BAN CHIANG POTTERY AND RICE

A Discussion of the Inclusions in the Pottery Matrix

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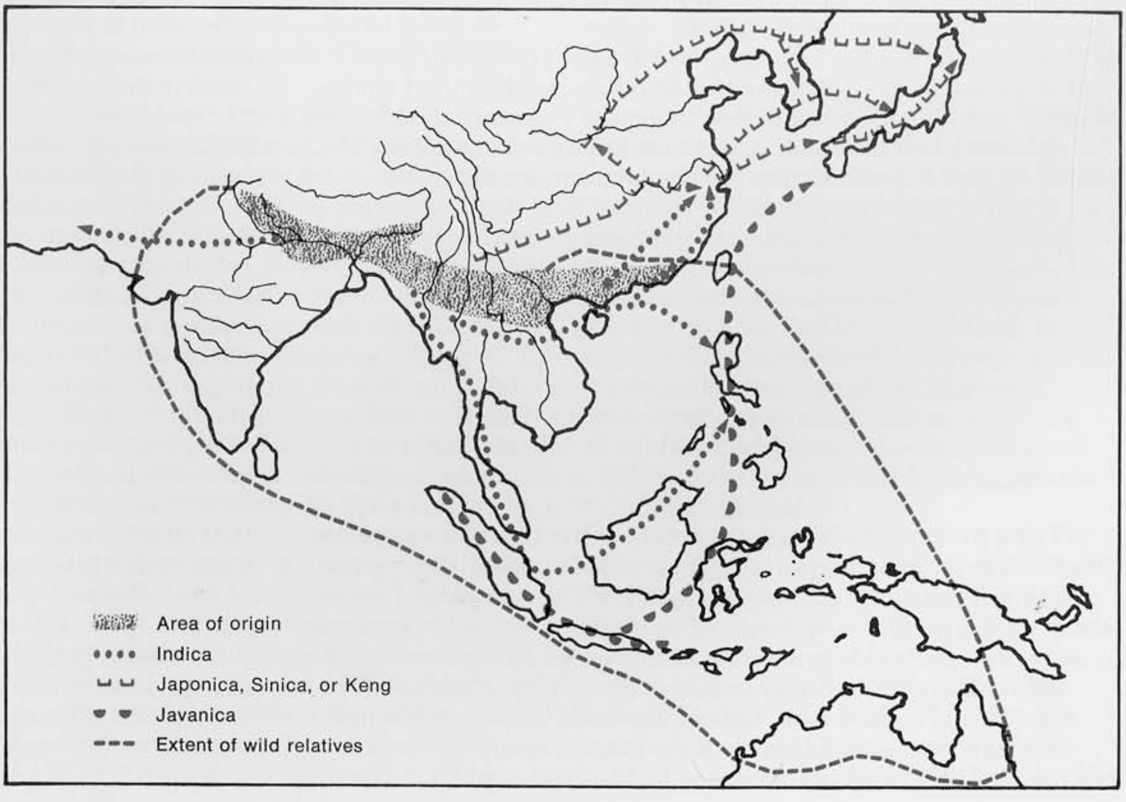
Rice *(Oriza sativa)* remains are hardly novel discoveries in Asian archaeology. Reported as grain husks or glumes, charred endosperms or as husk impressions in ceramics from north and south China, Japan, India, Pakistan and Southeast Asia including Indonesia, their influence on the investigation of agricultural origins has been considerable. (Figure 1).

With the possible exception of some of the materials from the Indian subcontinent (Vishnu-Mittre, 1974) the identification of *oryza* (rice) from archaeological remains in Thailand has undergone more critical scrutiny than other such Asian finds. The reader will note the writer's consciousness in these opening sentences, in which reference to rice remains has changed to the more non-committal identity of the generic *Oryza*. The amplified attention to the Thai material was due to the date of 3500 B.C. or earlier given to charred grain and husk impressions in pottery recovered by Donn Bayard (1970, 1971) from the site of Non Nok Tha. At the time, the only comparable date for early rice was in the 4th millennium B.C. from a Chinese site south of the Yangtse, reported secondarily by K-C. Chang (1973). The identification of *possibly* domesticated plants, none of them major grain crops like rice, in Hoabinhian levels some ten thousand years old (Gorman 1969, 1970) at Spirit Cave, together with the Non Nok Tha recoveries suggested a continuum of domestication that prompted Solheim (1972) to propose the controversial 'earlier agricultural revolution' for Southeast Asia. The much disputed theory of Carl Sauer (1952) advocating the primacy of Southeast Asian origins of Old World agriculture had found further material basis.

This formed the background against which Chet Gorman and I continued our collaboration in late 1973. He had begun work in northwest Thailand by excavating Spirit Cave, as well as two other cave sites



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Dispersal of races of *Oryza sativa* across Asia. (T. T. Chang, 1978).

in this region, prior to undertaking his major research program at Ban Chiang. My role was to complete an ethnobotanical study of the modern flora and its possible relationship to the Hoabinhian plant remains, whose preliminary identifications on publication (Gorman, 1969) had produced stir and scorn (Harlan and De Wet, 1973). The new excavations yielded more plant material for identification. This included nearly whole specimens from Banyan Valley Cave which the archaeologist had jubilantly labelled "RICE!!!" The results of the whole study were published (Yen, 1977), with due caution, and submitted to the eminent rice geneticist T.-T. Chang. He concluded (1976: 146) that they possessed "surface features more indicative of a wild form of rice." This is most significant since the mere mention of "rice" often implied its cultivation. Of course, in 1974 when I visited Gorman at Ban Chiang, we were not yet aware of Dr. Chang's determination, nor indeed that the carbon dating of the Banyan Valley Cave site would yield occupation dates extending only from 3500 B.C. to A.D. 700.

During the 1974 excavations at Ban Chiang, we could see, with limited equipment, that the pottery contained inclusions similar to those in Bayard's Non Nok Tha ceramics. The pronouncement of the geneticist Otsuka (1972) that the *Oryza* fragments were undifferentiable as wild or cultivated forms was to be confirmed by the palaeobotanist Vishnu-Mittre (1973). Subsequently, T.-T. Chang (1976:146) diagnosed a photomicrograph of Otsuka's sample as representing the husk fragments of an *Oryza* form 'intermediate between a wild race and the weed race.' That is, a plant that was disposed to colonize places where the soil has been disturbed, such as takes place with cultivation. The expectation that the sophisticated culture represented at Non Nok Tha—as judged by the richness of its artifacts—should be accompanied by an advanced subsistence base was somewhat dashed by this identification. Indeed, the 'wild' or non-cultivated identity of the *Oryza* remains from recent excavations in Thailand could have been construed to mean that a hunting/gathering economic base for the late Hoabinhian techno-complex of the Northwest was shared by the pottery-making, metal-forging people of the Northeast.

This unpromising start was nearly the finish of any extension of my collaboration in the Thai project to the northeast, but anyone who had the good fortune to work with Chet Gorman also knew of his powers of persuasion. In 1976, I found myself carrying a package of sherds from The University Museum where the laboratory analysis of the Ban Chiang material was proceeding (Gorman and Charoenwongsa, 1976). Final stratigraphic associations had not yet been worked out, but the random sample of 80 sherds from the various levels of excavation all showed evidence of *Oryza* husks (Yen, 1980).

