

DETERMINATION OF THE ORIGINAL FIRING TEMPERATURE OF CERAMICS FROM NON NOK THA AND PHIMAI, THAILAND

by

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Analysis

Twenty samples of ceramics from two Thai sites excavated by Solheim, Parker and Bayard (1966) were subjected to thermal expansion measurements to determine their original firing temperature. The project was undertaken by Meacham with the same procedures applied in an earlier analysis of pottery from Hong Kong sites (Meacham, 1978: 174 - 181). The measurements were again conducted by Dr L. K. Leung of the Department of Applied Science, Hong Kong Polytechnic.

The results of the analysis generally accord well with the ideal thermal expansion behaviour of ceramics elsewhere (Roberts, 1963) and an "equivalent firing temperature (T_{eq}) was in most cases determined which is "that constant temperature which would bring about the same amount of sintering as was achieved during the original firing" (Tite, 1969). It is quite likely, however, that the original firing was not even, and that T_{eq} thus represents a value somewhat less than the peak temperature to which the sample was exposed.

As in the case of the Hong Kong material, contraction of the Thai samples was observed relative to the sample holder, but conversion to absolute values revealed expansion in every case. In two instances when the samples were preheated to 400-600°C (releasing hydration and organic material), cooled, then fired to 1200°, relative expansion rather than contraction took place. The point at which sintering began (T_a) was very clearly exhibited but the resultant T_{eq} (940°, 950°) were consistent with the other results of samples which were not preheated. One sample which did show relative expansion above 900° also had a very well-defined T_a at 950°.

Another factor indicating that the results do indeed reflect the original firing temperature is the fact that a majority of the samples gave curves which very closely resembled that of a control piece (of Hong Kong potters' clay) fired for two hours at 1040-1060°. The T_{eq} of the control piece was estimated from its curve at 1010-1040°.

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The authors thank David Welch for his assistance with the sherd samples sent to Hong Kong for testing.

This article is also scheduled for publication in the *Journal of the Hong Kong Archaeological Society*, but without the graphs illustrating the thermal expansion curves of sherds tested which are appended herewith.

While it is true that mineral idiosyncrasies can give rise to misleading results (Tite, 1969), the general consistency of the results internally, with the control piece and with the expected pattern, seems to suggest rather strongly that the results reported below are an accurate reflection of the original firing temperatures.

Unlike the Hong Kong material, all but two of the Thai sherds had a distinctive T_a well above the quartz inversion disturbance observed at 570-620°. It would thus seem that few if any of the Thai sherds were fired in the lower range of 500-700° which was suggested for the earliest Hong Kong wares.

Sherds from layers 6-9 at Non Nok Tha gave T_{eq} result falling in the general range of 800-950°. No trend could be discerned from one layer to the next:

Layer 6 — 800-850°, 820-860°, 850°, 860-900°, 880-920°, 910-950°, 940°, 950°

Layer 7 — 800-875°, 900-950°, 900-975°

Layer 8 — 860-900°, 860-940°

Layer 9 — 750-810°

Sherds from Phimai, however, gave results of: 800-860°, 940-980°, 1150-1200° and 1150°. The latter two are well above the range seen in the Non Nok Tha material.

Interpretation

This project was initiated after a discussion between the authors on the significance of the results obtained on the Hong Kong material, and on one sample from the Yuan-shan Neolithic culture of Taiwan which gave a result of 1030°. Some of the ceramics from Non Nok Tha seemed to be fired to a comparable hardness, above the range attainable by open firing.

This observation now seems to be demonstrated. Open firings seldom exceed 800-850°, and this peak temperature is attained for a brief period only. An "equivalent firing temperature" for the best open-fired wares would thus be in the range of 600-800°. Virtually all of the Non Nok Tha ceramics tested were fired well above this range, and were probably subjected to peak temperatures of 1000° or more in a rapid firing, or sustained temperatures of 800-950°, in an enclosure, primitive kiln, clay-lined pit, or other partially closed firing situation. The high-fired wares of Phimai must have been produced in a well-constructed kiln capable of reaching at least 1200-1250°.

Nothing of the nature of a kiln has been found in the excavation of early sites in northeastern Thailand, though this sort of feature has been looked for during excavations. A kiln was found at a probable Dvaravati site (LP8) in Sahatsakan, northeastern Thailand (Solheim and Gorman, 1966:161), but this, at the most, would have been from 1,400 years ago and more likely around 1,000 years ago or less. This was hypothesized to have been used in making charcoal (not yet published). Present-day earthenware pottery in northeastern Thailand and neighboring Laos is fired in an open fire with no indication of the use of a kiln (Solheim 1964, 1967). Quite a sophisticated kiln is used for firing earthenware pottery today near Songkhla,

southern Thailand (Solheim, 1964: 155, pl. III*b*) but this type of kiln is thought to be of relatively recent origin.

