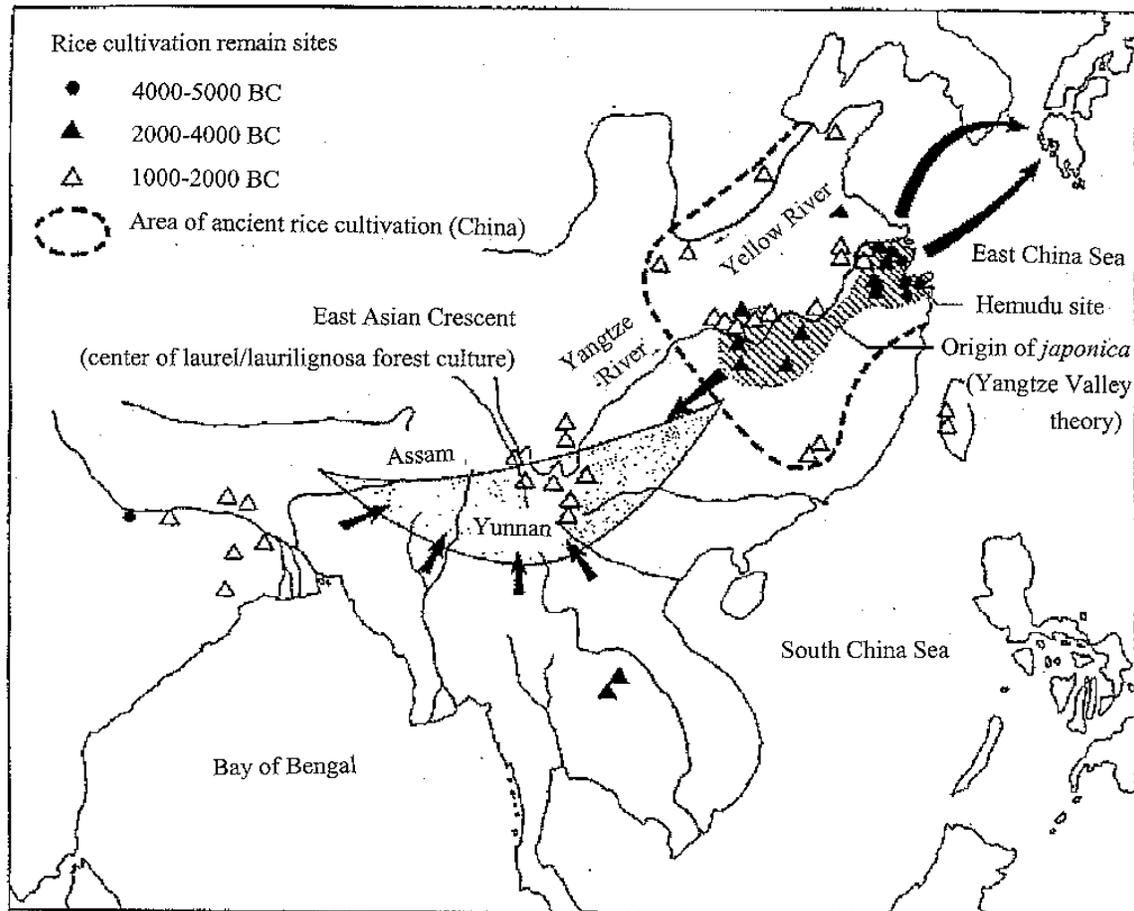


Figure. 1 The theoretical range of rice cultivation in Eastern Asia, including possible paths into Japan.

(Sato, nd)

### 1. Yunnan (Yi 2000)

This is the most popular theory, with support from domestic (Chinese) and international scholars. It suggests that rice originated in the Asian Fertile

Range covering Indian Assam to Chinese Yunnan (Figure. 1). This theory gained support due to the ideal environment, high number of wild and domestic species of rice and the close relationship between ancient and modern rice. This theory lacks archaeological evidence and relies on paleoecological records and isozyme analysis.

2. South China (Yi 2000; Wenhua 1989)

Ding Ying, an agronomist, first proposed this in 1949, saying that rice is tied to the South China region. This was reinforced by Tong Enzheng, linking this to area south of the Yangtze River. This theory is very difficult to prove as the ecology of the area differs depending on the location, and there are no data concerning rice cultivation from some sites.

3. Lower Yangtze River (Yi 2000; Wenhua 1989)

This theory arose from the 1970s excavation of the Hemudu site. This theory has now been refuted as evidence of older rice cultivation has been found elsewhere, particularly the middle Yangtze region. Through examination of the assemblage, Hemudu is revealed to have fully developed rice agriculture and lacking evidence of earlier cultivation. This site is now believed to be from a later cultural group.

