Phimai is the New Black:

Assessing the Standardisation of Kiln Fired Phimai Black Ceramics from the Iron Age Site of Non Ban Jak, Northeast Thailand

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A thesis submitted for the degree of Master of Arts (Archaeology) at the University of Otago, Dunedin, New Zealand

December 2016

Abstract

This thesis set out to ascertain the nature of the Phimai Black ceramic tradition at the site of Non Ban Jak, Northeast Thailand. The research was undertaken to assess the degree of visual standardisation through a form-plus-fabric analysis of ceramics over time and through multiple contexts across the site. This in turn led to an investigation into the nature of social organisation surrounding pottery production at Non Ban Jak.

Excavations at Non Ban Jak have revealed extensive residential quarters, burial chambers, and ceramic kilns. Along with a large ceramic assemblage, accurately dated context, and the evidence of production onsite, models concerning sourcing, cultural transmission, the nature of production, and previous models pertaining to Phimai Black could be assessed.

In one exploratory model, it was hypothesised that the ceramic tradition originated as an elite good that was widely exchanged, resulting in local imitation and standardisation in production and form across multiple sites. Through this research it can be seen that Phimai Black moved from elite ware to common ware, its production carried out by independent specialists who lived with, and catered for, the community.

Burial offerings in terms of the Phimai Black tradition were concluded to be highly standardised at Non Ban Jak. Regardless of status and wealth, it was the social norm to use certain ceramics for burial, this is seen in the sets of ceramics reserved for different age groups. Individual grief and status associated with the deceased was not necessarily expressed in ceramic offerings, but mainly in offerings such as gold, carnelian, and bronze ornaments. Social significance surrounding infant interment was prominent on site, these people would have put much social value on infant passing, as the most elaborate vessels were chosen.

The purpose of the Phimai Black ceramic tradition was to symbolise a community-wide goal to associate the deceased with an identity that reflected Iron Age communities across the Mun Valley. Phimai Black through time is seen to be made with a specific clay, showing that originally there was a set of ideals associated with these ceramics, linking to the emulation/imitation hypothesis. While vessel forms gradually transcended clay borders throughout the Iron Age, the standardisation of form highlights an effort to hold onto past beliefs, and to the identity of the wider community.

Acknowledgements

I wish to thank my supervisors: Professor Charles Higham, Professor Glenn Summerhayes and Dr Anne Ford. This thesis would not have been possible without your guidance, support, feedback and most of all, encouragement.

To Dr Rachanie Thosarat and the Non Ban Jak excavation team for practical field guidance, supplying samples and an introduction to Thai culture.

To my very diverse and wonderful friends from Archaeology and Anthropology, Evan, Ella, Alex, Jessie, Dylan, Tash, Julia, Jenni, Fran, Naomi, Tristan, Gabe, Nick S, Nick H, and Rebecca, my wonderful editor. You all have inspired and challenged me to do better and think creatively.
Thank you for the hangouts, chats, hugs, company and Fridays.
I wish you all well in your careers and future PhDs!

To the SEA postgraduate students Stacey, Lucy, Richard and Nathan. Thank you for the field work, data collection and topical (and not so topical) discussions over dinner under the setting Phimai sun.

For the ladies in the Caversham Women's and Purple Passions football teams, thank you for the best weekend matches, and support on and off the field.

Lastly to my parents, thank you for supporting and loving me.

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Chapter 1. Introduction

1.1 Research Outline and Objectives

This dissertation will explore the ceramic tradition known as Phimai Black at the site of Non Ban Jak, a settlement with an occupation period confined to the fourth and final period of the Iron Age in the upper Mun Valley (c. AD 300-600). This site is located 8 km west of Noen U-Loke, where all four Iron Age phases were found, and 11 km to the west of Ban Non Wat, where three of the Iron Age phases were identified. Both have yielded comparative ceramic vessels.

Phimai Black is a late Iron Age ceramic tradition found in moated sites that cluster in the upper Mun Valley in Northeast Thailand. The lustrous black vessels, regularly decorated with streak burnished patterns, are clearly identified relative to the ceramic traditions of other regions in Northeast Thailand. In one exploratory model, it was hypothesised that they originated as an elite good that was widely exchanged, resulting in local imitation and standardisation in production and form across multiple sites (Geary, 2007; 2010). One means of testing this model, is to examine the clay sources employed at different sites, the form of the pots manufactured and site specific decorative styles and techniques.

The site of Non Ban Jak is perfectly situated to test this model and assess the degree of standardisation as pottery vessels were found in abundance. Infants and children were interred in polished black globular vessels or within large lip to lip jars, while small black streak-burnished bowls were found to be common ceramic goods for adults (Fig. 1.1 and 1.2).

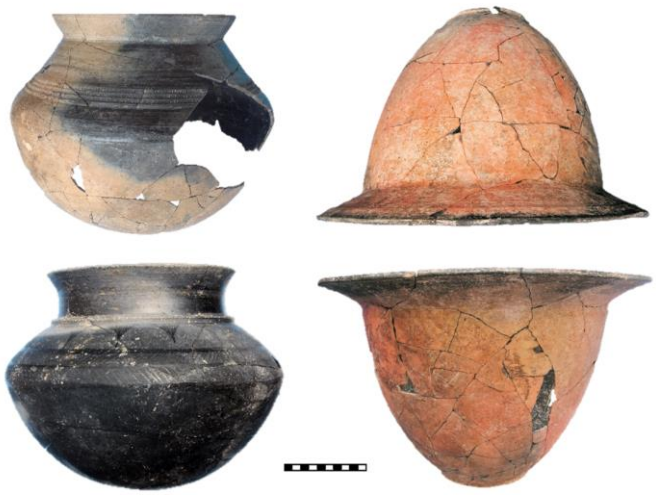


Figure 1-1 Examples of Phimai Black infant interment vessels, from top left clockwise cat. 1206, 89, 90 and 1262.

The more than 200 reconstructed vessels currently excavated from the site can arguably be said to be standardised through the three to four centuries of occupation at Non Ban Jak. The site was established around AD 220-380 in Iron Age 4 (Higham et al., 2014: p. 5), this was after the introduction of Phimai Black in Iron Age 3 (Geary, 2010). With such a large assemblage from dated mortuary phases and multiple contexts throughout the site, a detailed analysis of a specific Phimai Black ceramic tradition can be undertaken.

Figure 1-2 Examples of small Phimai Black bowls used as mortuary offerings for adults, from left cat. 788, 497 and 1349.

Non Ban Jak is a site of great significance as excavations have revealed a new dimension to the research of Northeast Thailand prehistoric pottery production. While previous excavations in Northeast Thailand have uncovered an abundance of mortuary contexts, excavations at Non Ban Jak have revealed extensive residential quarters, burial chambers and ceramic kilns. With the excavation of kilns at Non Ban Jak, this study is the first in the area to investigate the nature of a local Iron Age ceramic manufacturing site. Excavations carried out on the two mounds that comprise the Iron Age 4 site have also found that Non Ban Jak contains four well dated mortuary phases.

The methods of investigation include a form-plus-fabric analysis that focuses on samples from three field seasons at the site, these include a season at the Eastern Mound (2011) and two seasons in the Western Mound (2014-2015). The fabric analysis, carried out by portable x-ray fluorescence (pXRF) will identify fabric groups (chemical paste compositional reference units or CPCRUs). This is also the first chemical study carried out on the Non Ban Jak assemblage and the data gathered aims to identify form and fabric change through the four mortuary phases and between the domestic, production, occupation and burial contexts.

1.2 Research Questions

In order to ascertain the nature of Phimai Black Ware, the research undertaken here aims to assess the degree of visual standardisation through a form-plus-fabric analysis of ceramics over time and through multiple contexts across the site, which will then allow an investigation into the nature of social organisation surrounding pottery production at Non Ban Jak.

The study of standardisation is a common form of analysis for ceramic assemblages to identify types of production groups, specialisation, change through time, and how this economically relates to the chosen society (Blackman, Stein & Vandiver, 1993; Costin & Hagstrum, 1995; Roux, 2015). The standardisation of Phimai Black ware will be assessed through two theoretical frameworks, the first is cultural transmission theory (CT), which is the exchange of information as a means to explain the ‘variation, similarity and relatedness’ that can be identified within material culture assemblages (Eerkens &

Lipo, 2007: p.240). The second will be the application of a production typology by Costin (1991) which states that a focus on production factors, such as standardisation, can reveal degrees of craft specialisation and social structure, in turn providing insight into the context of production.

CT and Costin's production typology are applicable theories in illuminating the nature of pottery production at Non Ban Jak, giving an understanding and exploring internal and external influences surrounding the Iron Age assemblage, as well as possible community relationships and structure surrounding the craft.

Four main questions were proposed for the current research and were split into two groups to be answered in the discussion chapter. The first focused on the nature of production, fabric and form of the samples collected to assess their standardisation through time and across different context.

1. Are the tempers, manufacturing techniques and fabrics standardised through time and across the site?
2. Are the vessel forms standardised through time and across the site?

The second group of questions applied the current theory of cultural transmission and Costin's production typology to the data gathered and the archaeological context;

3. How will standardisation and variation in the assemblage be explained?

Cultural transmission theory is applied to the data gathered from the assessment of form and fabric through time and looks at the processes involved in the transmission of information between individuals. This theory was used to explore and explain reasons behind standardisation, evolution and/or variation in the entire assemblage.

4. What is the nature of pottery production on site?

The question here draws from the archaeological context to identify the possible types of social organisation surrounding pottery manufacture on site, this will be achieved through the use of Costin's production typology. Not only with the archaeological

context in question involve previous and current chemical and formal research, but also an investigation into the excavated kilns.

1.3 Methodology

To answer the questions proposed above a methodology was constructed of smaller questions, the following outlines these research questions and objectives. The first set of questions involve 1. The chemical analysis and 2. A formal analysis. The chemical analysis encompasses a sourcing study, the overall bulk chemical sample analysis, an investigation into temper types and identifying clay groups from kiln samples. While the formal analysis investigates vessel form in terms of terms of context, change over time and the pairing of form and fabric. These question are answered in the results section.

1.3.1 The Chemical Analysis

Sherd samples were collected from reconstructed or in situ vessels for chemical (clay and temper) and formal analysis. These sherds came from burials, domestic contexts and ceramic kilns. In association with the four mortuary phases, change through time and across context will be assessed. There are eight questions used to explore and explain the data gathered from the chemical analysis, these questions are categorised under sherd sample analysis, temper analysis, and vessels found within the kilns.

Ceramic and Clay Analysis

1. Do the ceramic samples gathered match the prehistoric clay groupings?

With the discovery of the kilns still containing vessels, the chemical groupings of the constituent clays have the potential to reveal sources for local pottery production. In knowing this, there was an attempt to source clay from the surrounding area to identify further possible local sources. Due to the lack of nearby sources, clays from prehistoric features such and clay floors and walls from the 2015 excavation were sampled on the notion that these features were made with local clays possibly from the moats and banks surrounding the site. A contemporary clay source called Tako Khonk from the village Ban Ta Ko was also sampled to compare against prehistoric clays and sherds.

2. How many CPCRUs are there?

The amount of CPCRUs identified within the assemblage gives insight into the amount of clay sources used on site and throughout time.

3. Do fabric groups change over time?

Change of clay groups through time is assessed through the mortuary phases to see if there is an exploitation of many fabric groups over time or if potters remain constant in their source choice. This question can also explore the possibility of multiple clays equalling different workshops.

Temper Analysis

Phimai Black ceramics were typically tempered with rice chaff that played a significant part in the creation of a thinner and lighter vessel, compared to previous ceramic traditions within the Bronze Age that were mineral tempered (Sarjeant, 2010). A temper that deviates from the norm can be an indication of a traded ceramic, an introduced ceramic tradition along with a change in technology (Summerhayes, 2000: p.32).

Temper will be identified through the use of a binocular microscope and the analysis of a sample of sherds on the electron microprobe.

4. How many types of temper are there?
5. Does temper change through time?

Vessels Found within Kilns

Vessels found within the kilns give the opportunity to explore pottery production at Non Ban Jak and link clay groupings and vessel forms to local production.

6. How many clay groupings can be identified from the kiln samples?

The groupings found within the kilns can indicate the number of local sources used to make and fire vessels on site. It must be noted that samples from a few isolated firings will not be a full representation of all the clay groupings and sources from the site.

7. Do the clays from the kiln samples match other ceramic samples from the site?
8. What forms were found in the kilns?

Vessels found in the kilns are evidence of the types of vessels that were manufactured at Non Ban Jak. As local production has not been identified in other Iron Age sites in the area, forms that are known to be made on site can create vital analysis and comparison analyses between the different ceramic assemblages.

1.3.2 The Formal Analysis

As this is the first time a form-plus-fabric analysis will be carried out on the assemblage at Non Ban Jak, a typology will be constructed from all the reconstructed vessels currently excavated from site, to in turn be able to understand and answer the following question surrounding physical form. Four questions were constructed for this section. Question 1 deals with the overall typology and outlines the different forms and sub-forms found on site, while the following questions (2, 3 and 4) are applied to each vessel form.

1. How many vessel forms are there?

The typology will be summarised into main and sub-forms to display the different types currently found onsite.

2. Are certain forms associated with certain contexts?

An assessment of the typology against context such as mortuary, domestic, occupational and production will be used to answer and investigate if forms are restricted to certain context.

3. Do vessel forms change over time?

This question assesses standardisation of forms through time. Each form and their sub forms will be studied for any physical changes through time/mortuary phases.

4. Are certain vessel types associated with particular fabric groups?

Finally, the clays used for each form are identified to see if a particular fabric was used for a specific vessel type.

Chapter 2. The Iron Age in Northeast Thailand

At a bird's eye view, one can easily spot the hundreds of Iron Age sites dotted across the Upper Mun River Valley (Fig. 2.1). Ringed by moats and banks, such sites were first identified by Williams-Hunt in the 1950s (Williams-Hunt, 1950). Soon after his publication, the first excavations commenced in Northeast Thailand. Since then the Mun River Valley has seen multiple projects and excavations to investigate the origins and beginnings of settlements along the Khorat Plateau and the subsequent rise of early states.

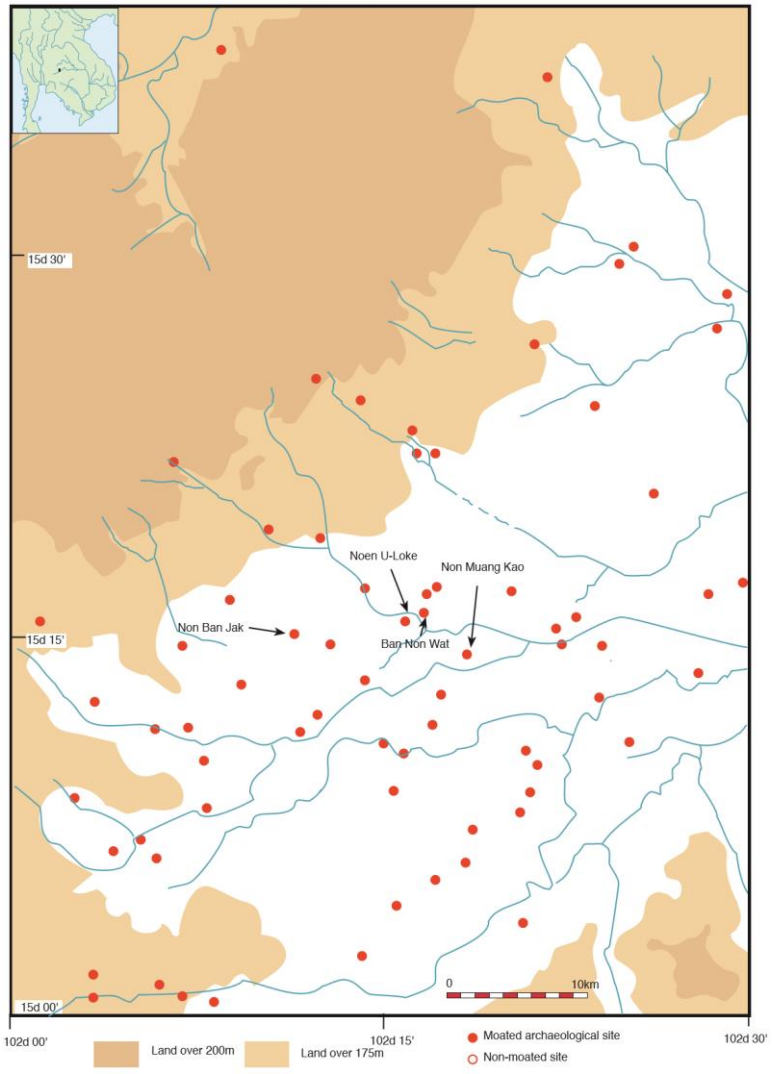


Figure 2-1 The Upper Mun Valley, showing moated sites (Higham et al., 2014).

A series of excavations have placed the initial occupation of the Khorat plateau by Neolithic rice farmers in about 1750 BC which was succeeded by the Bronze Age c. 1000-420 BC and then the Iron Age c. 420 BC – AD 600 (Higham & Rispoli, 2014: p.4). The Neolithic and Bronze Age peoples engaged in dry rice farming accompanied by hunting, gathering and raising domestic pigs and cattle. The Iron Age marks major changes including maritime trade that brought a new set of ideas and exotic goods up into the Khorat Plateau. Along with that, this phase saw forest clearance, wet rice agriculture, increase in population and expansion, Phimai Black ceramics, the forging of iron for farming tools and the construction of moats and banks around settlements (Higham & Rispoli, 2014; Castillo, 2011; Boyd & McGrath, 2001).

The following section will give a descriptive background of the Iron Age in Northeast Thailand. Previous research on the environment, trade and exchange and social organisation are key to understanding the context of the site of Non Ban Jak within a regional perspective.

The Environment

Pollen and phylolith research carried out by Boyd & McGrath (2001) on five Iron Age sites in the Mun River Valley gives us an insight into the environment of the time which included rice agriculture, grassland and native forests. Boyd & McGrath describe a landscape that had been modified by forest clearance and rice agriculture, punctuated by a brief period of forest regeneration. Following this was a renewed clearance of forest along with rice cultivation and the planting of arboricultural trees. These changes coincide with the occupation of the Iron Age moated sites and evidence of population increase in the region.

Environmental stress in the form of a decrease in rainfall meant that the rain-fed rice agriculture of Northeast Thailand relied on storage water in times of drought (O'Reilly, 2014; Castillo, 2011). It has been suggested that the control of water was key to social change in Iron Age sites, where a lack of rainfall would have stimulated storage of water through the construction of water fed moats surrounding the sites (Boyd & McGrath, 2001; Higham & Kijingam, 2013; O'Reilly, 2014; O'Reilly & Scott, 2015). O'Reilly

(2014) goes on to propose that an elite could have risen to supremacy over the population through a catastrophic dry season, turning water into a valuable commodity. A farmer in need of water would be indebted to the chief, such a debt can be paid off in surplus production, in turn creating a 'debt paid in agricultural output probably in perpetuity.' (p. 302).

There is no doubt that there was a surplus of rice in Iron Age sites in Northeast Thailand, people had the means to create an agricultural surplus, studies on health show a lack of malnourishment and its use for ritual purposes such as in the rice-filled burials at Noen U-Loke (Higham, 2014: p.250). Archaeological evidence has revealed the existence of iron ploughshares, found at Noen U-Loke and at Non Ban Jan. Ploughing the land is apparent at Ban Non Wat with the evidence of cattle/water buffalo management as seen in the cattle/water buffalo hoof prints of a possible holding area in the township (Iseppy, 2010) and of course, agricultural management seen in the increase of agricultural tools in found in burials.

Rice was supplemented by meat, fish and shellfish. Excavations at Non Ban Jak have revealed pits of containing the gastropod species Filopaludina and Pila and the dead were interred with fish and sacrificed pigs, deer, cattle and buffaloes (Higham et al., 2014).

Trade

The Iron Age in Mainland Southeast Asia marked the rise and increase of a maritime exchange network, trade with India, Vietnam and China (Higham & Rispoli, 2014). With that came new technology and wealth items into northeast Thailand such iron smelting and forging. Carnelian, agate and coloured glass beads in turn replaced the marine shell and marble that were popular in the Bronze Age (Higham, 2013: p.97).

Hard stone beads and glass beads have been found in many Iron Age burials across the Mun Valley, this is not surprising as the Valley is positioned between the East Chao Phraya Valley and the Mekong River (Higham, 2013: p.88). Even though the extent of wealth goods is not as vast and numerous inland compared to port cities in the south,

these exotic goods demonstrate the wide-ranging exchange network (O'Reilly, 2008: p.383).

Social Organisation

Burial evidence from the Bronze to the Iron Age has shown a change in social structure from small sedentary settlements with low ranking to high density townships growing in hierarchical structure. Such evidence includes the lack of hierarchical lineages in the Bronze Age compared to the clustering of wealthy adult burials and wealthy infant burials in the cemeteries of Ban Non Wat and Noen U-Loke that not only indicate hereditary wealth but also the existence of hierarchies in the Iron Age (O'Reilly, 2014).

The emergence of hierarchical lineages in the Iron Age is further explored by O'Reilly (2014) who proposes that the socio-political structure of the Bronze Age was based on a wealth-finance system, where wealth and status for some individuals was established due to the control over the production and/or the distribution of prestige goods. O'Reilly uses Ban Non Wat as an example where the elite could have established their standing in society due to the control of copper sources or exotic materials such as shell.

O'Reilly (2014) then proposes that there was a shift to staple-finance where the elite had control over water, an important resource in times of drought for crops. In sharing this resource to growers the elite could collect subsistence surplus, in turn this surplus could have been used to uphold the elite's position in society. Having said this, one must not think that the demand and distribution of wealth goods altogether died out.

O'Reilly's hypothesis is supported by evidence for climate change that saw increased aridity from about 200 AD (Wohlfarth et al., 2016). This, it has been suggested, stimulated a social response to construct moats and embankments to control water. Ownership and control over water and land to irrigate, in turn created the societal base for the early hierarchic polities seen in the historic states of Chenla and Dvaravati (Higham, 2016; Wohlfarth et al., 2016: p.9).

Control over the water within the moats and embankments would have been but one contributing factor to the changing nature of social organisation in the Iron Age from the Bronze Age. With the introduction of the maritime trading network and new and exotic wealth items would have acted as symbols of wealth and prestige, in turn, dividing the elite and the non-elite. Especially when political authority is not supported by a code of law, social inequality is sustained by exercising control over these items (Peregrine, 1991: p.2).

A shift to staple-finance would give rise to a staple surplus and as previously mentioned there was indeed evidence of a staple surplus of rice in Iron Age sites of Northeast Thailand. Settlements grew in number and size in the Iron Age, suggesting that there was a marked population growth, ensuring the importance of increasing agricultural production (Higham, 2013: p.100). An example of this would be the site of Non Muang Kao where initial occupation dates to 50 BC, halfway through the sequence at Noen U-Loke, hinting at a growing population and expansion of new settlements (Higham, 2014: p.254).

In terms of the population, current studies show a lack of evidence for the introduction of people from beyond the Khorat Plateau. In the case of Noen U-Loke, carbon and oxygen isotope analysis on teeth have revealed that people were locally born and raised (Cox et al, 2011). King et al. (2015) also came to a similar conclusion where strontium and oxygen isotope analysis of dental enamel from Ban Non Wat revealed that the few immigrants identified could have come from within the Khorat Plateau. This suggests that the development of society in the Upper Mun River Valley was not notably influenced by long-distance migrants.

Supporting biological evidence, material culture studies have shown continuity between the Bronze and Iron Age. While a change in production, marked by the introduction of high firing, there are still overlapping vessel types from the Late Bronze Age to the early Iron indicating a stable population base (O'Reilly, 2008: p.384).

Summary

In summary the Iron Age marked the introduction of new elements and changes within the environment, trade and structure of society. Expansion of townships caused populations to move and settle near rivers to construct moats and banks for the storage of water. This, in turn, would counter aridity and its impact on rice production. New technology and techniques meant that the introduction of iron forging created a new tool set for easier and quicker agricultural purposes. The construction of the moats and banks would have required a work force and with that comes a need for organisation. An established leadership would have gained more power and separation between themselves and labourers under O'Reilly's (2014) hypothesis that water control stimulated an emerging elite. The end of the Iron Age c. 600 AD saw the conclusion of the prehistoric occupation in the valley and the establishment of early states such as Chenla and Dvaravati (Higham, 2016).

2.1 Non Ban Jak

Non Ban Jak is a Late Iron Age site located in Amphoe Non Sung, Nakhon Ratchasima Province, Northeast Thailand. It is situated on a high oval mound spanning 360m with a width of 170m and is characteristically recognised as an Iron Age site as the mound is surrounded by two moats and banks dated to the 5th century AD (Higham et al., 2014).

The two moats separate the mound from the modern village of Ban Non Chua Khrut to the West and a Buddhist temple to the North. From mid-year the moats are full of green, newly grown rice while the mound itself is also used as farm land to grow crops such as pepper.

Non Ban Jak is an Iron Age 4 site in the chronology of the area, as mortuary rituals of the site matched the later sequence of Noen U-Loke, a site 8km east of Non Ban Jak exhibiting the full 4 phase sequence of the Iron Age (Fig. 2.2). Excavations carried out on the two mounds that comprise the Iron Age 4 site have also found that Non Ban Jak contains four well dated mortuary phases. The chronology of Non Ban Jak also extends into the historic period as the later layers show evidence of wheel thrown pottery and Buddhist artefacts associated with the Dvaravati culture from Central Thailand.

Non Ban Jak is but one mound site among the around 300 currently identified similarly formed sites along the Upper Mun River Valley which range in size and number of moats (O'Reilly & Scott, 2015). Not all of these sites were settled in the Iron Age, previous excavations in the area have revealed a chronology spanning from the Neolithic to the historical period, as seen in the site of Ban Non Wat. Upon transitioning into the Iron Age, moats and banks were added to Ban Non Wat. Moats are thought to be an Iron Age construction brought about by the drying conditions as a means to store and control water for rice paddy irrigation overseen by an elite.

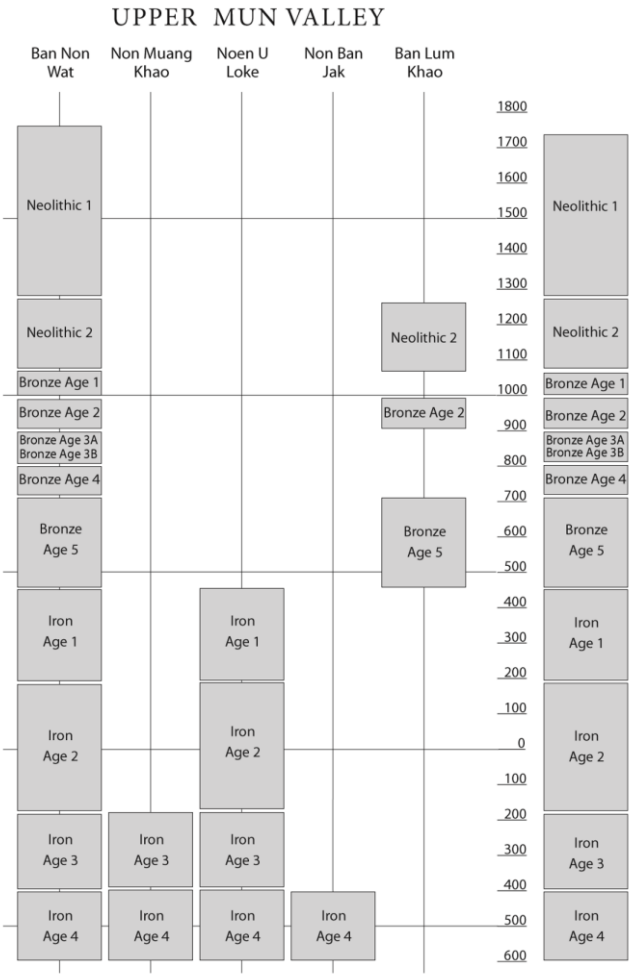


Figure 2-2 Chronology of the sites in the Upper Mun Valley courtesy of Charles Higham.

Non Ban Jak was a town established by settlers from another Iron Age site possibly from Noen U-Loke who as a result of population increase, broke off from the larger population to settle elsewhere (Higham, 2014: p.254). The settlement began with the construction of the first moat and bank and halfway through the occupational sequence another was added. The need for the second channel was possibly due to an increase of population, rice land and the need for more water. The people at this town are not overly wealthy compared to sites such as Noen U-Loke, there are individuals both adult and infant who have been interred with a variety of mortuary goods and wealth items such as gold earrings, ring and beads but these burials are rare.

Non Ban Jak's significance does not lie in a long chronology or an expansive site but in what has been excavated. The area has revealed extensive residential quarters, burial chambers and prehistoric ceramic kilns containing vessels (Fig 2.3 and 2.4). Domestic

spaces are rarely seen or found in the archaeological record in Southeast Asia, it is more common to find mortuary contexts and offerings used to discern activities of past peoples. Along with domestic spaces, the first prehistoric kilns containing vessels in any Khorat Plateau site have been found, therefore local forms and clays can be identified.

Figure 2-3 Photo of Burial chamber with burials 7 exposed and grave cuts of burial 8 and 9 in layer 2 of the Eastern mound. A lane can be seen to the left of the chamber (Higham et al., 2014).

Figure 2-4 Pottery vessels and an iron ploughshare within kiln B2 in Layer 5 of the Eastern mound (Higham et al., 2014).

2.1.1 Field Seasons

Non Ban Jak comprises an eastern and a western mound separated by a low area. Excavations have been carried out in all three of these parts of the site. The dip in the central region between the two mounds incorporated a Mortuary Phase 1 cemetery while the Eastern mound revealed house structures through the four Mortuary Phases with residential burials and kilns. While the Western mound has revealed structural remains through time there is also a prominent cemetery in the eastern quadrants beginning in Mortuary phase 1.

The following section will summarise the excavations at the Eastern and Western mounds, outlining the layers and highlighting major finds of the mounds excavated chronologically (Refer to Higham et al., 2014a, for more detail).

Eastern Mound

Excavations began at Non Ban Jak at the top on the Eastern mound in 2011. The Eastern Mound revealed structural remains of houses and two kilns for pottery firing. Within the 8 by 8 metre square there were six major layers reaching the natural substrate at 4.5 below the datum.

Layer 6

Layer 6 was the first layer of occupation with evidence of post holes, faunal remains and pot sherds.

Layer 5

Layer 5 contained structural remains of houses in the form of walls and clay floors along with the two ceramic kilns. One of the kilns (B2) had a rake out and two infant jar burials to the side, and within the kiln were complete ceramics and an iron ploughshare. The ploughshare is similar to that excavated at Noen U-Loke from Iron Age 3. The other ceramic kiln (B1) was located between two buildings and a large complete vessel was found inside. With layer 5 is also evidence of a fire in the form of heavily burnt floors in

multiple buildings, dating on a concentration of rice grains on a burnt area in this layer gives the C14 dates of 420-540 cal. AD (Higham et al., 2014: p.126)

Layer 4

Layer 4 showed an increase of occupation in the form of ash-filled hearths and Phimai Black sherds lying on the surface of layer 4 in comparison to layer 5. Along with house walls and floors, there is also occupation evidence of clay lined furnaces with iron slag and deposits of laterite. These could have been smithing furnaces and it is possible that this is evidence for the smelting of iron on site.

Layer 3

Layer 3 was a thin occupation deposit under the layer 2 structures evidenced by superimposed grey or red clay floors. This is an indication of re-flooring and consistent occupation.

Layer 2

Layer 2 consists of late Iron Age occupation with historic period pits dug into the layer. Along with the Iron Age occupational evidence seen in the plentiful Phimai Black sherds, there was much evidence for residential spaces and a burial chamber. A series of walls divided by lanes was found along with the interior of a room to the northwest quadrant, three burials were cut through the plastered clay floor (adult, child and infant) of the chamber and lip to lip Phimai Black bowls were situated in three of the four corners of the room, the last corner having been disturbed in antiquity. The presence of the bowls in the corners with the burials within suggest that this is a mortuary chamber and not a domestic space.

Layer 1

Layer 1 is the last layer of the occupation, it contains a series of pits full of Dvaravati period ceramics, animal bones (deer, cattle and water buffalo) and shell. Concentrations of burnt wattle and daub constructions were also found in this layer. The pits and

extensive shell midden is identical to the later layers in the Western mound showing the continuous occupation across the two mounds.

Western Mound

Layer 3

The earliest occupation of the Western mound is found in layer 3. Domestic activity is concentrated in the western part of the excavated area with clay floors, complete ceramic vessels and small areas showing evidence of burning. Within layer 3:3 in the eastern part of the area was three infant burials, in the west of this space was a large ceramic kiln. While burials are founds in residential areas it is also not uncommon to see them close to spaces that were used for industrial purposes (such as pottery production), for example infant jar burials were found next to kiln B2 in the eastern mound.

Mortuary phase 1 (MP1) burials are found within this layer and are split into two groups, Group A in the lower end of the site while group B is central. The early burials are largely dominated by infant jar burials showing a high degree of infant mortality in the early phase of occupation. The natural was found 2m below datum.

Layer 2

There is much evidence for domestic spaces and residential burials within layer 2. In the western area in layer 2:3 there is an indication that there had been a fire, seen in burnt clay floors with burials that has been interred post fire. More evidence for a domestic space in this area is seen in the clay floors and walls with evidence of areas for burning (for cooking) and sherds of Phimai Black. Occupation and activity is concentrated to the west of the opened area, seen in the pits and scattering of Phimai Black sherds.