With this result, I asked for a further series of sherds, this time with as accurate as possible a calibration with the Ban Chiang cultural sequence so that each sherd could be assigned to one of the phases Gorman defined. We were also interested in the organic content of the rough ceramic crucibles. These appear roughly at the time of the first iron and are of considerable interest in terms of organic inclusions and what may have been heat resistant temper.

Our hope was that this sequence might reveal a transformation of *Oryza* husk remains from 'wild' forms to those resembling the cultivated *O. sativa*. This optimism was 'tempered' however, by an immovable botanical fact—tiny fragments of grain husks cannot produce unquestionable Linnean identifications which generally require a complete herbarium specimen. We had to look for micro-characters within the limited archaeological material that might give us some *approximations* to species identity, and even more remotely, of the wild/cultivated differentiation. Most work of this sort, after the initial stages, produces an hypothesis to prove or disprove. Ours, which was partially stated by Yen (1980:142), can now be expanded as a prelude to the description of the material.

For the non-specialist who may find Dr. Yen's discussion too technical, the following explanation may be helpful. In general the situation has been suggested to be something like this. Wild rices have an irregular pattern of cells on the husk. This irregularity exists in terms of both cell shape and the arrangement between cells. Domesticated rice (*Oryza sativa*) is different. Here the husk cellular pattern is regular. Cells tend to be squarish and arranged in a regular 'checkerboard' pattern. It is presumed that the more regular the cellular pattern the more domesticated an individual sample can be said to be.

THE INFLUENCE OF THE MODERN VIEW OF RICE ORIGINS

"The Asian rice (*O. sativa*) evolved from an annual progenitor over a broad belt that extended from the Ganges plains below the foothills of the Himalayas, across Upper Burma, northern Thailand, and Laos, to North Vietnam and south China" (T.-T. Chang, 1976:143).

Our adoption of this scheme (Fig. 1) is possible only because of the splendid research done by plant geneticists of south and east Asia. The very wide geographic origin that transcends modern political and cultural boundaries, however, conforms to the definition by Harlan (1971, 1975) of a 'non-center' (in its more debatable relationship with the true 'centers,' in this case north China), where the domestication of one plant could occur many times within human history, and be dispersed over many thousands of square kilometers. A corollary to Harlan's theory may be that the directions of selection in the process, and the genetic nature of the subject species, were not necessarily the same in each location since they may have been separated not only spatially but temporally. This may find some support in the differentiation of modern races of rice into the groups Indica, Japonica or Sinica and Javanica (Fig. 1). Each of these has distinctive characters involving some genetic isolation between groups as well as anatomical and quantitative contrasts and geographic separation. Thus, at a very particular scale of study, rice remains recovered from several archaeological sites could exhibit significant intersite differences. It may well be that such variation would be expressed in the wild characteristics of cellular structure possibly detectable in the fragmentary husk inclusions in pottery. Such an hypothesis takes literal cognizance of the long held view that domestication is a process rather than an event—and thus evidence of domestication should include intermediate stages between wild and cultivated states. In the adoption of such an approach, the study of the material requires control comparisons, not only of domesticated rice but of the recognized close *Oryza* relatives as well. In terms of the identifications that have been made of the recently excavated Thai materials, this may suggest that the Banyan Valley Cave and Non Nok Tha materials represent different directions of domestication, different stages that yet did not form a connected series. Chang's identifications (see earlier), read carefully, may further suggest that the Non Nok Tha material could represent the man-guided evolutionary pathway towards rice that was closer than that from the northwestern site. Indeed, it may be that as more 'rice' remains are found in late Hoabinhian sites, examples of the blind alleys of domestication may be found—remains with wild characters, or those inseparable from wild *Oryza* forms. In other words, these would represent the discards in the progress of the dispersed process of rice domestication, which, in their day, held promise for their domesticators—early or incipient farming groups of Southeast Asia.

It is hoped that this digression into the sometimes vexing questions of agricultural origins may show its relevance in this report on Gorman's Ban Chiang pottery material. In the course of this study, we were able to include similar pottery material from the site of Ban Nadi. This is 25 km. southwest of Ban Chiang, and was excavated by Charles Higham (1981), one of the leading participants in Gorman's earlier work.

DESCRIPTION OF MATERIAL

During the 1974-75 excavations at Ban Chiang, occasional charred grains were recovered which Gorman identified as 'rice' (personal communication). These were often, but not always, associated with burial goods, the earliest of which, because of the incidence of painted pottery, could have been as early as 1600-1200 B.C. or Phase IV on the approximate chronology of Gorman and Pisit (1976). Inspection of this material confirmed that it was *Oryza* but its consistently small size possibly indicated that it was wild. On the other hand, three things suggest that the rice could have been cultivated:

(1) There is ample evidence that rice was already cultivated at this time in India and China.

(2) Shrinkage through the firing of the pottery and due to archaeological deposition could neither be eliminated nor allowed for. Experiments reported by Renfrew (1973:11) comparing fired and unfired grain samples of wheat, barley, oats and rye, offer us a cautionary note in this consideration of *Oryza*.

(3) Cultivated rices collected from indigenous subsistence farmers of northwest Thailand, include varieties that are no larger in grain size than those identified as 'wild' in the archaeological husk samples that had been excavated from Banyan Valley Cave (Yen, 1977:587).

In citing (3) we are obviously deferring to our previous discussion of the nature of rice origins in a non-center.

To further investigate this question of whether the Ban Chiang and Non Nok Tha rices were domesticated or not, we turned to the pottery sherds once again and the anatomy of cell structure as a possibility for identification. This is similar to the experience of Buth and Saraswat (1972) working on Indian archaeological materials, who stated that charred caryopses are better material for identification than charred grains, because of the preserved cellular details. Unfortunately, they did not specify 'the morphological and anatomical details to enable classification at least up to groups of species' (p. 33), other than to indicate the 'typical chess-board pattern of cells of husk in surface view' (pl. 1) as diagnostic of *Oryza* sp. As will be seen, this criterion was to prove inadequate in terms of our materials.

