

CERAMIC TECHNOLOGIES IN BRONZE AGE THAILAND

Brian Vincent

P. O. Box 5165, Dunedin, New Zealand

ABSTRACT

In the past two to three decades prehistoric pottery analyses in Thailand have developed to where scientific methods have become almost standard procedure. In particular, petrographic techniques, drawn from geology, allow a more detailed and precise understanding of pottery fabrics and potting clays. Assemblages from several regions have been analysed and a considerable database is now available. Broad descriptions of ware compositions, although limited as stand-alone single-site assessments, can provide important background information, with potting clay preparation techniques being of particular importance. Such information is especially useful when it applies to broad-scale regional or intra-site trends. This has encouraged the preliminary assessment presented here, as a first attempt to establish whether the available data can provide an overview of potting technology prior to and during the early Bronze Age in Thailand. A broad outline of potting technologies is given. In some regions the available evidence permits quite detailed assessments, in others the necessary data are sketchy or absent. In spite of this, an attempt will be made to determine whether the data can throw sufficient light on pottery technology complexity in the period prior to the presence of metal in archaeological contexts. Whether adjustments to traditional potting techniques occurred following the introduction of bronze will also be considered.

In early hand-made pottery, it has often been assumed that clay preparation techniques were dictated by tradition, in much the same way as pottery forms and decoration were supposed to characterise cultural traditions. We now know, of course, that pottery styles can readily be copied by the potter (Vincent 1988). But more compelling influences may be required for the potter to change basic technological

processes, such as clay preparation or firing, although the social parameters which effect such mechanisms are as yet not fully understood (Shepard 1956, 1964). For example, the emigration of potters, perhaps through marriage alliances, from one district to another could effectively change local methods from one tradition to another. These considerations aside, the broad-scale distributions of pottery, made under the rubric of any given clay preparation technique, should give some indication of the overall character of indigenous potting traditions region by region.

Clay preparation methods are dictated by the availability of suitable materials. Access to clays, and any additives needed to render them suitable for pottery making, can often be limited by the availability of suitable local natural deposits and transportation systems (Arnold 1985). Most clays require the addition of non-plastic materials (temper) to improve their quality. When abundant quantities of, for example, sand, are available, then this material could prove suitable. But some regions lack suitable natural deposits of non-plastic materials. The potter would, therefore, be compelled to seek alternative methods. Because once adopted, changes in clay preparation methods will be resisted for technological reasons it is important to establish that reliable supplies of such additives are readily available. New materials require testing and, because non-plastics are an important ingredient, changing them risks failures. The kinds and proportions of these additives are critical to a successful potting clay mixture. It would be most unwise to tamper with a successful formula unless it was absolutely necessary.

Potters who adopted naturally occurring temper additives would be constrained by their regional distribution. Those able to modify natural clays without the need to resort to such additives would be free to practice their craft wherever adequate deposits of potting clay could be obtained. At least three such modification methods are known to have been used. One involves pre-firing balls of raw clay to manufacture a synthetic non-plastic material. Once fired and crushed this material (grog) provides an

excellent alternative to natural substances. This specialised technique allows the potter a considerable degree of freedom because only one material, the potting clay, is needed. The second method exploits materials made available through other cultural activities, for example, the by-products of rice processing. The third technique combines elements of the first two methods. Instead of adding plant materials to the final clay mixture, these are added to the grog balls prior to firing. Once crushed, the resultant clay and plant material fragments are mixed into the raw unmodified clay as a temper (termed blebs or bleb grog, or in Thai "chua"). Any of these latter three methods would provide prehistoric craft potters considerable technical flexibility. Further, if potting was an integral component of their community these techniques would allow a degree of group mobility.

The division between naturally occurring and culturally produced non-plastic potting clay additives is fundamental. But whether culturally produced additives are synthetic constructs of the potter, or surpluses from some unrelated cultural activity, is not the central question. What matters is that natural deposits are uneven and randomly distributed around the globe, whereas the factors which determine the ability to manufacture non-plastic additives are cultural. The scale of these determinations is important because, at the intra-regional level, exchange of pottery from manufacturing centres could act to distort areal distributions of different wares. This is an important factor in Thailand where the geomorphology acts to divide the country into several separate physiological regions. As distributing substantial amounts of pottery is limited by its weight and available transportation systems, these constraints act to limit the extent of inter-regional pottery distributions. The above factors afford a degree of clarity to large scale, inter-regional assessments of prehistoric pottery distributions which would not necessarily be available when smaller scale, intra-regional samples are involved.