Layer 1

Layer 1 is the last layer of occupation with a mix of historic and late Iron Age material culture. Due to the levelling of the land, archaeological material is found very close to the surface. The historic layer consists of pits full of near complete Dvaravati ceramic

vessels, shell and animal bones dug into the later Iron Age burials and occupation. The historic period is commonly seen in the stratigraphy as a layer of orange coloured pottery.

Within the Iron Age occupation of layer 1, remnants of walls and clay floors were found embedded with postholes and burials were found cut through the floors. Occupation is seen via concentrations of Phimai Black sherds and shell pits and activity is concentrated to the west of the excavated area.

2.1.2 Mortuary phases

Out of the two mounds at Non Ban Jak, the Western has been excavated most extensively with a total of 450m^2 opened. This has given a clear picture of the mortuary sequence into which the Eastern mound burials fit. The following is a description of the four mortuary phases based on burials excavated and their subsequent mortuary offerings.

Mortuary Phase 1 (MP 1)

MP 1 consists of nine adults and fourteen infants which represent the initial settlers of Non Ban Jak. This phase is separated into two groups, MP 1A and MP 1B. MP 1A is in the southern end of the excavations while MP 1B is central. Due to the large area excavated and the concentration of the Group A burials suggest that this area was a cemetery.

The infants were interred in lidded jars with bronze offerings that matched the offerings for adults. Overall mortuary goods consisted of agate beads and pendants along with glass beads, a bimetallic iron and bronze ring, bronze rings for fingers and toes and bangles and an anklet. Even with the variety of mortuary offerings the burials were not wealthy in comparison to the Iron Age 3 at Noen U-Loke. In terms of ceramics, no individual had more than three vessels and were similar to those typical of Iron Age 3 sites.

Mortuary Phase 2 (MP 2)

MP 2 was grouped based on the burials and clay floors that were on a different orientation to the MP 1 burials. Within this phase there are 16 adults and 32 infants, the

infant mortality rate was higher than in the previous phase. Burials concentrated in the west and central parts of the excavated area. The first iron sickle and iron knife appeared within a burial but these artefacts were rare. Other mortuary goods for adults included spindle whorls and ceramics never exceeded three vessels. Infants were interred with more of a variety of offerings compared to adults such as gold, glass and agate beads, bronze bangles and rings. The ceramics for infants ranged up to five. A bird's egg was also found in burial 104, showing a mortuary practice shared with sites such as Ban Non Wat and Noen U-Loke. A large kiln was also found within this phase in the western mound. The kilns in the Eastern mound are also dated to this phase.

Mortuary Phase 3 (MP 3)

There were 16 adults and 19 infant graves in MP 3, which saw a rise in range and number of mortuary goods, ornaments were not only made from bronze or bimetallic metals but gold rings and earring were also found, however in very low quantities. Iron sickles and knives were now common, and bronzes in most adult burials also increased, however glass beads and animal offerings were rare in adult burials and glass beads were absent in infant burials. There was also evidence of woven fabric on bronze ornaments suggesting a type of clothing or the covering of the deceased with a shroud.

Along with the rise in mortuary goods and possible overall wealth, this phase showed a small decrease in infant mortality compared to the phases previous. Burials consisted of 16 adults and 18 infants. The burials were also found in rows and in line with walls and cut through floors from residential buildings. This is also the period where there is variation in infant interment, along with globular jars infants and children are interred in lip to lip u-shaped jars also seen at Noen U-Loke and Ban Non Wat. Other similarities to surrounding sites include a male burial who wore two bronze belts identical to those found in the Iron Age 3 graves at Noen U-Loke.

Mortuary Phase 4 (MP 4)

There were 11 adult and seven infant burials in this phase. MP 4 extend into the early historic period, as the site has been bulldozed and levelled for farming, much cultural material can be seen scattered across the surface. The mortuary rituals are the same as MP 3 and the burials were still seen to be associated with possible residential spaces.

Burials are located in the western part of the excavated area on the same orientation as MP 3.

The mortuary offerings for adults during this period consist of iron sickles, knives, spears, a point, machete and an axe. Gold earrings, agate pendants, bronze rings and earrings still present but in less numbers, ceramics do not exceed four vessels for adults and also infants. Infant offerings include bronze earrings, bangles and glass beads.

2.1.3 Kilns Excavated at Non Ban Jak

As of 2015, six kilns have been found at Non Ban Jak all around a metre in diameter and containing carbonised rice. To explain the presence of rice one can look to the charcoal burning kilns of contemporary Thailand. Rice husks are piled on top of the kiln for insulation and are also used as a fuel for burning. Rice husks are not only used as a fuel for contemporary charcoal kilns but also for the open firings during the final stage of pottery manufacture (Shippen, 2005). During the 2015 field season in the Western Mound rice was found in the daub of kiln feature. All of these examples show that rice husks were and are still common as a fuel and as an insulation material.

Out of the six kilns excavated at Non Ban Jak, two contained reconstructable vessels, these were kilns B1 and B2 from Layer 5 in the Eastern Mound. While other kilns across both the eastern and western mound contained carbonised rice there have been no reconstructable vessels recovered, these kilns also lack the structure of kilns B1 and B2, missing a rake out and tuyère, in turn suggesting firing pits for other purposes. One pit from layer 4:4 DD2 excavated in 2015 in the Western Mound contained an abundance of carbonised rice, a variety of sherds and an associated disturbed infant jar burial. A sample was taken from this pit under the assumption that it had possibly been used as a ceramic kiln.

Kiln B1 5:2 Feature 1

The first kiln found in the Eastern mound was Kiln B1, situated between two buildings on the same orientation. The building to the west of the kiln had been destroyed by fire. The kiln was located on the outside of this building and was oval in shape. The quantity

of collapsed daub suggested an enclosed dome roof and under the daub and within the kiln was a large pottery vessel (cat. 282).

Kiln B2 5:6 Feature 1

Kiln B2 was the second kiln found in the eastern mound, it was first identified as a circular black pit 1.20m in diameter filled with daub and charcoal. The kiln was associated with a rake out which was identified as a straight line of charcoal on the surface of layer 5-5 in the south-eastern quadrant (Fig. 2.5 and 2.6). Further excavation revealed that the line of charcoal contained broken pottery sherds leading to a circular black pit near the southern baulk (Fig. 2.7). According to Higham (pers. comm.) the rake out from kiln B2 matches the rake out of ash from modern day charcoal burning kilns in Northeast Thailand.

The excavation of the black circular pit showed that Kiln B2 was once a domed structure of wattle and daub, as the daub showed impressions of the once inner wooden stick structure. Within the remains of the dome a chimney or tuyère to channel air flow was found.

Similar black pits were found at the site of Noen U-Loke, however the structural features did not match the kilns at Non Ban Jak. While the pits at Noen U-Loke were identified as high firing structures their exact function could not be ascertained (Parr & Boyd, 2002). Asides from Non Ban Jak, no other prehistoric kilns are known to have been found in Northeast Thailand.

Figure 2-5 Layer 5:6 showing kiln B2 and associated rake out.

Figure 2-6 Layer 5:6 showing kiln B2 and associated rake out, infant jar burials are seen next to kin.

Figure 2-7 Left unexcavated kiln B2. Right excavated kiln B2 with vessels and iron ploughshare.

When all the daub was cleared seven broken vessels along with an iron ploughshare were discovered within Kiln B2 (Fig. 2.7). Ceramics were found in both Kiln B1 and B2. According to John Miksic and his work at the kilns at Bakong (20km Southeast of Angkor Wat), wattle and daub kilns are sealed up and fired, when the firing process is finished the kiln is broken into so the ceramics can be retrieved (NSC Archaeology Unit, 2013). A wattle and daub kiln will only last two to three firings as that is as much stress as the structure can handle (NSC Archaeology Unit, 2013). In knowing this, it is understandable that the ceramics left behind in both kilns were probably a part of the last firing. These ceramics would have cracked or broken due to a misfire or a break in the kiln structure.

Chapter 3. Phimai Black

Physical description and history

Phimai Black is a rice chaff tempered earthenware, easily recognised by its thin body and burnished streaks on a black or grey matte surface. First excavated at Ban Suai in 1966, Phimai Black has come to be known as a horizontal marker for prehistoric sites across the Upper Mun River Valley, this is due to its standard appearance and origins in the Iron Age (Welch & McNeil, 2004; Thosarat & Kijngam, 2004).

In their analysis of the Ban Suai material, Welch & McNeill (2004) propose that Phimai Black is a part of a wider pottery tradition which they have call the Phimai Tradition. This includes the use of rice chaff as temper and streak burnishing for decoration. The Phimai Tradition includes polished black chaff, plain black, red-yellow streak burnished, reddish-brown streak burnished, high fired brown streak burnished, slipped chaff and polished (other than black) (Welch & McNeill, 2004: p.529).

According to Welch (1984), this ceramic tradition fits within six periods of ceramic change for the Mun Valley, which include Tamyae (1000-600BC), Prasat (600-200BC), Classic Phimai (200BC-300AD), Late Phimai (300-600AD), Muang Sema (600-1000AD) and Lopburi (1000-1300AD). This chronology was proposed before the classification and dating of the Neolithic, Bronze Age, Iron Age and Historic period, undertaken on large sites such as Ban Non Wat and Noen U-Loke. Decades later, Phimai Black is now classified as a late Iron Age ceramic tradition, which was introduced in Iron Age 3.

Unrestricted bowls with a black interior and streak marked burnishing are a distinctive marker of the Phimai Black tradition. Such examples are seen in the ceramic assemblages of Non-U Loke, Ban Non Wat and Non Ban Jak (Geary, 2010; Higham et al., 2014). Phimai Black made its appearance in Iron Age 3, it represented a new regional ceramic tradition differing from the previous Bronze Age red wares as it was high fired, as seen in the colour of the exterior and blackened core due to firing in a reduced atmosphere.

Such an atmosphere could not be created in an open fire which the previous red wares were exposed to.

The rise of this regional ceramic tradition made its presence known across the Iron Age sites, however before the excavations at Non Ban Jak, no evidence for ceramic production in the form of kilns were evident in the valley. Phimai Black vessels in sites across the Upper Mun River Valley were suspected to have been produced off site by specialists within a regional political centre (Welch, 1989; O'Reilly, 2008: p.385).

The notion of a regional political centre producing Phimai black during the Iron Age and trading it through the Upper Mun River Valley is further explored by Welch (1989). Welch highlights the town of Phimai as a regional centre due to its role as a polity during the Khmer rule. Excavations at the Phimai Prasat have revealed a rich Iron Age deposit under the Khmer occupation, indicating that Phimai was not only an important centre during the Khmer rule but also during the Iron Age (Talbot & Janthed, 2001).

Welch (1989) outlines the possibility for the rise of craft specialisation and Phimai Black in the prehistoric Mun River Valley centring on trade at Phimai. Located on the Mun River, this waterway would have opened Phimai to exchange with communities and trading across the Khorat Basin. Craft specialisation at Phimai may have been encouraged by the need to sustain the growing population and political power. The rise of specialists at Phimai would have brought forward goods to trade for surplus in the form of rice and in turn increasing political control over other communities through the exchange of specialised goods (Welch, 1989: pp.20-21).

Research carried out by Geary (2007) investigated the hypothesis that Phimai Black was a product of centralised manufacture on the basis of the wide distribution and standard appearance over the Upper Mun River Valley. In the investigation Phimai Black was sampled from three sites; Ban Non Wat, Non U-Loke and Ban Suai. Geary found that the samples shared a standard form, colour, decoration and a standard temper (rice chaff) however samples from Ban Non Wat, Noen U-Loke and Ban Suai were grouped into three different clay sources for each of the three sites. In pointing out that each site manufactured its own Phimai Black, disproving the theory that Phimai Black was made in a central location.

Having said this, Geary does go on to discuss the emulation hypothesis, where it is possible that Phimai black may have originally been produced at one centre, possibly at Phimai, as an elite ware and traded to other communities for use in particular contexts like such as burial. It is possible that potters in these other communities may have begun producing vessels in emulation of this elite ware, conforming to a standardised production process while utilising local resources.

The ceramics at Non Ban Jak represents an assemblage that includes the Phimai tradition and other Iron Age ceramics that are rice chaff tempered, high fired yet not burnished or polished black. These ceramics and the site are from Iron Age 4 meaning that the assemblage would in Geary's terms, be the product of the emulation hypothesis. The current research explores that nature of the assemblage in the form of its elements of standardisation and change through time. The following section is an in-depth look at pottery production at the site of Non Ban Jak, outlining the production methods and a site specific typology for currently excavated vessels.

3.1 Pottery Production at Non Ban Jak

3.1.1 Type of temper

The temper used for the Iron Age ceramics at Non Ban Jak was predominantly rice chaff. Rice chaff would have been mixed with clay to be formed into balls and the fired and crushed to make temper, this is referred to as bleb grog (Vincent, 1988: p.88; or Bleb according to Welch & McNeil, 2004: p.528). This technique for making temper is also used by modern Thai potters (Sarjeant, 2008; Chapter 5).

Although bleb grog is the predominant temper in the manufacturing of Phimai Black ware, this temper style was not constrained to just Phimai Black and is not a unique development of the Iron Age. Sarjeant (2008) found in her analysis of the Ban Non Wat ceramics, that fibre temper was introduced into the site during Bronze Age phase 4. Further evidence supporting this conclusion comes from Non Nok Tha where rice chaff was also present in the clays of Bronze Age vessels (Higham, 2014: p.120).

The addition of rice chaff to the temper contributed to a thinner and more lightweight vessel compared to the earlier untempered and quartz tempered wares seen prominently in the Bronze Age (Sarjeant, 2008: pp.169-171).

3.1.2 Manufacturing - Paddle and Anvil

Vessels made at Non Ban Jak were shaped using the paddle and anvil technique, as paddle and anvil marks can be seen on the reconstructed vessels. While no anvils have been currently found on site, other evidence for this technique during the Iron Age come from Ban Non Wat, Noen U-Loke and Non Muang Kao, which share the same ceramic traditions as Non Ban Jak (Higham, 2007; 2010).

Other evidence for the paddle and anvil technique can be seen on the vessels themselves. By looking at a complete vessel, one can note that the thickness is not always consistent, there are dips in the interior where the anvil has left a mark. There is no evidence of wheel throwing in prehistoric Northeast Thailand, this technique would have come into the area during the historic period, but is no longer in use today.

3.1.3 Firing

Before excavations at Non Ban Jak, there was no evidence for the use of kilns in prehistoric Northeast Thailand. However, researchers have acknowledged that a visual examination of Phimai Black suggests that the pottery firing was under controlled conditions (Solheim, 1965 as cited in Meacham & Solheim, 1980: p.13). On the bases of this, Meacham & Solheim (1980) carried out a refiring test on ceramics from the sites of Non Nok Tha and Phimai. In subjecting the samples to thermal expansion measurements, they found that all Non Nok Tha ceramics were fired above 600-800°C, as well as the sherds from Phimai. Phimai also yielded two sherds that were high fired giving temperatures of 1150-120 and 1150°C.

In finding that all sherds from both sites were fired above the temperature range of an open fire, the authors hypothesised that the Non Nok Tha sherds were either subjected to rapid firing or sustained temperatures in an enclosed kiln, a clay-lined pit, or other partially closed firing pits. For the high-fired sherds from Phimai the authors suspect that

they may have been produced in a well-constructed kiln capable of reaching higher temperatures of at least 1200-1250°C.

Through Meacham & Solheim's research and the excavation of kilns at Non Ban Jak we can positively say that Phimai Black was fired in constructs other than open fires. While this experiment suggested that kilns were being used at Non Nok Tha as early as 3000BC, the site has now been dated on the basis of human bone collagen and is much later (Higham et al., 2014b) While the early dates are unreliable it is still plausible that kilns were used at Non Nok Tha with the rise of local metal working in the middle Bronze period.

In modern Thailand kilns are not commonly used for pottery production, unless for large scale production. For example the large storage jars known as 'dragon jars' from Ratchaburi, which are considered an essential and traditional item for the Thai household, are fired in brick kilns up to 80m long (Shippen, 2005). Smaller scale production for market or personal consumption within the Khorat Plateau is achieved through open firing (Shippen, 2005; Chapter 5).

There is one type of kiln that shares similar features to those excavated at Non Ban Jak, these are the charcoal burning kilns commonly seen smoking on road sides in rural Thailand. Higham (pers. comm.) draws similarities between the two types of kilns, both sharing the domed structure of wattle and daub, a chimney or tuyère to channel air flow, an area for the rake out and the covering of the structure in rice chaff for extra insulation (Fig. 3.1 and 3.2).

Figure 3-1 Charcoal kiln with entrance, photo courtesy of Charles Higham.

Figure 3-2 Charcoal kiln that has been deconstructed to collect the charcoal, note the can in the right of the structure which was used for airflow and the covering of rice chaff for insulation, photo courtesy of Charles Higham.

Other markers of kiln firing can be seen on the vessels themselves. Shangraw (1977) explains that black colour is achieved through the reduction in oxygen during firing by an enclosed kiln. The inside of the chamber is filled with carbon monoxide from the burning fuels which then becomes carbon dioxide when oxygen particles from metallic oxides in the clays are absorbed. The reduction process of this forms ferrous oxide resulting in grey coloured vessels (pp. 386-7).

Vessels of a darker grey or even black is the result of saturating the vessel in water before or after the firing or even adding damp organic matter to the kiln during firing (Shangraw, 1977). Ethnographic studies by Shippen (2005) describes Malaysian potters covering the vessels after firing in rice husk or sawdust to blacken them.

3.2 Form and Decoration

3.2.1 Form

The first typology concerning Phimai Black pottery was created in the 60s by Wilhelm G. Solheim (Solheim; 1965; Solheim & Ayres, 1979), around the time that the first excavations were taking place in Northeast Thailand. Solheim's typology was based on the excavations at Ban Suai, a mound site located in the town of Phimai, separated on the basis of three different types of earthernware (Phimai Black, thick fibre and sand-tempered), stone and porcelain. The typology was later refined by Welch & McNeill (2004), who added more detail to the ceramics in terms of their degree of firing, paste temper, surface treatment and surface colour identified in the Ban Suai sequence to create a classification to be used regionally.

The majority of the pottery from Non Ban Jak fall under the Phimai Black ceramic tradition with the exception of stoneware (cat. 1182, Form 13) early historic wheel thrown pottery (cat. 478, Form 11) and other Iron age high fired, rice chaff tempered ceramics (Form 5,6, 7 and 12). The latter are rice husk tempered and were high fired, however do not fall under the Phimai Black tradition (or even the overarching Phimai Tradition) as they lack the black colouring and streak burnish decoration that is typically Phimai Black. These vessels are present through the occupational sequence at Non Ban Jak, while not a part of the Phimai Black tradition they are made the same way and will be instead considered and classified as a part of an overall Iron Age ceramic tradition.

The following typology constructed by Charles Higham and the author is based on form with considerations to size and decoration. Already constructed typologies and ceramic studies in the area (Solheim, 1965; Welch & McNeill, 2004; Voelker, 2002; Sarjeant, 2008) were consulted when addressing the assemblage at Non Ban Jak, however on closer inspection new forms were identified on site that had to be included in the typology.

The following section outlines all forms found at Non Ban Jak, covering the material excavated from the beginning of excavations in 2011 to 2016, also including ceramics

not considered to be in the Phimai Tradition. The typology begins with the two basic forms, unrestricted vessels (bowls) and restricted vessels (jars).

3.2.1.1 Unrestricted Vessels

Form 1

Form 1 consists of small open bowls, there are at least six sub forms. The exterior of the bowls usually display wide apart horizontal streak burnishing on a black, grey, brown or red surface while the interior is mainly black with patterned streak burnishing. The interior burnishing patterns differ between forms, the two major patterns include a solar disc with streaks spiralling into the middle of the bowl, while the other is a set of tight rings. The average diameter of the bowls is 17 cm, however it is not uncommon to see a smaller replica of a standard-sized bowl. Lastly, in some cases holes have been bored into the base of the bowls, examples can be seen in forms 1A and 1D.

1A. Simple unrestricted vessel with a flat lip and a prominent ridge

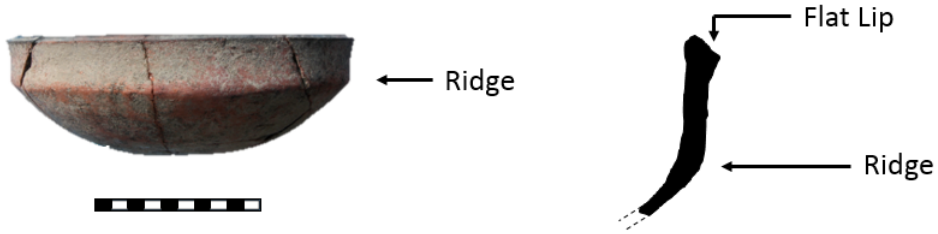


Figure 3-3 Vessel form 1A. Cat. 1162and rim profile (rim profile not to scale).

1B. Similar in form and size to 1A, instead has a rounded lip and a curved ridge.

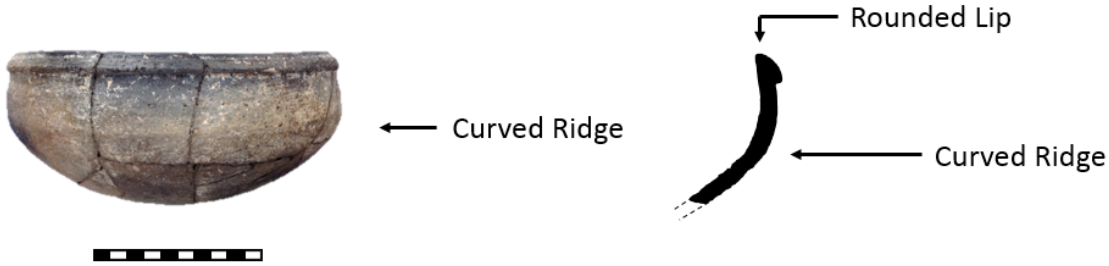


Figure 3-4 Vessel form 1B. Cat. 962, Burial 93 and rim profile (rim profile not to scale).

1C. Has a carinated shoulder under an everted rim. The rim is thicker than the other forms.

Figure 3-5 Vessel form 1C. Cat. 444, Burial 30.

1D. Simple bowls consisting of a gradual curve from the rim to the base.

Figure 3-6 Vessel form 1D. Cat. 582, Burial 57.

1E. Resembles 1D but has a small pedestal rather than a rounded base.

Figure 3-7 Vessel form 1E. Cat. 742, Burial 72.

1F. Similar lip to 1A but has no ridge and has a ring foot instead of a curved base.

Figure 3-8 Vessel form 1F. Cat. 583, Burial 58, showing ring foot.

Form 2

Large open bowls and lids with a simple contour.

2A. Large open bowls with a simple contour and a rounded rim. Maximum width of 45-50cm. Smooth but no polished surface, unlike 2B.

Figure 3-9 Vessel form 2A. Cat. 437, Burial 28.

2B. Large open bowls with a simple contour, a slight shoulder and an indented rim. The rim is more elaborate compared to 2A. Some were used as lids for infant mortuary vessels for form 3. Horizontal streak burnishing on exterior.

Figure 3-10 Vessel form 2B. Cat. 546, Burial 41.

Form 3 - V shaped infant mortuary vessels

These vessels are very large and deep and are usually accompanied by a lid (2B). The vessels consist of an everted rounded rim with a slight shoulder. From the shoulder the body angles in a V shape to a flat base. Horizontal streak burnishing is present on the exterior while the interior moves from diagonal streaks to horizontal from shoulder to base. Other decoration includes punctuates on the shoulder and in one case a bird applique (Cat. 302). Form 3 appear predominately in MP 1-2 as infant burial jars, these vessels are then succeeded by Form 4 in the later mortuary phases.

Figure 3-11 Vessel form 3. Cat. 1249, Burial 127.

Form 4 – U shaped infant mortuary vessels

Form 4 overall is U shaped. Starting from a wide everted rim this vessel gradually decreases in diameter to a flat base that has a slight ring foot. In terms of decoration these vessels have a plain body but horizontal burnishing streaks are found under the rim and on the black interior. Form 4 succeeded Form 3 as preferred infant burial jar in MP 3-4. These jars are usually found in pairs, lip to lip, with the head and feet of the infant within each jar.

Figure 3-12 Vessel form 4. Cat. 1163 and Cat. 1164, Burial 118.

Form 5

Form 5 is a relatively shallow bowl with a wide everted rim and cord marking on the exterior of the body. This is an uncommon form as only three of these vessel forms have been found.

Figure 3-13 Vessel form 5. Cat. 1220, Burial 122.

Form 6

Unrestricted bowl with a tall flared neck and a shallow body. The angle of the flared neck varies within the form grouping. These vessels have black interiors and are found in occupational contexts.

Figure 3-14 Vessel form 6. Cat. 385 and 382.

3.2.1.2 Restricted Vessels

Form 7

Globular vessels with everted rims and a small flared neck. There are two sub forms, these forms can be further defined by their decoration. Usually cord-marked, there are a few plain vessels, plain with two rows of incised vertical lines below the rim or smooth vessels with horizontal burnished lines.

7A. Smaller than 7B, circular body, small flared neck.

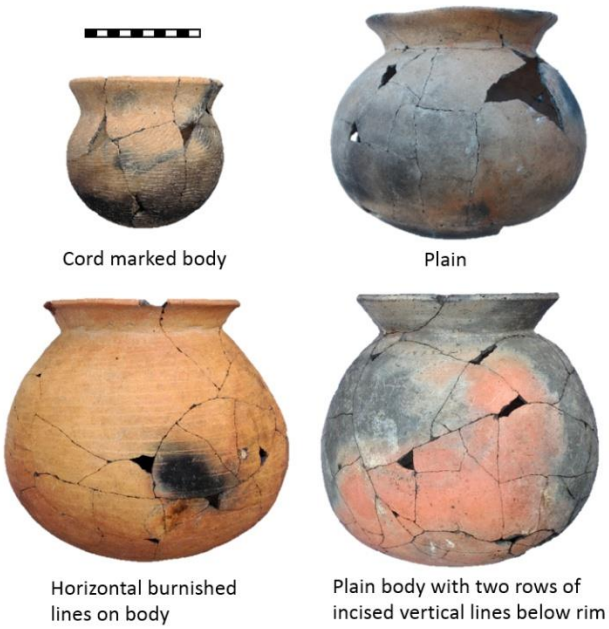


Figure 3-15 Vessel form 7A and decoration.
From top left Cat. 845, Burial 80, Cat. 1339, Burial 139, Cat. 774, Burial 76 and Cat. 789, Burial 77.

7B. Larger than 7A, with a body deeper than it is wide, small flared neck.

Figure 3-16 Vessel form 7B. Cat. 1233, Burial 123.

Form 8

Everted rim, cylindrical neck, a carinated shoulder with a rounded base. Compared to the other forms these vessels are highly decorated varying from rows of punctuates on the shoulder, horizontal streak burnishing on the body, herringbone, or other geometric patterns. Most vessels are burnished to lustrous black and are only found in MP 2 and 3 functioning as infant mortuary vessels.

Figure 3-17 Vessel form 8.From top left Cat. 1282, Burial 133, Cat. 1262, Burial 128, Cat. 1240, Burial 126, Cat. 1082, Burial 100 and Cat. 1206, Burial 121.

Form 9

Large globular body with a tall flared rim. Surface burnished with horizontal bands. The colouring and decoration suggest that this vessel is part of the Phimai black tradition.

Figure 3-18 Vessel form 9. Cat. 453 and accompanying lid, cat. 454 both from Burial 32.

Form 10

Large vessel with an everted rim and a sloping neck connected to a shoulder. While rice chaff tempered, Form 10 have thick walls as opposed to the usual thin walled Phimai Black and is not burnished making this vessel separate from the Phimai tradition. The exterior is plain however at the interior of the neck, directly below the rim there is a series of ridges. Only one complete example has been found (Cat. 282, kiln B1) the two other examples consist of rims with necks from the 2016 excavations at the Western mound (cat. 1467 and cat. 1475).

Figure 3-19 Vessel form 10. Cat. 282, from kiln B1 layer 5.

Form 11

Globular vessel with an everted rim and a sloping neck to a cordon at the shoulder. The bottom half of the body to the base is cord-marked. This form is not a part of the Iron Age ceramic traditions as these vessels are wheel thrown, lack rice chaff temper and black burnishing. Found within the historic layers of Non Ban Jak, usually within historic pits, these orange vessels share standard elements such as lip, shoulder and decoration, only to differ in the height of neck and overall size.

Figure 3-20 Vessel form 11. Cat. 478, Burial 36.

Form 12

Form 12 is similar in shape to Form 11 with a carinated shoulder. This vessel has an everted rim with a neck that curves to a sharp shoulder and carries onto a rounded base. This vessel is not part of the Phimai tradition as it lacks the stylistic black decoration, however shares the same manufacturing techniques. There has been only one example currently excavated from site.

Figure 3-21 Vessel form 12. Cat. 1123, Burial 112.

Form 13

This vessel is white stoneware, with a tall flared neck and a rounded lip. Only the rim and a small portion of the shoulder exists of Form 13, it was found contemporary with a Phimai Black vessel in MP 3.

Figure 3-22 Vessel form 13. Cat. 1182.

3.2.2 Decoration

All forms of decoration stated here have been outlined in Solheim (1965) and Solheim & Ayres (1979) apart from the addition of categories including; other geometric burnishing and applique.

Streak Burnishing

Streak Burnishing is a common form of decoration found on Phimai Black vessels. Burnishing was achieved by running the edge of a smooth stone along the surface of the vessel creating lines that shine after firing. Such stones were found as a mortuary offerings, for example Burial 68 of a male was interred with a lump of clay and a burnishing stone suggesting that the individual was a potter. Currently seven types of streak burnishing patterns have been identified at Non Ban Jak. The most common burnishing found on bowls and jars is called horizontal burnishing where streaks run horizontally around the vessel and can be found on the interior and exterior of rims and bodies. The following burnishing techniques are commonly found on the interior of Phimai Black bowls (Form 1). These bowls have a black interior with either, or a combination of radial, cross-hatch, and spiral burnishing. These patterns usually start just below the lip of the interior of the bowl and extend to the base (Fig. 3.23 and 3.24).

Figure 3-23 From the left, horizontal, radial and cross-hatch burnishing, courtesy of Geary (2010).

Figure 3-24 Radial and spiral burnishing.

Herringbone is an uncommon design at Non Ban Jak as only one example has been found (cat. 1262). The design is located on the shoulder of the globular black polished infant burial jar. While this design is rare at Non Ban Jak, it is not restricted to the site. Solheim (1965) mentions herringbone as one of the burnishing patterns in his Phimai Black typology.

The last streak burnishing pattern is categorised under other geometric burnishing, it includes only one design (Fig. 3.25) and is thought to be growing rice (Higham, pers. comm.). This pattern could be a reflection of the environment through the potter's eyes.

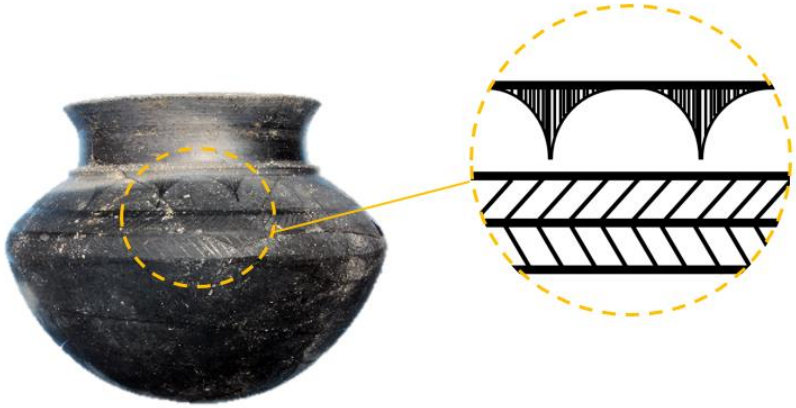


Figure 3-25 Geometric burnishing in the form of growing rice over herringbone on cat. 1262.

Polishing

Polishing the surface of the vessel with a smooth stone before firing creates a lustrous black surface. The best examples of polishing come from the Form 8 globular infant burial jars (Fig. 3.26) but can also be found concentrated in areas such as on the interior and exterior surfaces of bodies, shoulders and rims for bowls and jars.

Figure 3-26 Polishing and punctuates on cat. 1082.

Punctates

Punctates on Phimai Black vessels are rows of impressed small circles that can be found on the exterior of shoulders or on the point where the neck and the shoulder merge (Fig. 1.26 and 1.27). The circular impressions are possibly made using a hollow implement such as bamboo or bird-bone.

Figure 3-27 Three rows of punctuates.

Appliqué

Currently there is only one example of an added appliqué at Non Ban Jak, it is in the form of a winged bird located on the shoulder of a v shaped infant burial jar (Cat. 302, Burial 13).

Figure 3-28 Bird appliqué on cat. 302.

Paddle Impressed Techniques

Common paddle impressed techniques at Non Ban Jak include cord-marking, where cord like material is wrapped around a stick and rolled along the vessel. Also, net-

marking which is similar in decoration to cord-marking however is achieved by wrapping a paddle with net and repetitively striking or pressing the vessel.

Figure 3-29 Cord-marking on cat. 1233.

Chapter 4. Theory Section

Costin's Production Typology and Cultural Transmission

The following section presents the theories that are applied to the current research. The first is Cultural transmission theory which focuses on the assemblage itself. CT is used as a means to explore and describe the physical and visual factors that contribute to the standardisation, variation and/or evolution that can be identified within the ceramic assemblage. In conjunction with CT, Costin's production typology is applied to the data to describe the broader picture of the social organisation of pottery production at Non Ban Jak. This is achieved through the use of parameters used to identify and explore specialisation and the organisation of pottery production through the analysis of standardisation (Costin, 1986; 1991).