The excavations reported at Phimai (Solheim, Parker and Bayard, 1966; Solheim and Ayers, 1979) covered only small portion of a very large site. Considerable metallic slag was also recovered from the pre-Khmer levels with the Phimai black pottery, which was the Phimai pottery here tested. While no indications of a kiln were found, it is likely that kilns were in use on the site well back into first millennium BC (Solheim and Ayers, 1979; addendum). Visual examination gives the impression that the Phimai black pottery was well fired under controlled conditions (Solheim, 1965: 254).

With only a few large sites having been excavated over a considerable area, and these excavations having covered only a small percentage of the total site, it is still quite possible that partly underground kilns will eventually be found. Until such a kiln has been found it would be logical to hypothesize a surface enclosure of some sort that would facilitate a draft and higher temperatures than an ordinary open fire.

In conclusion, the Non Nok Tha ceramics, covering a span of time from before 3000 to *ca.* 1500 BC and ranging from early bronze use to early iron use, were fired at temperatures generally comparable to some of the contemporaneous Late Neolithic ware in Hong Kong and in Taiwan. It may be postulated from these results that a form of primitive kiln was in use in each area, and probably other regions of southeast Asia as well, as early as 3000 BC.

Significance

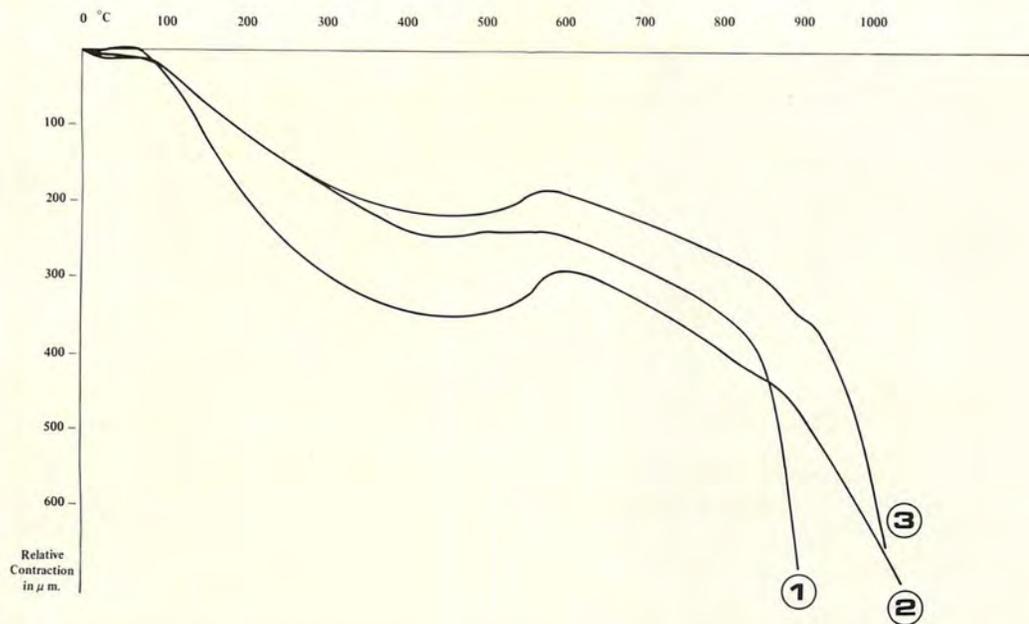
The authors do not know of any previously published specific evidence for the use of kilns in firing pottery in southeast Asia earlier than the Dongson kilns in northern Viet Nam or for the later local manufacture of stoneware in Cambodia and Viet Nam probably in the second half of the first millennium AD. Some French reports refer to a kiln for firing pottery at sites in Viet Nam but present no physical evidence for the kiln or for a high temperature of firing the pottery present. Janse reported kilns at the site of Dongson (1947: pls. 139, 142-43, 147-51, 158, etc.). According to recent chronologies, these kilns probably date to the second half of the first millennium BC. It has been suggested that the lack of kilns for use in the early metallurgy of northeastern Thailand presents a partial explanation for the manufacture of only relatively small bronze artifacts and no large ones, while the Dongson phase of northern Viet Nam prehistory with its production of large bronze artifacts must have had kilns (Solheim, n.d.).