TECHNOLOGICAL STUDIES BY REGION

Thailand can be subdivided into seven geophysical regions (Figure 1). Studies of prehistoric pottery technologies have been carried out on material from sites in the Central Highlands, the Central Plain, the Southeast Coast, the West Continental Highlands and the Khorat Plateau. Peninsular Thailand and the North Continental Highlands are not considered in this paper because appropriate data are unavailable. A selected sample of sites is discussed in the following sections. Except where noted, the petrographic examinations were undertaken by the author.

WEST CONTINENTAL HIGHLANDS

Ban Kao

This site lies on the river-terrace plain of the Kwae Noi River, at the western extremity of the Central Plain but sufficiently close to the West Continental Highlands to be included here, as the potting clay and temper probably derived from erosion of the Bilauk Taung Mountain Range. All of the "Early" and "Late" Neolithic wares have been described by Sørensen and Hatting (1967) as containing grit and/or mica. A very preliminary petrographic analysis has been carried out by the author on Ban Kao sherds kindly selected by Sørensen. All were tempered with sand mineralogically consistent with the local geology. Apart from two intrusive burials, no metal was found in the early phase mortuary contexts. Radiocarbon dates indicate that the site was occupied from c.2000-1400 BC (Higham 1996:260).

CENTRAL PLAIN

Ban Don Ta Phet

Located on the western margins of the Central Plain, this site comprises a cemetery within a circular ditch and bank measuring about 40 m in diameter. AMS dates obtained from rice temper in the pottery suggest that the cemetery dates to the early fourth century BC (Glover 1990:154). Johnson (1992:179) reports, following a petrographic analysis, that four of the five pottery fabrics recognized contain mainly sand tempers. One contained rice temper. Bronze and iron were both present at this site. A lack of Bronze Age sites in the western portion of the Central Plain led Glover (1991), to suggest that this area, while acquiring bronzes from sites to the east through exchange, may have made a direct transition from the Late Neolithic to the Iron Age.

Non Pa Wai

This site is one of over 50 in the upper reaches of the Lopburi River to the west of the Wong Prachan Mountain on the eastern fringe of the Central Plain. Two phases were recognized, the second, radiocarbon dated to c.1500 BC, featured the earliest copper smelting in Central Thailand (Natapintu 1991; Pigott 1992, 1994). Numerous small cup-shaped ceramic moulds, recovered in association with pottery and metal working equipment were tempered with organic material (Bennett 1990:115).

Chansen

Six phases, defined by pottery styles, were recognized at Chansen. Thermoluminescence and radiocarbon deter-

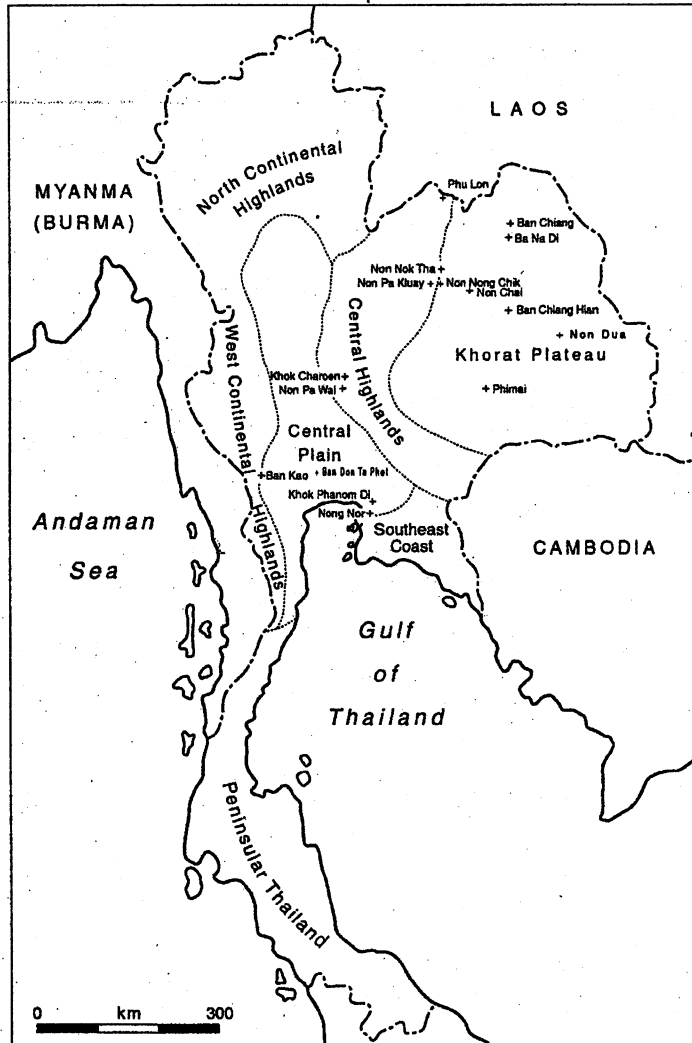


Figure 1: Geophysical Regions of Thailand (after Moorman and Rojanansoonthon 1968).