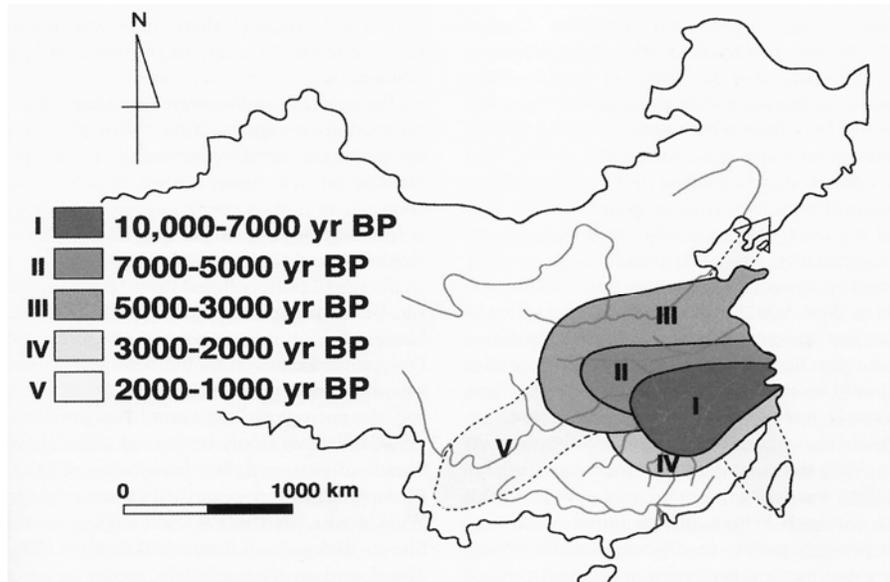


Figure 2 Proposed distribution pattern of rice agriculture in China (Wenming 2002)

4. Yangtze Basin (Yi 2000)

Based on new findings, this area is claimed by Yan Wenzheng as being central to the origin of rice cultivation, figure 2.

5. Middle Yangtze and upper Huai River (Yi 2000)

This is supported by various sites, particularly the Pengtoushan sites. Sites in this region possess partially developed rice agriculture.

6. Central South China (Yi 2000)

Zhu Laicheng, proposed that rice cultivation developed at the edge of the area covering 25-29 N. Lat. and 111-118 E. Long.

7. Lower Yellow River (Yi 2000)

This area was proposed by Li Jiangzhe, based on historical records, placing the origin of rice cultivation at 7-8000 years ago. However paleoecological evidence does not support this theory.

8. Bo River area of Jiangxi Province (Yi 2000)

This area was proposed by Zhang Peiqi, suggesting that rice cultivation began in the area 14000-15000 years ago.

9. Multiple site (Yi 2000)

This theory has been proposed by various scholars, as rice cultivation might have originated in multiple locations and then dispersed throughout the region.

10. Zhongnan Peninsular (Yi 2000)

This area was proposed by Fu Qing, based on the suggestion that rice did not exist in South China 10,000 years ago. This theory has now been disregarded as 10,000 years old rice remains have been found.

### **Environment**

The Yangzi river valley can be split into three sections: the upper, middle and lower river valley. The upper valley region is mainly the plateau and mountainous areas; this is also the site of the Three Gorges dam. The lower and middle valley is mostly alluvial plains with some hills and three large lakes, Dongting, Poyang and Tai lakes.

Even though the middle and lower valley are located in similar latitude and have similar environments, their archaeological records are very different. Therefore the two valleys are considered to be separate units to ease the description of their environments (Higham & Lu 1998; Lu 1999).

### **The Middle Yangtze Valley**

Lu (1999) noted that the environment of this region was reconstructed using geological data (geomorphic and sedimentary analysis), faunal and pollen analysis. The river valley was incised during the Last Glacial Maximum (LGM), to accommodate for the lower sea level.

There are reports of faunal remains being recovered from the Xiashu loess but the significance of this discovery is diminished by the lack of precise location. The presence of pollen from coniferous and deciduous trees indicates steppe environment during the LGM, with the average temperature 10-13°C lower than present, with 500mm of precipitation (900-1,400 mm at present).

During the terminal Pleistocene, there are many thoughts on the degree of forestation; Liu (1991) as cited in Lu 1999 believed that the area had some significant coverage while Xu (1985 as cited in Lu 1999) theorized that the area was only sparsely covered. Only after 15,000 B.P. did trees began to cover the area due to the increase in moisture. The temperature at the time is thought to have been approximately 4-10°C lower than present, with minimum precipitation of 500mm. The level of precipitation is determined by the presence of fur and spruce forest, it is the minimum amount required by these trees.

The pollen analysis from samples dated to the beginning of the Holocene indicates an increase in tree population, not just diversity but also amount of pollen. Wang (Wang et al. 1995 as cited in Lu 1999) stated that the temperature might actually be warmer than present by approximately 1-2°C. The area also saw an increase in water level, causing widespread sedimentation as the flow and dissection slowed.