The evidence presented here for the widespread knowledge and use of some sort of primitive kiln in the firing of pottery in southeast Asia, well previous to 2000 BC, makes it easier to hypothesize the local development of metallurgy in southeast Asia. With the higher temperature produced by such kilns it is much more likely that the accidental melting of copper, lead or tin could have taken place during kiln firings of pottery than in the lower-temperature firing in an open fire, and the observation of such phenomena might well have led to the invention of metallurgy somewhere in mainland southeast Asia. For some reason the use of this hypothesized kiln was dropped for firing earthenware in southeast Asia, although it may

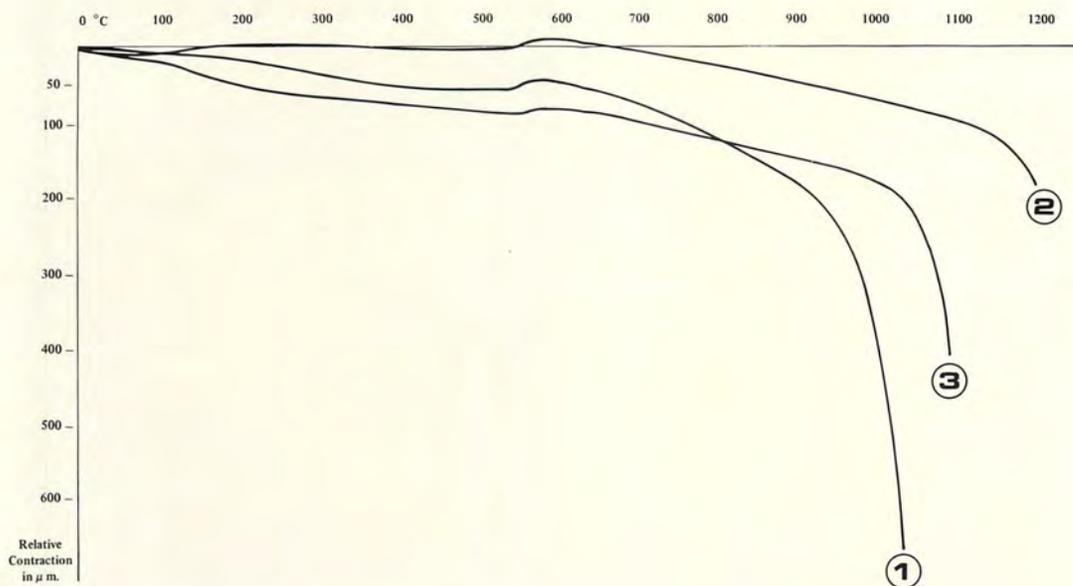
have led to the development of stoneware in one or more areas, with improved kilns, and the differentiation in manufacture and use of these two kinds of pottery. It is also quite likely that the ceramic kiln technology was adapted at a very early stage for metallurgical purposes, such as smelting and alloying.

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Graph 1. Re-firing curves for three samples from Non Nok Tha: (1) sherd from layer 6A, with temper of sand, laterite and fiber, original firing estimated at 840-860° C; (2) layer 6B, sand, laterite, fiber, 880-920°; (3) layer 7, sand, 900-950°.



Graph 2. Re-firing curves for two samples from Phimai and one control piece: (1) Phimai blackware, fiber and sand temper, original firing estimated at 940-980°C; (2) stoneware, fiber, sand and laterite, 1150-1200°; (3) control piece of potter's clay fired at 1040-1060°, estimated firing temperature from curve at 1010-1040°.



Figure 1. About 2300 BC, Middle Period 3.
Rim diameter, 9.9 cm; maximum diameter,
14.7 cm.
Discovered at Non Nok Tha, 1966.
One of the most common vessel forms excavated
from the site; variations of this form were found
in every layer from the earliest to Layer 3 (about
1600 AD).