4.1 Cultural Transmission

Cultural transmission is a powerful tool used to explain patterns and variation seen in material culture through time and space. Explanations can include the processes involved in construction and how this is transmitted between individuals while consistently undergoing modification through copying error, individual learning, experimentation or innovation (Eerkens & Lipo 2007: p.263).

Cultural transmission is not always visible within the archaeological record and according to Eerkens & Lipo (2007), requires the consideration and inclusion of content, context and mode to be able to explain patterns in material culture.

Content refers to the "cultural information" transmitted between individuals (Eerkens & Lipo, 2007). How that cultural information is being passed will affect the replication, these factors include the complexity of the content, the form in which it is transferred (written, verbal, visual), repetitiveness and lastly, how it is structured. In terms of structure, it is not uncommon for the content being passed on to require common cultural

knowledge with the donor group. Gandon et al. (2014) in a pottery copying experiment, found that regardless of the potter's skill the cultural learning niches played an important part in how the potter perceived the model (pp. 105-106). Therefore it is easier to pass information to those subscribing to the same or similar cultural tradition, this in turn will incur a smaller error rate for the replicated product compared to content passed to outsiders.

Context is the settings in which content is transmitted and can range from a classroom/group setting to a brief meeting. Status of the person/s transmitting the information and how the transferee views the teacher can affect the accuracy of content passed. Someone who is respected will transfer knowledge to the student with greater accuracy due to the enthusiasm of the student.

The mode of cultural transmission outlines how cultural information is transmitted and acquired, such as one on one learning or one to many. The direction of transmission must also be considered and can be generational (vertical) or between peers (horizontal).

All content is not always taken on board by the individual/s acquiring the information, for example in conformist transmission an individual experiments and chooses which information to take from many sources to be able to decide on the best method. Whereas prestige-biased transmission means that prestigious individuals have access to superior information, while others do not but copy that information in an attempt to attain 'social success' (Eerkens & Lipo 2007: p.251).

How information is packaged should also be considered when looking at the mode of transmission as certain elements of content may not be important but are still adopted. For example, a potter replicates a vessel in its entirety assuming that all elements are crucial to create the superior pot, when this might not be true. It is common to see a correlation between prestige-based transmission and packaged content.

Cultural transmission is a multifaceted theory, there are many factors to consider such as content, context and mode, and not all will be visible to the archaeologist. Considering this, it is understandable why various CT research revolves around conformist and prestige-based transmission within mode (Kohler, Vabuskirk & Russcavage-Barz, 2004;

Porcic, 2015), as a factor that can be measured, seen and tested against the contemporary world. Conversely, content and context require more clear archaeological insight and information pertaining to the past culture in question.

The multifaceted nature of cultural transmission theory can also create a flexible and usable method applicable to many different assemblages regardless of context. Even though this thesis cannot explain all reasons behind the nature of the ceramic assemblage at Non Ban Jak; the archaeological information gathered from the site, previous research and ethnographic material offers a chance to explore factors outlined in cultural transmission theory involving content, context and mode.

4.2 Standardisation, Specialisation and Pottery Production

The designs, physical forms and manufacturing techniques pertaining to the production of Phimai Black at Non Ban Jak seemingly point to an overarching standardisation within the potting tradition. While this is observed in the in the visual form, this may or may not be reflected in the clay analysis.

The aim of this research is to assess the degree of visual standardisation within the assemblage through a form-plus-fabric analysis of ceramics over time and through multiple contexts across the site. Previous research in this field commonly features the study of specialisation, which refers to the 'differentiated, regularized, permanent, and perhaps institutionalized production system in which producers depend on extra-household exchange relationships at least in part for their livelihood, and consumers depend on them for acquisition of goods they do not produce themselves.' (Costin, 1991: p.4).

It is not surprising that there is much research surrounding specialisation of material culture as activities such as specialised pottery production is a necessary process in the evolution of economic and political complexity. Research into standardisation along with other elements such as labour investment and skill reflect levels of specialisation, in turn showing how production is organised to cater for consumers (Masson & Rosenswig,

2005; Levine et al., 2015; Roux 2015). The leading theory in this field comes from Costin (1986; 1991; Costin & Hagstrum, 1995) who outlined four parameters that describe the organisation of production, these are context, concentration, constitution and intensity.

Context is where the nature of the producer-consumer relationship is identified through labour investment usually described as either attached or independent (Earle, 1981). Attached specialists create sumptuary goods for the elite while independent specialists produce utilitarian goods for subsistence. Concentration refers to the spatial relationship between producers and consumers, explaining transportation time and cost. Constitution refers to the group size and social relations of the production unit. These can range from household production in a domestic setting to factory or workshop. Constitution is also reflected in the amount of mechanical standardisation, for example a large workshop could be identified through more standard products as producers are using each other's tools, are in close proximity of each other and possibly under supervision equalling the minimisation of variation and error.

The last parameter is intensity, which refers to the amount of time devoted to a craft in relation to other tasks and is measured in skill in the assemblage. For example part-time would be a combination of pottery production with other tasks such as agriculture, there would be less proficiency due to interruptions and hiatuses in craft production. Full-time would mean the potter earns wages from their craft, vessels would tend to be more skilfully made, reflecting continuous attention to craft.

Through the investigation of the four parameters, Costin proposed eight idealised types of specialisation, these are individual specialisation, dispersed workshop, community specialisation, nucleated workshops, dispersed corvée, individual retainers and retainer workshop (for summary of types see Costin & Hagstrum 1995: p.621).

Along with Costin, Arnold (2000) and Rice (1987) agree that researchers must consider that there are multiple elements that will explain paste differentiation and that the organisation of production should not be reconstructed from a single measure. This includes taking into consideration factors such as form, temper, firing techniques, pastes, measurements, ethnographic research, and current literature. Arnold (2000) has shown that through ethnoarchaeological data, a variety of environmental, technological and

social factors influence paste variability. In turn showing the importance of understanding and exploring context within the chosen site. An example of this would be Roux (2015) who suggests that socio-economic changes such as the erasing of cultural boundaries between potting communities can be a major driver leading to standardisation.

With the availability of a large sample from reconstructed vessels at Non Ban Jak combined with form-plus-fabric analysis, manufacturing techniques, the evidence of ceramic production on site (kilns) and ethnographic literature; a thorough investigation into the four parameters leading to the identification of the types of specialisation can be used to investigate the nature of pottery production on site. The investigation will be used to explore and answer the following questions;

- Do the ceramics at Non Ban Jak reflect standardisation in form and fabric?
- Does the standardisation of ceramics at Non Ban Jak equal craft specialisation? If so, what type of specialisation can be identified?
- What can standardisation tell us about the nature of social organisation surrounding pottery production?

Chapter 5. An Ethnographic Study of Pottery Production at Ban Ta Ko

In order to familiarise myself with household pottery production in a modern context, I paid two visits to the village of Ban Ta Ko. The first consisted of an interview with Mrs Yai, the potter, on the 26th of January 2015. The second visit was to partake in the process of pottery production in her workshop. The purpose of the visits to the village was first, to understand the processes of current pottery production in the area, and investigate if any techniques could be linked to past pottery production at Non Ban Jak. Secondly I wanted to take clay samples from the source used by Yai and other villagers, this was to add a contemporary source to my overall clay source analysis. The following section and photographs outlines my experience during the second visit to Ban Ta Ko.

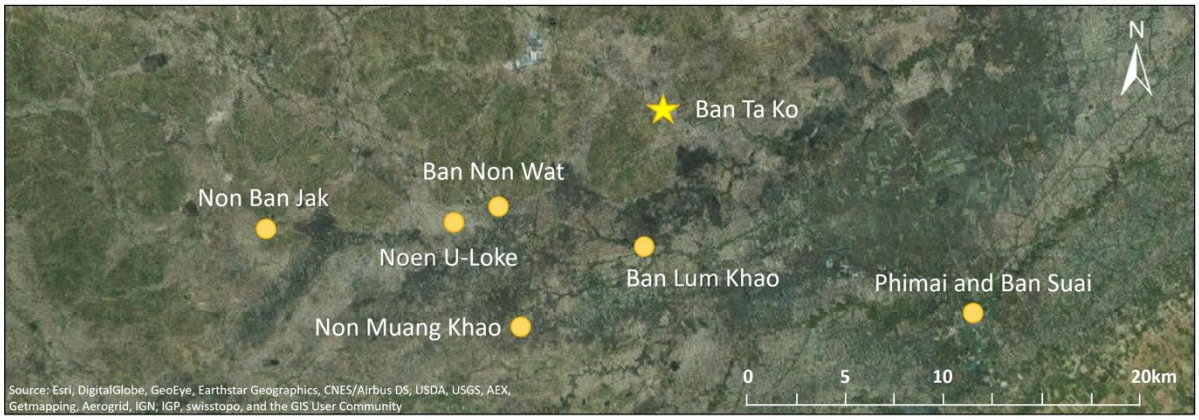


Figure 5-1 Map showing Ban Ta Ko in relation to sites with Iron Age phases in the Mun Valley.

I travelled to Ban Ta Ko on the 4th of Feb 2015 to record and partake in household pottery production and to take clay samples. I had met and interviewed Yai during my first visit and on the second visit I met her sister Eyang. Yai is 60 and has been making pottery for most of her life, the sisters are a similar age and learned the craft from their mother when they were 15 years old. Yai explained that the craft had been passed from mother to daughter over many generations.

In the interview I asked if there were gender roles associated with any of the steps in making the pottery. Yai said that there were none, she and her sister Eyang are the ones

who make the pots in the village, before it used to be everyone making pots. All the activities to do with pottery production are carried out by the two sisters.

The sisters make one vessel form, in two sizes. The first is a small globular pot to sell, while the larger version is for boiling water and food preparation also to sell and for personal use. The steaming vessels used for food had holes in the base and would sit on top of a pot full of water which in turn sat on a stand above a fire (Fig. 5.2).

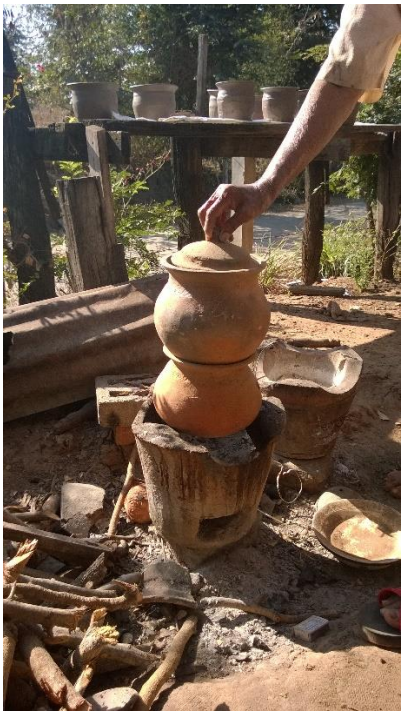


Figure 5-2 Steaming vessels.

During my second visit we made the larger version. The sisters use only one type of temper and one type of clay, which is used for both the temper and construction of the pots. The temper was prepared by mixing rice chaff and clay (Fig. 5.3). Oval balls formed from this and were then fired and crushed with a mortar and pestle. Yai tips the temper onto a sack and then dumps a lump of clay on the temper. She proceeds to mix the clay and temper with her feet, occasionally adding water until the mixture becomes smooth, while Eyang pinches it to check consistency.

Figure 5-3 Rice chaff and clay fired to be used as temper.

When the clay and temper are completely mixed, the sisters sit down to form the basic shape. A hollow cylinder is formed by hand then, when wide enough, Eyang uses a paddle and her hand as the anvil to create a smoother cylinder. Water is added occasionally during the paddle and anvil process. No wheel is used to form the pot. Eyang places the cylinder on a pedestal log that sits in the ground, she uses the paddle to flatten in the top of the cylinder in preparation to form the rim (Fig. 5.4).

Figure 5-4 Flattening the preform.

Forming of the rim

To form the rim Eyang places a soft, wet, and well-used banana leaf over the top edge and pinches the sides, while walking backwards around the pot (Fig. 5.5). The shape, size and angle of the rim is formed during this process. I was given the chance to form my own rim. I realised that the clay was incredibly malleable, any kind of pressure or change in angle determined the thickness and the direction of the rim.

Figure 5-5 Forming the rim.

After the forming of the rim, the preforms were left sitting in the sun to dry. At this stage the preforms are hollow, cylindrical, rimmed but without a base. (Fig. 5.6).

Figure 5-6 Preforms with finished rim but no base.

Clay Procurement

While waiting for the pots to dry a little I asked if we could see the clay source. On the day of the interview Yai described her very good clay source, the only one she uses. The clay is on public land and the source is called Tako Khonk. Yai has been collecting

clay from Tako Khonk for as long as she has been a potter, her mother and grandmother also used this source. According to Yai, the clay is so good that people come from all over to gather it.

The source is 1km away from the house, Yai usually wheels a cart to the source and digs and collects the clay herself. It took 3 mins in the car to get there, we drove along a road through the rice fields to the bank of a gully full of clay. We walked along the bank and even with all the clay surrounding us we still had to walk 2 to 3 minutes before Yai made her descent. Halfway down the bank Yai pointed to a hole dug deep within the clay. She reached in to pull out a lump of it. The clay was dark, moist and soft. As Yai handed me the sample she explained that even with all this clay around, the sisters travel a little further because they want the wet clay as all the clay along the top of the bank surface was hard and dry.

We walked along the dry cracked clay bank back to the car, only to find it stuck in the clay road that crosses between the rice fields. As I helped the car out in the beating sun I could understand why this was the season to make pottery. The sisters construct pots during the height of the dry season in February and March. For these two months 10-15 pots are made a day to sell to tourist shops and sometimes at the Sunday market. My visit coincided with the end of the rice harvest and the fields were being burnt before replanting. Making pots is a way to earn money when there is no work to be done in the rice fields.

After half an hour of many unsuccessful attempts to get the car out of the clay, Yai and I walked back to the house. We found Eyang, who had ventured back to the house earlier, already forming the pots from the preforms.

When we got back, Yai sat down with Eyang and positioned a pot on her lap and used the paddle and clay anvil to close the hole at the base. The paddle was dipped into a container of water and the water was transferred onto the anvil with the paddle to prevent the clay from sticking to the anvil. At this stage the neck is also smoothed out. The base is then widened into an angular form, and once wide enough the angles are smoothed out to complete a rounded base (Fig. 5.7).

Figure 5-7 Forming the base and the shape of the body.

It was obvious that the sisters had been practising this for years; they fell into a rhythm, turning the pot clockwise after 3 hits from the paddle (Fig. 5.8). They are systematic, focusing only on a certain area at a time and then rotate the vessel, never overreaching. In contrast, my attempts using the paddle were both erratic and messy.

Figure 5-8 The sisters Eyang and Yai forming the bodies of the vessels.

Decoration was then added to the base of the neck with a paddle that had an incised design. The paddle is pressed against the neck. During the interview, Yai explained that

the techniques for making pottery have stayed the same since her mother's time, however the design used to decorate the neck of the vessels have changed. Yai had a special paddle made for her with an inscribed design that she liked (Fig. 5.9).

Figure 5-9 Paddles and anvils the sisters owned.

While I was unable to attend the firing, I was told that pots are dried for 3 days and then placed upside down on dry wood, covered in straw and rice chaff and fired for an hour.

Chapter 6. Methods

The following chapter outlines the methods for the fabric and formal analyses. The first section describes the sampling and preparation processes for the sherd samples and modern clay samples. The second section describes the two machines used, the Portable Energy Dispersive XRF (pXRF), and the Electron Microprobe (EMP), why they were chosen, current research and analytical settings. Finally the statistical analysis is described, including the various processes and considerations used to manage and display the data.

6.1 Sampling Strategies and Preparation

6.1.1 Sherds

Pottery samples were acquired from the Eastern and Western mound excavations from 2011 to 2015. Body sherds or rims were sampled from whole or semi whole pots in situ, where the form could be identified. Rims were taken so that samples could be measured and that the differentiation of subgroups could be ascertained within form groups.

All samples come from reconstructed vessels from contexts that included mortuary, domestic, occupation and production. Mortuary specimens included ceramics from burials and burials within houses, domestic ware was anything associated with domestic activity such ceramics found near hearths and within residential spaces that were not considered associated with residential burials. Occupational ceramics came from areas that were not associated with either mortuary, domestic or production context but were known to be occupied by people. Finally production included ceramics from areas that were presumed to be used for pottery production such as kilns and rakeout.

Sherd Preparation for the pXRF:

Each sherd was formally recorded and photographed before the cutting process. A cross section of the sample was cut with an 8 inch diameter diamond blade circular saw. The sample was then abraded on the lap table with 240 grit to create a flat surface, this

is to prevent irregularities which have the potential to distort elemental ratios for quantitative light element analysis (Forster et al., 2011). The sample was then washed and left to dry overnight in the drying room at 20°C. The focus of the finished sample was to expose the core, as it is better to take readings from the core where less post-depositional changes have occurred than the outside (Niziolek, 2011: p.237). This also prevented the analysis of any slips added to the surface of the pottery, which may have contaminated results.

Sherd Preparation for the EMP:

Samples were cut with an 8 inch diameter diamond blade circular saw and were taken from the corner of a body sherd or a cross section of the rim. After cutting, the samples were then dried in the oven to ensure that there was no water within to interfere with the quality of the results. Once dry, the samples were impregnated with epoxy (West's System 105 with 206 hardener), this was achieved by applying epoxy to the cut surface of the sample and leaving it overnight to soak into the surface and harden. Impregnating the sample prevents minerals from being ripped from the surface during various stages of polishing, this is a precaution in case the epoxy does not fully soak into the sample during the making of the full briquette.

Samples were then placed in 2.5cm brass rings that were mounted with wax on glass slides and filled with epoxy, again left over night to set.

When the briquettes had hardened, the sample surface was ground down on the lap table with 240 grit, then washed and placed in the sonic bath for 5 minutes. The samples were then ground down on 400, 800, 1200 sandpaper and placed in the sonic bath to remove grit. An air gun was used if there was visible grit from the sandpaper. There was no concern for the sonic bath of the air gun dislodging and minerals from the sample as they would have been glued in by the epoxy.

Final polishing included a 10 minute run on a 3 micron lap and then 5 minutes on the 1 micron lap. This was done on the Kent 3 polishing machines equipped with a polishing pad of Struers 3 micron and 1 micron diamond paste. Between the two laps the sample was washed to remove any residue 3 micron polish to prevent scratching the sample during polishing on the 1 micron lap. The samples were cleaned with ethanol alcohol to

remove the last of the 1 micron polish. Finally, samples were carbon coated to eliminate charging effects during analysis in the EMP.

6.1.2 Clay source samples

Clay samples were collected from a contemporary source and from within the actual site of Non Ban Jak to compare chemical groupings against the eventual sherd groupings in an attempt to link groups of vessels to possible clay sources.

Ethnographic clays

Clay used for present day pottery production was collected from a source called Tako Khonk in the village of Ban Ta Ko. Raw clay from Tako Khonk, clay and temper mixed and a small fired vessel were sampled during a visit to Yai and Eyang's house, potters from Ban Ta Ko (Chapter 5).

Clays from Non Ban Jak

Clay samples that were collected from the site included clays from floors, walls, a stove and from within a pot. Samples were taken from deep within the floors and walls to bypass any build-up of organic residues from activities of prehistoric peoples. Such as, preserved fatty acids in floor sediments from storing or preparing plant and animal food items (Kanthilatha et al., 2014), which would have tainted the chemical signature of the original clay.

The reason behind sampling clay features within the site was due to a lack of nearby clay sources. Higham et al., (2014a) notes in the observations of the burial chambers in the eastern mound that the solid white clay walls of the chamber were possibly constructed using the left over clay from the construction of the moats and retaining banks that surround the site. The foundation walls of one chamber were 50 cm wide and in terms of energy expenditure it is not inconceivable that these clays were sourced from the moats and banks.

Site clays were collected and analysed to investigate a possible link between pottery samples and the clay from the moats and banks surrounding Non Ban Jak, in an attempt to identify local clay sources. In preparation for this, raw clays and clays fired at two

different temperatures were analysed to see if firing had an effect on the chemical signature of the samples, which would affect the groupings when compared to the site sherds. To overcome this obstacle, clays were fired to presumed Iron Age ceramic temperatures which is explained in the following section.

Clay Preparation and Firing:

Three batches of 13 clay samples were made from the clays collected at Non Ban Jak and Ban Ta Ko. These batches were unfired, fired to 800°C and fired to 1000°C.

To make samples appropriate to be analysed by the pXRF, the clays were first ground with a mortar and pestle to create a homogenous powdered material, distilled water was then added to the clay and balls were formed with the wet material averaging 2cm in diameter. The balls were then left in the drying room for three days at a temperature of 20°C.

Once the clays were dry, one batch was fired at 800°C while the other was at 1000°C. The decision to fire the samples at two different temperatures was to imitate the kiln process at Non Ban Jak. Due to the high firing of Phimai Black vessels two firing temperatures were chosen based on a firing experiment by Meacham & Solheim (1980). The authors found that their Iron Age ceramic samples from Non Nok Tha were subjected to a sustained temperature of 800-950°C while the samples collected from excavations at Phimai yielded temperatures of 1150-1200°C and 1150°C. (Meacham & Solheim, 1980: p.12). These temperatures also lay within the ethnothermometric data collected by Gosselain, where enclosed or kiln firings sit within the 600°C to 950°C range (1992: p.246).

Clay samples were placed in the furnace located at the Anthropology and Archaeology department at the University of Otago, the furnace was set to the respected temperature for an hour, then the temperature gauge was turned off and the samples were left in the furnace until they were cool enough to take out. Firing time was decided upon based on the length of time Yai used to fire her ceramics (Chapter 5) and other firing studies from Northeast Thailand (Meacham & Solheim, 1980; Vincent, 1988: p.134-7).

All fired and unfired clay samples were analysed by the pXRF. The data for the unfired and fired samples were examined to see if there was any significant change in elemental composure due to firing, the data were also compared against the ceramic assemblage.

6.2 Analytical Techniques

6.2.1 The Electron Microprobe (EMP)

The initial data analysis was undertaken on the JEOL Superprobe JXA-8600, residing in the Geology Department at the University of Otago. However, due to time constraints and the decommissioning of the probe, only a small portion of the sample could be analysed. A range of samples from the 2014 field season at Non Ban Jak were chosen to identify any dramatic changes in clay or temper through and across the site with a special focus on vessels from kiln B2 in the Eastern Mound.

An analysis of 17 samples on the probe yielded four CPCRUs and 3 outliers (Appendix B). Importantly, while under the probe the samples were seen to be relatively homogenous, which was due to the specific technique used to create the temper.

Ethnographic studies of pottery traditions from the area (Lefferts & Cort, 2000) and analysis on prehistoric ceramics (Vincent, 1988) have shown that a common practice to make temper is to mix and then fire both clay and rice husks to be crushed into a grit, otherwise known as bleb grog (Vincent 1988: p.88). The lack of variety or even presence of contrasting minerals other than quartz in the samples suggest a lack of temper variety but a use of bleb grog. Due to the lack of heterogeneous temper within the samples, the pXRF was chosen as it is known to work well with homogenous materials.

6.2.2 Portable Energy Dispersive XRF (pXRF)

Overview of the Machine:

The current analysis was carried out on a Bruker AXS Tracer III-SD portable energy dispersive XRF (pXRF) at the University of Otago's Department of Anthropology and Archaeology.

Data gathered from the pXRF are achieved through a shallow penetration of x-rays into a sample causing the excitation of electrons. Radiation dislodges electrons from the inner shell of the atom causing outer shell electrons to replace them. The energy released from excitation creates fluorescent radiation and is converted into electronic signals by silicon drift detectors (SDD). Each element has a characteristic energy and intensity, enabling a qualitative and quantitative analysis by detectors (Shakley, 2011).

Prepared samples are placed on the 4 by 4mm analytical window. Two settings were used for the pXRF, vacuum and filter. These allow the analyst to focus on elements of interest, for example the vacuum setting allows for the analysis of light elements while certain filters are best for heavy elements.

Unlike the electron microprobe, which was also used in this study, the pXRF is unable to carry out a separate analysis differentiating between tempers and clays. While the beam from the EMP can choose areas on the sample surface that are only of clay, the X-rays from the pXRF look at everything within the analytical window, in turn mixing the chemical data for both temper and clay. This would be problematic if the temper was sand, dirt, shell, etc from another area and added to the clay. However, due to the homogeneous nature of the temper used in the manufacture of Phimai Black vessels (Chapter Section 3.1.1), the pXRF was chosen as an efficient analytical technique for the clays.

Current research

The pXRF has been proven to be a successful and non-destructive technique for archaeological studies, including in situ surveys and settlement patterns (Hayes, 2013; Gauss, 2013), lithics (Sutton et al., 2015; Craig et al., 2007; Sheppard et al., 2011), glass (Liu et al., 2013), metal artefacts (Charalambous et al., 2014), cuneiform tablets (Goren et al., 2011) museum collections (Tykot, 2016) and paints and pigments (Snickt, 2010).

Portable XRF analysis of archaeological ceramics and sediments has become popular in the last couple of decades. The pXRF originated as a portable device for geological surveys (mining etc.) and is promoted to be a non-destructive method of analysis, requiring a minimal amount of sample preparation and the ability to analyse a large

number of samples quickly. Along with these appealing traits the pXRF requires minimal cost to operate and maintain compared to other analytical techniques.

The use of the pXRF is a highly debated technique in archaeology surrounding its suitability to analyse ceramics that are heterogeneous in nature. Even with the occasional cautionary disclaimers warning archaeologists against the technique there has been no halt to such research (refer to the following studies, Forster et al., 2011; Frankel & Webb, 2012; Buhring et al., 2015). The fact is that the pXRF is a useful analytical technique that is growing in popularity within archaeology, therefore parameters have to be outlined for the technique to be used properly, efficiently and consistently across the discipline.

Hunt & Speakman (2015) have an analytical protocol designed to make optimal use of the pXRF to match bench top ED-XRF analysis of ceramics and sediments. These include matrix matched calibrations, sample preparation and instrumental set up. However, the authors did conclude in their study that the pXRF cannot 'accurately quantify Na, P, V, Cr, Co, Ni and the L lines of Ba [and should not] be considered a substitute for fully quantitative analysis by WD-XRF, INAA and/or ICP-MS' (Hunt & Speakman, 2015: p.638).

Johnson (2014) found that even though there are known difficulties in measuring low Z elements, the protocol used for this research to measure K and Ca produced results that were 'on par' with more established instruments. The author also highlights potential problems to avoid with data collection and management such as sample preparation, instrument drift and calibrations, in turn pointing out that there is actually more time and thought that needs to go into analysis than previously claimed.

Reduced sensitivity for trace elements is also outlined in Speakman et al. (2011), in a comparative analysis between pXRF and INAA. The research concluded that there is general consensus between the elements that are common between INAA and pXRF, however INAA's ability to quantify trace elements may be the basic characteristic for defining ceramic groupings. The authors state that this is an important diagnostic feature for the American ceramics that they sampled but also state that this may not be the case for all sites. Whenever undertaking a ceramic sourcing study, it is important to have 'some priori knowledge of the chemical variability and the expected group structure so

that meaningful compositional groups can be constructed.' (Speakman et al., 2011: p.3495).

Buhring et al. (2015) in their study of Lapita ceramics from New Georgia, also emphasise the importance of incorporating previous research and different analytical techniques with the pXRF. For this study the pXRF proved to be a quick, non-destructive and successful technique to analyse a range of elements, to in turn identify CPCRUs within large assemblages. Previous mineralogical research and data were taken into account for ceramic sourcing and to identify pastes/clay recipes.

Finally, when shooting standards on the pXRF it is not uncommon for the machine to place certain elements low or high compared to their USGS reference materials, this does not mean that the groupings gained at the end of the analysis are not real. If the standards reflect consistency over the period of analysis then the clay data will reflect real values. While these groupings are real within the site examined, the discussion surrounding the comparison between sites and techniques is a different matter and falls beyond the scope of this research. Having said that Hein et al. (2002), in their inter-comparability study on the analysis of standard reference materials (SRM), present a calibration used by multiple techniques (XRF, NAA, ICP-MS, ICP-OES), for joint use of results obtained in different laboratories. (p. 553). It is only a matter of time before this is achievable for the pXRF.

Two themes run through the current literature; the expectation that the analyst must already have an idea of the qualitative nature of their samples and that the pXRF has difficulty accurately quantifying certain elements. In the light of the current literature, issues with the pXRF have been noted and precautions taken before and during use include:

- Have background knowledge on what you are going to find in your samples
- Optimal sample preparation (outlined in Chapter Section 6.1.1)
- Shoot standards periodically to monitor for instrumental drift
- Be aware of what elements the pXRF has difficulty analysing and calibrate your standards after every session to check; 1. That the machine is shooting similarly to a previous date and 2. If the machine is quantifying elements accurately to their USGS reference concentrations.

- Pick a calibration matrix matched to your samples, obsidian and mud rock are two common calibrations used for sediments and ceramics (Speakman et al., 2011; Hunt & Speakman, 2015). A calibration can be adjusted to suit your samples, it is optimal to have standards within a calibration that have similar elemental concentrations to those in your samples (Johnson, 2012; Hunt & Speakman, 2015)

6.3 Analytical Settings (pXRF)

Each sample was analysed for both light and heavy elements. Light elements setting analysis under vacuum was conducted on an x-ray tube voltage of 15keV and a current of 45µA. Elements tested were Na, Mg, Al, Si, P, S, K, Ca, Ba, Ti, V, Cr, Mn, Fe, Co, Ni, Cu and Zn. Heavy elements setting analysis included a voltage and current of 40keV and 30 µA with a green filter (Al, Ti, Cu). Elements tested were Mn, Fe, Co, Cu, Zn, Ga, Th, Rb, Sr, Y, Zr and Nb.

The filter modifies the shape of the spectrum and, depending on which filter is chosen, will determine which elements are analysed. The green filter was chosen for this analysis based on previous pXRF studies on ceramics (Hunt & Speakman, 2015).

Samples ran for a live time of 180 seconds for vacuum and 300 seconds for green filter. Originally all vacuum samples were to be shot on a 300s live count, vacuum samples were instead shot at 180 seconds to cut down analysis time on the more than 200 samples. According to Newlander et al. (2015), a count time of over 180 seconds has little effect on the accuracy of pXRF data, this was also tested on the pXRF by the author and was found to be accurate.

The standard used was USGS BHVO-2 Hawaiian Basalt, which was shot at the start of each run and after every sixth sample during the analyses. This was done to assess instrumental drift by calibrating the standard at the end of each session to see if the machine was quantifying elements accurately to their USGS reference concentrations over the period of analysis (Tables 1 and 2).

6.3.1 Calibration:

Vacuum samples were calibrated using Bruker's mud rock calibration, which uses 26 mud rock samples. The green filter samples were calibrated using Bruker's obsidian calibration, which uses 40 obsidian standards. All data were converted to ppm using Bruker's software S1CalProcess. Different calibrations were used for vacuum and filter instead of one calibration (either obsidian or mud rock), as the obsidian calibration for the vacuum did not include the elements of interest and there was no mud rock calibration for the green filter. Unfortunately, the mud rock calibration for the yellow filter was unavailable during the time of analysis.

6.3.2 Data transformed:

Data were logged transformed (base10) to distribute the raw data normally. This prevents elements with large concentrations from dominating the analysis (Niziolek, 2011: p.250). For example, clays are a silicate and contain a lot of Si that would overshadow a small measurement from a trace or raw earth element. Log transformation normally distributes the data so that all elements can be seen.

6.3.3 Elements excluded:

Elements were excluded from the study based on their relative standard deviation (RSD) for all the BHVO-2 standards shot over the period of analysis (Tables 1 and 2; Appendix D), and any element near a 20% error rate was excluded. If elements were in both vacuum and green filter, the one with the closest average to the USGS reference material was chosen. The elements left were put through a PCA and the Component Matrix for both sherds and clays were assessed to identify elements that did not contribute to the variation in the PCA. The axes of a PCA are driven by the highest and lowest variables, those elements sitting in the middle and not contributing to the variability were excluded.

The following elements in green were kept in the study:

Table 6.1 BHVO-2 standards shot on the vacuum settings for the pXRF. Green represents elements that were kept, yellow had high RSDs, orange had low variance and pink elements are those that look better in the other setting.

Vacuum	*Average (ppm)*	*STD*	*RSD (%)*	*USGS recommended values (ppm)*
NaKa1	3970.572	210.2991	5.296442	16400
MgKa1	6724.213	1524.079	22.66554	43600
AlKa1	49342.44	2887.311	5.851576	71600
SiKa1	153317.2	5982.173	3.901828	233000
P Ka1	477.225	99.7192	20.89564	1200
S Ka1	4662.049	532.0592	11.41256	
K Ka1	3413.686	85.41598	2.502163	4300
CaKa1	60031.67	1111.57	1.851639	81700
BaLa1	2360.991	466.5525	19.76087	130
TiKa1	12562.61	224.7785	1.789265	16300
V Ka1	305.6002	32.41972	10.60854	317
CrKa1	1.679158	2.61948	155.9996	280
MnKa1	583.9491	16.68491	2.857255	1290
FeKa1	37850.34	690.7779	1.825025	86300
CoKa1	25.8285	0.346477	1.341451	45
NiKa1	50.04303	3.414234	6.822598	119
CuKa1	-9.85202	2.138531	-21.7065	127
ZnKa1	59.8717	5.642413	9.424173	103

Note: USGS numbers in bold are information values not recommended values, as supplied by the USGS certificate of analysis.