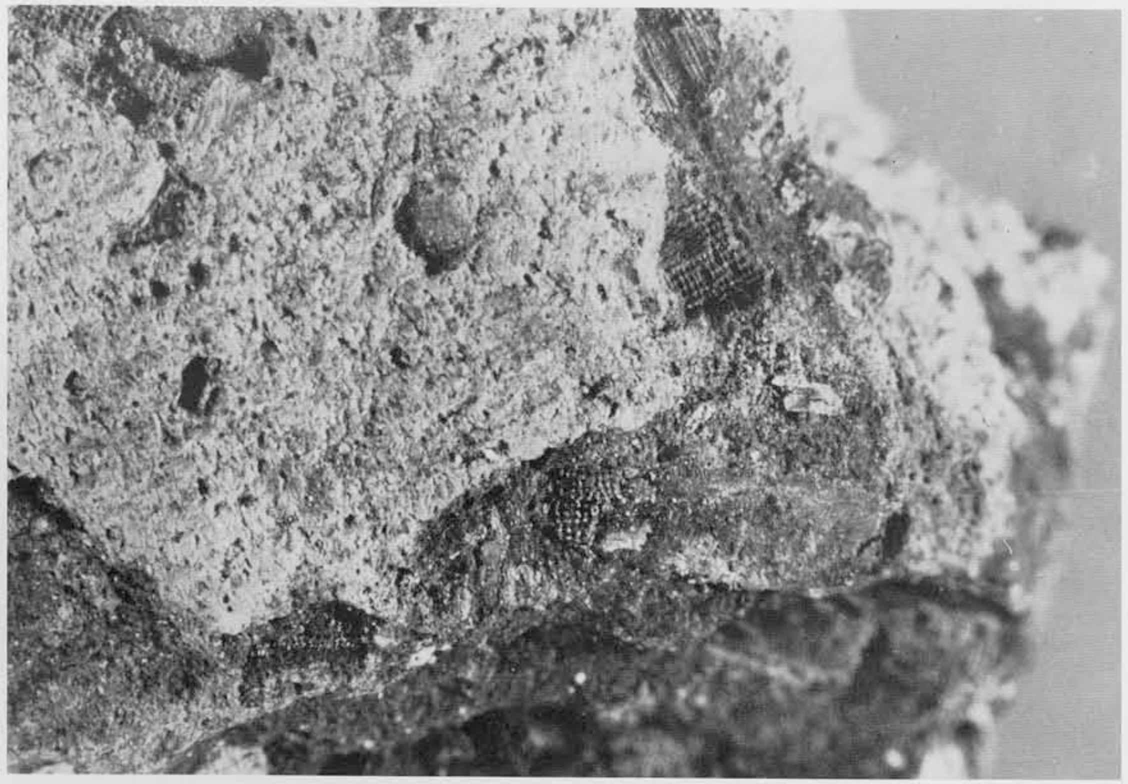
The study of the first 80 sherds from Ban Chiang allowed us to settle on a technique for the investigation of the second set of 67. We adopted three initial approaches:

1. *Low-power light microscopy:* At 18-20x magnification, we could distinguish two predominant forms of *Oryza* remains: impressions that were of a chess-board pattern, and the still identifiable, actual remains of husks. Generally, only the impressions were detectable on the inner and outer surfaces of sherds. The direct evidence of husks themselves, first found on the broken edges, as well as further impressions, could be more consistently seen by making new breaks across the sherds. Figure 2 shows a particularly productive sherd, with a concentration of impressions and burnt husk on a broken facet.
2. *X-ray inspection:* Owen Rye suggested an adaptation of an x-ray technique that he had used (Rye, 1977) in the study of pottery temper, to quickly detect organic content. We found that although all the Ban Chiang sherds contained organic matter, there was considerable variability in content or density, but we could not associate these differentials with position on the pot of which the sherd was originally a part. It was noted, however, that the four rim sherds in the first sample of 80 were among the lowest in density scores for organic matter.
3. *Scanning electron microscopy* (SEM): John Preston of the SEM Facility at Australian National University suggested the use of this form of microscopy to overcome the difficulties that we were having in defining the cellular structures in our material using a normal light microscope. After we had coated the freshly broken sherd fragments with gold, the high resolution capability of the SEM enabled us to see clearly husk and impression with associated structures. Figure 3 exemplifies the utility of this approach to the material. All fragments of husk as represented in the pottery were of minute proportions, the maximum being 1000 μ at their longest dimensions.

It was obvious that the SEM would be the major tool for the study of the second, calibrated group of sherds requested of Gorman. Some limitation, however, restricted the choice of sherds. Gorman had to be certain that he did not require the sherds later for thermoluminescence dating, since both x-ray (Rye, 1977) and SEM (John Head, personal communication) would have adverse effects on the material for that purpose.

By using the photographic attachments of the SEM, it was not only possible to obtain a permanent record of the scanning of each sherd but, standardized at three magnifications, the prints could be used for more extended, detailed observations and measurements.

An integral part of the study was, of course, the determination of cellular char-



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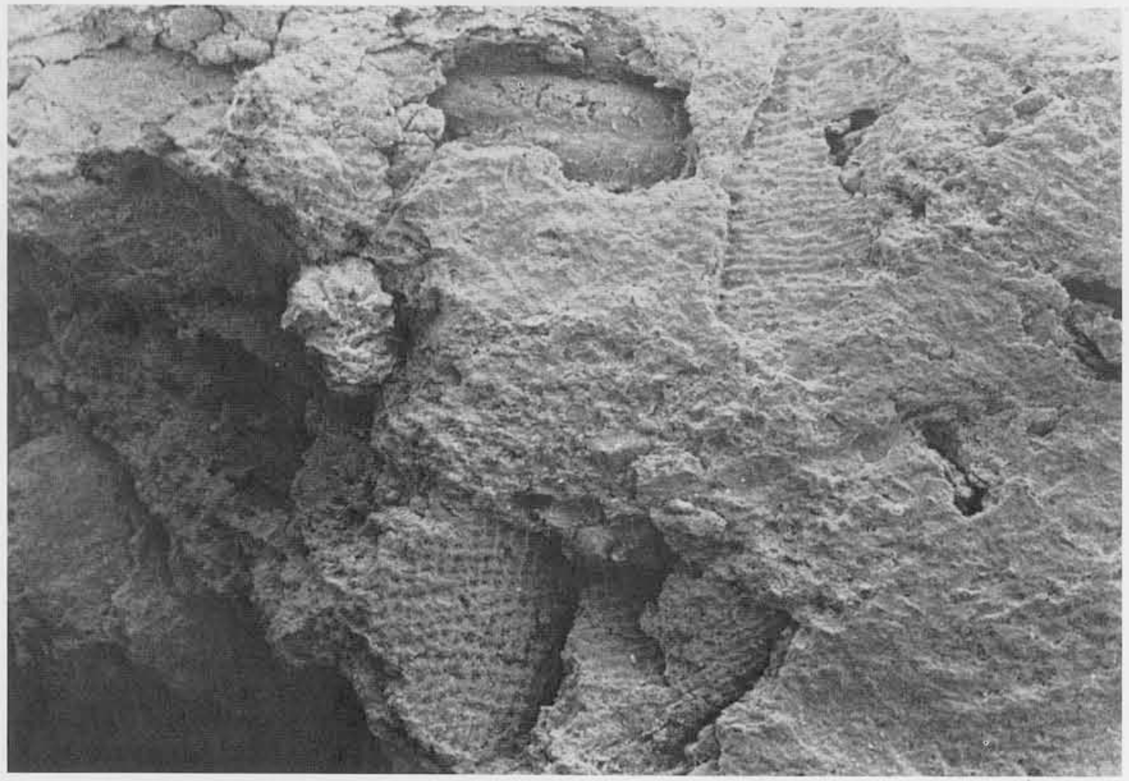
Ban Chiang pottery under low power light microscopy (x18). This sherd is extremely rich in *Oryza* husk remains, especially at the broken edges; distinct impressions also visible on the external pot surface (upper left), demonstrating the chessboard arrangements of husk cells, typical of rice.



3
SEM picture at low magnification showing a fragment of *Oryza* grain embedded into pottery matrix (top center). The impression to the right is of the reverse or inner surface of a husk fragment. To the bottom center is a group of impressions and actual husk pieces.