minations suggest Phase 1 dates c.600 - 400 BC, and Phases 2 - 6 from c.AD 50 to the mid second millennium AD (Bronson 1976, 1979). During Phase 1 mineral temper dominated pottery fabrics. From Phases 2 - 5 vegetable temper was very common or dominant. Iron and bronze artefacts were recovered from both major periods.

SOUTHEAST COAST

Khok Phanom Di

Four discrete Ceramic Periods (CPs), defined by clearly different pottery traditions, have been identified at this site. Radiocarbon determinations suggest that CP1-3 inclusive span the period c.2000 - 1500 BC. CP1 is characterised by sand-tempered local wares restricted to the lowest 30 cm or

so of a 6.8 m deep stratigraphy. CP2-3 encompass a 5 m deep cemetery when local wares were tempered with orthodox grog. CP4 local wares were tempered with either rice husk or bleb grog. Rice and bleb-tempered exotic wares entered the site throughout the sequence in very limited quantities. Metal was absent from the excavated area, and no evidence of metal working was detected.

Nong Nor

This site lies about 14 km southeast of Khok Phanom Di. Two separate phases are evident. Radiocarbon determinations date Phase 1 to c.2400 BC and Phase 2 to c.1200 - 800 BC (Higham 1996:276). Phase 1 pottery is tempered with sand and many of the types are identical in form (O'Reilly 1998:161) and fabric to CP1 Khok Phanom Di local wares (Vincent: forthcoming). Of 211 Phase 2 vessels examined for fabric, 82.5% contained rice (Debreceeny 1998). Phase 1 lacked metals but some Phase 2 graves contained bronze artefacts.

CENTRAL HIGHLANDS

Khok Charoen

This site is located in the Pasak Valley to the east of the Central Plain. The excavators subdivided the sequence into four periods. Petrographic analysis revealed granitic rock fragments in Period 1 fabrics, sand in Periods 2 and 3, and grog in Period 4 (Watson et al. 1986). A Period 3 fabric contained grog and rice in association and this is diagnostic of bleb temper. Although the chronology has not been clearly established, stylistic parallels with Non Pa Wai pottery suggest a mid second millennium BC to early first millennium BC sequence. No metal was recovered.

The Phu Wiang Region

Non Nok Tha

Three major periods are apparent in the ceramic spectrum, based on temper. Sand comprises 92% of Early Period (EP: c.2000-1500 BC) tempers; Middle Period (MP: c.1500-500 BC) tempers are 67% sand and 26% chaff, and Late Period (LP: c.500 BC-AD 200) tempers are 50% sand and 50% chaff. No metal was recovered from the earliest two phases, EP1 and EP2. Bronze first appears in EP3 and MP graves.

Twelve sherds, presumed exotic by Bayard, have been examined in thin-section. Some MP examples, probably derived from the lower Mun River area, contain sand temper. Others, mineralogically consistent with a middle Chi Valley source, contain bleb temper, while orthodox grog features in sherds consistent with an upper Chi/Petchabun Piedmont source. LP wares mineralogically consistent with the Upper

Chi area contain either bleb or rice temper. The chronological distribution of exotic temper species suggests that orthodox grog occurs early, followed by bleb grog and then rice or other plant material.

Non Pa Kluay

At Non Pa Kluay all the provenienced wares were sand tempered and associated by the excavator with EP or MP Non Nok Tha vessel styles (Wilén 1989). No bronze was recovered from securely provenienced burials, but some was found outside the grave contexts.

Western Udon Thani and Loei provinces

Three of 61 sites recorded in this region have been excavated: Non Sila, a first millennium BC stone axe quarry in Udon Thani province, plus Phrik Mound (Non Phrik) and Pha Phim Cave (Tham Pha Phim) in Loei province (Rutnín 1988; Leyavanija 1997). The Non Phrik habitation mound yielded polished stone tools, a large quantity of potsherds, iron artefacts, spindle whorls and grinding stones (Leyavanija 1997:196). Four sherds examined in thin-section contain coarse sand-sized igneous rock fragments, probably of volcanic origin. Their mineralogy matches Pa Mong Survey surface-collected sherds ("Na Ngua buff", Bayard 1980). It is consistent with the local geology.