Table 6.2 BHVO-2 standards shot on the green filter settings for the pXRF. Green represents elements that were kept, yellow had high RSDs, orange had low variance and pink elements are those that look better in the other setting.

Green Filter	*Average (ppm)*	*STD*	*RSD (%)*	*USGS recommended values (ppm)*
MnKa1	962.6734	29.7332	3.088607	1290
FeKa1	74856.19	1847.113	2.467548	86300
CoKa1	59.39288	7.658275	12.89426	45
CuKa1	405.1065	67.45507	16.65119	127
ZnKa1	195.7534	7.387462	3.773862	103
GaKa1	19.80072	0.824007	4.161502	21.7
ThLa1	1.686196	0.767098	45.4928	***1.2***
RbKa1	7.793788	0.667806	8.568442	9.8
SrKa1	336.0956	5.827504	1.733883	389
Y Ka1	24.72151	0.789942	3.195364	26
ZrKa1	141.2925	2.674797	1.893092	172
NbKa1	15.39964	0.676078	4.390216	***18***
RhKa1	0	0	Null	

6.3.4 ArTax

During the bulk analysis on the pXRF, the data were through ArTax version 7.4, Bruker software. ArTax gives a visual account of the elemental peaks within the sample and a bulk amount can be displayed as a spectrum to be able to see the varying elemental quantities across samples. This tool was not used to quantify or qualify the data for the statistical analysis, instead it was used to keep track of which elements and concentrations were present within the samples, to assess or identify groupings and elements that were possibly significant to Non Ban Jak. In turn making sure that all elements present within the samples were included within the calibration.

The spectrum was considered during element elimination and acted as a visual verification of presence, especially at the stage where the data could not be assessed with the eye after it had been logged transformed. For example, Copper and manganese could have been potentially excluded from the analysis due to their lack of contribution to variation, however there are outlying peaks in the spectrum for these elements pointing towards possible sample outliers (Appendix C). Considering that copper is an important natural resource in the Khao Wong Prachan Valley more so than in the Khorat Plateau (Pryce et al., 2010), and that manganese was a prominent element in Bronze Age ceramics (Sarjeant, 2008), then already there is the potential for different clay groups and sources.

6.3.5 Elements from previous analyses

Elements of note from previous research in the area were also considered during the analysis. Sarjeant (2008: p.165) found that the major variation in clay was attributed to the following elements in her analysis of the Bronze Age and Iron Age ceramics at Ban No Wat: phosphorus, manganese, and titanium. Sodium and iron showed the most uniformity across the samples. Geary (2007: p.65) found that it was the differing levels of sodium and calcium that attributed to the separation of the ceramics from three Iron Age sites in her analysis (Noen U-Loke, Ban Non Wat and Ban Suai). While phosphorus was omitted from the current analysis due to its high RSD the other elements were kept.

Elements were not only excluded based on their role in the current statistical analysis but also had to be checked due to the nature of the activities carried out in their lifespan

and post-depositional changes. Niziolek (2011: pp.236-241) compiles elements that can change concentrations within vessels due to firing, use and deposition.

Phosphorus was taken out of Niziolek's analysis due to its ability to change concentrations within porous ceramics during cooking, food storage or phosphate leaching into the ceramic from the organic plants within the soils. Also, the following elements are known to change in levels after deposition; Calcium, Manganese, Potassium, Cesium, Barium, Sulphur, Strontium, Zinc and Lead.

The current analysis did not involve Cesium or Lead, both Phosphorus and Barium were taken out due to high RSDs. Sulphur and Strontium were excluded as they did not contribute to variation. The raw numbers for Calcium, Manganese, Potassium and Zinc were assessed through the mortuary phases to see if there was a change due to burial depth, no such trend was observed.

6.4 Statistical analysis

All statistical analyses were carried out in SPSS 23, analyses included hierarchical clustering (HCA), discriminant analysis and principal component analysis (PCA). In terms of a ceramic analysis, a PCA is a useful visualisation tool that graphically plots the chosen elements with the highest amount of variance, in turn reducing the number of attributes (elements) into a two dimensional plot (Drennan, 2009: pp.299-300). Sample clustering is identified by distance on a scatter plot representing groupings by chemical relation, these are called chemical paste compositional reference units (CPCRUs) (Bishop et al., 1982; Summerhayes, 2000).

Once the author was satisfied with the elements chosen for the analysis, a PCA trial run was executed for all samples. It became apparent that while the PCA was a crucial tool in the assessment of elements within the data, it was unable to show clear groupings due to the large data set and the presence of outliers influencing the clustering. Hierarchical cluster analysis based on Ward's method was then used to better visualise the clusters.

Ward's method is a form of hierarchical cluster analysis. This multivariate analysis creates a dendrogram of the data set based on the variance of the samples and not the distance, unlike the principal component analysis. It uses an agglomerative clustering algorithm to combine individual cases together to form multiple clusters laid out quite like the branches of a trees (Drennan, 2009: pp.309-310).

This approach was used to analyse the data in steps leading up to the main analysis, beginning with the smaller data sets and minor research questions.

1. Ward's method and PCA was carried out on the clay samples to assess relationship of the samples collected from the site and from Ban Ta Ko.
2. Then all samples (clays and sherds) were examined together to identify any vessels grouping with clays.
3. Finally the main analysis was undertaken and only the sherd samples were put through a series of hierarchical clustering using Ward's method to filter out outliers, identify core groups and within those groups, subgroupings.

Eventually all outliers were identified and along with their chemical separation from the other groups, their context and forms were also assessed to identify any other contributing factors to their separation. Niziolek, in reference to Baxter (2001) and Glascock (1992), explains that outliers tend to affect the clustering of large data sets during multivariate analysis and should be removed (2011: p.251). The outliers were then taken out of the analysis for the final HCA and PCA that are displayed in this thesis. Outliers are important in showing possible trade and interactions between communities or even with outsider cultures, therefore outliers are further discussed in chapter section 7.1.5.6.

Once all samples were assigned to a clay group and the total amount of groups had been identified, a discriminant function analysis was used to verify the accuracy of these groupings. Discriminant function analysis is a way to predict membership of already established groups. The optimal combination of the variables are decided upon through multivariate F testing to identify significant variation between groups. Percentages of the group accuracy is presented and the data can be irritated to reach optimal accuracy (Poulsen & French, n.d.; Drennan, 2009: p.225).

Chapter 7. Results

The following chapter presents the results of the chemical and formal analyses on the samples. The first section outlines the fabric analysis in a three step approach to assess possible relationships among the samples. The first analysis was of all the clay samples, collected from Non Ban Jak and from the modern village of Ban Ta Ko (chapter section 7.1). The second study was a comparison of the clays and all the sherd samples to assess possible relationships and an attempt at clay sourcing (chapter section 7.2), lastly only the bulk sherd analysis was carried out (chapter section 7.3).

The sherd analysis is the main focus of this thesis and begins to answer the questions proposed in the introduction (chapter section 1.3.1) by investigating the amount of CPCRUs, fabric through time and across multiple context, types of temper, and the on-site production techniques, such as the use of kilns.

Following the presentation of the fabric results, the second section deals with the formal analysis using the typology of the current forms excavated at Non Ban Jak (chapter section 3.2), in turn assessing changes in vessel form through time and context.

7.1 Clays

7.1.1 Aim and sample collection

The clay samples were collected from Non Ban Jak and from the contemporary potting source at Tako Khonk in the village of Ban Ta Ko. The Non Ban Jak site samples included archaeological clays from floors, walls, a stove and from within a pot, while the samples collected during ethnographic research consisted of raw clay from the source, a raw clay plus temper mix and a fired vessel.

Clay was used at Non Ban Jak structurally in house floors, walls, stoves, figurines and kilns. The collection of modern clay from Ban Ta Ko was undertaken to see if any matched that from the prehistoric structures or ceramics. This analysis is further explored in chapter section 7.2 where clays are compared against sherds.

The clay samples were analysed in three different states: raw/unfired, fired to 800°C and fired to 1000°C. This was undertaken to test if samples separated chemically based on firing temperatures, in order to erase the bias where raw samples and fired sherds may separate due to the state of the sample and not the difference in clay source.

Samples 2 fired at 1000°C could not be analysed as they cracked and disintegrated into powder shortly after firing. Due to time constraints, disks were not made of the samples for analysis. However, both the raw and 800°C states of sample 2 were included in this analysis.

The current analysis investigates the relationships between the prehistoric clays collected from site and the contemporary clays. There were 30 samples in total in their fired and unfired states together with the single Ban Ta Ko ceramic. Seven CPCRUs were identified, the following descriptions and table (Table 7.1) summarises these groupings.

Group 1 (Samples 1, 3 and 8)

Unfired and fired samples for 1, 3 and 8 clustered in this grouping, showing that there was little to no chemical change during firing. Each sample was used as a building/structural material and came from layers distinctively apart in time.

Group 2 (Sample 2)

Group 2 contains unfired sample 2, while group 4 contains sample 2 fired to 800°C. As seen in the dendrogram for the clays, the unfired and fired samples for sample 2 separate out significantly compared to other fired and unfired samples e.g. sample 9 from group 3 and sample 4 from group 6 (Fig. 7.1). In the PCA (Fig. 7.2) both states for sample 2 are close to each other and separate from the other samples, showing that there is no relationship with the other samples and that while they are from the same source, firing temperatures play a major part in the chemical separation.

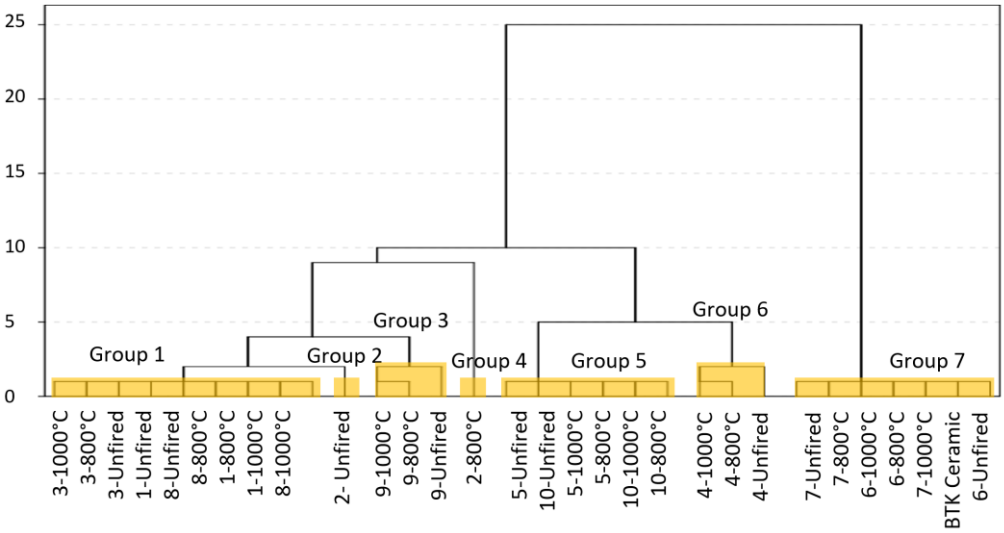


Figure 7-1 Dendrogram of clay samples using Ward's Method.

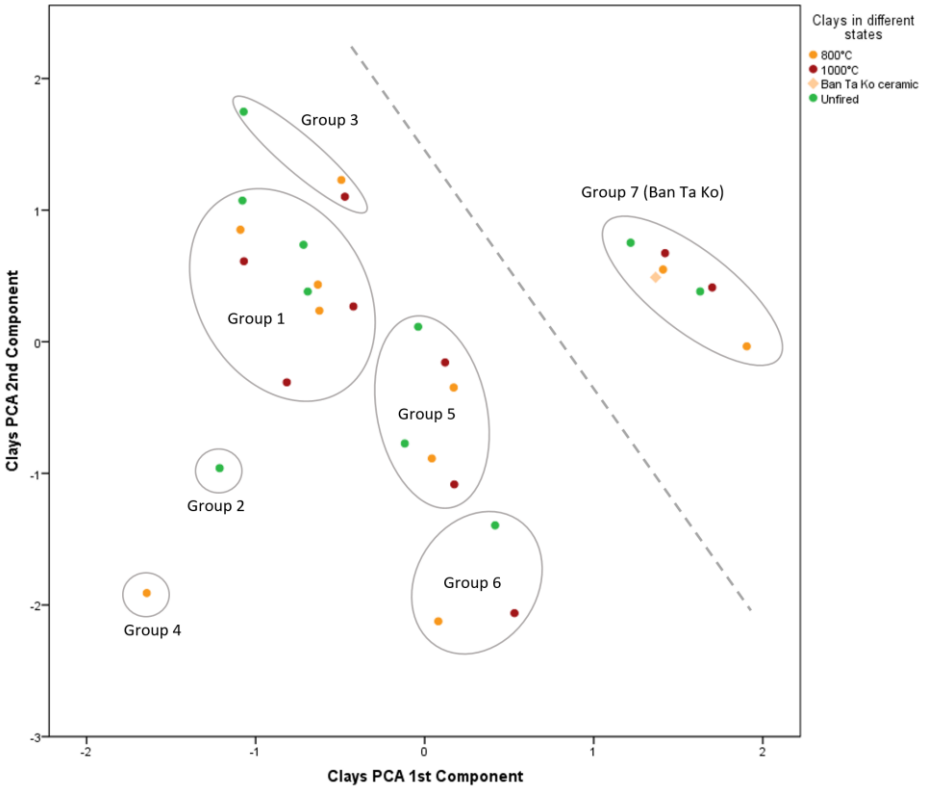


Figure 7-2 . PCA of Clays showing a separation between Groups 1 to 6 and Group 7, the Ban Ta Ko clays.

Group 3 (Sample 9)

Group 3 consists of sample 9 in its fired and unfired states. While these three samples cluster in the PCA, the dendrogram shows that they are similar but the raw sample is further separated (Fig. 7.1).

Group 4 (Sample 2)

Group 4 contains sample 2 fired to 800°C.

Group 5 (Samples 5 and 10)

Samples 5 and 10 in their raw and fired states clustered in group 5. Sample 5 is from a red clay floor while sample 10 was clay found within pot cat. 1217.

Group 6 (Sample 4)

Group 6 consists of sample 4 in its fired and unfired states. Like sample 9 from group 3, the dendrogram for sample 4 shows that while both fired samples are chemically similar the unfired sample can be further separated.

Group 7 (Samples 6, 7 and ceramic from Ban Ta Ko)

Group 7 consists of sample 6 a clay and temper mix from Ban Ta Ko, sample 7 raw clay from the source at Tako Khonk, lastly there is a sample of an outdoor fired ceramic from Ban Ta Ko. All of the ethnographic samples from Ban Ta Ko clustered in group 7 in their raw and fired states, they were chemically distinct from the prehistoric samples (Fig. 7.1).

Table 7.1 Clays collected and analysed in their fired and unfired state.

GROUPS	Samples	State	MP1	MP2	MP3	MP4
Group 1	1 *Stove*	Raw			YES	
		800°C				
		1000°C				
	3 *Clay Floor*	Raw		YES		
		800°C				
		1000°C				
	8 *White Wall*	Raw			YES	
		800°C				
		1000°C				
Group 2	2 *white floor*	Raw			YES	
Group 3	9 *Clay floor*	Raw	YES			
		800°C				
		1000°C				
Group 4	2 *White floor*	800°C			YES	
Group 5	5 *Red clay floor*	Raw		YES		
		800°C				
		1000°C				
	10 *Clay found within pot*	Raw			YES	
		800°C				
		1000°C				
Group 6	4 *Clay found in layer DD2 2:1*	Raw				YES
		800°C				
		1000°C				
Group 7	6 *Clay and temper mix*	Raw	All samples come from Ban Ta Ko and the clay source of Tako Khonk			
		800°C				
		1000°C				
	7 *Clay from source no temper*	Raw				
		800°C				
		1000°C				
	BTK ceramic	Outdoor firing				

7.1.2 Summary of the Clay CPCRUs

Do the clays from Non Ban Jak match the ethnographic clays?

The ethnographic clays and the prehistoric clays are chemically distinct as witnessed in the dengrogram and PCA (Fig. 7.1 and 7.2).

Does firing have an effect on the groupings?

Raw vs Fired

While Group 1 and 7 show no difference between raw and fired states, this is not the case for all samples. On further inspection Groups 3 and 6 show that firing does change the chemical makeup of the samples. This is not witnessed in the PCA but is noted in the dendrogram. Also, sample 2 is chemically distinct according to firing temperature (Group 2 in unfired state, Group 4 when fired to 800 °C). Unfortunately, there is no sample 2 fired at 1000°C so there is no way to see if it would have clustered with the other high fired sample.

800°C vs 1000°C

There is little to no difference between samples fired at either 800°C or 1000°C.

Tempering

Since all the ethnographic samples cluster in Group 7, it is concluded that bleb grog used as a temper does not affect the chemical composition of the finished product. The PXRF does not distinguish between the raw clay from the source (sample 7), the unfired clay and temper mix (sample 6) and the Ban Ta Ko ceramic, in turn reinforcing the homogeneity of the samples. This is also significant in comparing manufacturing techniques of the present with the past.

For further analysis:

Group 1 contains three samples that are of the same source in their fired and unfired states, but from different time periods. These samples are taken from MP2 and 3, suggesting that people used the same source material for structures throughout time. Considering the amount of time and effort to gather materials and construct the features in question, it is not implausible to conclude that the source used would be local, possibly taken from the surrounding banks and moats. In turn Group 1 gives an insight into the local geology of Non Ban Jak, the next step is to see if these clays match any ceramic samples.

Phimai Black vessels were high-fired ceramics, and based on the results for Groups 3 and 6, the higher-fired samples will be kept to be compared against the sherds. Raw clays will be removed from further analyses as they may contribute more to background noise, creating or hiding groupings that may or may not be there. To in turn investigate whether structural material created through the use of clay from the moats and embankments can reveal a possible clay source exploited by the potters at Non Ban Jak.

7.2 All Samples (clays and sherds)

Aims: Sherd and clay samples were analysed by means of Ward's method to see if the prehistoric vessels from Non Ban Jak clustered with the clay samples collected from the site and from the contemporary village of Ban Ta Ko (BTK). This was undertaken in order to identify possible clay sources. In conjunction with the potential pairing of clays and vessels, the aim was also to identify outliers for the later sherd study. Outliers have the potential to create chemical noise, in turn influencing the clustering into a distribution that may or may not be an accurate representation, therefore it is important to identify such samples (outlined in chapter section 6.1.4).

194 sherds and 19 clay samples were put through a hierarchical cluster analysis (HCA) using Ward's method. The clays clustered separately from the vessels and formed groups similar to the previous clay analysis. Four vessels from Non Ban Jak were found within

these clay groups, cats. 1220, 1294 and 1182 within the Ban Ta Ko source and cat. 525 within the Non Ban Jak clays.

To verify clay and vessel clustering, these vessels were put through a HCA with only the clays. The analysis showed that while cat. 1220 is a match to the Ban Ta Ko samples, cat. 1294, 1182 and 525 did not positively cluster with the clays. These vessels were then deemed outliers and taken note of for the final analysis which included only sherd samples.

Clay sample 2 fired to 800°C separated from the clays and clustered close to a group that was separate chemically from the rest of the samples (group B expanded on in chapter section 8.1 - 'Fabrics'). A further HCA analysis of only these samples together showed that sample 2 did not positively cluster with this group. The placement of sample 2 is explained by the nature of the HCA; if a sample is not chemically similar to the majority then it will be placed with the most chemically dissimilar groups, when in actual fact these samples may not be related at all.

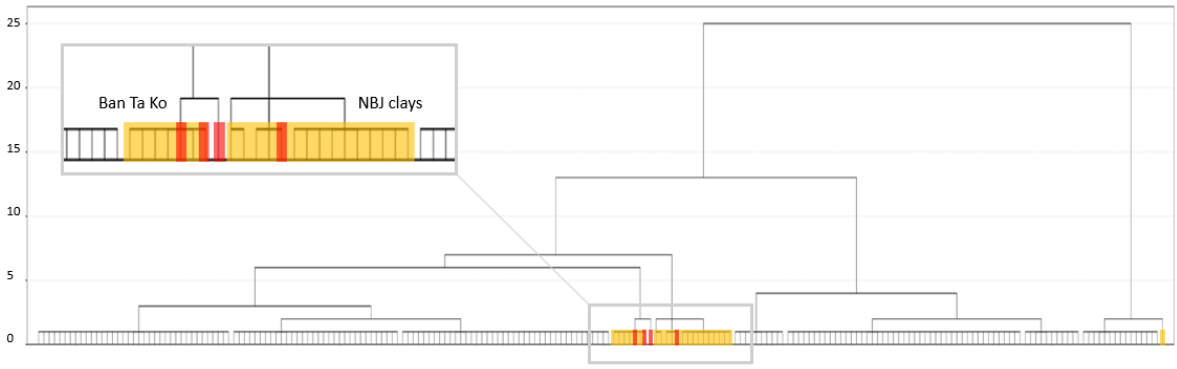


Figure 7-3 HCA showing the clay groups compared to the sherd samples. The two orange groups are of the BTK and NBJ clays, Sample 2 fired to 800°C can be seen in the far right. The following sherd samples have clustered with the clays. From left to right cat. 1220, 1294, and 1182 in the BTK clays, and cat. 525 in the NBJ clays.

7.3 All Sherds

Aims: This is the main analysis within this research and the data gathered were used to answer questions posed in chapter section 1.3.1. As outlined in chapter section 6.1.1, HCA was used first to identify clusters in the large data set, this was then checked against a discriminant analysis and displayed through PCA.

The dendrogram for Ward's method showed two main groups A and B. Group A contained most of the samples and clusters while group B comprised a singular cluster, chemically distant from A. Group B was taken out of the analysis so that Group A could be further examined and vice versa. While B was deemed to be its own group, Group A revealed many subgroupings and outliers.

Outliers

Along with the four outliers identified in the previous clay and sherd analysis two more outliers were identified:

- **Cat. 1294** was identified in the all sample analysis as an outlier and then continued to separate out in the sherd analysis. The raw data displayed in ArTax showed that Cat. 1294 peaked higher than any other sample for Mn in the green filter (Appendix C).
- **Cat. 1182** is a white stoneware vessel and due to the completely different manufacturing technique and definite exotic origins it was unsurprising that it separated from all the other vessels.
- **Cat. 525** was noted as an outlier in the sherd and clay analysis, cat. 525 continues to separate from the other samples and is an outlier not only chemically but as the only form of its kind currently found at the site
- **Cat. 1316** is an example of a common form found at Non Ban Jak (Form 1A). ArTax showed that it peaked higher than the other samples for copper and zircon in the green filter (Appendix C).
- **Cat. 1220** and the **Ban Ta Ko ceramic sample** clustered side by side in all the HCA analyses. These two samples were treated as outliers from the same

source and taken out of the main analysis as together they jumped from group to group through the different HCA undertaken.

All outliers are deemed chemically different and are treated as individual non local samples not only due to different clays used (Cat. 1294, 1182, 1316, and 1220 and BTK) but in some cases form (Cat. 1182 and 525). All outliers were taken out of the assemblage for the final HCA which revealed no more outliers, these groups were then checked via discriminant analysis.

Discriminant analysis

For a discriminant analysis the analyst has to know the total amount of groups they think there are based on clustering in the HCA. The problem with HCA is that the branches can lead to many different clustering formations, and while the horizontal axis shows the distance or dissimilarity between clusters, it is up to the analyst to determine the cut-off point that will yield the correct number of clusters. Defining clusters depends on what the analyst thinks makes archaeological sense, based on knowledge of the nature of the samples (Drennan, 2009).

The HCA showed three large groups so the first approach was to group the clusters into three, creating Groups A1, A2 and B. The discriminant analysis showed that 93.2% of original grouped cases correctly classified, while a near accurate result, the graph produced indicated samples separated from the groups centroid, especially seen in group 2 (Fig. 7.5).

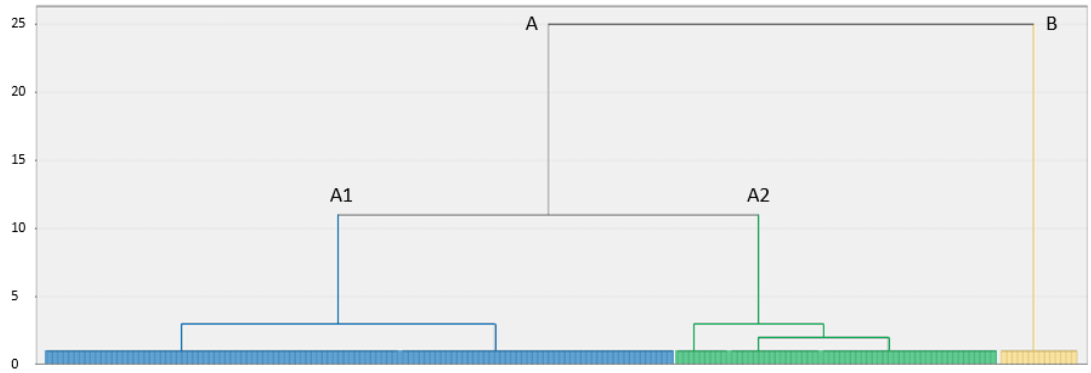


Figure 7-4 HCA of groups chosen for the discriminant analysis, A1, A2 and B.

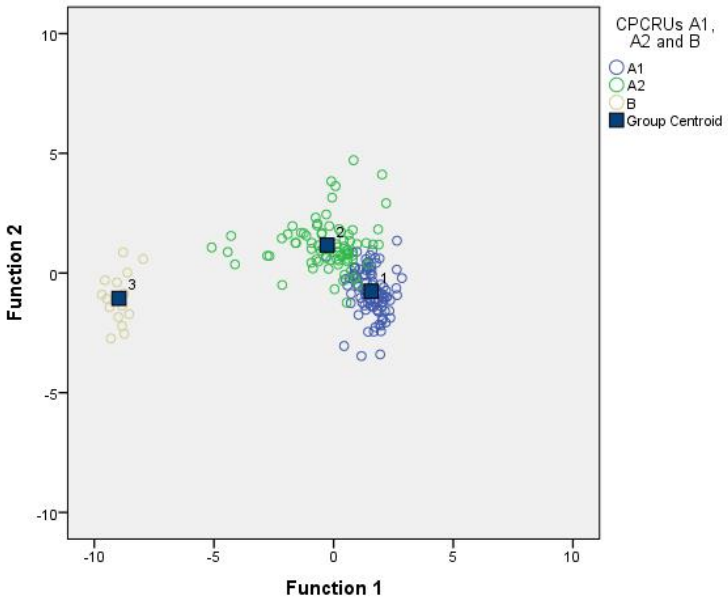


Figure 7-5 Groups A1, A2 and B from fig HCA displayed through a discriminant analysis. Groups A1 and A2 present samples that are not close to the group centroid indicating that these groups are not accurate.

With the possibility of more groupings, the next tier on the dendrogram was chosen and 6 CPCRUs were analysed (Fig. 7.6). Groups 1 and 2 found within A1 were spatially too close together to not be a singular grouping while the rest separated out (Fig. 7.7). The accuracy of this grouping was 82.8% and less accurate than the previous analysis.

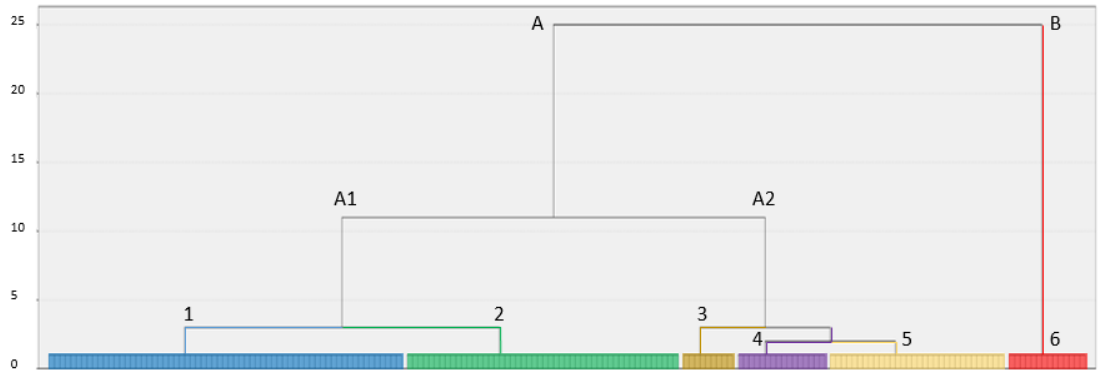


Figure 7-6 HCA of groups chosen for the discriminant analysis, 1, 2, 3, 4, 5 and 6.

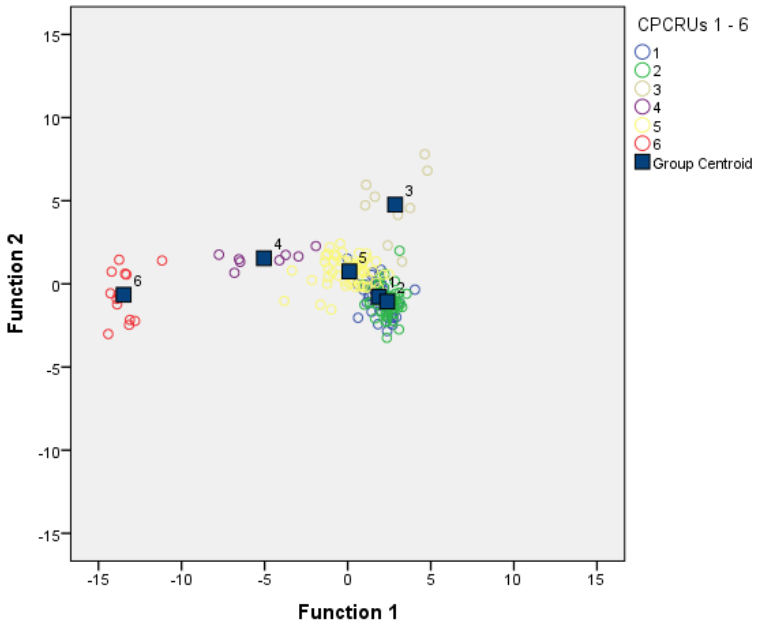


Figure 7-7 Groups 1, 2, 3, 4, 5 and 6 from fig HCA displayed through a discriminant analysis. Groups 1 and 2 found within A1 are spatially too close together indicating that these groups are not accurate.

Finally five groups were settled upon and scored a 92.2% of original grouped cases correctly classified, samples were then moved based on predicted group membership in SPSS, having done so the final output was 100% accurate (Fig. 7.9). After the data had been checked through DA and deemed accurate, data were then were then presented on PCAs showing components 1&2 and 1&3 (Fig. 7.10 and 7.11).

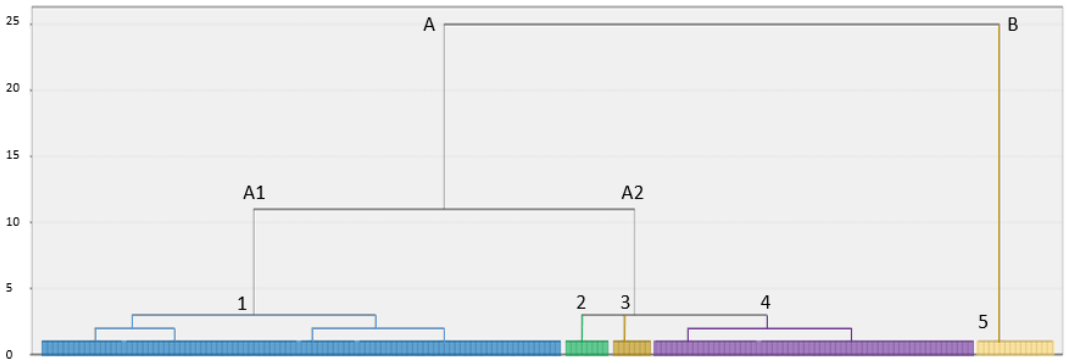


Figure 7-8 HCA of groups chosen for the discriminant analysis, 1, 2, 3, 4 and 5.

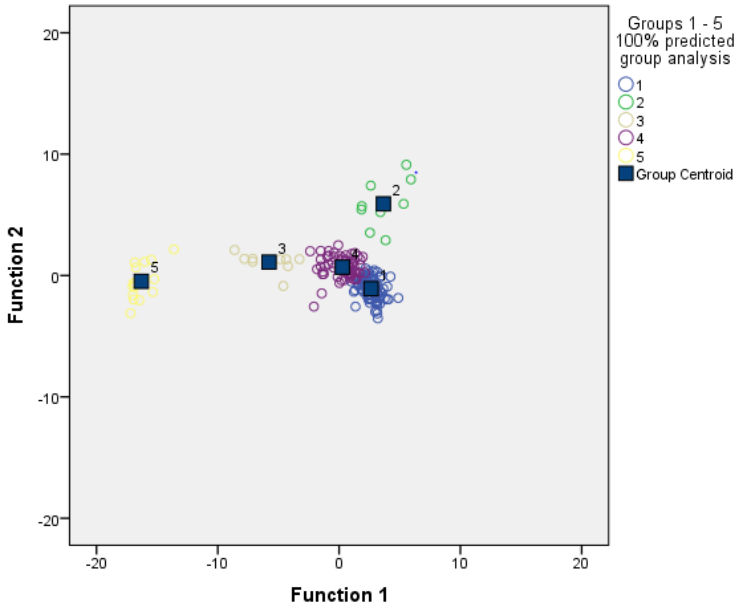


Figure 7-9 Groups 1, 2, 3, 4 and 5 from fig HCA displayed through a discriminant analysis. Final output is 100% accurate.