### **The Lower Yangtze Valley**

This environment of this area has been investigated since the 1970s; therefore the reconstruction can be more accurate. From several boreholes, the recovered pollen was analyzed to give sequences from 30,000 to 4,000 B.P. (Xu et al. 1987 as cited in Lu 1999).

From 21,000 to 18,000 B.P., the area was populated by coniferous and deciduous trees, along with herbs and ferns (Xu et al. 1987 as cited in Lu 1999). This indicates a temperate climate when compared to the dryer and cooler climate at the beginning of the LGM. During this period, the sea level has been shown to be 155 m lower than present. The pollen assemblage went through a significant change between 18,000 and 15,000 B.P., marked by the decline of arboreal trees and fern, but saw the increase in herbs population. This type of pollen assemblage is often associated with steppe environments with temperatures 5-6°C lower and 400mm less precipitation than present (Xu et al. 1987 as cited in Lu 1999).

The pollen assemblage from Zhenjiang indicates a more moderate climate; both drought-resistant herbs and hygrophilous plants were present. This is a significant shift from previous assemblages, tree pollens now compose up to 46-47% of the assemblage

after 15,000 B.P., with oak becoming a major component of the population (Xu and Zhu 1984). The shift in assemblage is the reflection of the climate becoming warmer and moister than the previous stage.

After 13,700 B.P. the warming trend reversed itself and the climate once again became colder and dryer. During this stage, the diversity of pollen in the assemblage decreased substantially, with pollen of drought-resisting herbs dominating the assemblage. The climate is thought to be approximately 6-7°C below present and precipitation of around 500-600 mm (Xu et al. 1987 as cited in Lu 1999). The cooler climate during this period coincides with the Younger Dryas period, in which there is evidence that rice cultivation was terminated in the region, only to restart again once the warmer and moister climate returns. Between 10,850 and 10,000 B.P. the climate varied, with fern becoming dominant in the area, along with the accumulation of peat sediment. The climate at this stage is thought to be warmer and moister than previous (Lu 1999). The warming trend continued past 10,000 B.P. at which trees, once again, became dominant in the area, making up to 93% of the pollen within the assemblage. The profile indicates a more temperate to sub-tropical environment.

The sea level also changed significantly in the past, as mention above from 16,000 to 14,700 B.P. it was 155 m lower than present (Geng 1981 as cited in Lu 1999). This exposed the continental shelf and in turn caused the Yangtze River to carve deeper into the river bed, the water level was 47 m lower than present (Yang 1986 as cited in Lu 1999). By 12,000 B.P. the level was between 56 m and 61 m lower, and continued to rise, until a sharp drop between 11,100 and 10,900 B.P. (Lu 1999).

## Rice

### Soil

Rice is not a particularly difficult crop to grow given the right climate. The main requirement is the abundant water supply. The amount of water required is approximately enough to inundate the seedlings for four to six months. The perfect soil for this use is often found in the alluvial plains; therefore these are the regions of most rice paddy fields (Barnes 1990).

The field's conditions must also be selected or modified to maximize the level of nitrogen fixation and other organic matter; permanently flood fields or too little water could affect the N<sub>2</sub> fixing process. There are many factors in determining the level of these nutrients that must be carefully monitored in the paddy fields. Too high a temperature would lead to rapid decomposition of organic matters and eventually the build up of undesirable byproducts. Rice is also one of the few crops that require silica as part of the nutrient makeup in the soil. The silica coats the motor cells making them rigid, these cells as phytoliths can be used to identify the species of rice present (Barnes 1990).

The detection of prehistoric rice paddy fields is very difficult, as the regions are still being used for the same purpose by present day farmers. Unlike corn/maize fields, which are often plowed, and therefore located through the change in soil layers; rice paddy fields are flooded and muddy making any soil pattern indistinguishable. At present, one of the most reliable methods is to detect the level of iron and manganese that leached into the subsoil, through a process called aquorization. For this to occur the soil must be porous so that the minerals can leech out when the field is inundated during the growing

season. However this did not occur with every field due to the differences in soil material. In Japan, some fields can be farmed for centuries without aquorization occurring. This process is actually beneficial to the growing of rice as it removes the harmful byproducts of organic degradation, approximately 10-20 mm of movement per day provide the highest yield (Barnes,1990).The fields can also be located through extensive excavation, the boundary bunds and ditches can be uncovered showing the location of ancient rice fields. This process shows the changing of field location and size, even the canal layout from the past (Barnes 1990).