Pha Phim Cave was the only burial cave found in the survey region. It revealed a single inhumation burial which suggests a date prior to AD 600-700 (Leyavanija 1997). A sherd examined in thin-section revealed an igneous petrology. The fabric is tempered with a granitic or granodiorite coarse sand. Polished stone artefacts were also recovered, but no metal was present.

Pa Mong Survey Area

Representative sherds surface collected from the Loei sites of Non U Mung and Non Na Nong Khong have been examined in thin-section. In each case the sand-tempered fabrics display a clear igneous association consistent with the local geology.

Phu Lon

This early 2nd to 1st millennium BC copper mining complex lies on the southern bank of the Mekong River. Three different wares were noted which suggests that several groups visited the area (White and Pigott 1996:153). According to Vernon (cited by White and Pigott 1996:158), the Phu Lon data reveal no clear ceramic ties to Ban Chiang Cultural Tradition sites. Vernon (1996) analysed 91 Phu Lon crucible fragments. Most were tempered with rice chaff and 31 were lagged with a quartz-rich silty layer to improve their

thermal qualities and extend their life. This lagging method mirrors that used in the Ban Na Di crucibles which post-date the first mortuary phase at that site (Higham 1996:235). Pigott and Natapintu (1988) suggest mining was seasonal and undertaken by visiting groups from some distance away.

KHORAT PLATEAU

Mun Valley Roi Et sites

Non Dua

This site is grouped with Don Taphan and Bo Phan Khan. All three are subdivided into three phases characterised by related pottery styles (Higham 1977). Phase 1 is dated to c. 500-1 BC, Phase 2 to AD 1-700, and Phase 3 from AD 700-1000 (Higham 1996:218). At Non Dua, 62% of Phase 1 wares contain "fibre" and 38% "clay" tempers. During Phase 2, 68% contain "fibre", 23% clay and 8% sand temper. At Non Dua during Phase 3, 31% contain fibre, 48% clay and 19% sand temper. No Phase 1 data are available for Don Taphan or Bo Phan Khan. During Phase 2, 99% of pottery at both sites contained fibre, and during Phase 3, 87% and 93% respectively. Samples examined in thin-section are dominated by rice temper, but some contain orthodox grog. Iron was present in basal Non Dua (Higham 1977).

Upper Mun Valley

Phimai

Welch and McNeill (1991) identified five cultural phases in the Phimai region, (Tamyae (1000 - 600 BC), Prasat (600 - 200 BC), Classic Phimai (200 BC - AD 300), Muang Sema (AD 600 - 1000) and Lopburi (AD 1000 - 1300)), based on excavated pottery and radiocarbon dates. Tamyae phase pottery contains fine sand temper, while Prasat and Classic Phimai phase feature rice chaff, and Muang Sema phase ware contains fine to coarse sand (Welch 1985). Although early Tamyae phase pottery is sand tempered, initial settlement by colonists who practiced rice agriculture is suggested by Welch and McNeill (1991:223). Iron is evident at or near the beginning of the Prasat phase and bronze jewellery is present in Phimai phase graves at Ban Prasat.

Chi Valley

Non Chai

The excavators identified five phases at Non Chai, radiocarbon dated from c. 400 BC - AD 200 (Bayard *et al.* 1986). Red painted, bleb tempered pottery with curvilinear designs dominate throughout the sequence. This ware type subsequently spread throughout the northern Sakon Nakhon Basin (Vincent 1988). Bronze and iron were present in Phase 1 contexts at Non Chai.

Ban Chiang Hian

Radiocarbon results from Ban Chiang Hian suggest that layer 11 dates from c.1300 - 900 BC, layers 9-10 from c.900 - 600 BC, layer 6-8 from c.600 - 1 BC; and layer 5 from c.AD 1 - 500 (Chantaratiyakarn 1984:579). Chantaratiyakarn provided the author with 115 sherds for petrographic analysis. Silty or sandy fabrics dominate throughout the sequence. One bleb tempered sherd was present in each of layers 11, 10 and 9, and one rice-tempered sherd was recorded in each of layers 9 and 8. Clay moulds and crucibles were concentrated in layers 6-8 and bronze fragments in layer 8. Layer 7 contained iron.