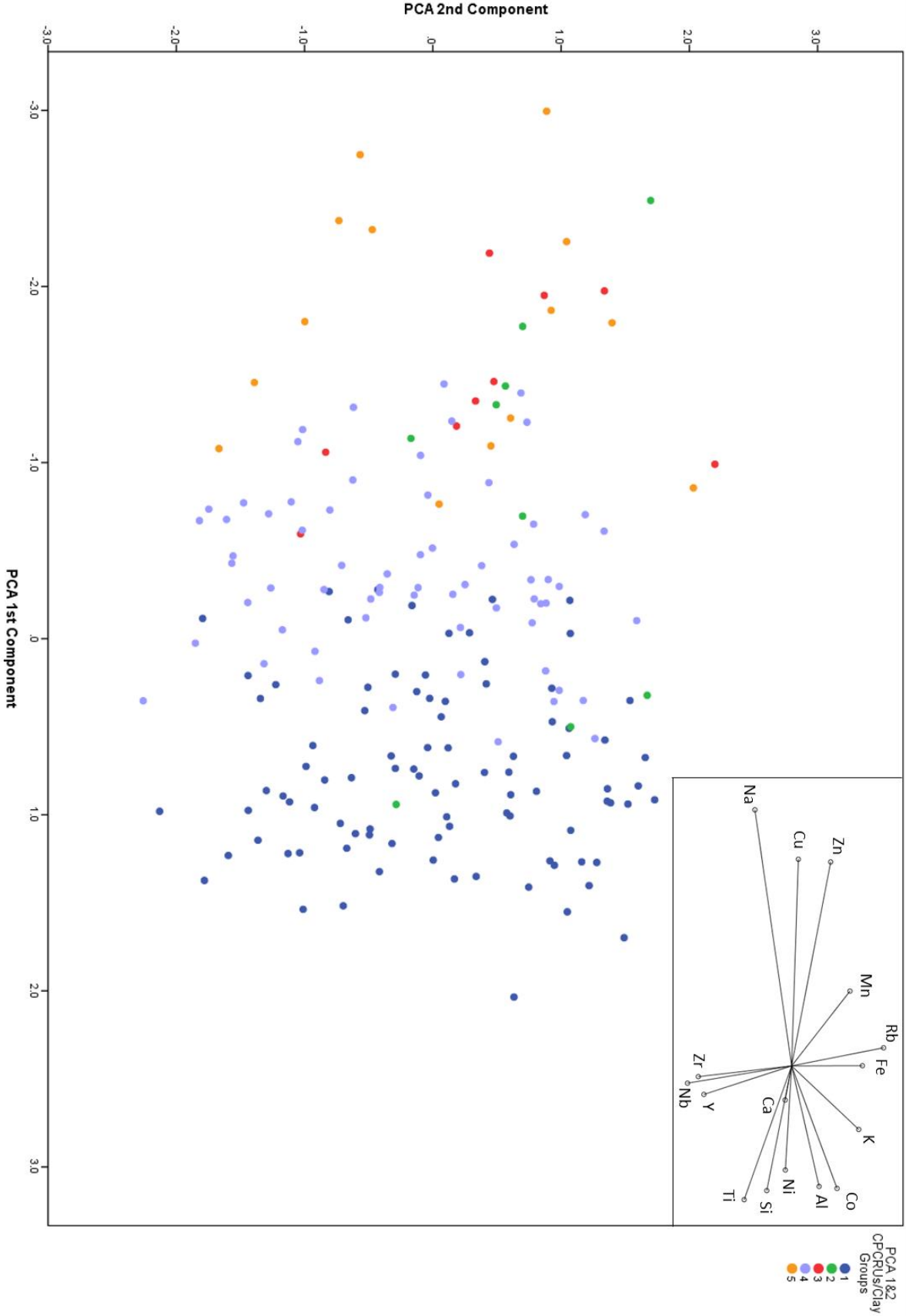


Figure 7-10 PCA 1&2 with loading plot showing the elements that attribute to sample spatial distribution

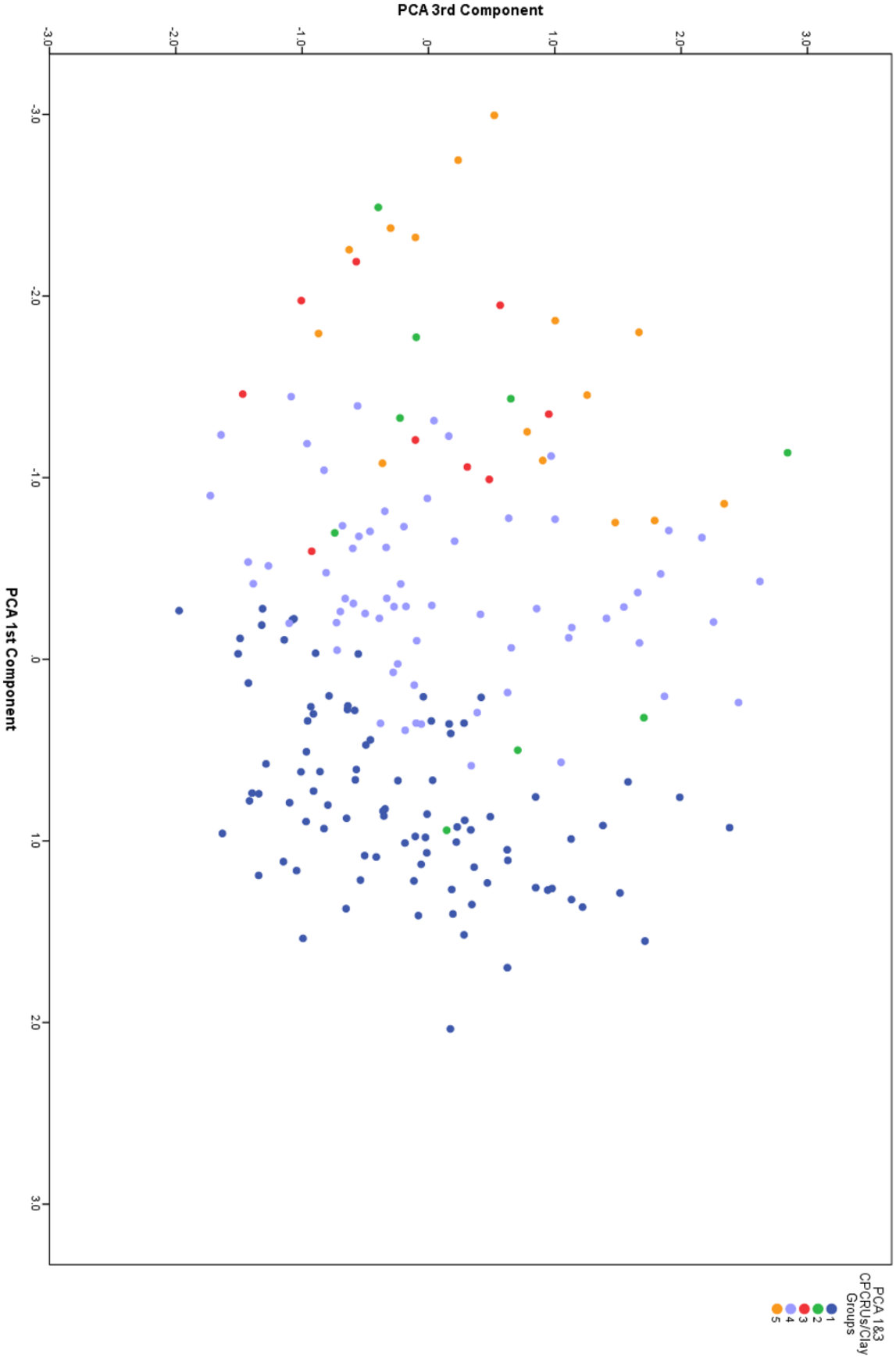


Figure 7-11 PCA 1&3

7.4 Results of the Chemical Analysis

The following uses the chemical results for the clay, all samples and sherds analyses described in the previous section to answer the questions outlined in chapter section 1.3. These concern the assessment of standardisation through time and across the site, and thereby consider the nature of on-site pottery production which is then further explored in the discussion section.

7.4.1 Ceramic and Clay Analysis

1. Do the ceramic samples gathered match the prehistoric clay groupings?

Cat. 1220 is a match to the contemporary clay source of Tako Khonk at Ban Ta Ko. No ceramic samples grouped with the clays from Non Ban Jak which were thought to be gathered from the surrounding moats and banks. The prehistoric potters must have exploited a different source.

Based on Arnold's (1985; 2000) threshold model, known Iron Age sites were plotted across the landscape along with the coordinates of Ban Ta Ko using Archmap. Buffers were then applied to the sites to assess possible interactions and shared clays source areas. Arnold's threshold model describes the distances potters will travel to collect sources, based on ethnographic data he proposed that potters preferred a distance of 1km. The second threshold was at 3km for temper sources and 4km for clay sources. The third and final proposed distance is 7km for tempers and clays. Figures 7.12 and 7.13 represents each site and the corresponding buffers.

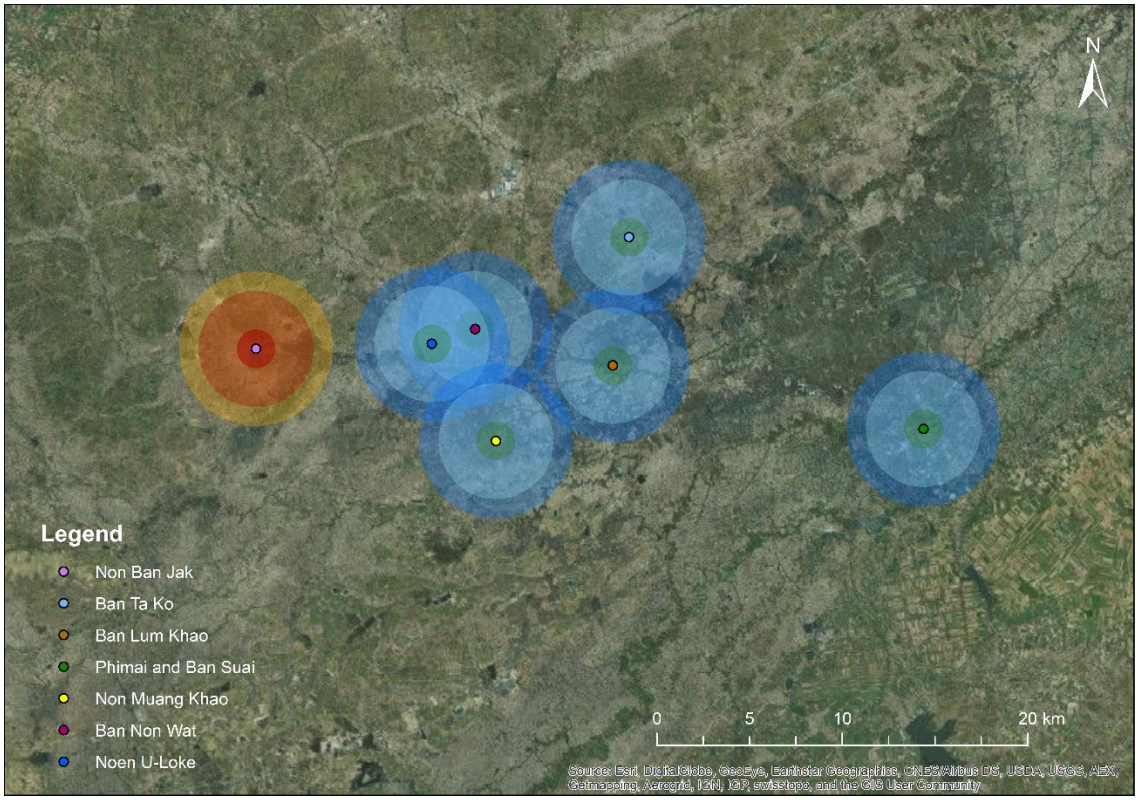


Figure 7-12 1, 3 and 4km buffers around Iron Age sites and the village of Ban Ta Ko. Red to yellow buffers represent Non Ban Jak.

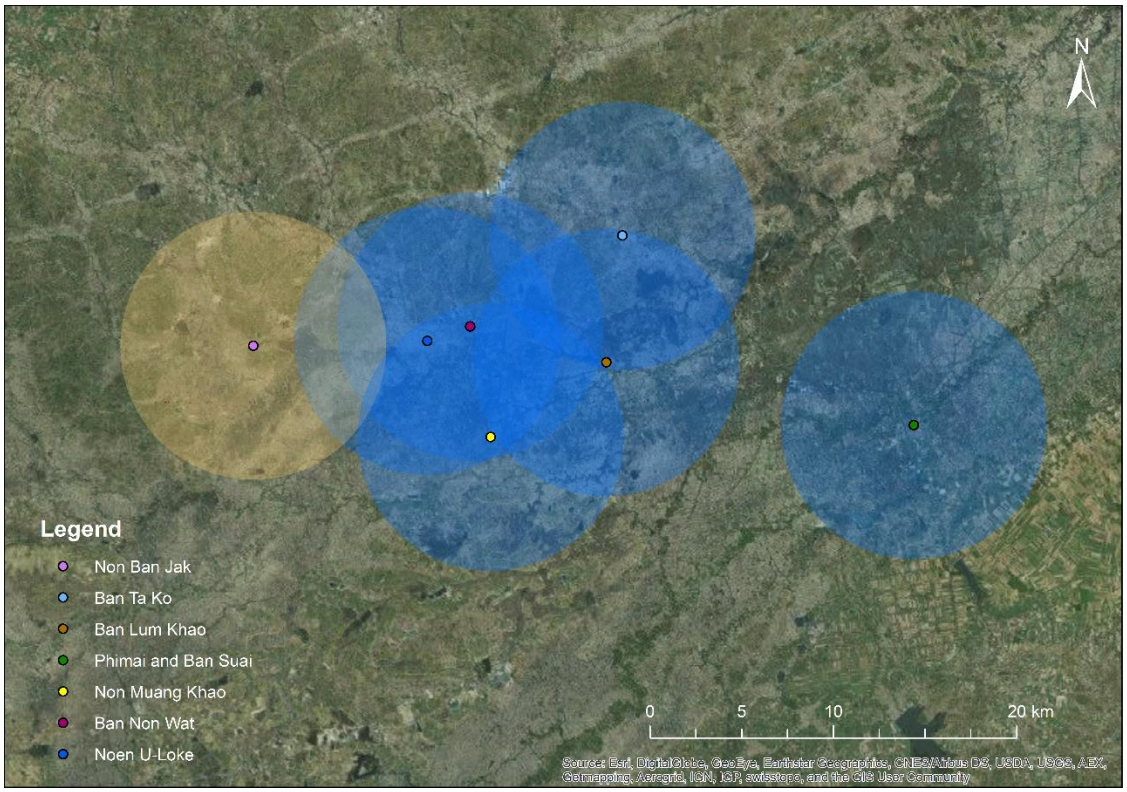


Figure 7-13 7km buffer around Iron Age sites and the village of Ban Ta Ko. Yellow buffer represents Non Ban Jak.

The reasoning behind cat. 1220 matching a source from Ban Ta Ko may not have been through clay procurement but possible introduction through trade or someone from Ban Ta Ko settling at Non Ban Jak. While both figures show that all sites are relatively close to one another, Non Ban Jak and Ban Ta Ko are very far away from each other in terms of clay sourcing.

Both maps show overlap of clay procurement around the Ban Non Wat and Noen U-Loke area, while Non Ban Jak is not included in this interaction in fig (Fig. 7.12), the second map shows that if people were travelling within 7km there may have been possible overlap of use of clay sources.

2. How many CPCRUs are there?

There are five CPCRUs in total, four from Group A and Group B is its own cluster (see Fig. 7.8).

3. Do fabric groups change over time?

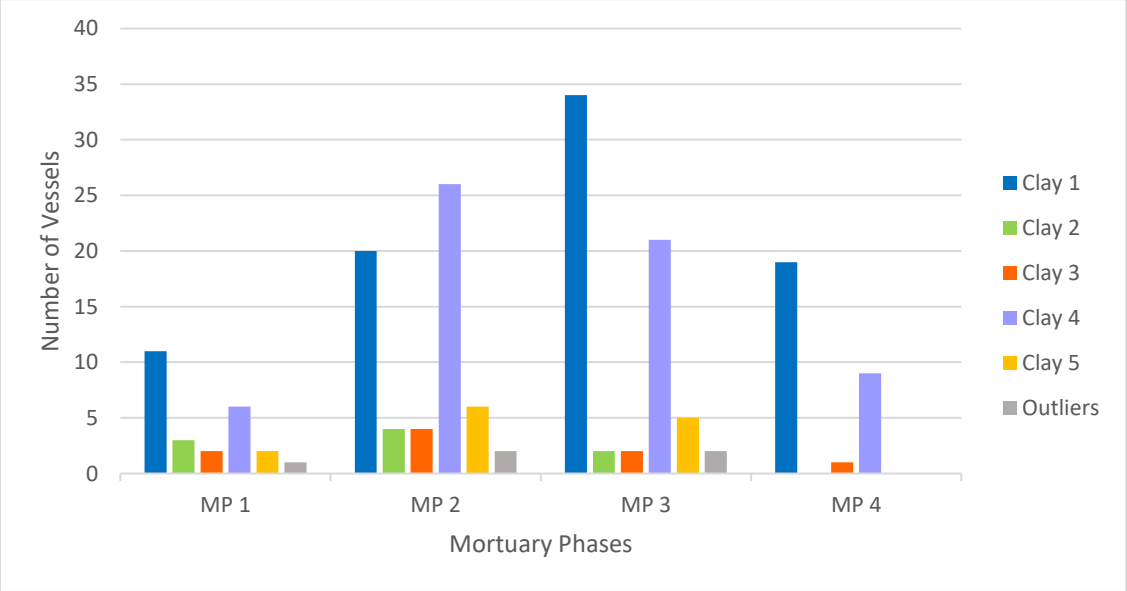


Figure 7-14 CPCRUs with associated mortuary phases.

The data shows that there was exploitation of all five clay groups from MP 1 to MP 3. However, there is a decrease in production at MP 4 where only Clay 1, 3 and 4 are used and not as many ceramics were being manufactured. There is also the consistent use of Clay 1 and 4 throughout the mortuary sequence, Clay 1 was the most used, followed

by Clay 4. Clays 2 and 5 were rarely used and were absent during MP 4 while Clay 3 was present in all phases but in very low frequencies throughout. Lastly, Fig. 7.14 shows that pottery production intensified mainly in MP2 and into MP 3.

7.4.2 Temper Analysis

Aim: To identify the types of temper within the assemblage as the change in mineral inclusions can reflect a change in technology (Summerhayes, 2000: p.32) or identify possible imports into the site.

An analysis of 17 samples under the electron microprobe assessed the homogeneity of the tempers before the bulk pXRF analysis, along with this a binocular microscope was used identify non rice chaff tempers across all samples. The results from these samples showed that rice chaff inclusions did vary in amounts and that there were also sub angular pieces of bleb grog, quartz and small traces of potassium feldspars and rutile (Fig. 7.15).

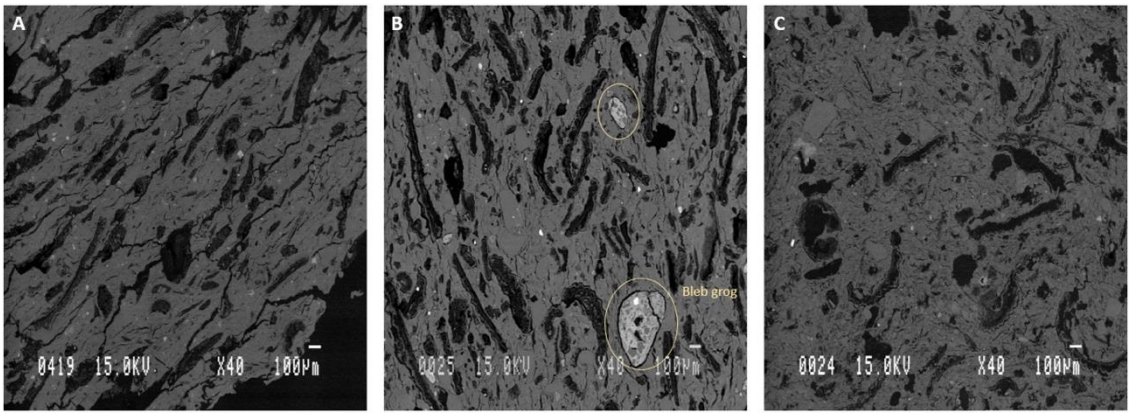


Figure 7-15 Pictures A to C of Cat. 304, 383 and 314 show the differing densities of rice chaff, the presence of bleb grog, and potassium feldspars and rutile scattered though the samples as small white fragments. Monographs were taken with the electron microscope at 40x.

There was no doubt that rice chaff played a prominent role in the temper recipes at Non Ban Jak. Not only is the porous topography of the ceramics visible to the naked eye, but this temper type is heavily recorded in previous research and is still a prominent temper recipe used today (chapter section 3.1.1). Only three vessels in this sample were identified as having a different temper.

4. How many types of temper are there?

There are three different types of temper: rice chaff, no chaff and stoneware. Chaff is used for 194 samples while two are attributed to no chaff and one to stoneware. While cat. 1182 (stoneware) and cat. 150 (no chaff) separate chemically from the samples at Non Ban Jak, cat. 478 clusters with Clay 4 (further discussion of outliers in chapter section 8.1 – 'Temper').

5. Does temper change through time?

Rice chaff was the preferred temper used in the construction of Iron Age ceramics and would have played a significant part in the creation of a thinner and lighter vessel, compared to previous ceramic traditions within the Bronze Age. While the use of rice chaff has been found to have started in the Bronze Age for moated sites across the Khorat Plateau, it dominated within the Iron Age.

Non Ban Jak is an Iron Age 4 site so there is no evidence of the transition from sand or other mineral tempers to rice chaff which is more clearly seen in sites such as Ban Non Wat which have the transitional phases from Bronze to Iron. Rice chaff temper is the dominant recipe at Non Ban Jak and used for all types of vessels on site. It is not only seen in Phimai Black vessels but also used for those not included in the Phimai tradition such as Form 7, the globular jars.

The two vessels that were identified as having a different temper from the rest of the samples are treated as outliers and possible imports into Non Ban Jak as they were chemically dissimilar to the rest of the fabrics. These include stoneware, as an import found in MP 3 and cat. 525 a large globular cord marked pot (Form 7B) found in the first mortuary phase.

Cat. 478 is an example of temper change through time and is a part of Form 11. Form 11 vessels are found in MP 4 associated with other historic artefacts such as Buddha figures identified as being part of the Dvaravati culture. The clay for Cat. 478 falls into local Clay 4 indicating the introduction of the Dvaravati ceramic tradition in the form of

either people coming onto the site bringing with them their pottery tradition as well as culture, or the movement of the culture and religion without immigrants.

7.4.3 Vessels Found Within Kilns

Aim: The kilns at Non Ban Jak are the first Iron Age kilns still containing pottery vessels excavated within a moated site on the Khorat Plateau. Herein lies the opportunity to investigate the nature of local Iron Age ceramic manufacturing. The vessels themselves can also give chemical groupings, suggesting clay sources for local pottery production.

Samples were taken from potsherds lying among the rake out associated with kiln B2, also from the reconstructed vessels within the kiln and from around the kiln. These samples come from layer 5, representing an early occupation of the Eastern mound that corresponds to MP 2. One sample was also collected from a possible kiln in the western mound.

6. How many clay groupings can be identified from the kiln samples?

There were four clay groups found within the samples collected from around the western kiln, around the Eastern kiln, the Eastern kiln rake out and the Eastern kiln itself. These groups are Clays 1, 3, 4 and 5 (Fig. 7.17). These clay groups found can be considered to be local clays as they were found in production areas on site, this is further explored in section 8.1 – 'Farbics'.

Out of the seven reconstructed vessels from Kiln B2 in the Eastern mound, five were sampled (Cats. 312, 313, 314, 316 and 317). The fabric analysis showed that they belong to Clay groups 1, 4 and 5 (Fig. 7.17). It must be noted that there is no reconstructed vessel for cat. 320 (Clay 1) and cat. 315 and 318 were not sampled (fig. 7.16).

Cat. 1259, a fragmented and unknown vessel was excavated from a pit full of daub and carbonised rice in DD2 Layer 4:3, MP 3. This vessel was found to be a part of Clay 1, matching three other vessels from Kiln B2. While the Western kiln does not share the same features as kiln B2, the fact is this was a firing pit of some function and if indeed a kiln, results show that while archaeologically the site is divided into the Eastern and

Western mounds, the clay groups span not only through time but across the site, showing that potters from different areas of Non Ban Jak using the same clay source.

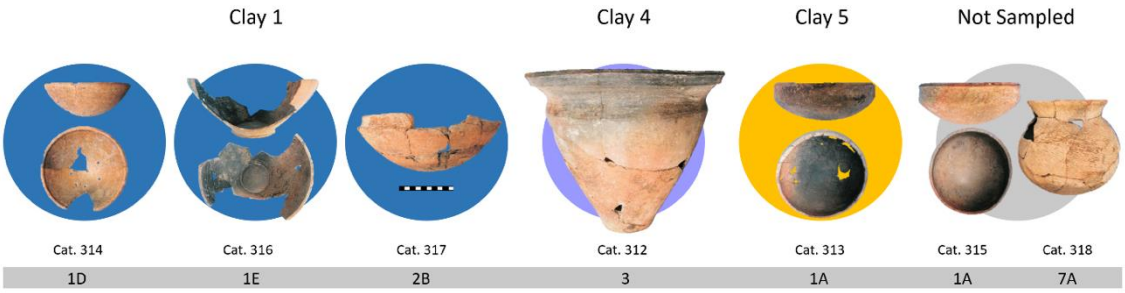


Figure 7-16 All reconstructed vessels and their clay groups from kiln B2 also associated vessel forms along the bottom

7. Do the clays from the kiln samples match other ceramic samples from the site?

Yes, kiln samples are found in all groups in the site except Clay 2. Fig. 7.17 shows that clay 1, 3, 4 and 5 were collected and fired on site.

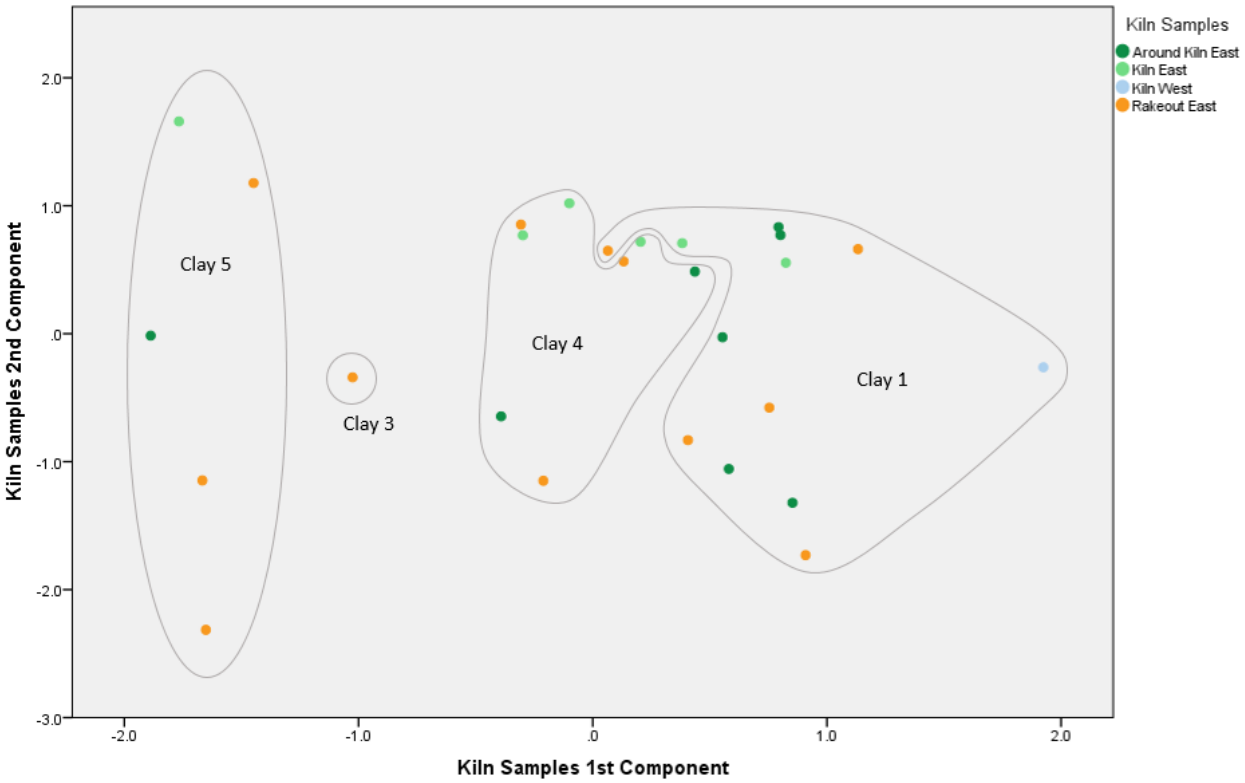


Figure 7-17 PCA of all the kiln samples.

8. What forms were found in the kilns?

Forms 1A, 1D, 1E, 2B, 3 and 7A were found within the kiln (fig. reconstructed vessels). They are common forms found at Non Ban Jak in burials, also examples were found in occupation and domestic contexts.

Cat. 312 is an infant mortuary jar common to MP 1 and 2. The kiln was found within MP 2, showing that these types of infant jars were made on site and not traded in for mortuary practices.

Cat. 314 is a standard 1D small bowl, the only exception is that it has holes bored into the base. Examples of these types of bowls in the site can be found lip to lip in pairs. The top bowl has holes in it while the bottom bowl has none. Ethnographic research carried out by the author has concluded that these types of vessels could be used for steaming food (see chapter 5). However, paired Phimai black bowls are generally an indication of a burial nearby, it is possible that these vessels could have taken on a different role in a mortuary context, such as incense burners or food for the dead.

Cat. 317, in form is a part of the Phimai tradition however this particular vessel has not been burnished or polished black. These forms are found used as infant interment vessels.

Cat. 318 is a small cord-marked globular pot, while tempered in the same way that Phimai Black vessels are, it is not a part of the burnishing tradition. This Iron Age vessel is a common adult mortuary offering.

Cat. 313 and 315 are typical 1A Phimai Black bowls found not only through NBJ but in other Iron Age sites and contexts on the Korat Plateau.

Cat. 316 is a pedestalled Phimai black bowl, another bowl common in mortuary contexts but in the later phases.

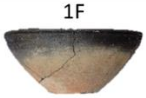
7.5 The Formal Analysis

Aim: The ceramics from Iron Age moated sites on the Khorat Plateau are allegedly standardised in form not only across these sites but through time. This section presents a detailed assessment of forms through the mortuary phases, answering questions presented in chapter section 1.3.2, taking particular interest in the number of vessels per group, use or context, fabric, decoration and the nature of sub forms through time within a larger group. This assessment uses a typology constructed and outlined in background section 3.1.2, and will test if the assemblage from Non Ban Jak is truly as standardised as has been suggested.

Q.1. How many vessel forms are there?

Within the unrestricted and restricted vessels groupings currently excavated at Non Ban Jak, thirteen have been identified along with subgroups, the following table summarises the groupings presented in background section 3.1.2.

Table 7.2 The forms of ceramic vessels currently excavated from Non Ban Jak

Form 1	
1A 	Simple unrestricted vessel with a flat lip and a prominent ridge
1B 	Similar in form and size to 1A, instead has a rounded lip and a curved ridge
1C 	Has a carinated shoulder under an everted rim. The rim is thicker than the other forms
1D 	Simple bowls consisting of a gradual curve from the rim to the base
1E 	Resembles 1D but has a small pedestal rather than a rounded base
1F 	Similar lip to 1A but has no ridge and has a ring foot instead of a curved base

.

Form 2	
2A 	Large open bowls and lids with a simple contour and a rounded rim
2B 	Large open bowls and lids with a simple contour, used as lids for Form 3

Form 3	
3 	V-shaped jars

Form 4	
4 	U-Shaped jars

Form 5	
5 	Shallow bowl with a wide everted rim

Form 6	
6 	Unrestricted bowl with a tall flared neck and a shallow body

Form 7	
7A 	Globular vessels with everted rims and a small flared neck
7B 	Larger than 7A, with a body deeper than it is wide, small flared neck

Form 8	
8 	Everted rim, cylindrical neck, a carinated shoulder with a rounded base

Form 9	
9 	Globular large body with a tall flared rim

Form 10	
10 	Large vessels with an everted rim and a sloping neck connected to a shoulder

Form 11	
11 	Globular vessel with an everted rim and a sloping neck to a cordon at the shoulder

Form 12	
12 	Everted rim with a neck that curves to a sharp shoulder and carries onto a rounded base

Form 13	
13 	White stoneware, with a tall flared neck and a rounded lip

7.5.1 Summary of results: vessel forms

The following section is an in-depth analysis at each vessel type and its corresponding subgroups. Each description answers the questions 2, 3 and 4 outlined in introductory section 1.3.2 concerning form change over time and associated context.

7.5.1.1 Form 1 – Phimai Black Bowls

Form 1 consists of 6 subgroups; 1A through to 1F. 1F consists of only one sample excavated from site and was not sampled in this study. There are 59 samples in total. Fig 7.18 shows the forms through the Mortuary Phases. 1B is the dominant sub form in MP 1 and 2. 1C is only seen in MP 1. While 1B peaks in MP 2, 1A, ID and 1E are introduced. In MP 3 and 4, 1A is the most popular sub form followed by 1E, around these phases 1B and 1D phase out.