4
Cell shape characters of *Oryza* husks (from T.-T. Chang, personal communication)

Species	Cell Shape	Trichomes-Papillae	Cell Wall Thickenings
O. perennis	square, rectangular	present	double wall, serrated
O. spontanea	square with raised cells (gives a small roundish appearance)	few	thick, cell walls not distinct
O. rufipogon	square	few	thick wall, distinct (gives a roundish appearance to cells)
O. sativa (indica)	big squares	none	double wall
O. sativa (japonica)	small squares	none	thick double wall

acteristics of contemporary wild and cultivated forms of *Oryza* as control comparisons with the archaeological material. We coated whole grains as we had coated the sherds and scanned them at the same magnifications. Table 1 incorporates the control samples used, representing species recognized as having an ancestral role in the evolution of rice. The problems of taxonomy, such as the questionable separation of *Oryza rufipogon* and *Oryza perennis*, are here skirted by simply presenting the identification of the donor, and the provenience of each sample. The Table also includes the anatomical features provided by T.-T. Chang (personal communication) as possible differentiating features between wild species and cultivated rice. For the latter, we used modern, highly bred varieties and cultivars collected from subsistence farmers of northeast and northwest Thailand.

An ancillary control was the SEM photography of plant parts other than the husks, which we thought might be found in the pottery. These included sterile glumes (the husk glumes with which we are dealing are called 'fertile'), awns (the usually elongate attachments at the distal end of the husk, often characteristic of wild species and subsistence varieties of domestic rice), petioles or the stemlet attachments of the grain to the main stems of the plant, stems and leaves. We were also prepared for the identification of grain fragments—and less so for the remains of other species—but we have controls available of two of the commonest weeds, *Chenopodium* and *Amaranthus*, associated with modern rice paddies and swiddens (wet- and dry-land traditional cultivations).

As far as parts of *Oryza* other than husks are concerned, they are virtually absent in the pottery, except for the very occasional inclusion of grain fragments (Fig. 5). While, perhaps due to frequency of differential preservation through firing, the husks predominate, it is highly likely that this reflects the condition of the grain after harvest. The significance of this innocuous observation is treated in the following section on pottery making.

ORYZA HUSKS AND BAN CHIANG POTTERY

Although it may not seem so, we already have data on which some implications regarding the manufacture of Ban Chiang pottery may be drawn:

(1) Since *Oryza* husk particles have been found in every sherd we have examined, it is a justifiable contention that such inclusion was a part of pottery-making techniques throughout the cultural sequence. Rye (1981:33) has noted the use of crop plant waste as temper, citing straw remains in southern Arabian ceramics. He states that its function is to reduce shrinkage and improve the workability of clays that are too plastic. He also notes that much organic matter is burnt out in firing, leaving voids which interrupt cracking in cooking vessels due to thermal stress.

(2) Again, according to Rye, uniformity and fineness of inclusions of organic matter indicate that they are more likely to be deliberate additives to the paste than natural occurrences in the original clay matrix.

(3) The relative purity of the organic remains indicates something of the nature and derivation of the husks prior to inclusions as temper. Its most likely condition is that they are the winnowed byproduct of milled grain or caryopses. Such a procedure conforms to agricultural practice with rice in modern Thai villages where stored grain, from threshing floors after harvest, is milled according to individual household requirements prior to each meal. Since the large wooden mortars for milling are seldom moved from their position near houses, stockpiles of husks accumulate from winnowing. The earlier threshing process, by which the dried bundles of spikes brought in from the field at harvest are divested of the whole grain (with husk still intact for storage), also eliminates most of the appended structures of the grain (awns, if any, petioles, leaves, stems) through the first winnowing. This contrasts with other Southeast Asian practices, such as in the Philippines, where such hill people as the Bontoc (Jenks, 1905) and Ifugao (Conklin, 1980) store their grain as dried bundles. Milling consists of the pounding of these bundles. If these winnowings were used for pottery making, fragments of grain *appendage* material would be expected in the paste components.

Rye (1981:34) makes the suggestion that the inclusion of such post-harvest material indicates the seasonality of pottery making, but agricultural storage is a factor that may limit adoption of this idea in the Ban Chiang case. What we do not know is whether such storage techniques existed any time in prehistory, whether any of the archaeological evidence for structures is mute testament of the presence of specialized or unspecialized granaries (e.g. granaries are a part of residence structures in Ifugao, whereas they are smaller discrete and specialized structures in modern north Thailand). Be that as it may, the paucity of evidence for plant genera other than *Oryza* in the Ban Chiang pottery reflects not only the deliberate nature of its inclusion, but also the careful nature of grain harvesting which excluded contaminants such as weed species at the milling stage.

Of course, one may suggest that such contaminants are destroyed differentially on firing. However, if modern village practice is considered relevant, collections of winnowed husk material from northwest Thailand made by the writer from freshly milled grain were notable for the absence of other species. However, despite the vigorous pounding, the surviving husk remains were considerably larger than those found in the archaeological sherds. Further and more direct ethnographic observations have been made on the association of rice husks with pottery making in the region of Ban Chiang. Observations by Gorman and Joyce White indicate that the incorporation of rice husk into matrices of modern pottery is done in two stages: first, a mixture of clay and rice husk in approximately equal proportions by volume is fired in regular shapes, round, cylindrical or brick-like, and then stored. When pot making is undertaken, these are crushed and added to fresh clay, again in the same proportion, as a sort of 'grog,' which is strictly defined as crushed damaged pottery sherds (Rye, 1981:33). Gorman collected small samples of three stages of pottery manufacture—the fired primary mixture of clay and husk, the crushed grog, and a body sherd of a finished pot. The first sample was the most revealing, since the husk fragments and imprints were much larger than those in the archaeological pottery, with many nearly whole palea and lemma (the two separate parts of the glumes enclosing the rice grain). The grog however, had been so thoroughly ground that there were only a few structures confidently identifiable as rice husk. In the SEM scanning of the sherd, we were unable to find evidence equivalent to that in the excavated pottery.