Ban Kho Noi and Non Noi

Both sites lie less than 15 km from Ban Chiang Hian on a tributary of the Chi River. No radiocarbon dates are available. The excavators considered the pottery to be closely related to that of Ban Chiang Hian. A total of 36 sherds, mainly rims, have been examined in thin-section. They include sandy and rice-tempered Roi Et fabrics and other pottery with bleb and/or rice temper. Basal contexts at Ban Kho Noi included three clay mould fragments and iron slag.

Sakon Nakhon Basin

Surface Collected Pottery

Sherds collected from 29 intensively surveyed sites (Kijngam *et al.* 1980), have been analysed in thin-section and hand specimen. Sand temper was present in one site, orthodox grog in 18, bleb grog in 24, rice temper in 25, and vitrified wares were collected from five sites (Vincent 1988). Many sites lie near the confluences of streams, close to low-lying, regularly flooded land suited to rice agriculture.

Ban Na Di

This site revealed a clear stratigraphic sequence interspersed with flood water sand lenses. The lowest 2m comprised layers 6-8 (L6-8). The excavators divided a L7 - lower 6 cemetery, with 60 burials, into three mortuary sub-phases (MP 1a-c). A clay furnace for bronze working, crucibles and broken ceramic moulds were recovered within this context. A major stratigraphic break occurred at the L5/6 interface. L6, which lacked sand lenses, marked the end of MP1. L5 was given over to bronze casting. L4 contained MP2. Radiocarbon determinations at first suggested an initial second millennium BC - c.900 BC occupation phase, with MP1a-c dated from c.900 - 400 BC, and L5 from c.100 BC - 200 AD (Higham and Kijngam 1984:32). But Higham (1996:204), has since argued for a 600 - 400 BC date for the cemetery.

From the outset, local pottery featured orthodox grog temper and moulded forms. But this changed at the L5/6

interface when it was replaced by a new tradition mirroring Non Chai and upper Chi Valley red painted wares with bleb grog temper. Prior to the abrupt change at the L5/6 interface, at first a few and then increasing amounts of the red painted Chi Valley wares were imported. Analysis of site survey collections demonstrate that these wares are common to many Sakon Nakhon Basin sites. This distribution could reflect a gradual infiltration of people from the south into the Sakon Nakhon Basin (Vincent 1988). Sites such as Ban Muang Phruk (10 km southwest of Ban Na Di), were probably first occupied at this time. Red painted bleb grog pottery dominates throughout the Ban Muang Phruk sequence.

Rice phytoliths and characteristic fabric voids demonstrate that the early Ban Na Di potters sometimes added rice husks and straw (in addition to the usual orthodox grog temper), to special vessels reserved for mortuary ritual. Incidental rice inclusions are also present in several fabrics throughout the sequence.

Ban Chiang

The chronological framework of this major site features 10 ceramic phases, grouped into three major periods based on mortuary vessel forms (White *et al.* 1991:188). The author is currently undertaking a study of the ceramic assemblage. Preliminary assessments by Vernon indicate the presence of three groups based on quartz sand, grog or plant material tempers. Grog and sand dominate the Early Period (EP), plant material the Middle Period (MP) and grog the Late Period (LP). A minor amount of EP pottery contains plant material and similarly some LP wares include sand temper.

The Ban Chiang chronology has been the subject of debate. Initially the EP was dated from c.3600 - 1600/900 BC, the MP from 900 - 400/200 BC and the LP from 300 BC - AD 300 (White 1986:279). These provisional dates are being re-examined using AMS dating of carbonized rice temper (White 1997:103). They support White's (1986) estimate of an early second millennium BC date for the first appearance of bronze.

DISCUSSION

Sites with detailed sequences can be conveniently divided into those with metal and those without. Those without metal include Khok Phanom Di (KPD) and Nong Nor. The earliest pottery at both is tempered with sand. At KPD sand is replaced by grog temper during the period 2000-1500 BC and after 1500 BC by rice or bleb grog (Vincent 1988). Pottery throughout the Ban Kao sequence contains sand temper. At Khok Charoen, from c.1500 - 900 BC, local wares were tempered with sand or grog. During EP1 and 2 at Non Nok Tha (considered by Bayard [pers. comm.] to date to the late 3rd millennium BC), the pottery was tempered with sand, as were Non Pa Kluay wares prior to c.1500 BC. Finally, at Ban

Chiang during EPI and EPII pottery was either tempered with sand or grog. EP1 and EP11 pre-date 1500 BC (White 1986, 1997). These seven second millennium BC sites share the same characteristics (Table 1). All lack metal, all feature sand-tempered pottery and all date to 1500 BC or earlier.