### **Wild rice (*O. rufipogon*)**

This plant is a perennial plant that will regenerate itself by ratooning (Lu 1999). As with most modern rice species, it is an aquatic plant belonging to the sub-tropic to tropic climate zone. This climate condition is higher, in both temperature and rainfall, than those required for growing millets. According to Lu (1999), common wild rice can survive with annual temperatures above 16°C and 1,000 mm or rain, but during seedling stage, it can survive temperatures as low as 2°C. The species also requires continuous supply of water for optimum growth, usually less than 1m in depth, and this condition led to most of the rice growing in swampy areas that are permanently flooded. The plant itself can be differentiated from cultivated rice; the awn tends to be longer, thicker with more developed needles. The seeds are more dispersed and fewer in number when compared to those of cultivated rice (Yasuda 2002).

Its range during the during the LGM (Last Glacial Maximum) would not have reached the Yangtze river valley as the maximum temperature (4-10°C less than present) was below the growth condition for *rufipogon*. However it could have been growing

along the 25-28°N latitude zone (Lu 1999). This discovery indicates the possible time period in which wild rice usage could begin in the Yangtze River Valley.

### **Method**

My main source is a thesis written by Dr Tracey Lu (1999) who is currently a professor at Chinese University of Hong Kong. Through her work I was able to obtain information which would otherwise be unavailable to me, as she has access to Chinese literature and other sources. Her thesis provides me with background information to both the region and the associated archaeological sites along the Yangtze River Valley.

The other significance source of information comes from the internet, at a site posted by Bryan Gordon, of the Canadian Museum of Civilization (<http://http-server.carleton.ca/~bgordon/Rice/index.htm>). This site is a field report of a recent (1999) expedition to China. Apart from providing direct information, it also post links to translated and edited sources from both Chinese and Japanese literature. These sources range from published papers, to paper presented at a conference. Unfortunately, some of these references were not dated, making them very difficult to place in the chronology of rice cultivation.

I have compiled data from various literary sources that is available to me. These contain data regarding the various aspects of prehistoric rice usage and cultivation in Eastern China, Korea and Japan.

All the dates and data were from pottery, fossilized grains or phytoliths. Of these sources, pottery provides the most information on rice usage, but it does not provide evidence for speciation of the grains involved. The fossilized grains themselves provide

the most accurate dates and also provide the possibility of speciation, however the significance of this is controversial. The weakest evidence for rice cultivation comes from the phytolith analysis.

### Phytolith

The method of phytolith extraction is outlined in Pearsall (1989) and by Harvey and Fuller (2004). The process itself is lengthy, involving dissolving the sample in solvent to remove organic matter and then repeated centrifuging to remove heavier particles. To make the data quantifiable, the sample can be weighed before and after processing. This allows the calculation of phytolith density (Harvey and Fuller 2004). There are certain phytolith that can be used to identify plants, Zhijun (1998) used the 'double-peaked glume cell' which is specific to genus level in his paper. Since there is overlap in physical characteristics between wild and cultivated rice phytoliths (Sato et al 1989), this method will only provide significant information when it is statistically analyzed. Houyuan Lu et al. (2002) also used rice phytolith to trace the origin of rice cultivation, using bulliform cells (figure.3). Lu (2002) noted that phytoliths belonging to wild rice have fewer than 9 highly variable and irregular 'scale-like decoration', while those of *O. sativa* have between 8 -14. Further work on distinguishing the two species by using this method was performed by Sato et al. (1989), his results suggest that it is possible to separate wild and cultivated rice phytolith by using  $Z^1$  and  $Z^2$  tests. With  $Z^2$  wild species overlap those of *O. s. indica* while  $Z^1$  results lie between *indica* and *japonica* cultivars.

The use of phytoliths will not provide necessary information regarding the volume of plants grown, as the amount of phytolith production in living plants varies according to growth condition and environment (Harvey and Fuller 2004). Harvey also suggests that

the different types of phytoliths can be used to indicate the processing site for rice. She (Harvey) stated that during the first stage of processing the plant, stalks are still present which would be identified by the bulliform cells. At final processing in which the husk is removed, glume cells would be dominant in the phytolith assemblage, as they are from the husk.

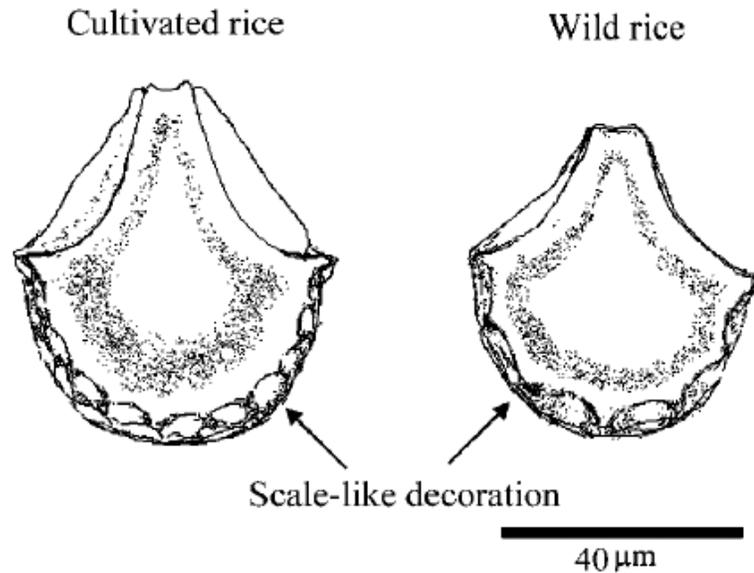


Figure. 3 Bulliform phytolith, showing decorative differences between wild and domesticated rice