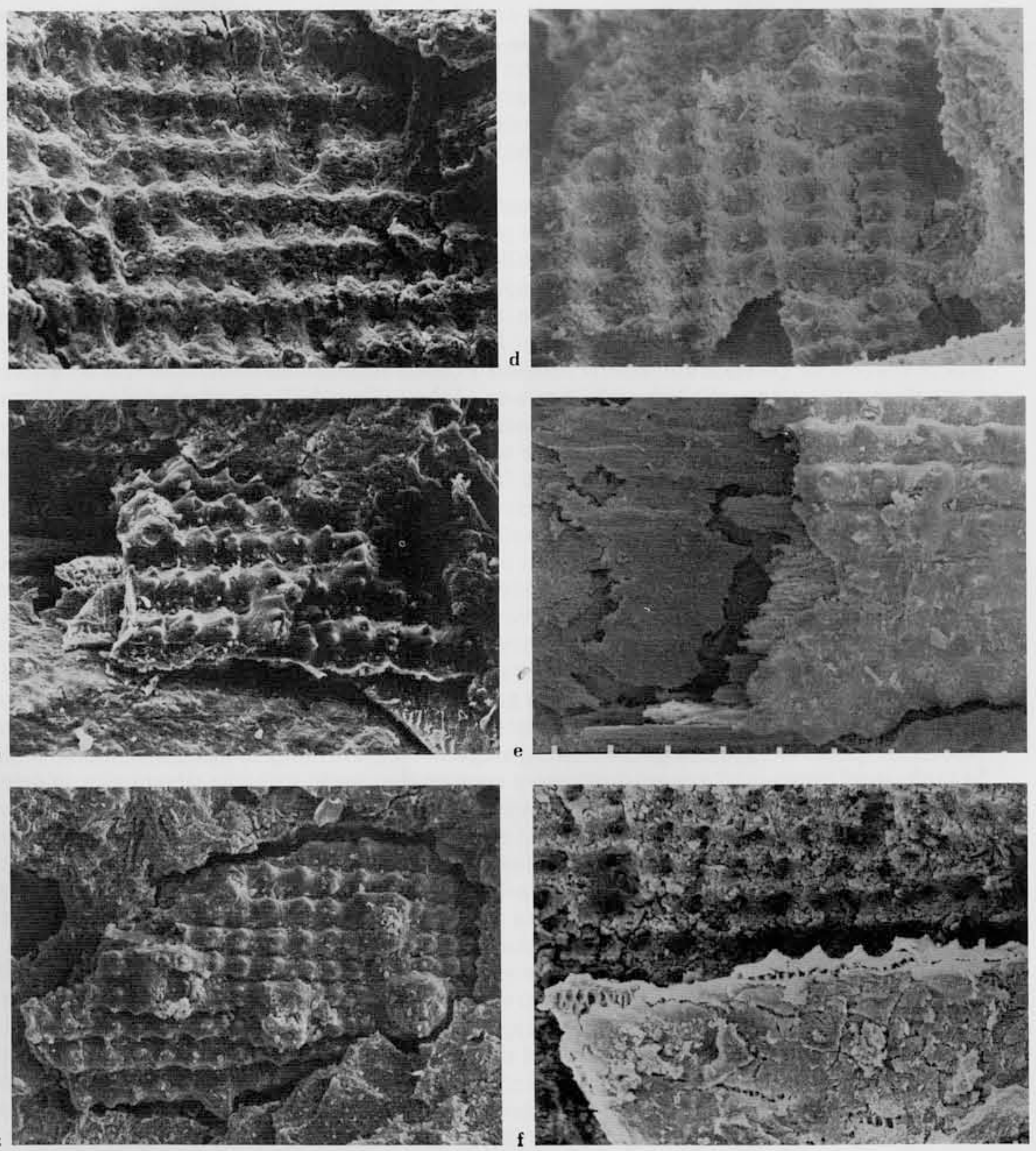
On this sampling then, admittedly a small representation of modern northeast Thai potting technique, it would seem that the prehistoric incorporation of husk material into the pottery paste was effected by some similar secondary reduction of its size, not as drastically as evidenced in the ethnographic example. Perhaps this reflects something of the function of pots, for in modern times, with the universal adoption of metal culinary gear, the heat resisting property in cooking use is hardly an imperative.

Whatever kind of economy we are addressing at any stage in the prehistoric Ban Chiang sequence, whether grain agriculture or a form of grain harvest in a hunting/gathering pattern, one thing seems certain. The conversion of a subsistence byproduct to an 'industrial' use is a constant from the beginning of the sequence, through all of its cultural transformations.

TOWARDS IDENTIFICATION

This section describes, in summary, the survey of the Ban Chiang sherds representing Phases I to VI in the cultural sequence and comparisons with the control—wild species and cultivated rice. The husk impressions, whose frequency was greater than the actual husk remains, had to be included in the study, despite the possibility that some qualitative and quantitative features of the cells might be obscured during the original process of pottery manufacture, e.g. flattening by pressure, or indeed, the effects of firing. However, the husks themselves would also undergo undefinable distortional influences. Figure 5 illustrates, with both impression and husk responsible for the imprint, that spacing of cells at least corresponded. The characters studied (see Table 1) then, are differentiated on this basis in this description and comparison with controls.

Cell shape: The surface structure of the grain husk cells is recognized as an important taxonomic character but, generally, such criteria have been applied only to the differentiation of sectional partition of rice (e.g. Kihara and Katayama, 1959), using an impression method on fresh material. The choice of 'control' species (Table 1) for our



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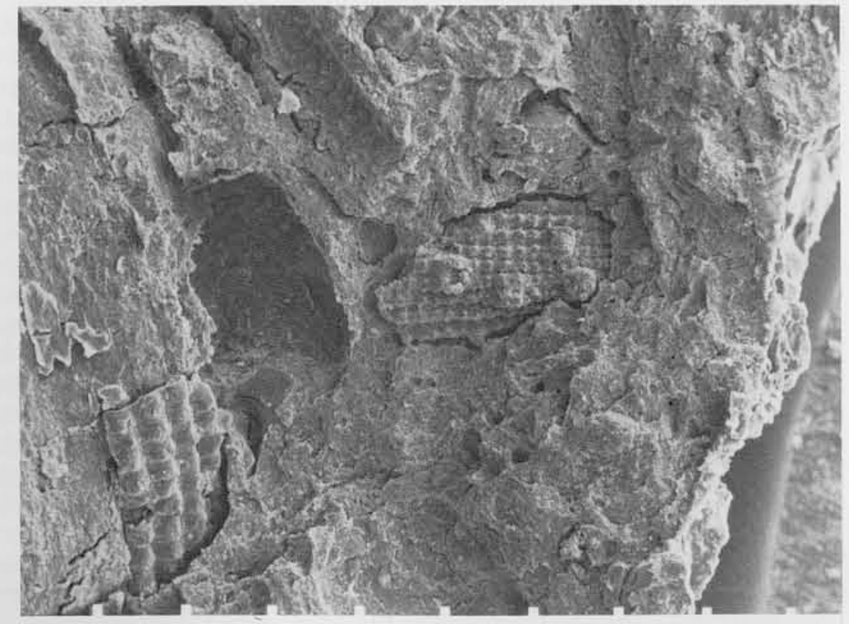
A series of SEM photographs of husks and impressions in the six phases of Ban Chiang pottery; from **a**, representing Phase I to **f**, representing Phase VI.