Sites with metal include Ban Don Ta Phet, radiocarbon dated to 390-360 BC (Glover 1990:155), which revealed ceramic fabrics which contain either sand or rice. Nong Nor Phase 2 (c. 1200-800 BC) pottery is dominated by rice temper and at Non Pa Wai during Phase 2 (c. 1500 BC) casting moulds and pottery also contain rice temper. At Chansen from c. 600 BC, although mineral temper is dominant, vegetable temper is also present (Bronson 1976:128). In the Middle Period (c. 1500-500 BC) at Non Nok Tha chaff is present in 26% of the sample and exotic wares contain bleb temper. Rice dominates the Phase 1 (c. 500 BC) assemblage at Non Dua. Tamyae Phase (c. 1000-600 BC), pottery at Phimai is sand tempered, but rice agriculture may have already been established and rice chaff temper is present by the Prasat Phase (c. 600 BC) and possibly earlier. In the Chi Valley, rice temper is present from c. 900 BC at Ban Chiang Hian and bleb tempered wares characterise the ceramic assemblage at Non Chai from c. 400 BC. Within the Sakon Nakhon Basin, although grog is the favoured tempering method, rice is also evident in local pottery during early MP1 (c. 1100-900 BC) at Ban Na Di and rice is present in Middle Period (c. 900-300 BC) pottery at Ban Chiang. At Phu Lon, rice was used to temper crucibles as early as c. 1100 BC.

In contrast to pre-1500 BC sites, each of these 12 sites share a different set of characteristics. All contained metal, all feature pottery with rice and all date to 1500 BC or later (Table 2).

The oldest bronze industries in Thailand are considered by Higham (1996:245) to fall within the period 1500-1000 BC. Bayard (1996-7) suggests 1500-2000 BC. White (1997:103-6) favours an early second millennium BC date for its appearance at Ban Chiang, based on AMS dates from rice in burial pottery with "impeccable provenience", and which provides direct evidence of pre-1500 BC (calibrated) bronze in Southeast Asia. White and Pigott (1996) report a mid-second millennium BC appearance of copper at Non Pa Wai.

Consensus on when bronze metallurgy first appeared in Thailand aside, it is note-worthy that no ceramic spectrum which lacks rice is associated with bronze. But some sites which lack metal include rice tempered wares, and some of these wares were locally made. For example, at Khok Phanom Di, rice and bleb temper was used by the local potters after 1500 BC, when potting dominated the excavated area. Although not detected, it is difficult, given that 99.7% of Khok Phanom Di remains unexcavated, to conclude that metal is totally absent (Bayard 1996). The

absence of bronze at Khok Charoen is less puzzling as the chronology rests on just two TL dates (Watson 1979:55), leaving it open to revision.

Excavated sites in the Western Udon Thani and Loei Provinces provide limited technological data as the pottery examined in thin-section lacked rice or grog, and surface collections from the Pa Mong region sites were all tempered with sand (Vincent 1988). Bayard (1980:130) noted that to the west, (Phu Wiang and Na Klang), pottery with sand temper contrasts with "rice chaff and prepared temper" (i.e. grog) pottery to the east and south (Ban Chiang, Roi Et, Phimai). Within the Sakon Nakhon Basin, rice or bleb grog dominated the surface-collected assemblage. Many of these sites were located near land suited to rice agriculture (Kijngam et al. 1980).

CERAMICS AND METAL WORKING

An ability to process raw clay into grog or to exploit culturally-derived tempering materials would free potters from reliance on suitable natural substances, thus conferring technological flexibility and group mobility. The association of rice-tempered pottery with agriculture and metal working

Table 1: Clay preparation techniques in Thailand: pre-metal sites

Site	Period (BC)	Temper
Ban Kao	2000-1400	sand
Khok Phanom Di	2000-1500	sand, grog
Non Nor Phase 1	2400	sand
Khok Charoen	1500-900	sand, grog
Non Nok Tha	Early Period 1 & 2 (2000-1500)	sand
Non Pa Klua	1500	sand
Ban Chiang	Early Period 1 & 2 (pre 1500)	sand, grog