## DNA

More recently more analysis has been performed on the genetics of various rice species, particularly *Oryza sativa indica* to determine its source. This is used to determine the species of rice present in the archaeological record. Two types of DNA are extracted from modern rice plants; non-nuclear (chlorophyll) DNA (maternal line) and nuclear DNA (both lines) (Sato nd). The chlorophyll DNA provide a method of tracing the ancestry of the specific organism and trace divergence from other population. With rice, this method shows that *O. s. indica* and *O. s. japonica* have different maternal lines, representing completely separate populations. This information suggests that the two

could not have evolved from a single source. Sato then proceeds to examine DNA from carbonized grains, found near in the Yangtze River area, finding that each derived from *japonica*.

DNA is also used by Londo et al. (1996) to determine that *O. rufipogon* was likely to have been domesticated twice at separate times to give rise to *O. s. indica* and *O. s. japonica*. Londo's method involves using three specific regions of the plant's DNA, one from chlorophyll and two from nuclear DNA. The significance of this analysis will be discussed later in the paper, but it suggests that *O. s. indica* could possibly be the result of random hybridization between *O. s. japonica* and other wild rice species in the area (figure 4).

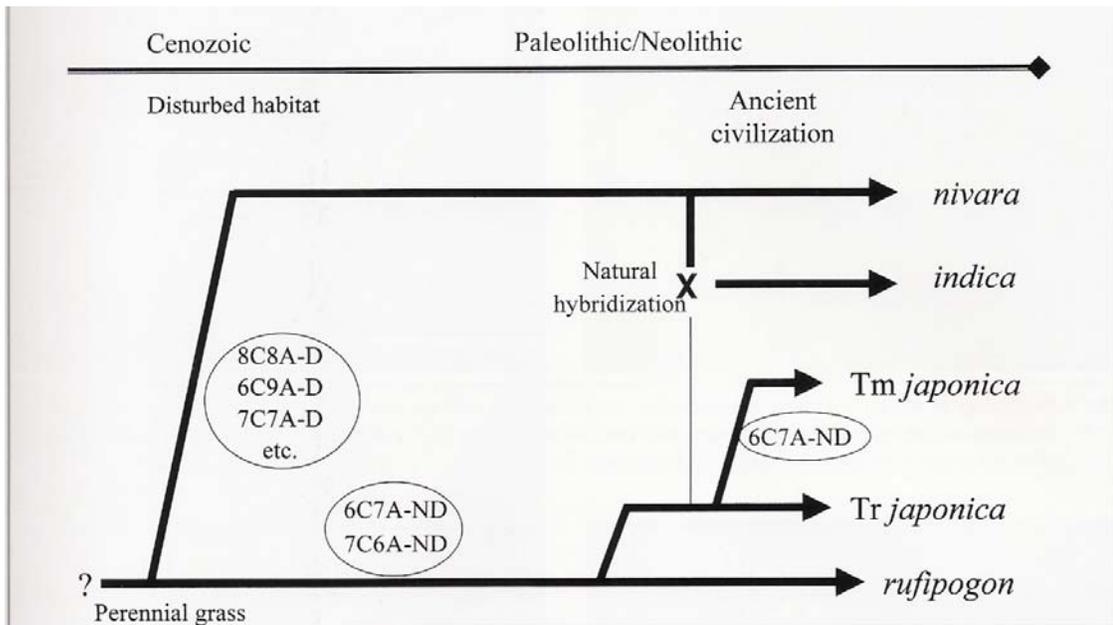


Figure 4. Representation of possible relationship between *O. s. japonica* and *O. s. indica* and *O. rufipogon*. (Yasuda 2002).