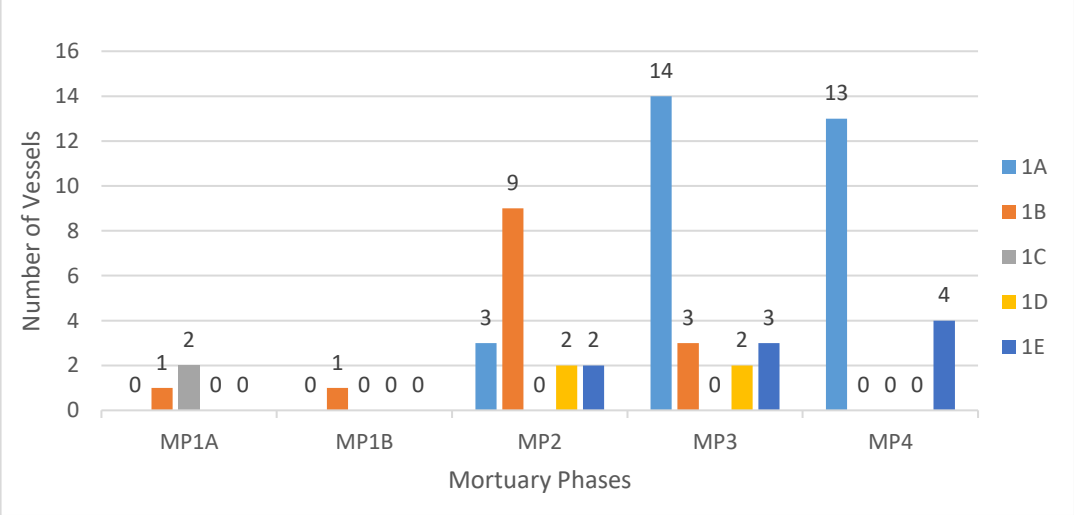


Figure 7-18 Form 1 sub forms through the mortuary phases.

Q.2. What context is Form 1 found in?

Fig 7.19 shows that all sub forms were found in burial contexts. The production category refers to the vessels found in the Eastern kiln (B2), 1A, 1D and 1E were found in this kiln. 1A and B were present in occupation and only 1B and 1E were found in a domestic context, indicating a preference for Phimai Black bowls as mortuary offerings. This is backed up by the bowls found in occupational context which were mostly found in pairs placed lip to lip. These bowls, while not directly associated with burials, were

found characteristically near burials. This is not the case every time and not all vessels could be clearly associated with nearby burials therefore many of these bowls have been place in the occupation category. While 1A is a popular bowl form, not once does it show up in a domestic context, suggesting that these bowls were only used as mortuary offerings.

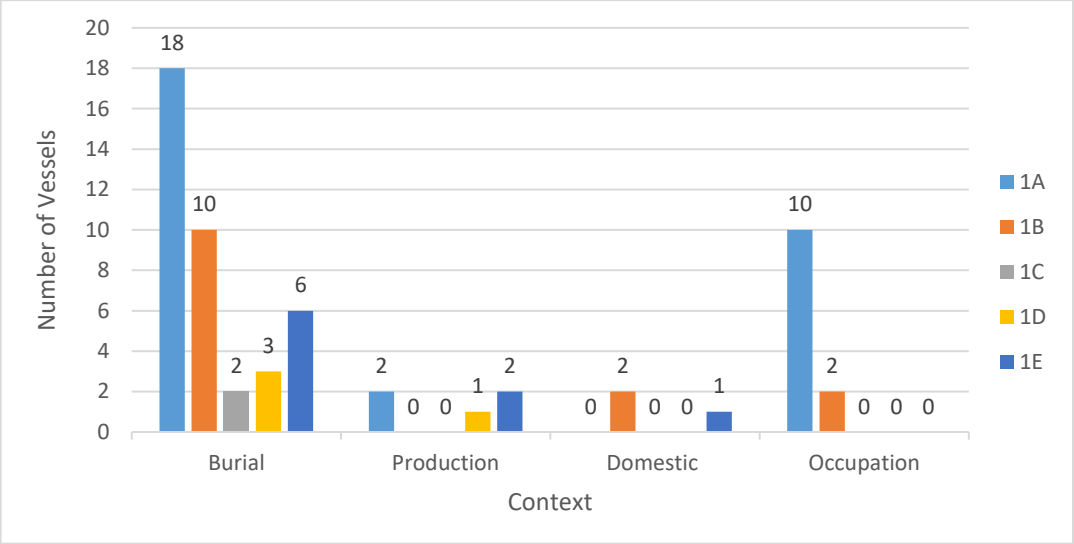


Figure 7-19 Form 1 sub forms and associated context.

Q.3. Does Form 1 change over time?

MP 1 - Sub forms present: 1B and 1C

The first Phimai Black bowl forms found on site were 1B and 1C (Fig. 7.20). 1C is a thicker ware compared to the later Phimai black bowls (Form 1A), this type can be likened to the Phimai Black wares excavated at Ban Suai (Thosarat & Kijngam, 2004).

1C is fully black in colour and either polished black or burnished to appear polished while 1B is mottled in colour with gaps between its horizontal streaks running around the body. Mottling is also present in the other Phimai Black vessels such as on Form 2B and 3. This is a reflection of uneven temperatures during firing. The lack of finished polishing or black colour and the presence of mottled vessels is a change in technique or a loss of a technique. 1C possibly reflects an earlier style of Phimai black from the donor settlement as it is only present in MP 1.

Figure 7-20 MP 1A and MP 1B Phimai Black bowls, Forms 1B and 1C and associated clays.

MP 2 - Sub forms present: 1A, 1B, 1D and 1E

At this phase we see the introduction of 1E, the pedestal bowl with a black streak burnished interior. These bowls are also seen at Noen U-Loke where the whole vessel is black, not just the interior, this is not seen at Non Ban Jak (Higham & Thosarat, 2007: p.240).

MP 2 also marks the introduction of 1A and 1D which are forms that were made on site as cat. 314 and cat. Cat. 313 were found in the kiln B2 area. 1A and 1D were possibly introduced forms and decoration (spiral burnishing on interior) as these vessels are seen throughout sites along the Khorat Plateau. This suggests interaction with other communities or new people coming to the site.

There are two outliers made with unknown clays, these are Cat. 1294 (Form 1B) and 1316 (Form 1A). These vessels are common forms found at the site, the presence of these two common bowls yet made with different clays indicates the popularity of the forms outside the site. Again suggesting maybe not only the move of the vessel into the Non Ban Jak but also new people.

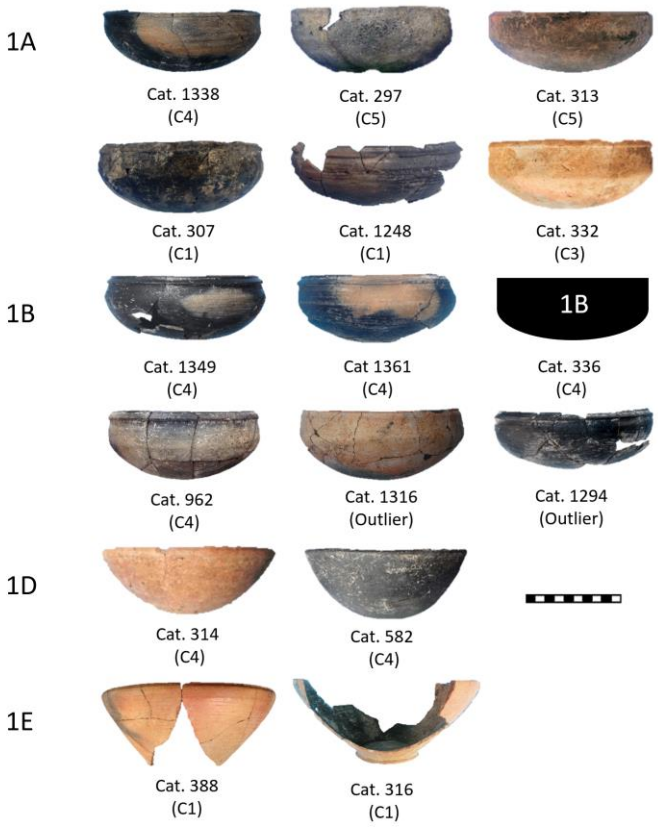


Figure 7-21 MP 2 Phimai Black bowls, Forms 1A, 1B, 1D and 1E.

MP 3 - Sub forms present: 1A, 1B, 1D and 1E

Form 1A is the most popular bowl type being made on site in this phase and are identical even between clay groups. 1B, 1D and 1E are found in very small quantities, reinforcing the popularity of 1A. Lip to lip vessels are also present within this phase not only 1A bowls together but these forms used as lids for other vessels such as cat. 1232 as a lid for a Form 7A, globular pot, showing the versatility of Form 1.

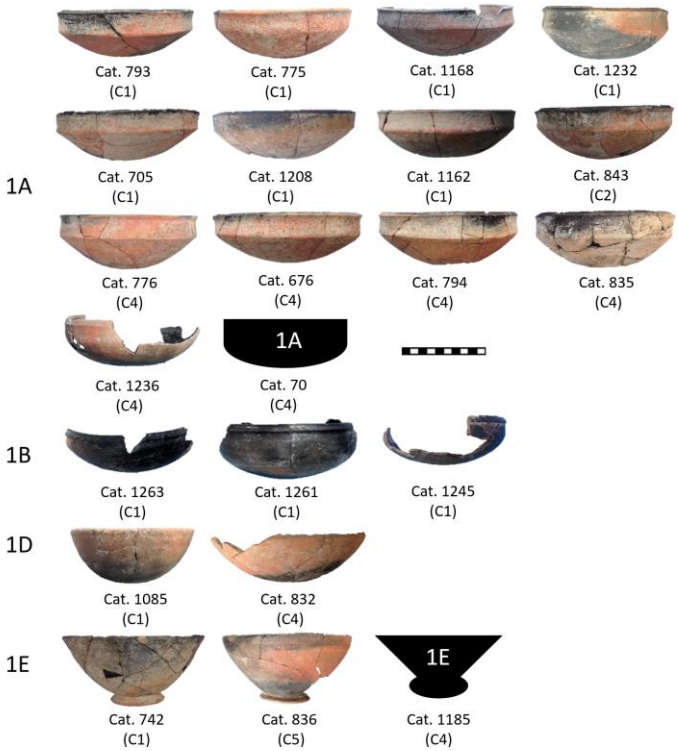


Figure 7-22 MP 3 Phimai Black bowls, Forms 1A, 1B, 1D and 1E.

MP 4 - Sub forms present: 1A and 1E

MP 4 sees the drop off of sub forms 1B and 1D. Form 1A still the most frequently made bowl type and has the same physical form since its introduction in MP 2. Many of the samples for 1A in this phase were found in pairs, lip to lip (Fig. 7.23). 1E is also present at this time and are being made in different sizes.

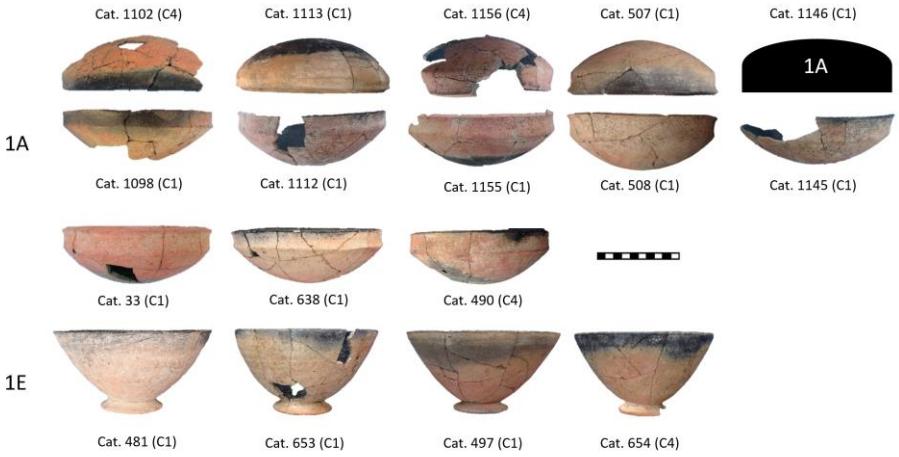


Figure 7-23 MP 4 Phimai Black bowls, Forms 1A and 1E.

Q.4. Is Form 1 associated with a particular fabric group(s)?

Clay 1 was the most used clay, followed by clay 4. Clay 2, 3, 5 and the outliers consisted of very small samples.

7.5.1.2 Form 2A and 2B – Large shallow bowls and lids

Form 2 consists of shallow bowls. There are a total of 11 vessels from MP 1 and 2 (Figs. 7.24 and 7.25).

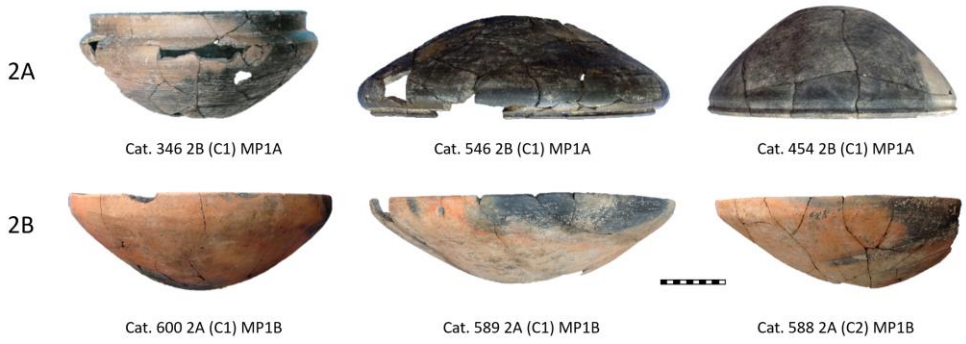


Figure 7-24 First row Form 2A from MP 1B and Second row 2B from MP 1A.

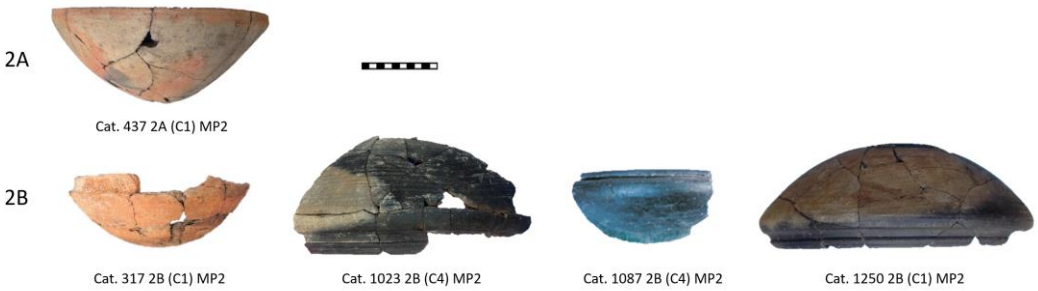


Figure 7-25 Form 2A and B from MP 2.

Q.2. What context is Form 2 found in?

All 2A and 2B were found in mortuary contexts with the exception of cat. 317 which was found in the Eastern kiln. MP 1 is split into two burial groups, MP 1A and MP 1B, based on orientation of burials and spatial separation between the groups. 2A are found in Group B while 2B are in Group A.

2B are commonly used as lids for V-shaped jars (Form 3) for infant interment. 2A were also used as infant interment vessels where the infant was placed in the shallow bowl (cat. 600) or just as mortuary offerings (cat. 588 and 589).

There is a clear divide between the bowls in MP 1. It is not a divide in use, as cat. 346 while made in the Phimai Tradition was used in the same way as a 2A and not as a lid, instead the infant was placed in the bowl. The difference is reflected in design where 2B are black and burnished in the Phimai Tradition and 2A, while still made with rice chaff, are plain.

Q.3. Does Form 2 change over time?

Form 2 only lasts for two mortuary phases and both sub forms stay the same through time. However, there is one outlier, cat. 454 from MP 1A, which is similar to the 2A shallow bowls but its rim and black design reflects the Phimai tradition. Cat. 454 is a lid to a globular vessel (cat. 453) which is burnished as black, both vessels are the only examples of their sub form found on site.

Q.4. Is Form 2 associated with a particular fabric group/s?

Form 2A and 2B are mainly made with clay 1 with one 2A sample belonging to clay 2 and two 2B vessels belonging to clay 4.

7.5.1.3 Form 3 and Form 4 – V and U shaped burial jars

Form 3 and 4 are both mortuary vessels. Form 3 are V-shaped jars and were usually lidded. They are found in MP 1 and 2, there are 8 in total. Form 4 are characteristically U-shaped jars, there are 23 in total, five are from MP 2, fourteen from MP 3 and four from MP 4.

Q.2. What context are Forms 3 and 4 found in?

Both are found in burials. Form 3 is used only for infant or neonate burials, these vessels were usually lidded and had punctuates on the shoulder just below the neck. The

only other vessel type that has punctuates on it are the Form 8 polished Phimai Black globular jars.

Form 4 are usually found in pairs, lip to lip, either encasing infants or the head and feet of children. Form 4 is burnished in the Phimai tradition but does not share the decorative punctuates found on Form 3.

Q.3. Do Forms 3 and 4change over time?

A formal assessment of Form 3 and 4 through time at Non Ban Jak shows that Form 3 was the preferred infant interment vessel in MP 1 and was then superseded by Form 4 during MP 2. MP 2 contains vessels that share elements from both Form 3 and 4, suggesting that Form 3 could have transitioned into Form 4 later in the site.

Vessels were placed in either Form 3 or 4 based on shape of body and rim. As mentioned before Form 3 is V-shaped in the body while Form 4 is U-shaped. Through time Form 3 loses its straight V-shape for a more rounded body. The rim also changes from elaborate and incurving to a wide outward flare. In comparing these two forms it is possible to see a transition of the idea of Form 3 over time (Fig. 7.26).

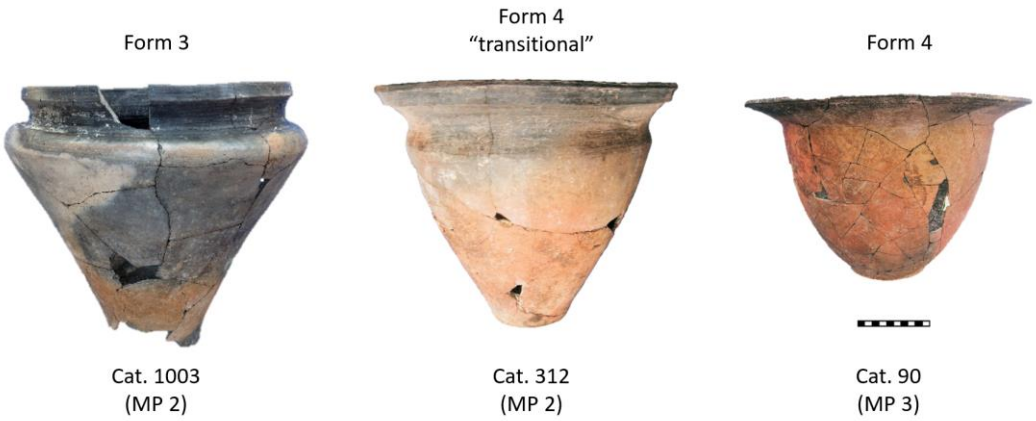


Figure 7-26 Change of vessel Form 3 to Form 4.

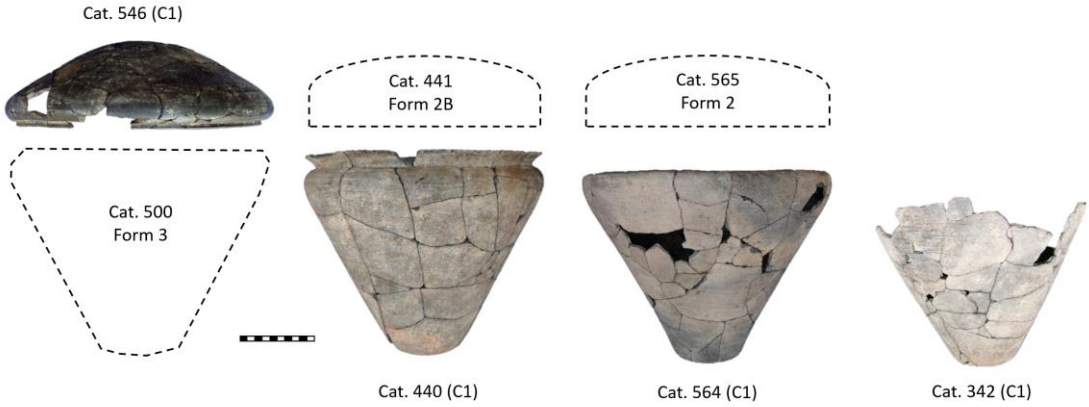


Figure 7-27 MP 1A Form 2B and 3

Figure 7-28 MP 2 Form 2B (lid) and 3 (jar).

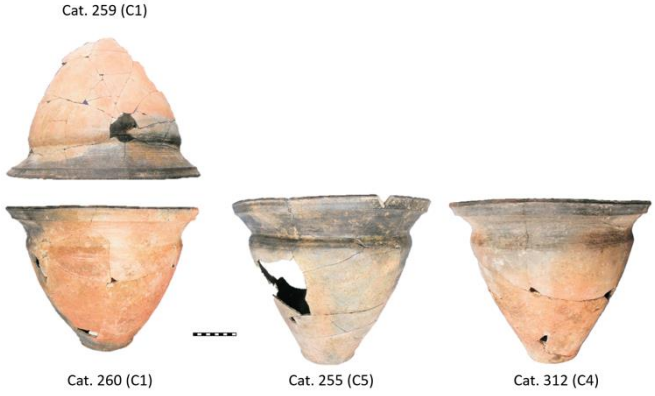


Figure 7-29 MP 2 Form 4

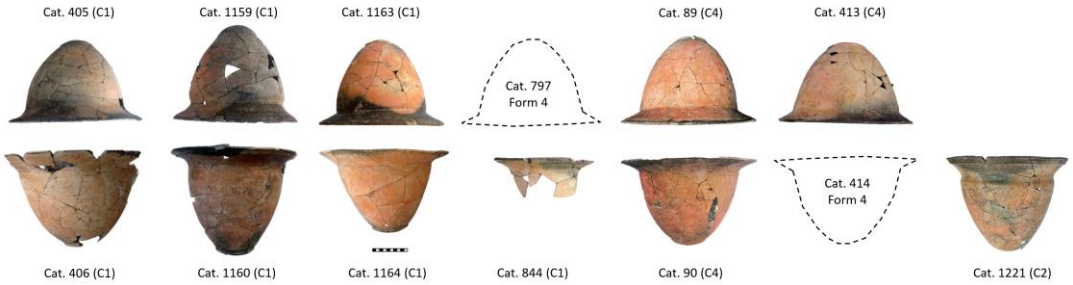


Figure 7-30 MP 3 Form 4.

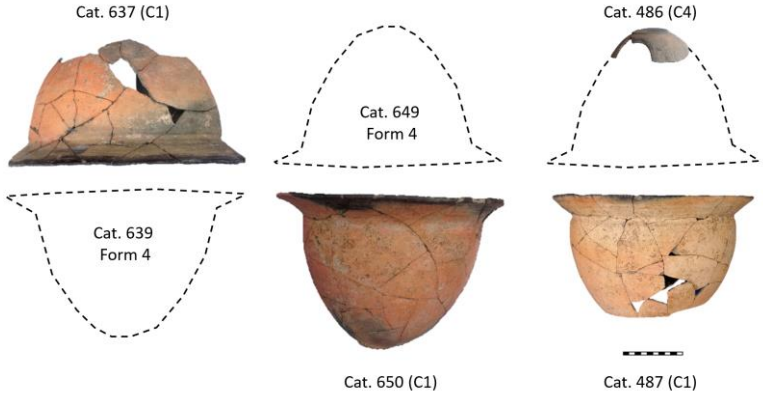


Figure 7-31 MP 4 Form 4.

Q.4. Are forms 3 and 4 associated with a particular fabric group(s)?

All Form 3 vessels are made with clay 1, showing standardisation of these infant burial jars through time. Form 4 is made with clays 1, 2, 4 and 5 in MP 2, Clays 1, 2 and 4 in MP 3 and 1 and 4 in MP 4. No clay 3.

7.5.1.4 Form 7 – Globular vessels

Form 7 consists of 2 subgroups; 7A and 7B, those vessels that could only be partially reconstructed were labelled as only Form 7. There are 46 samples in total and Fig shows these vessels through the Mortuary Phases. 7A is the dominant sub form throughout the mortuary phases except for in MP 4. 7A also is at its height of production in MP 2 and 3.

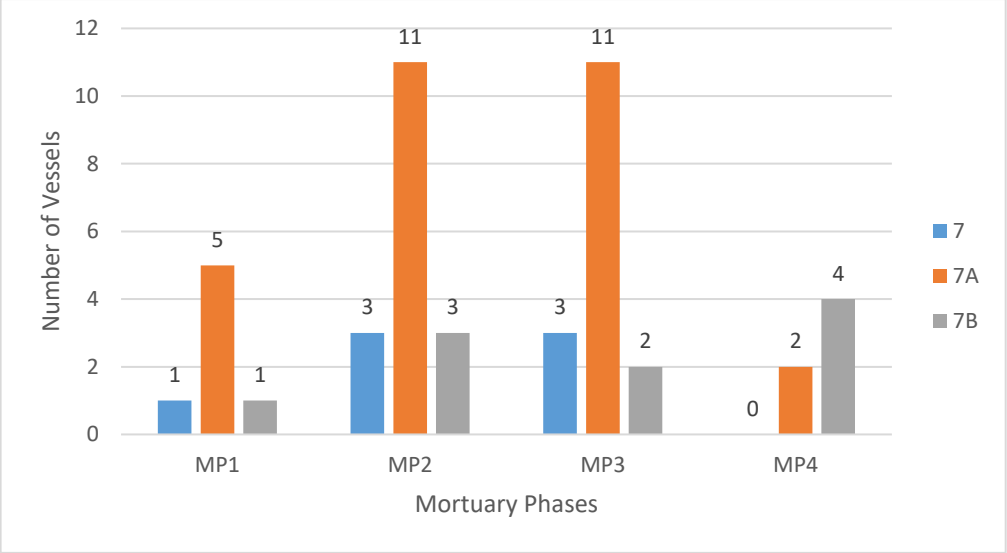


Figure 7-32 Form 7 and the associated mortuary phases.

Q.2. What context is form 7 found in?

All sub forms can be found in burial contexts. 7 and 7A are found in domestic and 7A is also seen in the production area showing that it is made on site. 7B is only found in infant interment vessel/offerings while 7A is smaller and was used as a mortuary offering, possibly containing food. The shape of Form 7 reflects that of a storage vessel, it is unsurprising that these vessels were also found in domestic context as they may have contained food and or water.

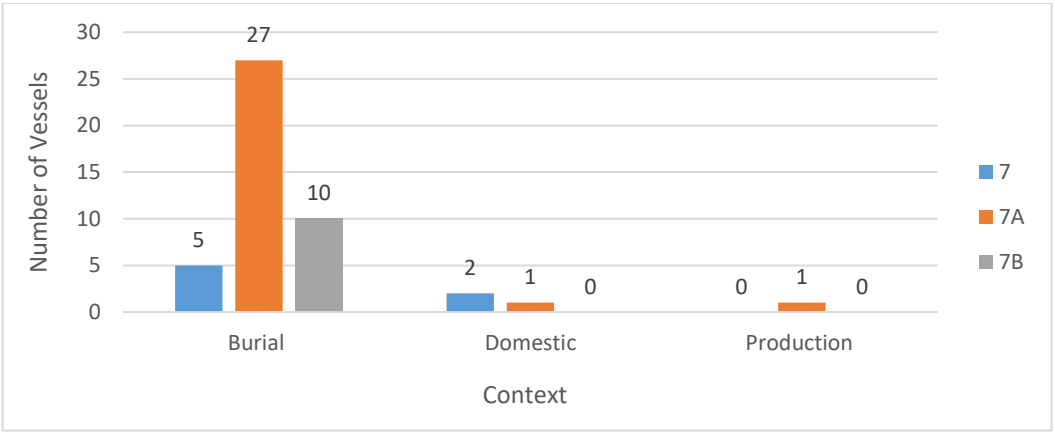


Figure 7-33 Form 7 and the associated context.

Q.3. Does form 7 change over time?

MP 1

There are two types of decoration used for Form 7, this is mainly cord-marking on the body plus the one smooth plain pot (Cat. 1339). All are made with rice chaff temper. 7A with a cord-marked body is the dominant form across MP 1A and 1B.

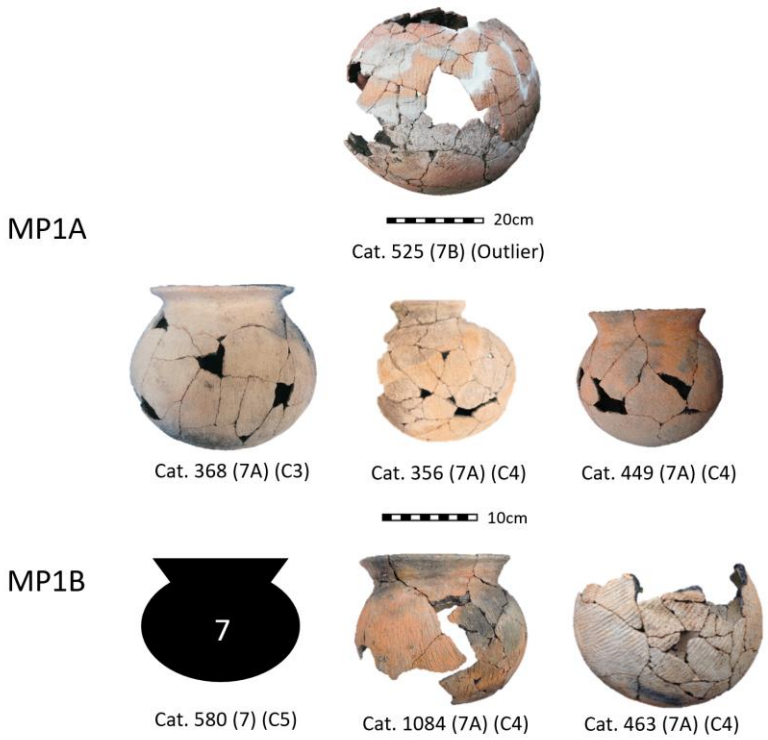


Figure 7-34 Form 7, 7A and 7B vessels from MP 1A and 1B WITH associated clay.

MP 2

7A is again dominating the Form 7 assemblage at this phase. These small globular vessels share similar necks and rims however differing in body decoration which includes plain, plain with burnished streaks, polished with burnishing streaks and cord marking. Cat. 993 and 1018 differ in a slightly carinated lower body and share burnishing streaks for body decoration.

MP 2 is the first phase that burnishing on globular vessels is witnessed as opposed to just cord-marking. Showing that potters use decoration from the Phimai Tradition on vessels that are not a part of the tradition.

7B shows some variation in form in MP 2, for example cat. 1015 and 1292 have a slight carination at the shoulder and another near the base making the vessel more angular than the spherical bodied vessels. Also, there are variations in the height of the rims and the shape of the lip. Indicating less standardisation in the larger forms than in the smaller.

Figure 7-35 Form 7 vessels from MP 2 with associated clay.

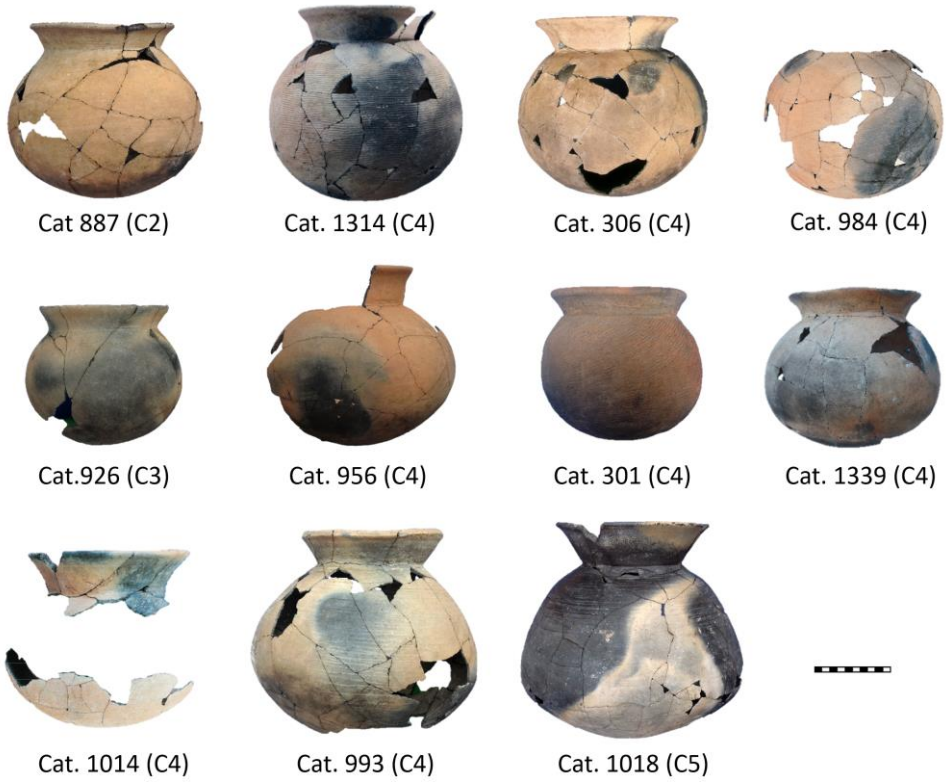


Figure 7-36 Form 7A vessels from MP 2 with associated clays.