Table 2: Clay preparation techniques in Thailand: sites with bronze

Site	Period	Temper
Ban Don Ta Phet	390-360 BC	sand, rice
Non Pa Wai Phase 2	1500-1000 BC	rice
Chansen	600 BC	mineral and vegetable
Non Nor Phase 2	1200-800 BC	Rice
Non Nok Tha	1500 BC	sand, chaff, exotic blebs
Phu Lon	1100 BC	rice (crucibles)
Non Dua Phase 1	500 BC	Rice
Phimai: Prasat Phase	600 BC	Rice
Non Chai	400 BC - AD 200	Blebs
Ban Chiang Hian	900 - 600 BC	Rice
Ban Na Di	1100 - 900 BC	grog and rice
Ban Chiang ¹	900 - 300 BC	Rice

suggests that they were integrated. It seems untenable that a food resource would be wasted when alternative materials had previously been successfully exploited for temper, for even rice chaff has food value for domesticated animals (Thompson 1996:141). Reliable supplies of surplus rice by-products were clearly available and used to temper pottery, but whether this was correlated with changes in clay preparation for metal working is unclear.

Rice temper or bleb grog is associated with bronze working at Ban Chiang and related sites (Vernon 1997:107) and Ban Na Di (Vincent 1988). A striking feature of crucible tempers at these sites is the high proportion of rice chaff. Of 87 Ban Chiang fragments analysed, 78 (or almost 90%) contain rice, as do all five from Ban Tong and all three from Don Klang. Of two considered from Ban Phak Top, one contained quartz and the other clay temper. Although Vernon (1997:107) notes that "the placement of some fragments in a chronological stage may be approximate since an assessment of disturbances and resultant displacement for fragments has yet to be specified. Therefore, the results at this time can be suggestive rather than conclusive ..." A different distribution was evident at Ban Na Di. A clear change to rice tempered crucibles occurred in layer 6, whereas earlier crucibles contained orthodox grog (Vincent 1988:263).

It is important to note that some Ban Na Di crucibles are composed of exotic ceramic materials. Thirteen early crucibles, (below L6), are composed of clay from Nong Sung about 8 km to the southwest, but a spicule-rich clay from Nong Kham Din, also 8 km distant to the southwest, was concurrently being used by the local potters (Vincent 1988:83). Only five early crucible fabrics were composed of the latter clay and one of these includes orthodox grog and rice particles. A single crucible was heavily tempered with sand in a fabric whose mineralogy strongly suggests a source close to the Phu Phan Range about 8 km to the east. Similar exotic sand was used to lag the crucible interior.

A lack of suitable clay at Ban Na Di meant that better quality material had to be imported. Firing and shrinkage tests demonstrate that the Nong Kham Din and Nong Sung clays were equally suited to pottery making (Vincent 1988:62). The early local potters exploited the former, but following a major cultural change when a new industry replaced the early tradition with novel Non Chai style types, Nong Sung clay was favoured (Vincent 1988). It is important to note, however, that Nong Sung clay was used for early period crucibles. Either clay would have suited crucible or pottery-making in both traditions; it would, therefore, be unnecessary to import clays from two different sources for pottery and bronze-working respectively. This suggests that the early period crucible clay was selected by non-local metal workers.

With the establishment of the new potting tradition, inferior local clay was used for some crucibles. But one is composed of a distinctive micaceous clay consistent with a Ban Thong Than source, about 45 km northeast of Ban Na Di (Vincent 1988:263). This distance is considered uneconomic for transporting raw clays without access to suitable waterways (Arnold 1985:55). No waterways were available for transporting Ban Thong Than clay to Ban Na Di. This could suggest that either the crucible or the clay was carried by itinerant metal workers who visited Ban Na Di to carry out bronze-casting. It would also explain the use of alternative clay sources for pottery and crucibles during the early period.

Early period Ban Na Di pottery was of relatively poor quality. Most pots were moulded on a template and their irregular shape and overall composition reflect a lack of skill. Some blending experimentation is evident, probably to conserve imported clay, but severe shrinkage cracks rendered some vessels unusable. Paints or slips were not used. Figurines were merely air-dried, probably to avoid firing failures which may have been common (Vincent 1984:695). Crucible and mould preparation, furnace construction and the melting and casting of bronze would appear beyond the early potters' abilities without expert supervision. Clay moulds, cores and wax for casting bronze jewellery were recovered (Higham 1996:232). The delicate moulds required a knowledge of clay levigation, a technique not evident amongst the early tradition pottery.