## Result

14C dating of rice : oldest reported from each site

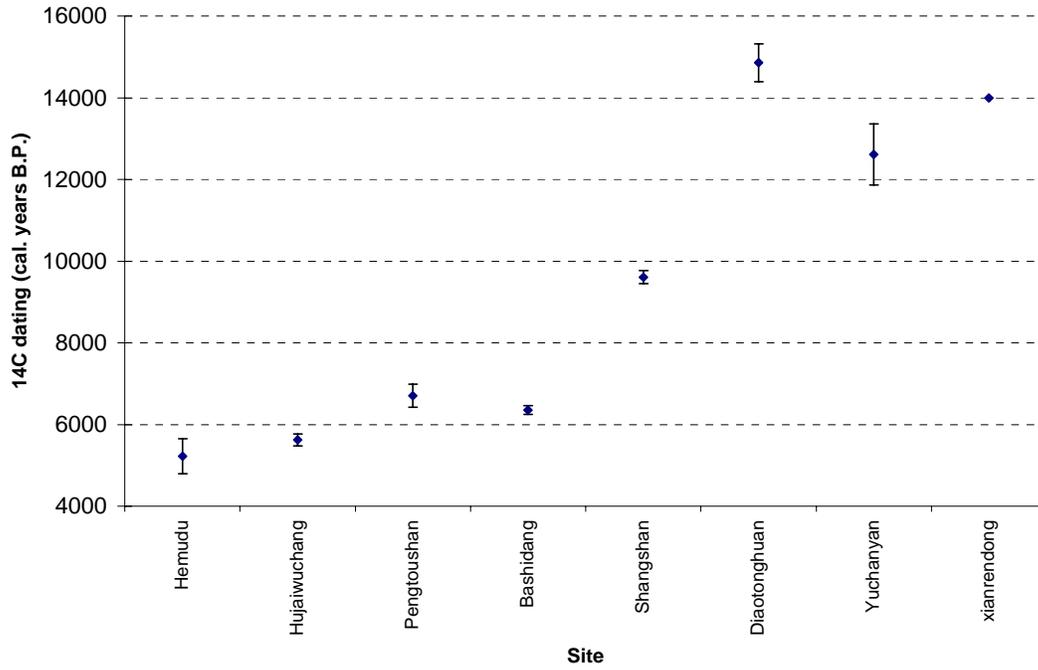


Figure. 5 Calibrated 14C dating of rice remains from sites within the Yangtze River Valley.

Table 1. Source material and 14C date from each site

Site	Source material for 14C dating	cal. 14C date (B.P.)
Bashidang	individual charred grains	6355 ± 105
Diaotonghuan	Phytolith	14857 ± 465
Hemudu	individual charred grains	5225 ± 425
Hujiawuchang	charred husk in pottery temper	5625 ± 145
Pengtoushan	charred remain in pottery temper	6705 ± 285
Shangshan	charred remain in pottery temper	9610 ± 160
Yuchanyan	phytoliths and presence of paddy field	12616 ± 748
Xianrendong	Phytolith	14000