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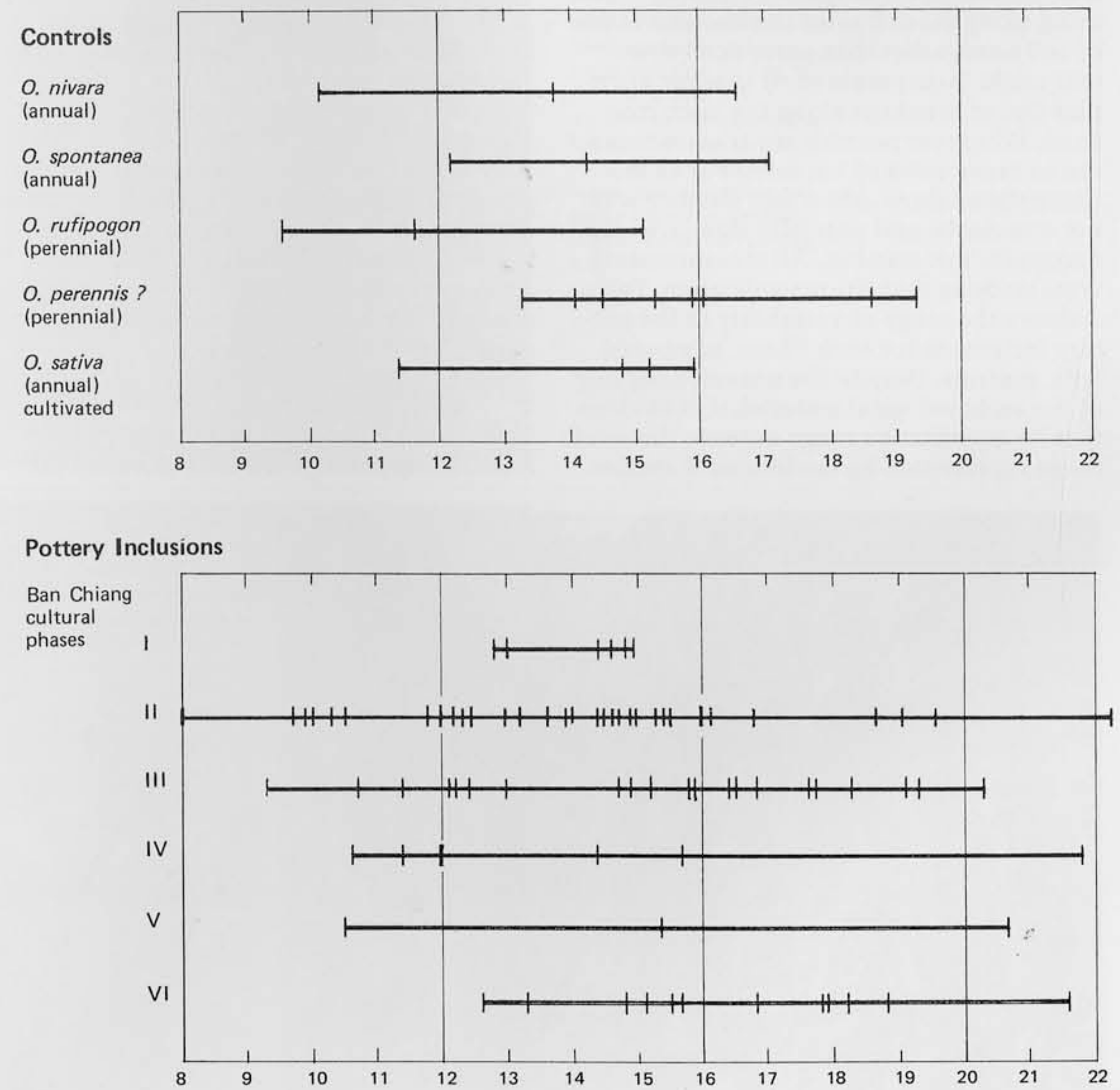
SEM photograph of a Phase III sherd illustrating cell size differences between two husk fragments of *Oryza*. Fragment to right is represented at higher magnification in Fig. 4c.

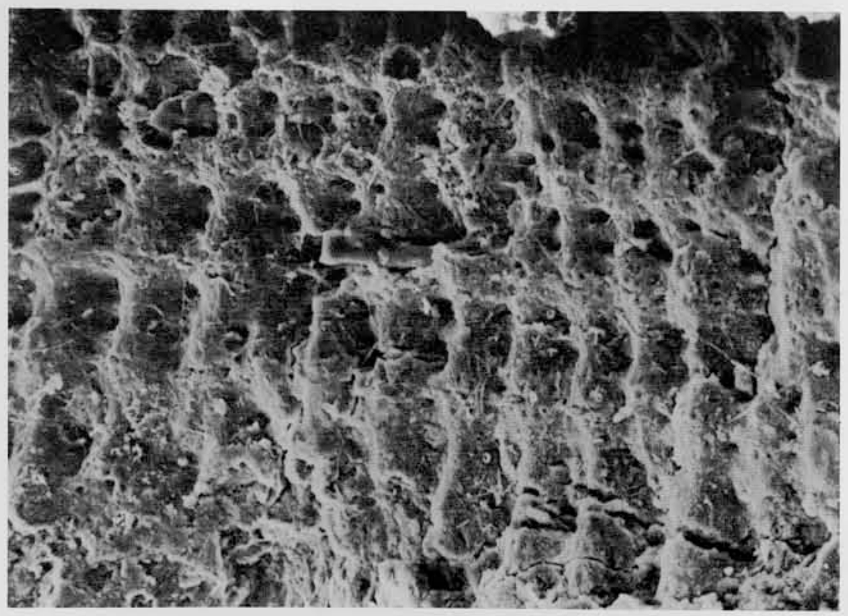


7
A comparison of cell length/index of husks in *Oryza* species (Controls) and archaeological material (Pottery Inclusions). Although this represents only a partial result from the SEM study, and is subject to sampling error (see text), the variable nature of the archaeological material seems convincing, and may indicate hybridity in the 'rice' populations represented.
Each point on the scales represents, in the case of the controls, a single sample of the species; in pottery inclusions, a single measurable fragment. Numbers = 10μ.

project was based on the characteristics of the preliminary electron microscope scanning of the pottery material from Ban Chiang. Since the cells all showed a square or rectangular basic construction, with relatively smooth tubercular projections, we knew that the archaeological material would be represented in the Sativae section of *Oryza*. It may be seen from inspection of the photographs of the pottery material, however, that there is abundant variability in cell structure nevertheless, but, as we have already noted, we cannot assign all of this to the intrinsic nature of the *Oryza* material it represents, any more than to the possible distortions that could be the result of the ceramic manufacturing process.