The earliest Ban Na Di furnaces, associated with melting and casting bronze, were built from modified local clay. Thin-section examination revealed a dense fabric with a high proportion of non-plastics. This reflects a different preparation technique to that preferred by the early MP1 potters. The high proportion of non-plastics would allow unbound water to escape the clay mass rapidly without catastrophic collapse. This is clearly evident in the regular fracture patterns and overall shape retention of the furnaces, and reinforces the notion that different, highly skilled, artisans were involved in working bronze.

Establishing a bronze foundry requires technical knowledge beyond that of an untrained craft potter. In each step there are new concepts to master. For example, apart from specialised clay preparation techniques, a detailed knowledge of the thermal capacities of clay bodies is needed because higher temperatures than those used for pottery firings are involved. In addition, how to duplicate templates, a knowledge of metal alloys and the need to lag crucibles to minimize thermal shock, all require metal working skills. Without appropriate apparatus and materials unskilled workers are likely to fail and, as there is no on-site smelting evidence, failures would have risked wasting valuable metal.

In villages where potting was difficult, due to a lack of skill or suitable materials, it seems reasonable to assume that complex metal working processes would need to be introduced by foreign craft specialists. Over time, because perfecting such complex new skills requires instruction, supervision and practice, metallurgical techniques may have been passed on. This proposal is of course speculative but it might help explain the Ban Na Di evidence discussed above.

Bayard (1996-7) proposed a gradual village-to-village spread of metal-working technology following local, not long-distance, trade in bronze artefacts. He envisaged a later and slower diffusion of moulds and crucibles, while piston bellows, bivalves, lost wax casting and alloy ratio selection skills could have spread through trading and marriage alliances.

Higham (1996) considered alternative hypotheses: either (1) bronze was traded from China, possibly down the Mekong River, or (2) an earlier independent development of smelting copper occurred in Southeast Asia. In Higham's view the latter could only be sustained if sites unequivocally dated to within 2100-1800BC are found, but the first hypothesis finds support from Pacey (1990:vii) who considered that "the most important factor was that the achievements of one society stimulated people elsewhere to make different but related inventions". Thus contact with bronze artefacts along with alloying and casting methods would stimulate the establishment of a local bronze industry which would create artefacts modelled on traditional forms to fulfil local needs.

Given that the advantages of metal would stimulate keen interest, it is difficult to imagine that metal workers and traders would readily divulge the complex techniques needed to potential customers, at least not at the outset. It seems more likely that such valuable methods would be closely guarded "trade secrets" for fear their value would diminish rapidly once they became commonplace. A prudent artisan might wish to keep such skills secret for as long as possible, a response, for example, exhibited by European masons during the second millennium AD (Knight 1983), and probably the Hittes regarding iron technology (Hodges 1970:145).

An alternative hypothesis is that skilled itinerant metal workers initially plied their craft village-to-village using ingots prepared at sites such as Non Pa Wai and Phu Lon. For local potters to experiment with valuable bronze alloys without detailed instruction and practical training would be hazardous. In time, perhaps partly merely through observation, local craft workers may have developed confidence in metal working themselves, but they would be unlikely to have immediately adapted to its intricacies.

Massive evidence for large-scale copper smelting and ingot casting at Non Pa Wai (Pigott 1992, 1994) and mining at Khao Phu Kha (Bennett 1989) and Phu Lon (Pigott and Natapintu 1996-7), indicates that bronze-working quickly developed into a major craft. But given an absence of highly skilled local practitioners, the rapid adoption of metal-working throughout Thailand seems unlikely. It seems more likely that metal-working would be quickly mastered by some local artisans, but others took much longer, and for many it lay beyond their immediate capabilities. Exotic crucibles and metal-working evidence from Ban Na Di indicate that itinerant specialists, at least in the initial stages, fulfilled local demands for bronze artefacts.

Finally, it is proposed that rice-tempered pottery is correlated with the adoption of rice agriculture and bronze metallurgy into much of Thailand. If so, most sites which contain stratigraphically secure pottery with rice or bleb temper should post-date c.1500 BC. The Khok Phanom Di ceramic evidence suggests that rice agriculture pre-dates 2000 BC in Central Thailand. Thus it seems reasonable to suggest that bronze also made its first appearance in Thailand during the 3rd millennium BC. Sites which contain the earliest bronze are likely to be difficult to detect, but the extensive processing of copper at Non Pa Wai indicates that local metallurgy was well established by the mid 2nd millennium BC.

NOTE

¹ Since this paper was presented new evidence suggests that rice may have been present much earlier at Ban Chiang. It is intended to address this issue in a forthcoming publication.

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