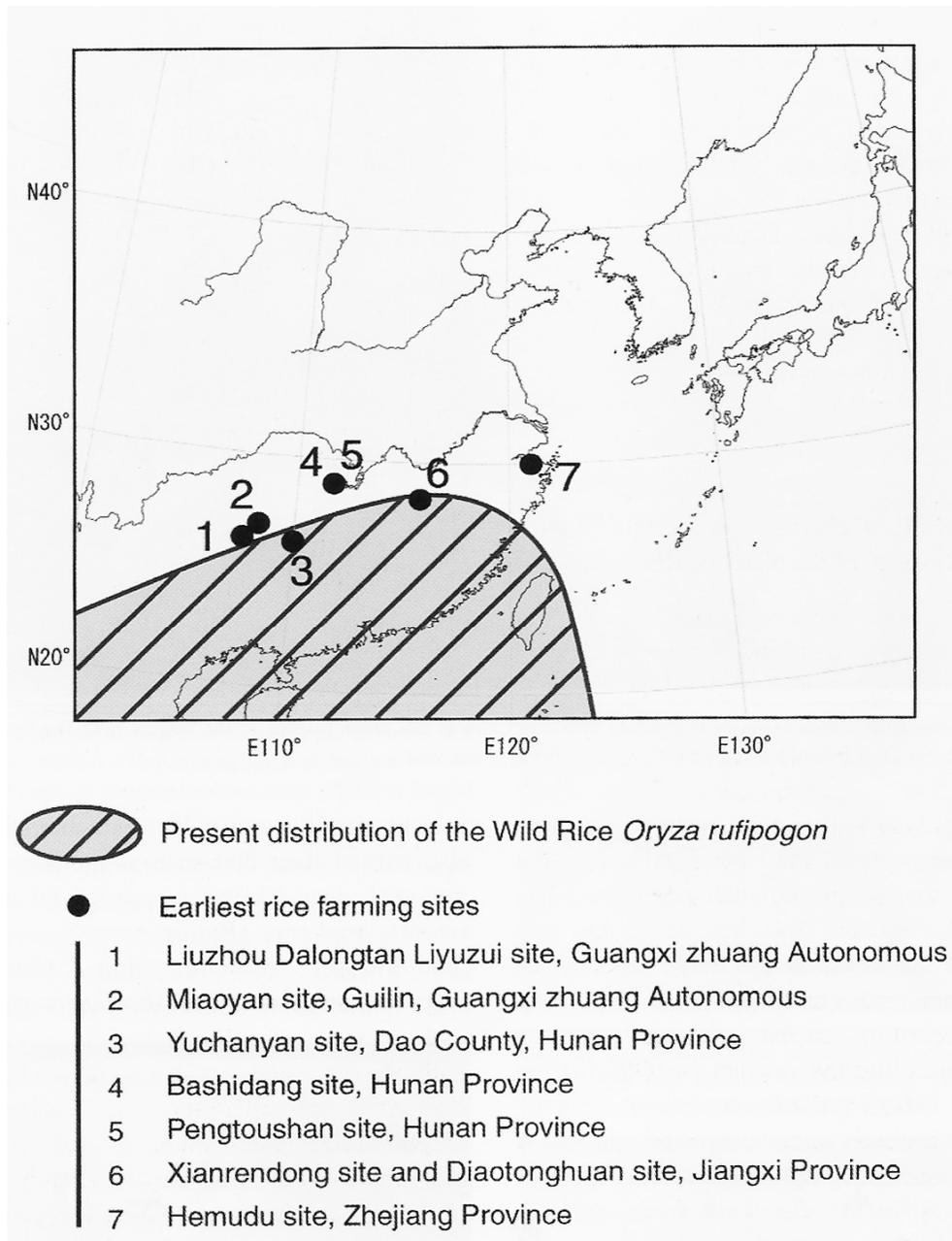


Figure. 6 Map of Southern China, showing the various archaeological sites and range of modern wild rice. (Yasuda 2002)

### Discussion and Conclusion

By examining the data provided above, it is clear that rice was most likely part of the diet as far back as 15,000 years B.P. However, one must also take into account the suggestion that domesticated rice was also present at that time period, bases on the

phytolith evidence (Lu et al. 2002). Even though there are some differences between bulliform phytoliths of wild and domesticated rice (figure. 3), it is only through statistics that identification can be made. This led me to believe that phytoliths could be use as an indicator for the presence of rice within the assemblage, but it could not determine the presence of domesticated rice. At Diaotonghuan and Xianrendong, both cave sites near Dong Ting Lake in the Middle Yangtze Valley region, only the high density of rice phytoliths present in the layers prevents the deposit from being classified as natural. The high density would suggest that rice was brought into the cave by human inhabitants.

Only through the presence of rice stalks and husks being used in pottery temper did I begin to accept that rice cultivation had begun. Wild rice (*O. rufipogon*) has very low yield and significant time would be needed to collect the amount of rice required. The first evidence of rice being used as pottery temper came from the Shangshan site in the Lower Yangtze River Valley (Jiang and Lie 2006). This site is thought to be a sedentary village, as evidence of dwellings and pits were found during the excavation along with numerous stone tool artifacts. However after the Shangshan site, there is also a break in the development of rice cultivation particularly with rice being used a pottery temper. It wasn't until Pengtoushan, that pottery of similar style was found, with a developing rice cultivation system. It was at Bashidang that the first carbonized grains were recovered, the amount of grains present in a small area (15,000 grains in less than 100 m<sup>2</sup> area) (Anping 1998), strongly suggest that the inhabitants have successfully cultivated *O. rufipogon* and through grain morphology comparison some have concluded that the plant was in the first stage of evolution toward cultivated rice (*O. sativa*) (Anping 1998). Pengtoushan is also credited by some (Crawford and Shen 1998) to be the site of the

oldest domesticated rice grains. The rate of development for rice cultivation is thought to be quite rapid, as by Hemudu (5225 ± 425 B.P.), the process has been fully developed, along with a distinct shift in phytolith and grain morphology towards *O. sativa*, however rice husks and stalks were still being used as pottery temper.

Data from figure. 5 only represent the oldest date recorded at each site, with associated source of dating material; Yasuda stated numerous dates in his book which predates that ones that I used, but he did not provide the source for those dates. In order to determine the period in which rice was first cultivated, I felt that the source material would provide strong evidence of the process. Phytoliths, as stated above, are produced by living plants, and are therefore affected by changing climate and growth environment. Phytolith density from one site could not be compared with another due to this variability. Zhijun (1998), through comparative analysis of phytoliths within the Diaotonghuan site, found that the shift between wild and domesticated rice phytoliths throughout the site was abrupt and significant. He concluded that the site represents a temporal map to rice domestication within the area, as the percentage of wild rice phytolith decreases, while that of domesticated rice increases with time (figure 6).