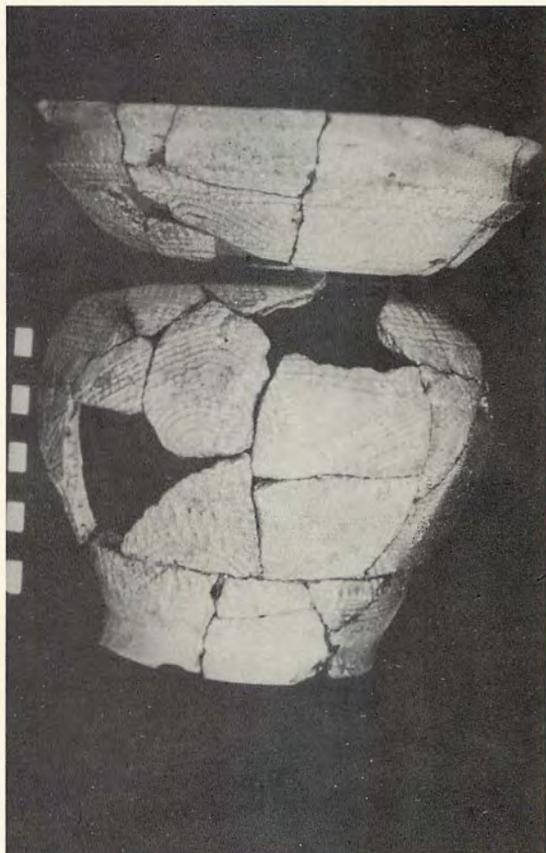


Figure 2. Before 3000 BC, Early Period I.
Discovered at Non Nok Tha, 1968.
The pattern on the body is an impressed,
running curvilinear scroll.

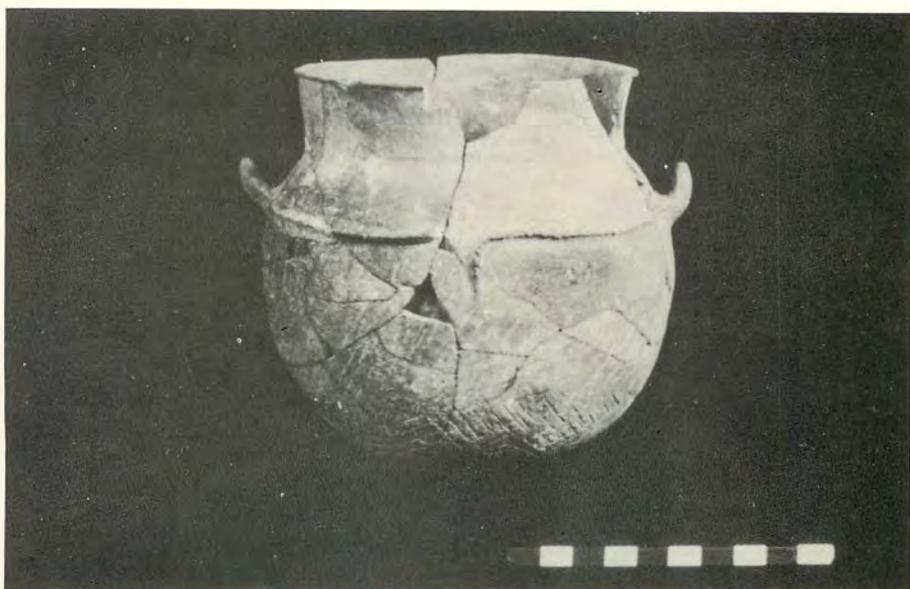


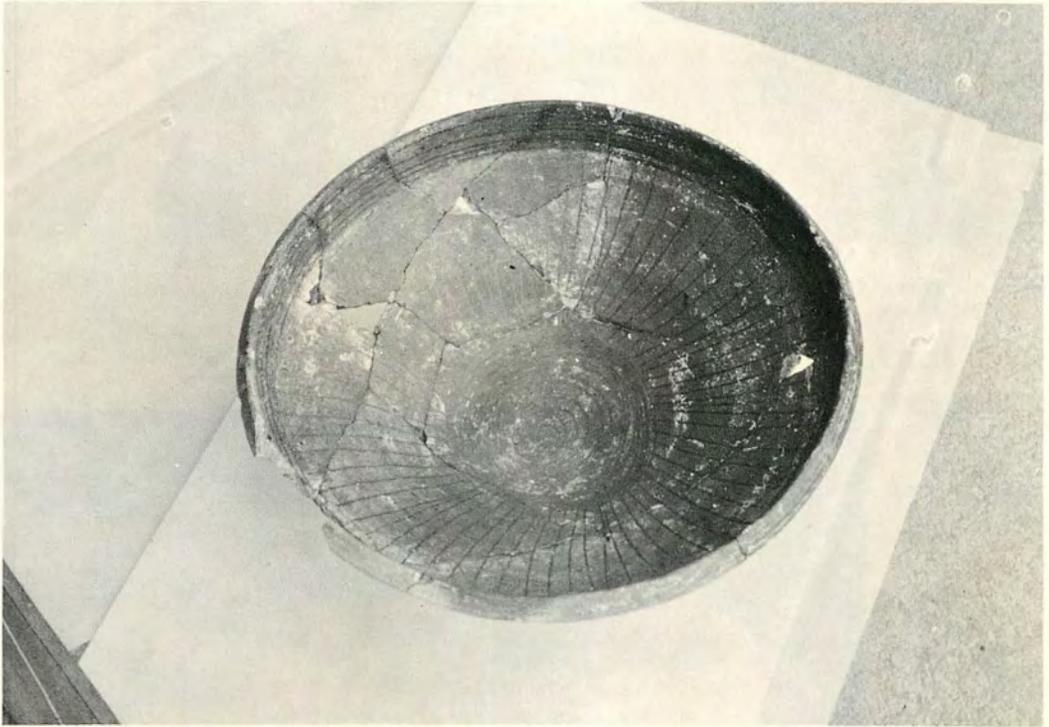
Figure 3. About 2500 BC, Middle Period 2.
Discovered at Non Nok Tha, 1966.