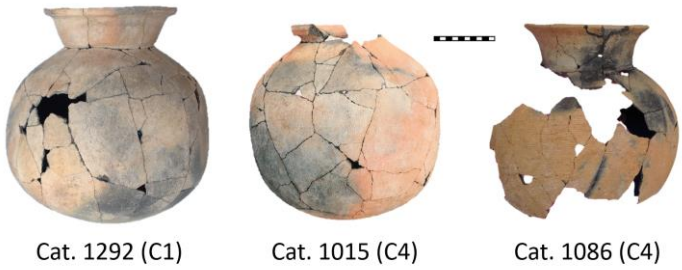


Figure 7-37 Form 7B vessels from MP 2 with associated clays.

MP 3

Globular vessels are still a common mortuary offering and cord-marking is the most popular design in MP 3. MP 3 introduces another type of decoration, which is plain body with incised nail marks below the neck of the vessel. The two 7B vessels from this phase differ physically. Cat. 1233 is a larger form of a cord-marked 7A while cat. 517 differs in lip and body shape that can be considered more oblong that globular (Fig. 7.40).

Figure 7-38 Form 7 vessels from MP 3 with associated clay.

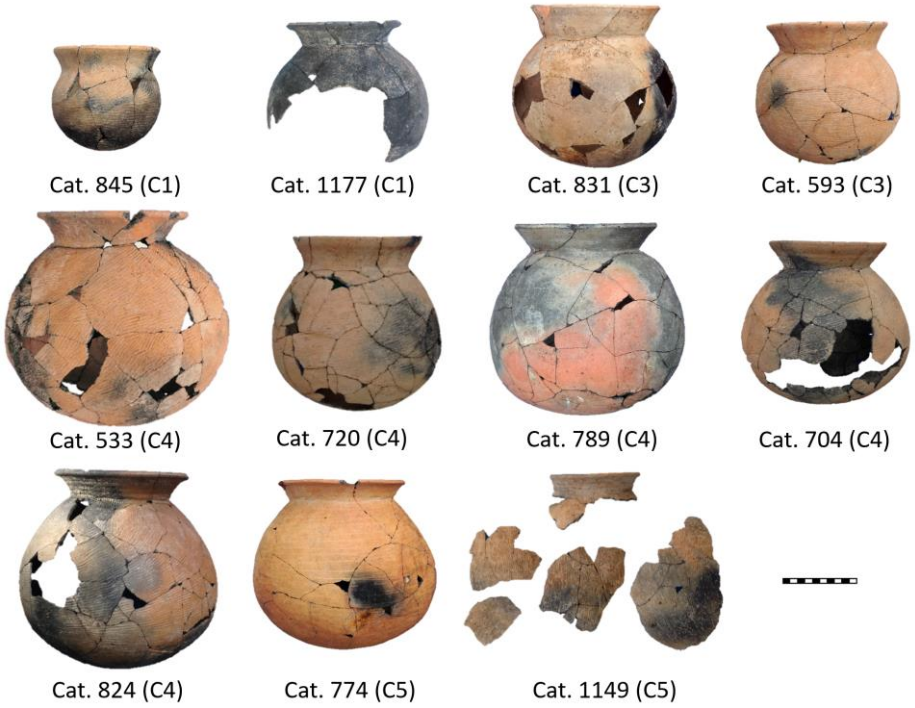


Figure 7-39 Form 7A vessels from MP 3.

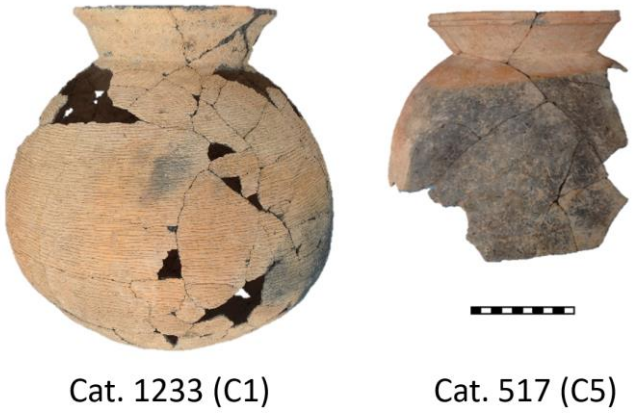


Figure 7-40 Form 7B vessels from MP 3.

MP 4

Ceramic production significantly decreases in MP 4, there are two Form 7A vessels that are similar physically as they are both small and cord-marked, with very short and small flared rims. In the Form 7B assemblage there are four vessels in total and three of them are identical however made with different clays (Cat. 110, 630 and 636). All vessels in this phase are cord-marked.

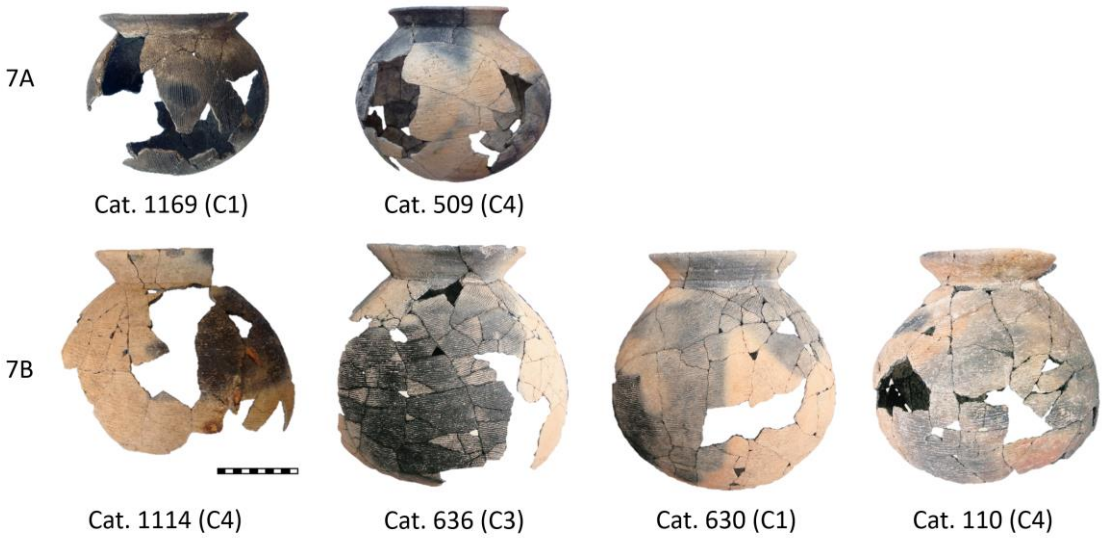


Figure 7-41 Form 7A and B vessels from MP 4 with associated clay.

Q.4. Is Form 7 associated with a particular fabric group(s)?

Form 7 is mainly made with clay 4, other clays were also used to create these vessels but in low numbers. The findings here differ greatly to the vessels in the Phimai Tradition which were mainly made with clay 1.

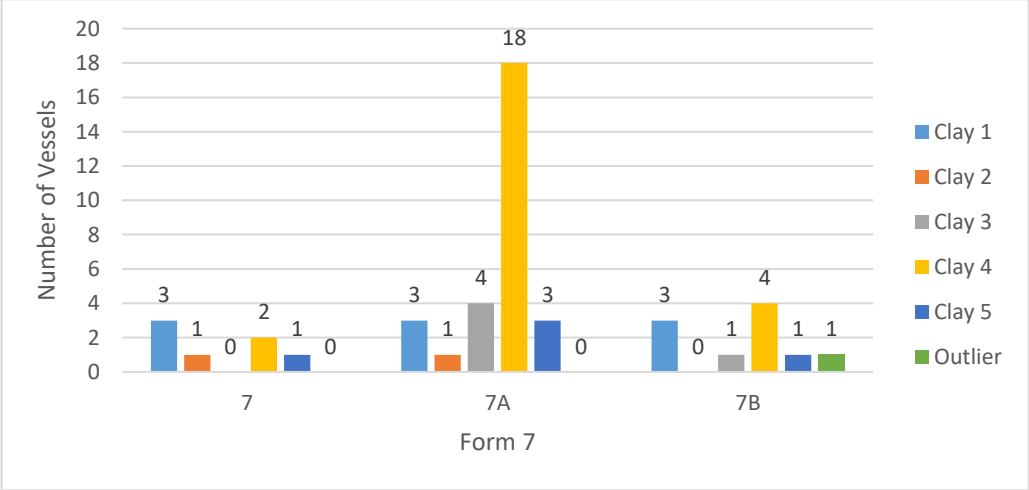


Figure 7-42 Form 7 and associated clays.

7.5.1.5 Form 8 – Globular Phimai Black Vessels

Form 8 consists of 11 samples found in MP 2 and MP 3. Based on other Iron Age excavations, Form 8 can be subdivided further into groups based on rim type and location of punctuates. This form and some examples from Form 3 and Form 2B are the only vessels that have punctuates and currently, this decoration has not been seen on other vessels at Non Ban Jak. Punctuates on Form 8 range from singular to multiple rows located either on the merge between rim and neck or just above the shoulder.

Q.2. What context is Form 8 found in?

These jars are usually found as infant interment vessels, yet two were found in a domestic context (cat. 1178 and 1186). Cat 1282 contained no infant but was found in a secondary burial for a mid-aged female.

Q.3. Does Form 8 change over time?

There are not enough sub forms throughout the phases to assess change through time, however there are replica Form 8 vessels excavated elsewhere, two identical vessels within sub-form 1 (cat. 304 and 1240), and the quality of manufacturing suggests that these forms are set forms found throughout the Mun Valley. It is possible that Cat. 1171, 1178 and 1186 are imitations or variations of Form 8. These vessels share the same burnishing technique and a similar form, however are slightly misshapen and are not as polished or black like the other sub forms.

Figure 7-43 Form 8 from MP 2 and 3, with associated clays.

Q.4. Is Form 8 associated with a particular fabric group?

All samples are made with the Clay 1 with the exception of two for Clay 4 (cat. 1186 and 1257) and two for Clay 5 (Cat. 304 and unknown form cat. 1269).

7.5.1.6 Outlier Vessel Forms

There are seven vessel forms that are considered to be outliers in the current Iron Age data set, separated from others based on obvious physical dissimilarities (Fig. 7.44). For many of these vessels only one example has been excavated on site (Form 9, 12 and 13), only a handful have been found (Form 5, 6 and 10), or the form exists outside the Iron Age (Form 11).

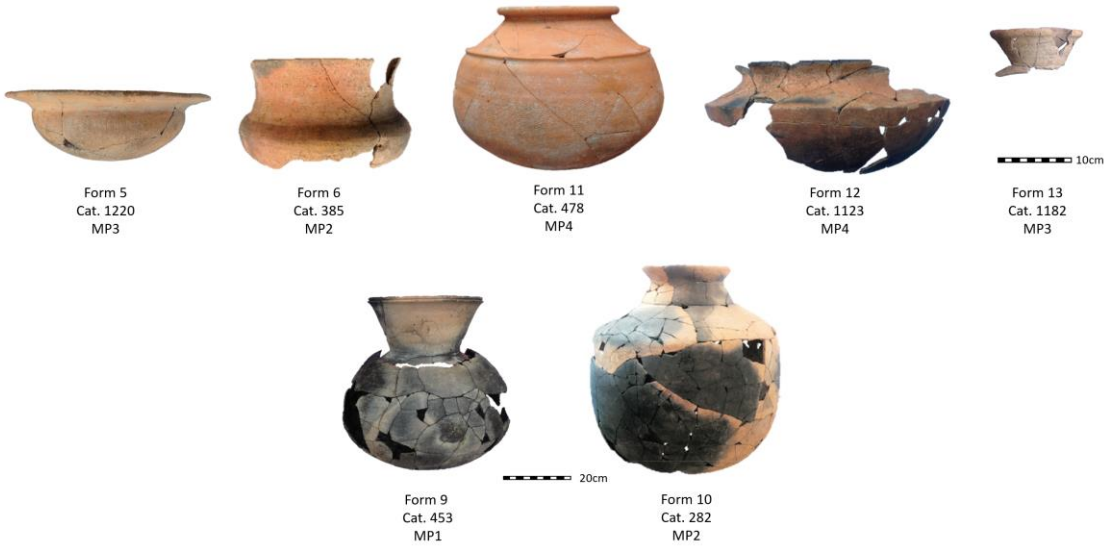


Figure 7-44 Outlier vessel forms, the top row 10cm scale while the larger vessels on the bottom have a 20cm scale.

Form 5

These bowls have wide everted rims and a cord-marked body, only three examples have been found and differ in depth of the body. This form is also a thicker ware compared to the thin Iron Age vessels. The sample in this study comes from the western mound in MP 3 (cat. 1220) where it was found with an infant burial, either as a mortuary offering or a lid to a Form 4 that encased the infant.

Form 6

Form 6 are shallow bowls with tall slightly flared necks. These vessels are not found in burials, the only examples have been found in occupational contexts, suggesting that this form was used for domestic purposes. Flared necks were a common feature in the Bronze Age ceramics at Ban Non Wat (Sarjeant, 2008), these ceramics were possibly used to serve liquids (Higham, 2014: p.187). Form 6 could have had a similar purpose.

Form 9

Form 9 was found in MP 1A, it is the only vessel of its kind. Its rim was made to accompany a lid and is similar to the early Phimai black bowls found lip to lip (Form 1B) indicating that this form is a part of the Phimai tradition. The lid that accompanies Form

9 (cat. 454) is significantly larger than the rim suggesting that this lid was not originally meant for the globular pot.

Form 10

Form 10 is a very large thick ware that was tempered with rice husk and high fired. Only one complete vessel has been found, this was in kiln B1 in MP 2 indicating construction and firing on site. The other two example were found in the 2016 excavations in the western mound, only the rims and partial shoulders were found. While made with Phimai Black techniques, this vessel is not considered a part of the tradition and as it is not streak burnished or polished black. It is similar to the Form 7 vessels which were also high fired and rice tempered but did not share the decorative motifs of Phimai Black. These vessels are therefore categorised as just Iron Age ceramics.

Form 11

Form 11 is an orange mineral tempered vessel from the historic period. These vessels are wheel thrown and are highly standardised in appearance only varying in size. Such vessels are associated with the Dvaravati culture and their presence is seen on site in MP 4 in the form of historic pits full of Dvaravati material. The sample was from a pit that has been dug through an Iron Age burial.

Form 12

The only example of its kind excavated on site, differs greatly from the usual forms. Similar in appearance to the Dvaravati style than anything in the Iron Age. This vessel was found in a burial of a young man in MP 4 along with another vessel of an unknown form.

Form 13

Form 13 is stoneware and the only one of its kind excavated on site. Stoneware was not locally made during the Iron Age and it is not until the historic period that stoneware manufacture begins within Thailand (Grave et al., 2000). Indicating that the origin of this vessels was from an exotic source.

Chapter 8. Discussion

The aim of this dissertation is to assess the nature of Phimai Black ware. As set out in chapter one, four research questions were proposed to assess the nature of standardisation and pottery production at Non Ban Jak. The following section is a discussion that aims to explore and answer these research questions. The first two questions summarise the main findings pertaining to the tempers, manufacturing techniques, fabrics, and vessel forms, in terms of standardisation through time and across the site. The last two questions address models of standardisation by applying the two theoretical frameworks to all the findings from the current research. Both theories use cultural transmission and Costin's production typology, to investigate and describe the nature of the assemblage and pottery production at Non Ban Jak. This will be followed by a summary on what this thesis has contributed to our understanding of Phimai Black Ware.

8.1 Research Questions revisited

1. Are the tempers, manufacturing techniques, and fabrics standardised through time and across the site?

Temper

The dominant temper at Non Ban Jak was rice chaff, as seen through time and across multiple contexts. The temper was also standardised across the different vessel forms, not only in Phimai Black vessels but also in the other Iron Age non-black and unburnished forms 5, 6, 7, 10, and 12. Only three of the 194 samples analysed were tempered with anything other than rice chaff: Cats. 1182 (stoneware), 478 and 525.

Cat. 1182 and 525 were outliers in the chemical analysis while the historic pot fell within Clay group 4. Cat. 478 is a historic pot with Dvaravati affinities introduced in the later phase at Non Ban Jak (MP 4). It was made with a local clay, indicating that Dvaravati derived vessels were being made on site.

Cat. 525 is a large and thick cord-marked globular pot from MP 1, only the body is present. The fact that this vessel was one of the first on site and is made of a clay that does not group with any other fabrics identified, suggests that this vessel was made with a non-local clay. Cat. 1182 is also made with a non-local clay, and with a manufacturing technique that was not present in the area during the Iron Age. This stoneware vessel was found in an occupational area in MP 3 near a clay path, along with a Phimai Black vessel. Cat. 1182 is the only one of its kind found on site, and would have been brought or traded into Non Ban Jak from another location.

Figure 8-1 Temper outliers cat. 525, 1182 and 478.

Manufacture

The use of rice chaff as temper for a lighter, thinner, more porous vessel, constructed through the paddle and anvil technique, characterise the Phimai tradition. These manufacturing techniques span not only time and different forms at Non Ban Jak, but are also widely reported in other sites, such as Ban Non Wat and Noen U-Loke, where clay anvils have been found and the use of rice chaff temper is also prominent. This shows regional standardisation of manufacturing technique.

Fabrics

The following section discusses the results for the fabric analysis and is divided into two sections; fabrics through time, and across the site.

Summary of Fabrics through Time

Five CPCRUs have been identified at Non Ban Jak, together with five outliers. According to the hierarchical cluster analysis, the five CPCRUs are divided into two groups, A and B (Fig. 8.2). These differ chemically, suggesting two separate clay sources. This finding is also seen in the loading plot for PCA 1&2 (Fig 8.3).

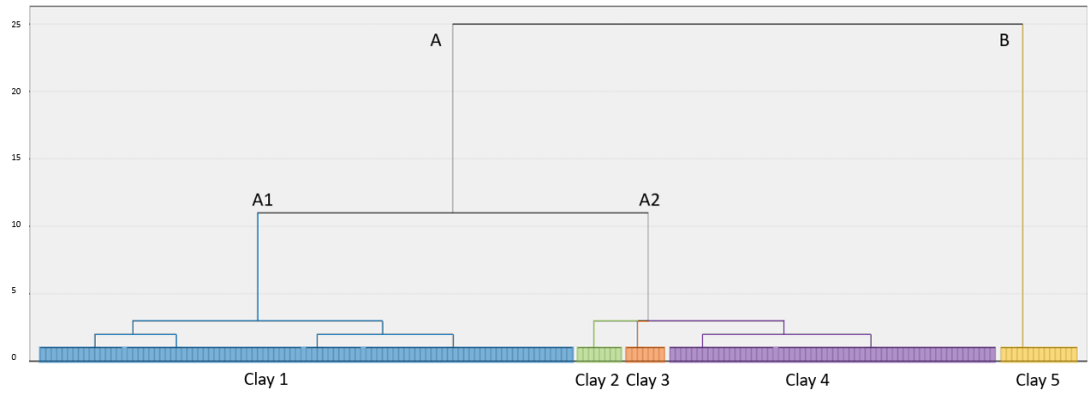


Figure 8-2 Hierarchical cluster analysis of different clay sources.

There is a clear separation of Sodium, Copper and Zinc from the other elements within the loading plot. In comparison to the PCA, samples in Group B are chemically distinguished from the other clay groups on the basis of these three elements. If only considering the PCA, Clay 3 could also be said to be driven by Na, Cu and Zn, however the HCA shows that Clay 3 is not chemically similar to Group B (Clay 5), but is closer to Clays 2 and 4 (Fig 8.2). It is important to consult all methods of data analysis appropriate for the particular research, as the PCA displays only one view of otherwise three dimensional data. Relationships displayed should always be checked through other methods.

Previous chemical analyses have shown that copper is not a prominent element within the Bronze and Iron Age ceramic assemblages in the area. Geary (2007) reported that it was the differing levels of sodium and calcium that separated the ceramics from Noen U-Loke, Ban Non Wat and Ban Suai. Sarjeant (2008) however, found that the major variation in clay at Ban Non Wat was attributed to phosphorus, manganese, and titanium, while sodium and iron showed the most uniformity across the samples.

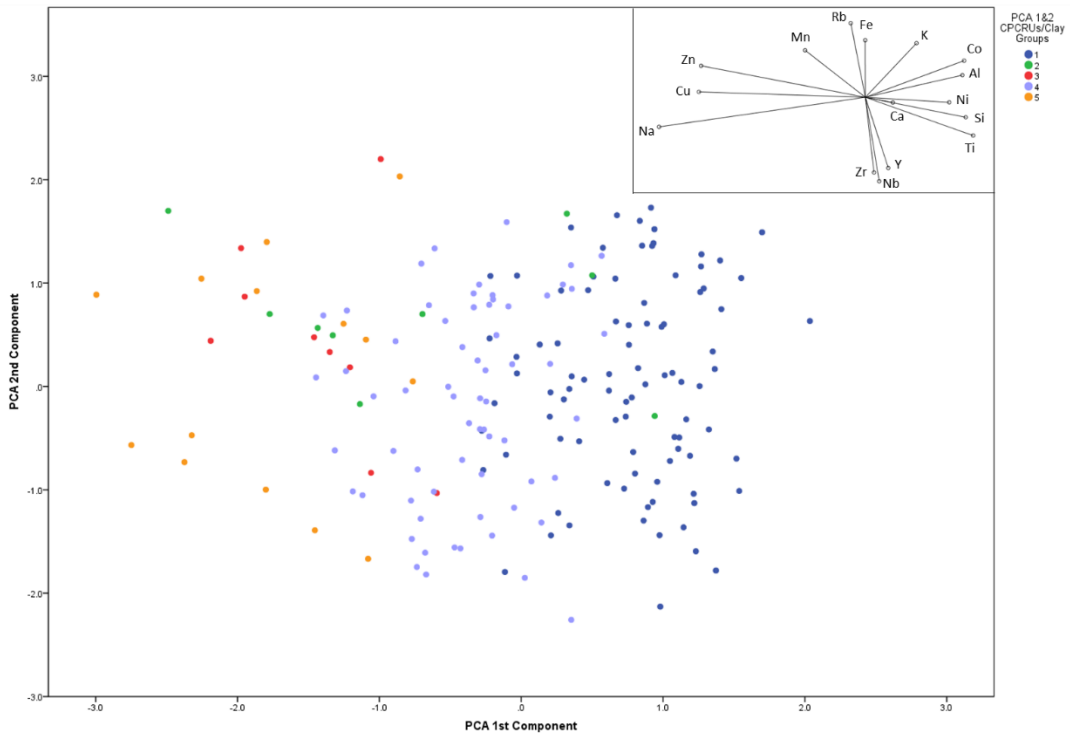


Figure 8-3 PCA 1&2 with Loading Plot.

Copper is geologically and archaeologically associated with the Loei Petchabun Volcanic Belt and prehistoric copper production sites concentrated in the Khao Wong Prachan Valley, both areas lying east of the Khorat Plateau (Pryce et al., 2010: pp.238-239). This indicates that clay sources high in copper may have been from an area further east of Non Ban Jak, suggesting that samples from Group B, which are high in copper, are not from a local clay source while the clay groups within A share an underlying geological signature.

Evidence suggests that there is more to Group B procurement than just making vessels. Use of Group B started early in MP 1. The sample from MP 1 is from an area dedicated to burials while domestic or living areas are further to the west (Higham et al., 2014), this area was used as one of the first cemeteries at Non Ban Jak. Vessels made with Group B found in this cemetery, and its chemical separation from Group A, suggest that Group B is not a local source to Non Ban Jak, but possibly a source that originated from near the donor settlement. Either these vessels would have been brought with the first settlers, or potters were travelling back to a familiar clay source. Evidence of its use in kiln B2 (Cat. 313) suggests that potters were travelling back to that source and

gathering the clay in MP 2. Its eventual phase out in MP 4, the limited use of it over time, and the preferred use of Clays 1 and 4 from Group A (Fig. 8.4) suggests:

- It may have been too much effort to gather Group B when other sources that work just as well were closer (assuming that Group A is local).
- Group B could be a source associated with another town such as the donor settlement, therefore we must take into account the possibility of territorial right over the land/area.

The reliance on clay from Group A through time, the shared underlying geology of this group, and the fact that most of Group A clays (with the exception of Clay 2) were found in kiln B2 suggests that the CPCRUs in Group A are local. While this cannot be confirmed without a proper sourcing study, the interpretation is supported by Geary (2007; 2010). While her formal analysis showed that the manufacturing, temper and physical appearance of Phimai Black vessels were highly standardised across Ban Non Wat, Noen U-Loke, and Ban Suai, the chemical analysis showed that samples from the three sites grouped independently of each other, indicating local production of a regional ceramic tradition (Geary 2010: p.71). In considering this, Group A represents the local source for ceramic production at Non Ban Jak while Group B is exotic.

Along with Group B there are two other clays that were not used prolifically on site, these are Clays 2 and 3. Both were found to be in Group A, and therefore possibly local sources. In terms of vessels made, these clays were used to make a range of common forms found on site and across the Mun Valley, these included 1A, 1B, 2A, 4, 7A, and 7B. Clay 2 was also used to make Cat. 453 which is Form 9 from MP 1. As these clays were used at the beginning of the site settlement phase, they were probably then associated with the donor settlement, this is thought of especially for Clay 2, which made Cat. 453, a vessel that represents a very early form of the Phimai Black ceramic tradition most definitely associated with the donor settlement. Clay 2 was not found in the kiln, suggesting that these vessels could be from a source associated with the donor settlement, or were brought to site from the same place, indicating continual interaction with neighbouring groups and shared clay sources.

Most samples from Non Ban Jak belong to Clay 1 or Clay 4, and there is a reliance on these through time (Fig 8.4). During MP 2-3, pottery production was at its peak along with wealth reflected in the amount and range of mortuary goods. Clays 2, 3, and 5, do not rise in use as dramatically as clays 1 and 4, showing a reliance on local sources and in turn standardisation of local clays through time by potters on site.

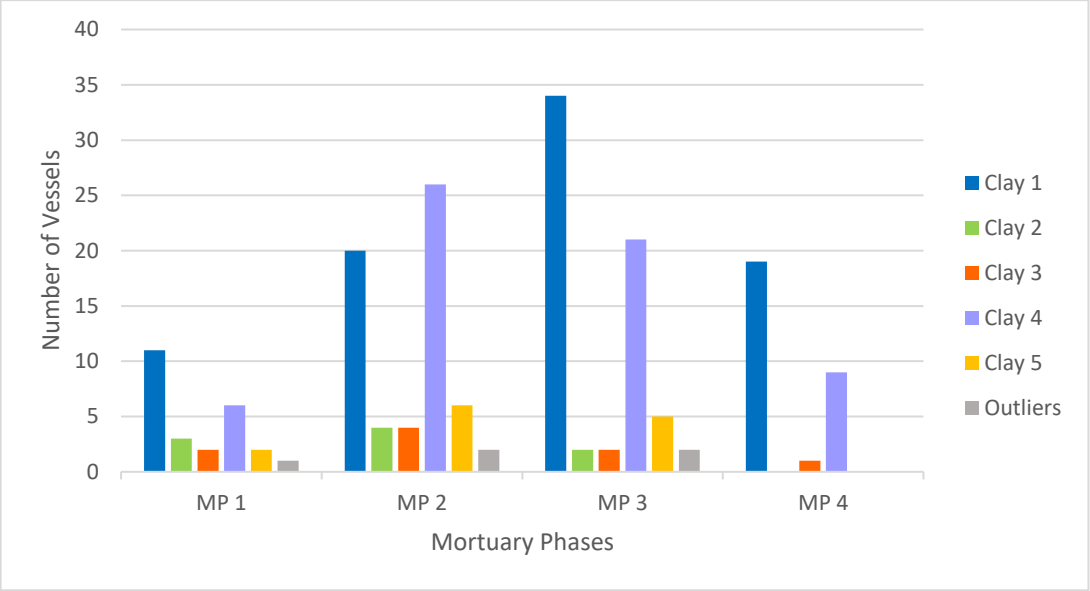


Figure 8-4 CPCRUs with associated mortuary phases.

Summary of Fabrics across the Site

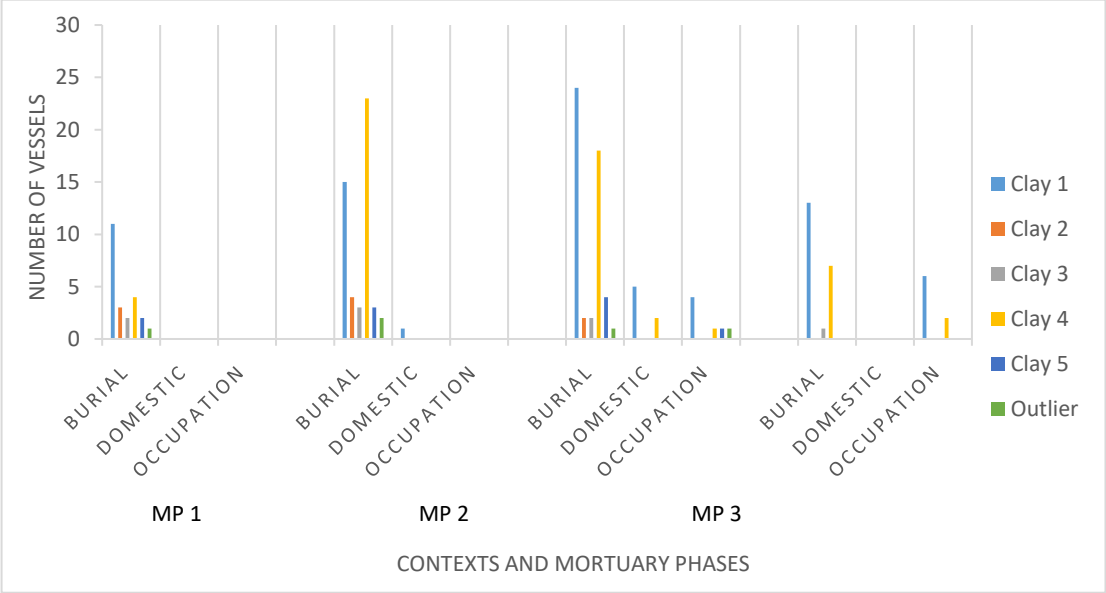


Figure 8-5 Clays through the Mortuary phases and their associated context.

Even though there is only a small sample from domestic and occupational contexts compared to mortuary ceramics, general trends seen in mortuary ceramic fabrics are also reflected in these contexts. Thus in MP 3 and MP 4, Clay 1 is the most used across all contexts, followed by Clay 4. This shows not only the popularity of the two clays, but also that Clay 1 and 4 were not exclusively used to make mortuary vessels. This in turn indicates that potters did not restrict particular clays to particular contexts, showing high standardisation of fabric across contexts in the sense of Clay 1 and 4.

2. Are the vessel forms standardised through time and across the site?

The assemblage of complete pottery vessels from Non Ban Jak was divided into vessel forms. This has led to a consideration of function and context. Change over time in the preferred forms was then considered in the context of the four mortuary phases. The following section summarises these findings in terms of each form and their connection to one another through the mortuary phases and over multiple contexts.

Form 1

Form 1 is an open bowl, and is divided into six sub-forms. There were changes in the incidence of the sub forms over time, but form 1F has not been included, as there is just one specimen. Forms 1B and 1C were the first Phimai Black bowl forms on site. These forms were thicker, and usually polished black both internally and externally (Fig 8.6). In MP 2, Forms 1A, 1D, and 1E were introduced. These have black and spiral burnished interiors. Forms 1A and 1D are shallow bowls, while IE has a pedestal base. These bowls are thinner and are usually only black in the interior. 1E forms are seen in other sites, but are completely black (e.g. Noen U-Loke in Higham & Thosarat, 2007: p.240), suggesting that while the form stays the same, potters chose not to burnish and polish their output.

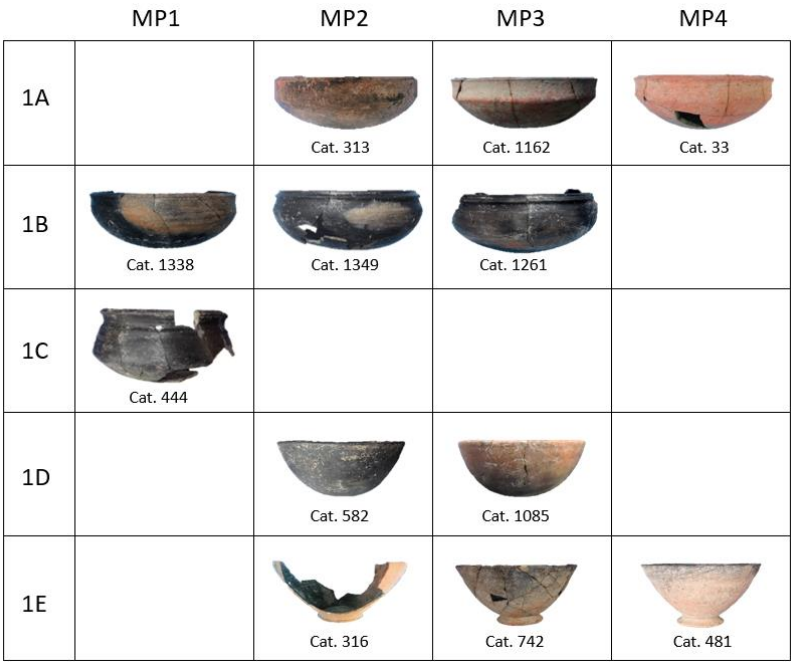


Figure 8-6 Changes in Form 1 vessels over time not to scale.