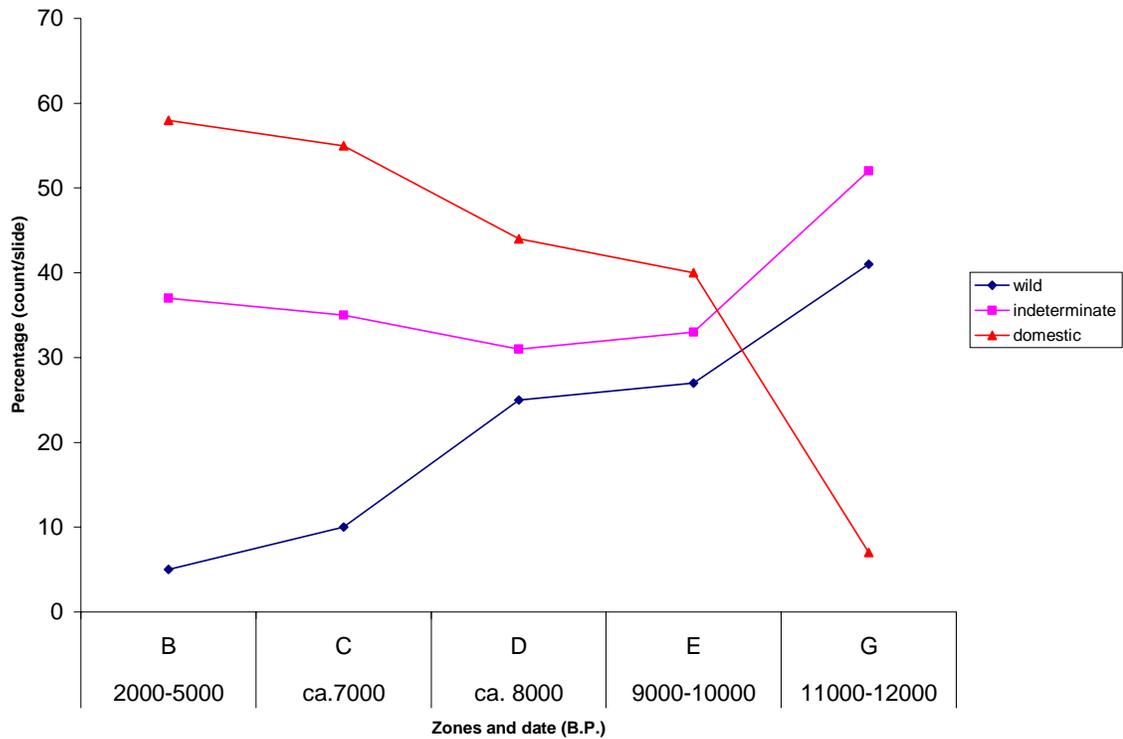


Figure 6. Showing the shift in percentage of various rice phytoliths within the Diaotonghuan site. Zone F is omitted as there were no phytoliths present in the sample.

It was only with the presence of rice being used as pottery temper that I felt comfortable with the date for rice cultivation. As I have stated above, the amount of grains needed to be collected to make pottery is high and wild rice could not provide such an amount. This evidence tells me that rice must have been cultivated during this period, but as the grains and stalks were charred and crushed during the manufacturing process, it is almost impossible to identify the species involved. This lack of speciation is not particularly important as the plant would have been at the very beginning of domestication and morphologically very similar to the wild plant thereby making speciation very difficult.

By Hemudu, as the cultivation process had finished and inhabitants were growing rice actively, the phytolith morphology has gained significant changes from the wild plant.

However since phytoliths are a result of a biological process, the shape and decoration are not uniform leaving certain area of overlap. While individual grains might be difficult to identify, the ratio between wild and domesticated rice phytoliths could be determined for the whole assemblage. This is the same for grain morphology, especially when trying to differentiate between *O. s. indica* and *O. s. japonica*. As shown in figure 4 that *O. s. indica*, within the Yangtze River Valley, originated as a result of random hybridization, I am going to ignore the separation of the two subspecies and will treat them as *O. sativa*

To attempt to separate cultivated rice into two subspecies within the archaeological record, grain morphology and, if viable, DNA analysis of carbonized grains are used. The information gained from this type of analysis is further hampered by the DNA analysis of modern indica rice, which indicates that it may have originated in Eastern India. Others have suggested that the two subspecies split off either very early in the domestication process or as a result of hybridization between the domesticated and wild plant. However, the full analysis of this problem is beyond the scope of data available for me.

In the final analysis of the data available, I had to weigh the source material against the data provided, as stated above. The most important evidence are the carbonized grains, but they only appear in sites that have developing rice cultivation practices. While phytoliths do not indicate the volume of rice present, they indicate the presence of rice at the site. It seems to me that rice was first used in the Dong Ting Lake region, in the middle Yangtze region around 10,000 years B.P., was then transmitted to other cultures both up and down the river, finally resulting in the massive scale cultivation we see today. To pin point the exact time when rice was domesticated is practically impossible, as morphological shifts would be very subtle. Since we are dealing with organic products,

there will be differences among the grains of a single species, making the task of identification much more difficult. As I often stated, only through the amount of rice remains present in the archaeological record could we acknowledge that cultivation has begun.

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