Figure 4. Phimai blackware, discovered 1966.
Rim diameter, 10.8 cm; maximum diameter, 14.7 cm.



Figure 5.



Two examples of Phimai blackware; no provenience.

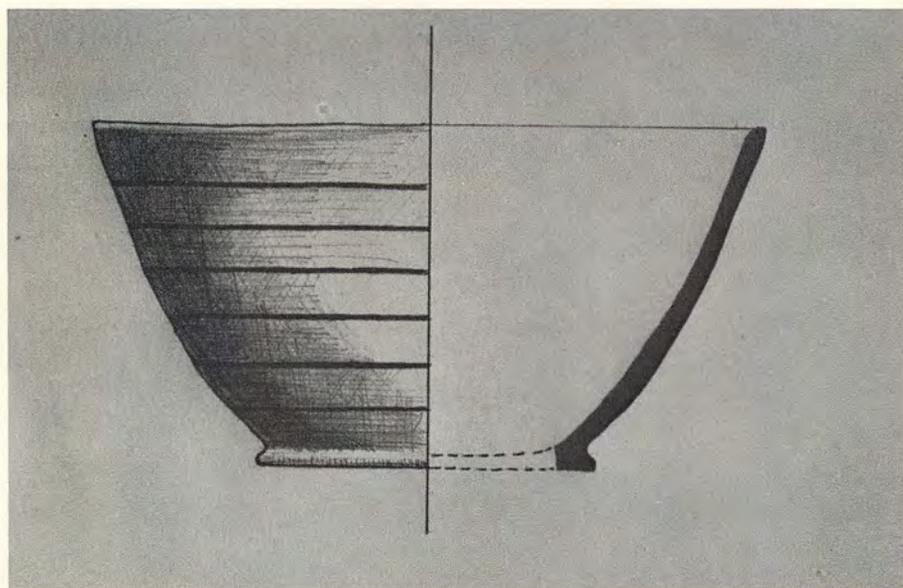


Figure 6. Phimai blackware, discovered 1966.
Height, 5.7 cm; rim diameter 11.3 cm.

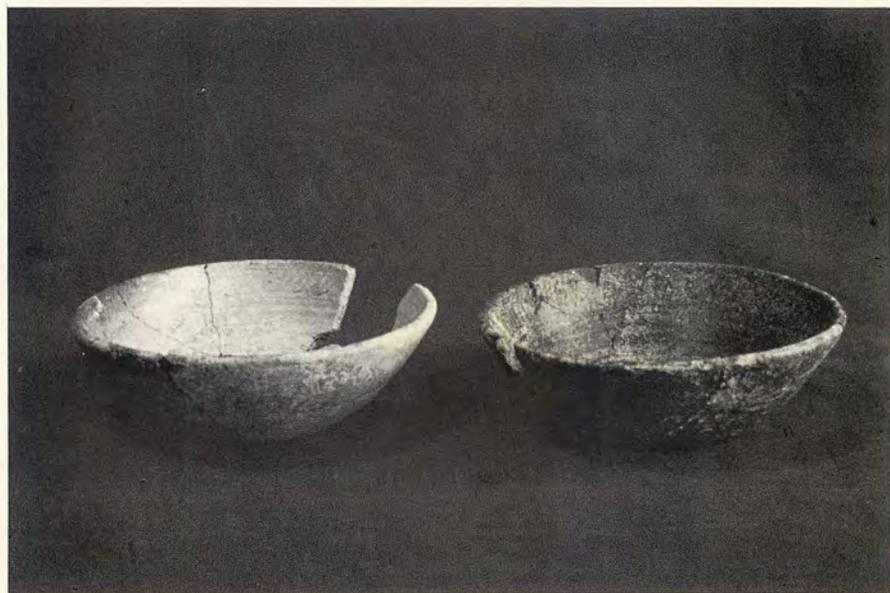


Figure 7. Phimai blackware, discovered 1966.
Rim diameter: (left) 12.6 cm; (right) 12.4 cm.