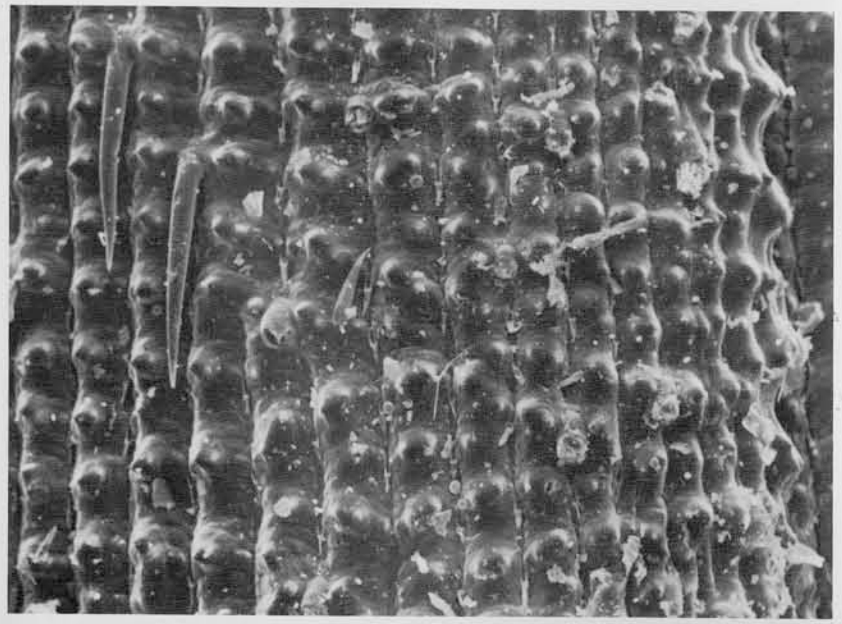
Cell size: The variability of shape is paralleled in size. On representative testing of individual cells, the square shape of the archaeological material was confirmed, so that we attempted to quantify size by measuring along the cell rows to obtain an index of cell size (rather than across cell rows that might incorporate error in some examples due to breakage along the inter-row axis). Wherever possible we tried to measure as many rows of ten cells; but as the illustrations show, often that number was not attainable, and normally three was the maximum row number. All measurements were made on the 100 μ magnification. Table 2 shows the range of variability in the pottery inclusions for each Phase, compared with controls. Despite the uneven sampling of the archaeological material, it is obvious that its quantitative range exceeds the *total* range represented by modern wild species putatively involved in rice parentage. We might indulge in speculations of the manufacturing effects in terms of shrinkage at one end of the range of variations of the size index, and expansion due to compression at the other. The clustering of the cell measurements of most of the pottery husk fragments towards the middle of the range, however, may be more significant. Perhaps controlled experiments on pottery making —the effects of the working and firing on rice husk particle inclusions—may be warranted to elucidate the seemingly greater variability of measurable cell size in the archaeological material than observable in control species. If, however, we could accept the results at their face value, it might be possible to account genetically for what is, after all, an asychronic comparison. For the control species have been through some 2000 years longer process of 'natural' selection than the archaeological material. We do not know the quantitative characteristics of those species at that, and earlier, times. The wide variability of cell size in the pottery inclusions may then be reflections of a wider range of variability in the parental material of 5,000+ years ago, or it may be that hybridizations of wild species, some perhaps gathered for grain, produced segregation for the cell size character that was transgressive of the parental range. Such expectabilities are theoretical configurations that may well be applicable to the early phases of domestication.

Trichomes: In our first SEM survey of the Ban Chiang pottery, we did not notice the



8
A husk impression in a sherd from Phase II, showing an embedded spike-like body (upper center) identified as a fossilized trichome, probably from the husk fragment responsible for the impression.

hair development on the husk fragments, so that the indication, on this criterion alone (see Table 1), was that the inclusions represented cultivated rice. However, with the use of higher magnifications, nearly every husk fragment showed signs of breakage of the inter-row trichome features. Moreover, it was in a few examples of husk *impressions* that actual detached trichomes could be detected, while other impressions showed long indentations that *could* represent trichomes, the actual tissues being lost in the firing process. The potential reversal of 'identification' of all specimens as wild *Oryza* was soon qualified by the observations in the control cultivated rice samples from northern Thailand, when a high percentage were found, even under normal light microscopy, to evidence the presence of trichomes. While it seemed that densities of hair development were lower in cultivated varieties than in wild species (Figs. 9, 10), the small dimensions of the pottery-included fragments, in relation to their position of origin on original husks, made such relative values meaningless. This can be illustrated in reference to Figure 9. If a husk fragment is extracted from the center or sides of the caryopsis, trichome development is dense; from the intermediate positions, trichomes are less frequent. This applies to all material—wild species, or those cultivated varieties with hair development.



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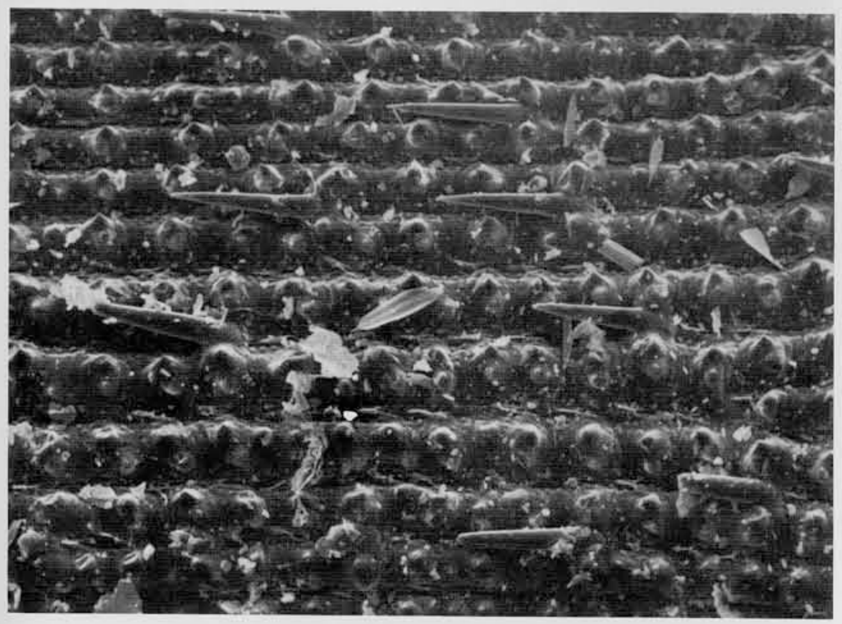
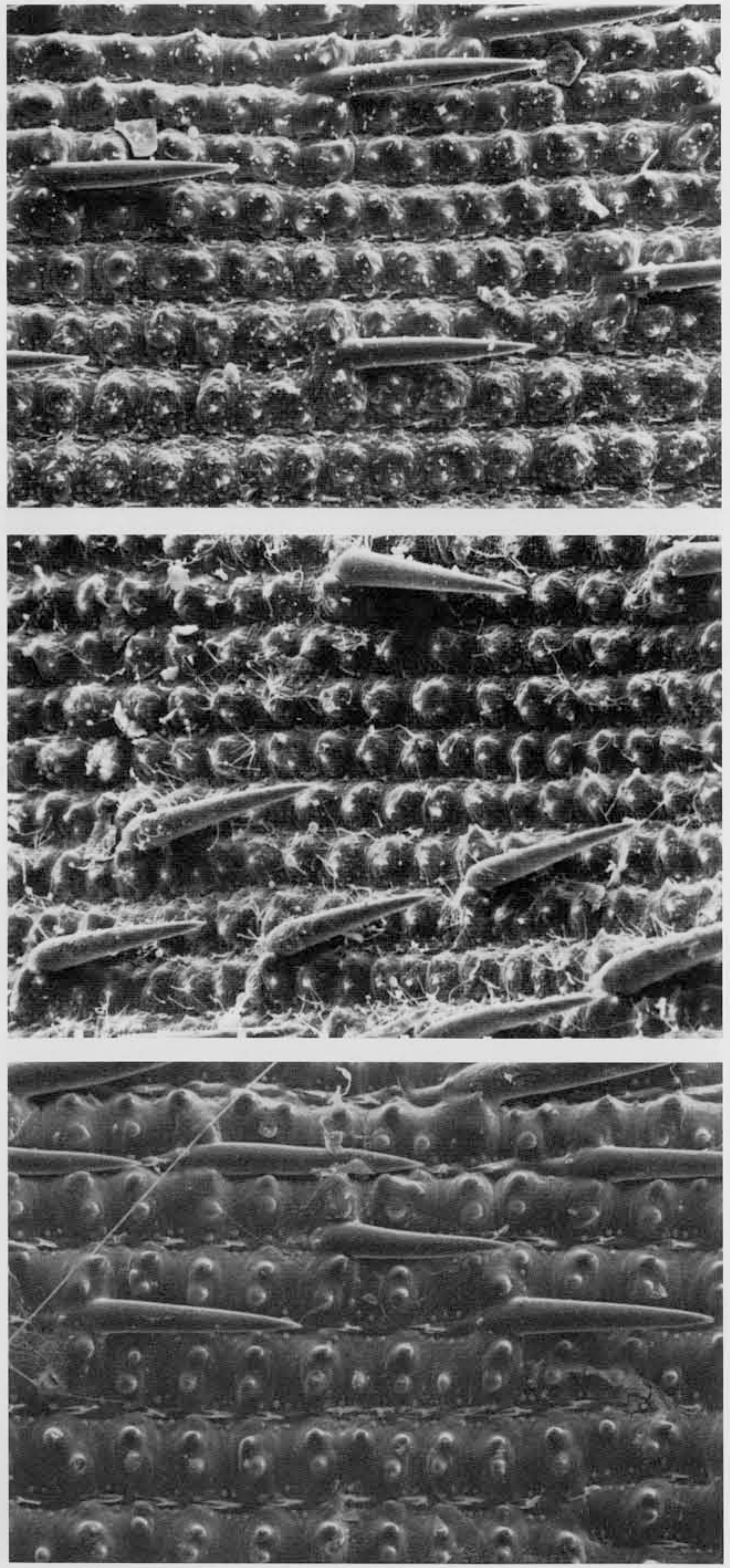


b

9
The controls: 2 cultivated rice varieties collected from subsistence farmers in northeast Thailand. SEM photograph of husk surfaces at same magnification as Fig. 5. Note in **a** that the trichomes visible on the left are broken on the right of the field, to leave 'scars' similar to those found in archaeological material (cf. Fig. 5c).



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The controls: Surface of husk cells of 3 species of *Oryza* posited as ancestors of cultivated rice; **a**, *O. rufipogon*, **b**, *O. nivara*, **c**, *O. perennis* (or *O. rufipogon*).

a b c

TOWARDS INTERPRETATION

The differentiation within the Sativae section of *Oryza* through husk cell comparison can only rely on the most brittle of comparison, a discovery that had to be made in this project since, as T.-T. Chang (personal communication) has said, every worker with SEM 'has skipped the hull [husk] and only studied the endosperm and embryo.' Should we rue the absence of other associated plant structures in our material, or, ideally, comparisons of herbarium standard (virtually whole) plants, let us see what one rice authority says: "In point of fact, there is no character which distinguishes *O. rufipogon* Griff. from *O. sativa* except that of early and complete shedding of the grain even before it is fully ripe and dry." (Grist, 1953:265).

Our pottery 'rice,' if it had contained recognizable grain attachment structures (pedicels and rachillae), *might* have told us more; whether the grain 'shattered,' that is, fell to the ground before harvest, or was non-shattering, which is generally regarded as an advance due to gene selection. This argument for advanced genetic composition is based on the more-or-less common sense notion that 'wild' species of cereals including rice would be predominantly shattering types since this would promote the seeding process under untended 'wild' conditions. When man entered the picture and began to harvest these plants he would tend to select the non-shattering varieties since the seeds on the head of grain would be likely to remain together when plucked or hit by a sickle. Thus, over long periods of harvest we believe that gradually plant populations were shifted from being predominantly shattering to non-shattering. It must be remembered however, that the perennial *rufipogon* form is not thought to be the immediate progenitor of the annual *sativa*. That status is reserved for the annual and wild *nivara*, so what are the possibilities of distinguishing *sativa* from *it*?

Indeed, T.-T. Chang's identification of the Non Nok Tha material as intermediate between a wild race (presumably *sativa*, a further complication) and a weed race may be as serviceable (and non-committal) an identification as we can apply to our study material. We may hypothesize that what we are looking at is a mixture of quantitative genes affecting the expression of husk cell structures, some of which were retained (e.g. large, squarish, thicker walled cells) in more developed rice varieties, some subject to negative selection that was never completely eliminative (e.g. trichome formation).

There is abundant testament (e.g. Grist, 1953; Oka, 1980 in a collection of his earlier essays on rice evolution) that modern populations of rice, not subject to pure line selection but grown in proximity to wild *Oryza* populations, will often exhibit gene exchanges. It is thus not unlikely that populations of 'rice' already cultivated 5,000 years ago *should* show a similar effect of hybridity. As stated elsewhere (Yen, 1980), early domestications (and not necessarily the first or only) must be hard to identify, especially when they are evolved, and still evolving through a process of hybridization and selection. In a non-center situation, the directions of selection may be narrow in terms of total variability, but broad in terms of human preference and the element of chance in the unconscious aspects of selection. Perhaps the Ban Chiang rice in those early times was *relatively* uniform in the utilitarian characters of yield constancy and satisfaction of human preferences—the variability being a desirable feature of genetic buffering against environmental amplitudes. We may never recover husks from early Asian sites that are exactly like those of modern commercial varieties, but we contend that the difference between our archaeological material and some of today's indigenous subsistence rices is narrower than would be expected from some model of simple lineal progression of evolution of wild to cultivated. That plant domestication is a process rather than an event is a theoretical concept hard-won since the early studies of de Candolle (1886). Perhaps it is a part of this process that Ban Chiang reflects.

We return to the archaeological context of the Ban Chiang finds. To this writer, it would be incredible for that civilization to have been founded and maintained for over 3,000 years on a grain gathering economy. We have described the culture as sophisticated as evidenced by the material manifestation of the structure of the society—metallurgy, ceremonial burial practices, animal husbandry, pottery making, and the elaboration of elements of personal adornment that utilize more than natural materials for their effect. Changes there were, not of structure, but within the elements of the components of that structure (style, iron added to bronze, etc.). That Ban Chiang could parallel the Near Eastern examples of Flannery (1969), in which sedentary village life in early settlements occurred *before* plant domestication, is unsupported by our plant evidence—for the persistence of 'wild' characters through our sequence contrasts with the evidence of wild-to-cultivated conversion in the Iran and other western Asian examples. Flannery (1973: 274 *fn*) himself, however, conditions his original argument with the caution that wild characters in plants do not prove their non-cultivation . . . our very point.

A classic criterion in archaeology for the presence of cultivation is the quantity of direct plant evidence. We may not have weights and numbers to support our contention of agriculture throughout the Ban Chiang sequence, but the quantitative *implication* is there, embedded by consistency and persistency of rice husk fragments through the stylistic modulations of the surfaces of the pottery through nearly 4,000 years.

The final question is the provenience of Ban Chiang rice (one notes the increasing boldness of the identification), and subjective caution prevails. The immediate origin could have been the next village; the ultimate origins could have been nearby or thousands of miles away in the vastness of the Southeast Asian non-center. We turn directly to the prehistorian, for what we seek is inevitably bound to the tracing of the origins of Southeast Asian civilizations in the archaeological records that surely must be forthcoming.

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Acknowledgments

I must thank the following colleagues at The Australian National University for their thematic and technical assistance and support: Jim Allen, Jack Golson, Prue Gaffey, Mark Chandler and Jill Johnston, and especially John Preston of the SEM Facility. I will always be grateful for the opportunities that Chet Gorman offered me to participate in his research projects. His response would have been, "Mai pen rai!" Important however, would have been the improvements on what I have written here, through our now irrecoverable discussions.

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