Each sub-form is standardised through time; early Phimai Black forms, which include 1B and 1C, do not evolve into other sub forms, such as 1A. The nature of bowls through time shows movement from an older style (Forms 1B and 1C) to settle on a newer (Form 1A), this is seen in the rise in popularity of form 1A from MP 2 to the end of the occupation.

Rather than sub-forms evolving through time, this standardisation shows a trend for moving from an older to a newer, distinctly different sub-form, for example, a shift from using Forms 1B and 1C to Form 1A. This is seen in the rise in popularity of form 1A, spanning MP 2 to the end of the occupation.

Concerning the standardisation of Form 1 over multiple contexts, results show that all sub-forms were present as burial offerings. Only 1B and 1E bowls were found in domestic contexts. While 1A vessels were found in occupation contexts, they were often found in pairs, lip to lip and in close proximity to a burial, indicating that even though 1A was a popular bowl form, it was not used for domestic purposes, being preferred for ritual use.

Form 2

Form 2 is present only in MP 1 and MP 2 burials with the exception of cat. 317, which was found in Kiln B2. Through these phases 2A is standardised in form, but there are some variations within 2B, for example, cat. 454 is unique in form, while cat. 346 and 317 are very similar to one another, likewise cat. 546, 1023, 1087, and 1250 are all very similar in form.

A few Form 2 vessels are only present during the early phases of occupation at Non Ban Jak, which phase out with Form 3. That Form 2B ceramics were often used as a lid for Form 3 explains their contemporary disappearance. Both Forms 2 and 3 came to site with the first settlers, representing an earlier form of fully black polished and burnished Phimai Black ceramic tradition.

Forms 3 and 4

It is difficult to assess fully the standardisation of Form 3 through time, as not all elements of the vessel survive. Frequently the rims are not found, or are too wet to be reconstructed. However in lieu of this, the bodies of these vessels show an overarching angular V-shaped form. Decorative motifs, including burnishing and punctates around the rim, are also a common design found on Form 3 vessels, with Cat. 302 as the singular exception. Not only does the rim differ, but there is an added appliqué in the form of a bird just below the shoulder.

It is not until we look at Form 3 and Form 4 together that we see the true nature of these vessels. Form 3 was first introduced in MP 1, as the preferred infant interment vessel, superseded by Form 4 during MP 2. Some Form 4 vessels in MP 2 share elements from both Forms 3 and 4, potentially the result of a copying error, leading to a transitional form. To date, no Form 3 vessels have been found in MP 3.

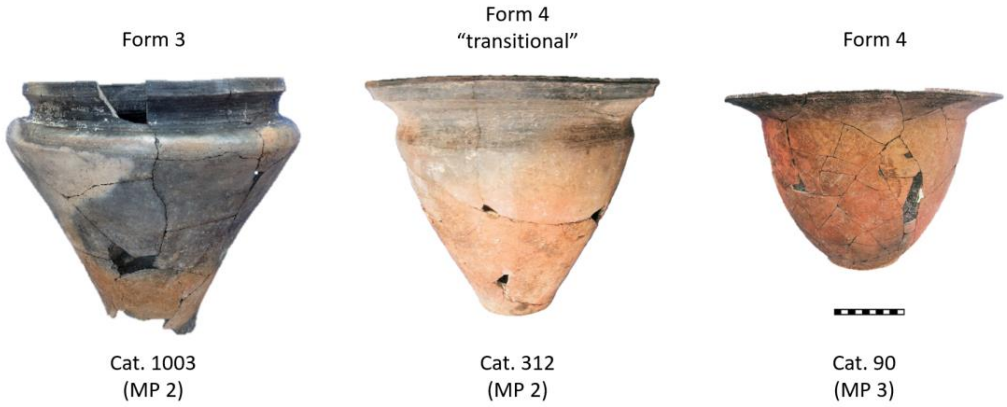


Figure 8-7 Change of vessel Form 3.

In summary, the data show that Form 3 was highly standardised in MP 1 before developing into Form 4. Form 4 was also highly standardised in physical appearance, and restricted to mortuary contexts as either lip to lip infant interment vessels, or to encase the head and feet of children.

Form 5

Form 5 vessels have thicker walls than most of the Iron Age forms - three examples have been excavated from site, only one of which was used for this study. The clay of this sample matches the clay sample gathered from the village of Ban Ta Ko.

Form 6

Form 6 bowls are similar to the liquid serving vessels found during the Bronze Age at Ban Non Wat (Higham, 2014: p.187), suggesting a similar use for domestic activities at Non Ban Jak. These vessels were not found in a mortuary context and are not of the Phimai Black ceramic tradition. The sample in this assemblage was found near Kiln B2 and made with Clay 1 indicating that this form was made on site.

Form 7

The globular vessels that comprise Form 7 are not a part of the Phimai tradition and have been categorised only as Iron Age ceramics. Form 7 makes up a quarter of the reconstructed assemblage and is found throughout all phases.

The nature of Form 7 does not reflect high standardisation. There are two forms within Form 7 (A and B) which differ in size. Form 7A is more standardised and smaller than 7B, although both can show distinct variation in neck size, rim structure, body shape and decoration. This difference in standardisation between forms could be related to skill. As Roux (2003) outlines, larger vessels require more skill. Smaller vessels with less embellishments and unexaggerated forms are prone to fewer errors.

Although it contains a few identical vessels, standardisation of Form 7 is not as high as Phimai Black, where forms can contain many sub-forms that are replicated through time. While the form itself does not reflect high standardisation, the clay analysis shows otherwise. Two major clay sources were used over time, these are clay 1 and 4. While clay 1 was used to make the majority of Phimai vessels, clay 4 was mostly used for Form 7, showing a high standardisation in terms of clay use.

Form 7 was mainly used in a burial context, with only three vessels within the sampled assemblage found in domestic contexts, mostly likely for food storage and preparation. Form 7 is variable through the ages, while Phimai Black is standardised with elaborate decoration. The globular shape of Form 7, a shape that is commonly seen in a contemporary context to hold food or liquids (Shippen, 2005), could have held food offerings for the deceased. The high levels of variation and individuality in Form 7 vessels suggest that they could have been made by relatives of the deceased to hold burial offerings.

Form 8

Form 8 consists of black polished, globular vessels that have punctates located above the shoulder. Within Form 8 there are obvious sub forms divided by type of rim, neck, location of shoulder, and punctates. The subgroups within this form are standardised within the assemblage at Non Ban Jak, and similar vessels have been found in other sites e.g. (Fig 8.8). The nature of these vessels can be likened to the Phimai Black bowls (Form 1) as they are highly standardised within their own subgroups.

Figure 8-8 Form 8 vessels from Non Ban Jak and Noen U-Loke. Cat. 1206 and 1282 from Non Ban Jak and Cat. 1901 and 1027 from Noen U-Loke.

The overall craftsmanship of Form 8, the polishing and added decoration, suggests a high level of skill, detail, and effort invested by the potter. Labour investment and the obvious decorative separation from other forms suggest that Form 8 could be a prestige good. Prestige goods are usually associated with an elite as a symbolic and material differentiation between classes (Peregrine, 1991). When comparing the mortuary data, burials containing Form 8 vessels fail to reveal an elite; there is little evidence for inherited wealth save for one burial (burial. 117, cat. 1161). The inconsistent findings suggest the significance of Form 8 at Non Ban Jak may lie within the realm of elite association, as these forms increased in presence during MP 3 during a time of enhanced pottery production and wealth. However, the data more specifically outline that the purpose of these vessels was not necessarily to show a difference in status, but to show that these people held great value on the interment of the young compared to other age groups.

The Form 8 vessels found in domestic and occupational contexts seem to be of lesser quality compared to the other sub-forms (Fig. 8.9). Cat. 1171, 1178, and 1186 look like imitations of the other black polished sub-forms, with streak-burnishing instead of full polish, and large punctates instead of intricate small rows. Cat. 1178 and 1186 were found in domestic contexts, suggesting that these particular Form 8 vessels were allowed to be

used in contexts other than mortuary, while fully polished vessels were strictly used for infant interment.

Figure 8-9 Imitation form 8 vessels.

Form 9

Form 9 is a large globular jar used for infant interment, it is associated with an earlier style of the Phimai Black ceramic tradition originating from the original donor settlement.

Form 10

Form 10 is a large Iron Age vessel made on site. The only complete vessel was found in Kiln B1 in MP 2, while the other partial examples were found in occupational contexts during the 2016 Western mound excavations. These large vessels were possibly used for water or food storage, and are a glimpse into the possible domestic vessels on site, of which there are only a few.

Form 11

Form 11 is a historic vessel from the Dvaravati culture. In the late period at Non Ban Jak there is evidence of the introduction of Dvaravati influence or people on site in the form of pits full of historic material such as Buddha figurines, small oil containers, tablets, and highly standardised orange mineral tempered pottery. The historic sample in this assemblage was made with Clay 4, suggesting that these people were using clay from the surrounding area to produce their own styled pottery. Currently there has been no

material evidence of interaction between the Dvaravati people and the Iron Age occupants of Non Ban Jak, as no burials have shown a mixing of material culture, and there is a gap in occupation between the historic and late Iron Age, as seen in the archaeological stratigraphy.

Form 12

Form 12 is rice chaff tempered vessel made with clay 1. The use of local clay alongside Iron Age temper techniques, suggests that this vessel was made within the wider Iron Age community.

This vessel was a mortuary offering for the young male in burial 112, who was also interred with another vessel of an unknown form (cat. 1124) which was not included in the overall typology as there was not enough of the vessel for categorisation.

The presence of two unique vessels suggests that this individual was from another settlement, and was buried with vessels from his own culture or home.

Form 13

East Asia/China was the main distributer of stoneware to the Thailand area before large scale production began in sites such as Sisatchanalai during the historic period (Grave et al., 2000). Evidence of stoneware production in China possibly dating to the late 6th century (Medley, 1989: p.89) falls within the occupational date of Non Ban Jak, and suggests that cat. 1182 originated from China. This would not be unusual, as maritime trade networks linked India and China to Mainland Southeast Asia; iron smelting and forging, along with glass artefacts, would not have been the only technologies and material culture to make it to the Upper Mun Valley (Higham & Rispoli, 2014: p.15).

8.2 Nature of Phimai Black Ware and Pottery Production at Non Ban Jak

3. Explaining standardisation and variation in the assemblage

The third question deals with the nature of the ceramic assemblage from Non Ban Jak, and applies cultural transmission theory (CT) to the results from the form-plus-fabric analysis, as a means to explore and identify reasons for standardisation and variation (CT outlined in chapter 4). This section is site-specific, and an in-depth analysis of the ceramics over time, and through multiple contexts, to identify internal and external influences. This section is divided into three parts that explore prominent themes identified in the assemblage. This was achieved through the assessment of cultural transmission factors, such as content/cultural information, context, and mode.

The Nature of transmission and early cultural information

The vessels found within MP 1 include many forms that are only present within this phase (Forms 1C, 2A and 9), or do not extend further than MP 2 (Form 2B and 3). These vessels are either fired black, or fully polished black and decorated with streak-burnishing (with the exception of 2A which is only internally black). Full black polish is not a popular trait in the later phases. Potters tend to reserve black burnishing for the interior of bowls and infant burial jars, the exception being the polished Form 8 jars introduced in MP 2.

The earlier assemblage and its particular type of burnishing and decoration is associated with an earlier form of the Phimai Black tradition, originating from a group/culture from the donor settlement. The remnants of this culture are seen up until MP 2, in Forms 1C, 2B, and 3. Form 2B with 3 are superseded by Form 4 as the preferred infant and child interment vessel, while Form 1A becomes the popular small bowl form. Form 8 is introduced at this juncture, in turn suggesting a move away from old culture/settlement and a shift towards the use of other circulating vessels (such as Form 1A), as well as an uptake of a different type of prestige good for infant interments (such as Form 8 in MP 2).

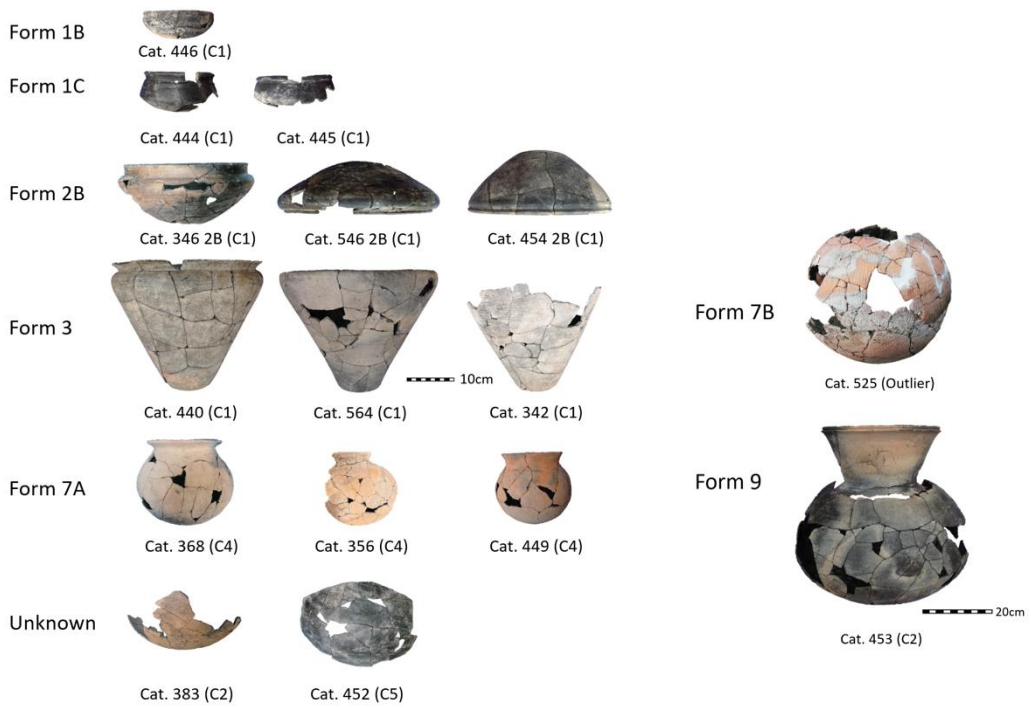


Figure 8-10 MP 1A vessels with associated forms and clays.

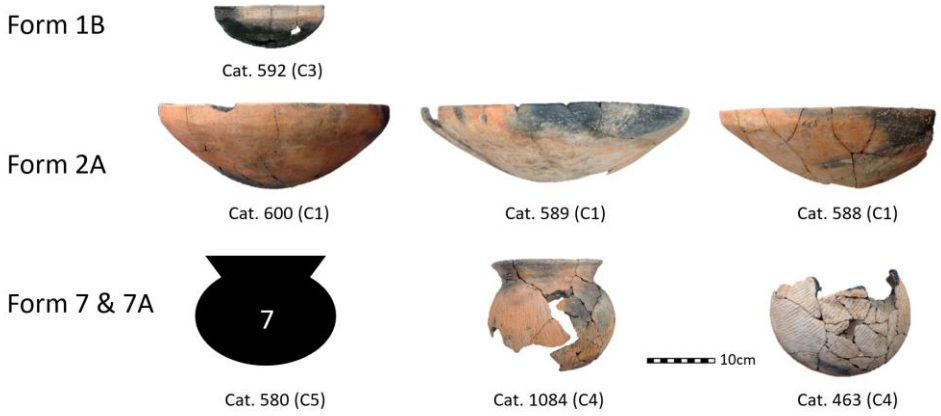


Figure 8-11 MP 1B Vessels with associated forms and clays.

Henrich (2004) explains that when a population decreases in size complex technologies tend to be lost while simple technologies are maintained or even improved. In conjunction, Kline & Boyd (2010) in their research on island populations, observed that larger populations will have a more complex tool kit than the smaller. In the case of Non Ban Jak, the knowledge of certain forms may have been lost due to the decrease in population, even though the firing technique, use of rice husk temper, thin walled vessels, and decorative burnishing streaks were maintained.

The form in which cultural information is transferred is clearly seen in a few examples in the assemblage, for instance, Form 3 and its accompanying Form 2B lid was superseded by Form 4. The change from two decorative and elaborately made vessels, to the more simplistic and smaller Form 4, suggests that the cultural information may have only been in a physical and visual form. Over time the copying error accumulated, resulting in the shift from Forms 3 and 2B, into Form 4. Certain decoration remains the same, such as the black and streak burnished interior.

This is also the same for Form 9 which is the only example of this form within the assemblage. Both Form 3 and 9 were used for infant interment, and are larger than the preceding vessels used for the same purpose. This could be a reflection of skill onsite, as there may have been a lack of potters who could produce large vessels.

In terms of ceramic production, there may have been a socially conscious or unconscious disassociation with the donor settlement, which has resulted in the cutting off of complex cultural information. This would have resulted in the loss of techniques used to create specific forms, in conjunction with the change of preference for other vessels. Common cultural knowledge, such as Phimai Black burnishing and high firing is maintained, but the transmission of cultural information for ceramic production ended.

A description of context and pottery production onsite

As outlined below in Question 4, the possible setting in which cultural information was transmitted at Non Ban Jak may have been in a group or family setting within a household. Working with the same people and learning the same techniques incurs greater standardisation, which would explain the high standardisation of vessels onsite. The high standardisation, and the inter-site variation between Phimai Black ceramic assemblages, suggests that each site has their own style of Phimai Black. This expands the context of transmission from household to town site and not beyond, suggesting nucleated ceramic production in sites across the Plateau.

The mode of prestige wares, their imitations and innovations

Prestige-based transmission as a form of mode is witnessed onsite, through the imitation vessels of Form 8 (section 8.9). As described previously, Form 8 vessels are

deemed to be prestige goods in the fact that they are well-made compared to the other vessels onsite. One subgroup of this form does not fit this category, and while they are manufactured and decorated in a similar matter also sharing the same purpose, these vessels are not high quality compared to the other Form 8 ceramics.

These subgroup vessels have been deemed as imitated wares, and it is possible that potters onsite were trying to recreate other Form 8 vessels. We can liken this to prestige-based transmission, where the original potters have knowledge of superior ceramic-making skills, while others imitate the product to either attain social success, or to create the imitated good for the same purpose at a lower cost.

According to Schumpeter (1961), after imitation comes creative innovation. Innovation can be described as a by-product of imitation – examples of this on site are cat. 302 and 1262, where two unique designs are present: bird appliqué, and geometric patterning. Considering that these vessels are from groups that are highly standardised, it is interesting to see variation in design. The embellishments on these vessels make them more decorative than their replicas, and they are made with the same clay typical of the Phimai Black tradition, Clay 1.

To understand why these vessels are different to the others, we must look at their intended use. Not only standardised in form but also context, these vessels were strictly associated with infant interment. According to Cannon & Cook (2015) individuals coping with loss can lead to exceptional mortuary treatments that differ from the social norm (p. 405), therefore it is possible that the infants were in some way connected to the makers of the vessels.

In Iron Age sites of the Upper Mun Valley, there is a trend in ceramic mortuary offerings. Infants were interred in Form 2, 3, 7B, and 8, while children had their feet and heads placed in matching Form 4. Finally adults were buried with Form 1, 5, 7, and 12.

The social norm surrounding burial offerings, in terms of ceramics, is highly standardised, suggesting that regardless of status and wealth it is the social norm to use certain ceramics for burial. Individual grief and status associated with the deceased is

expressed in grave goods, such as gold and carnelian, not necessarily Phimai Black ceramics.

The fact that Form 8 is seen in other sites for infant interment, and that these vessels can be considered prestige goods, possibly means that the Iron Age society puts more value on infant passing than older children and adults. This is reflected in the standardisation of ceramics for age group, individual grief, and the individual decision to inter the deceased with multiple grave goods.

4. Exploring the nature of pottery production on site

Through the results gathered from the analysis, Costin's typology of production was applied and tested to see if the nature of ceramic production could be identified at Non Ban Jak. Through the investigation of four parameters, a type of specialisation from the eight outlined was recognised (chapter section 4.1). Costin pulls together terminology and elements from previous research on production, to create a typology that is structured to be both rigorous and fluid, in the notion that the researcher has to identify and explore many different parameters to be able to fully classify their chosen production context. The following section will outline the four parameters from Costin's production typology, and explore these factors in the context of Non Ban Jak and the results from the current research.

Context

Context refers to the relationships between producers and the consumer demand for their wares, described in terms of attached and independent specialists. Attached specialists are those who manufacture elite goods that hold political and social symbolism. These goods divide the social groups, and usually stay within the elite economy. In contrast, independent specialists create utilitarian and domestic goods that circulate within a subsistence economy (Costin, 1991). It must be noted that goods from both attached and independent specialists may not always circulate in their original spheres, a knowledge of the exchange system is advised.

To identify the type of specialist, we must look at what context vessels were found in to identify the demand of the ware. The majority of Phimai Black ceramics discovered

were used as mortuary interment vessels or for offerings. There are some examples of possible domestic wares – these are Form 6, 7A, and 10, which are not part of the Phimai tradition. Costin describes the parameter of context as the nature of the demand for a particular good. Therefore all Phimai Black forms (1 to 4, 8, and 9) along with other non-Phimai ceramics (5, 7, and 12) found in burial contexts were mainly used as mortuary offerings, while other Iron Age ceramics were for domestic use (6, 7A, and 10). Form 11 and 13 are either historic, or outliers on site. As burial was the most prominent context, the results then suggest that the demand for ceramics at Non Ban Jak, in terms of the current assemblage, was mainly for mortuary practices.

The standardisation of Phimai Black burial wares shows that these ceramics were important to the population, reflected in the standardised set of ceramics for each different age group. Masson & Rosenswig (2005) in their research on post-classic Maya pottery, found that certain ceramics carried long-term importance and a high degree of social visibility, and were therefore highly standardised. The opposite was seen in food storage and preparation vessels, which is suggested to be a result of potters being more open to innovation (p. 380).

Form 7 vessels found in mortuary and domestic contexts are highly variable. While innovation may be a good reason to explain the vessels in the context of domestic spaces, the presence of form 7 in burials suggests that individuals were making these vessels as offerings for the deceased. This reflects more personal manufacturing, and leans towards independent specialisation.

While many of the ceramics from Non Ban Jak are socially significant as mortuary goods, these ceramics do not distinguish between the elite and non-elite. These vessels are found throughout the many types of burials regardless of gender and wealth, with the only divisions seen for age groups. The lack of elite association is an indication of independent specialisation rather than attached.

While no such elite ceramics have been identified, one form found on site can be considered a prestige good. Form 8 are strictly used for infant interment and have been deemed to be a higher quality of ceramic in terms of manufacturing and decoration, as outlined previously. These vessels do not seem to be associated with an elite, but reflect

social significance surrounding infant interment. These vessels could have been traded onto site, the reasons for this are that similar examples have been found across the Mun Valley. If not this then these vessels were imitated by onsite independent, skilled potters.

Concentration

Concentration describes the spatial relationship between competing individuals or groups of producers, and the consumers. This parameter also considers the resource distribution through the application of access/allocation models, for example, Arnold's threshold model (refer to section 7.4.1) or chemical analyses.

Spatial relationships can be ascertained through the location of production areas. Kilns were found in the eastern and western mounds, also near residential spaces. Kiln B1 was found between two residential structures. There was no evidence of large scale pottery production within or around these house structures, suggesting small scale household production.

Kilns found throughout the site also show that there were many artisans distributed across the town. The reliance upon two major clays through time, and the evidence of these clays (among others) found to be used for vessels within kiln B2, suggests that the potters lived in direct association with the sources and their consumers. This is nucleated production and is supported by Geary's findings where Ban Non Wat, Noen U-Loke and Ban Suai also exhibited nucleated production.

Constitution/Scale

Constitution describes the size of the working unit and the social relations of the individuals who create the goods. These can range from household production, where crafts are manufactured in a domestic setting by one person or a small group of related individuals, to factory or workshop, where production entails a large facility staffed by unrelated individuals.

Size of production unit can be inferred through the size of the facility and the placement, therefore family production will be near domestic spaces, while staffed workshops will be located in a non-domestic space unrelated to the individual. There is

no evidence of facilities or large workshops at Non Ban Jak, kilns being found throughout the town close to domestic spaces and residential houses. Kiln B2 had infant jars interred next to it, and the kiln and burials were contemporary, suggesting that these production spaces are indeed attached to the potter.

Costin also states that constitution can be reflected in the amount of mechanical standardisation. For example, a large workshop could be identified through more standard products, as producers are using each other's tools in close proximity of each other, and possibly under supervision equalling the minimisation of variation and error.

Many of the ceramics at Non Ban Jak are indeed standardised in form and clay, however communal firing found at kiln B2, and the identical forms found throughout the Mun Valley, suggest that the knowledge behind creating these forms was widely known, and that pottery production at Non Ban Jak reflects household production catering for the community.

Intensity

Intensity refers to the time devoted to craft production in relation to other economic tasks. This includes part time, where the artisan partakes in part time or even seasonal jobs such as agriculture, while other artisans work full time, and their job pays for their lifestyle. Costin (1991) states that identifying the range of economic activities in which the artisans participate can give a better indication of intensity (pp.16-18). While this can be a hard factor to identify in the archaeological context for this site, it can subsequently be supported through ethnographic work.

Ethnographic research in the area shows that pottery production is carried out after the harvesting of rice as a supplementary income when not working in the field (Lefferts & Cort, 2000; Shippen, 2005). Pottery production is undertaken in the hotter and dryer months, so the clay preforms can dry before firing, and not crack. We must not expect that pottery production stops during other seasons, it just intensifies when there is a lack of agricultural demand (Hagstrum, 1989).

Due to year-round demand for mortuary ceramics, the variability of Form 7 and evidence of communal firing, it seems that pottery production at Non Ban Jak would be

an all year round activity. Most definitely during the dry season, production would have increased.

Summary

Applying Costin's production typology to the results from the current research has shown that the nature of pottery production at Non Ban Jak coincides with individual specialisation from Costin's eight-part typology for the organisation of specialist production; 'Individual specialisation: autonomous individuals or households producing for unrestricted local consumption.' (1991: p.9-10)

Clay results show a reliance of two clay sources through time, however this does not reflect two workshops. Clay 1 was used to make Phimai Black ceramics, while Clay 4 was mainly used for Form 7. There were no restrictions on clay sources as vessels were communally fired, as seen in kiln B2. If there was a restriction on sources, by an elite for example, then that restriction would extend to separate firing, however in this context potters were firing communally.

Due to the demand for mortuary goods, production would have been an all year round activity, hitting its production peak in the dry season. This was not large-scale full-time production, even with the high level of standardisation, small scale producers can develop motor habits and skills comparable to high-rate producers (Roux 2003: p.779). This shows that standardisation should not be considered an absolute indicator for full-time production by full-time potters. Lastly, potters lived close to consumers, other producers and sources, carrying out nucleated production as artisans within, and catering for, the community.

Chapter 9. Conclusion

This thesis set out to ascertain the nature of the Phimai Black ceramic tradition at the site of Non Ban Jak, Northeast Thailand. The research was undertaken to assess the degree of visual standardisation through a form-plus-fabric analysis of ceramics over time and through multiple contexts across the site. This in turn led to an investigation into the nature of social organisation surrounding pottery production at Non Ban Jak.

The author set out to analyse what was presumed to be an assemblage of Phimai Black ceramics from the site of Non Ban Jak; while the assemblage contained many different forms of Phimai Black, as well as examples of non-black vessels of the Phimai tradition, there were also vessels that did not belong to this ceramic tradition.

The typology contributed to the assessment of form through time and across multiple contexts. By combining vessel forms with their associated CPCRUs, and the four dated mortuary phases, a general trend could be seen; Phimai Black ceramics were mainly made with Clay 1, while Clay 4 contributed to most of the globular Form 7 vessels, which were not a part of the Phimai tradition. The data also showed that Phimai Black ceramics were almost always associated with burial contexts, while other ceramic traditions could be seen across multiple contexts.

This contrasts with Welch & McNeil's (2004) suggestion that Phimai black bowls found at Ban Suai site may have been used as serving dishes. The site of Ban Suai is located close to the Phimai Prasat, and was an important Iron Age centre (Talbot & Janthed (2001). It is not implausible to think that Phimai Black may have had a different purpose within a larger centre, compared to what it meant socially in town sites further away. Other media, such as wood and leaves, could have been used for serving dishes at Non Ban Jak. More domestic and residential spaces need to be excavated to further investigate this matter.

An in-depth look into burial ceramics showed that there were sets of Phimai Black ceramics associated with different age groups, reflecting high standardisation for mortuary practices. Individual grieving was exhibited in offerings of Form 7 vessels,

which were not a part of the Phimai tradition and were highly variable, indicating that they could have been made by individuals related to the deceased. Wealth and status were shown in the form of other mortuary goods interred with the individual, such as gold, agate, and bronze ornaments, not necessarily ceramics. Lastly, polished infant interment vessels (Form 8) were deemed to be a prestige good that reflected a social significance surrounding infant interment.

9.1 Models Tested

Non Ban Jak is a site of great significance, which has revealed a new dimension to the research of prehistoric pottery production in Northeast Thailand. Unlike previous excavations in Northeast Thailand that have uncovered an abundance of mortuary contexts, excavations at Non Ban Jak have revealed extensive residential quarters, burial chambers, and ceramic kilns. Along with a large ceramic assemblage, accurately dated context, and the evidence of production onsite, models concerning sourcing, cultural transmission, the nature of production, and previous models pertaining to Phimai Black could be assessed.

9.1.1 Clay Sourcing

Previous sourcing studies have focused on samples from contemporary villages and known sources from the surrounding areas. Sarjeant (2008: p.234) in her study of clay sources near Ban Non Wat found that the electron microprobe was not the ideal technique in the differentiation between chemically similar raw clay sources. Bearing in mind the state of the clays and the lack of sources near the site, a different approach was taken when considering clay sourcing at Non Ban Jak.

Clays were gathered from features within the site, and from the potting village of Ban Ta Ko. These samples were analysed in their raw states and also fired to temperatures that imitated Phimai Black firings (chapter section 6.1.2). The results showed that there was no connection between the prehistoric ceramics from the site, and the clays gathered from the moats and banks to make the house structures at Non Ban Jak. The samples from Ban Ta Ko did however match cat. 1220, a Form 5 vessel from MP 3 that was identified as being made from a clay that did not match any other found within the

assemblage. This suggests that the Form 5 vessel was introduced to Non Ban Jak from a community that used a source close to the village of Ban Ta Ko. As this is the only example of the Ban Ta Ko clay found onsite, it suggests that there was a lack of ceramic exchange with these people.

The clay data showed that people were not using clay from the moats and embankments that surrounded Non Ban Jak and that they were exploiting sources further from site. Using GIS to apply Arnold's Threshold model (1985; 2000) to the Iron Age sites across the valley, showed the basic probabilities for the distance travelled by potters, and the possibility of high interaction and shared clay sources with other sites, such as Noen U-Loke (chapter section 7.4.1). This research has shown that potters would travel further than the moated areas around the settlement, indicating that clay sources held a social significance to Non Ban Jak that linked them back to the donor settlement.

9.1.2 Cultural Transmission

This research was not put forward to try and prove or disprove Geary's emulation hypothesis, as Non Ban Jak was an Iron Age 4 site, and too late in the sequence, as Phimai Black was introduced in Iron Age 3. The research instead set out to assess the nature of pottery production post-emulation, to see if vessels were still standardised, or if people had moved on from Phimai Black, which possibly lost its appeal after its widespread trade and imitation.

The data suggest that the assemblage in MP 1 reflects an earlier Phimai Black ceramic tradition from the donor settlement. As a result of a small population breaking off from the donor settlement, certain technologies were lost, while the simpler were maintained (Henrich, 2004). This was seen in Forms 3 and 9, while common cultural knowledge such as kiln firing and decoration were sustained.

Copying error was witnessed in the assemblage, which contributed to the shift from Form 3 to 4. Imitation was also present on site, as the prestige good, Form 8, was imitated to carry out the same purpose as the original presumably for a lower cost. After imitation came innovation, seen in the form of decoration added to infant burial jars (cat. 1262 and 302). As the only two innovations currently identified on site, these were interpreted as

personal grief; as explained by Cannon & Cook (2015), loss can lead to exceptional mortuary treatments.

Burial offerings in terms of the Phimai Black tradition were concluded to be highly standardised at Non Ban Jak. Regardless of status and wealth, it was the social norm to use certain ceramics for burial, this is seen in the sets of ceramics reserved for different age groups. Individual grief and status associated with the deceased was not necessarily expressed in ceramic offerings, but mainly in offerings such as gold, carnelian, and bronze ornaments. Social significance surrounding infant interment was prominent on site, these people would have put much social value on infant passing, as the most elaborate vessels were chosen (Form 2B, 3, 7B, and 8).

9.1.3 Costin's Production Typology

Phimai Black is a ceramic tradition associated with societies leading into the rise of state in the Upper Mun Valley, and future ceramic research in the area holds much potential. The nature of the Iron Age communities and rise of states is a current research topic being explored in the area (O'Reilly, 2014; O'Reilly & Scott, 2015; Higham, 2016), as there is a lack of information about these communities. Excavations at Non Ban Jak are the first in the area to reveal extensive residential quarters, burial chambers, and onsite pottery production in the form of kilns.

An investigation into ceramic production involves the social organisation of artisans on site, such research can reveal what part production played in the economy of an Iron Age society and its subsequent rise of states. Ceramic production is an understudied subject in the Mun Valley, due to the lack of contextual production evidence found at sites, and the absence of reconstructed vessels from full Iron Age assemblages. Noen U-Loke and Non Ban Jak are the only two examples of accurately dated sites for which full Iron Age assemblages have been reconstructed. Out of these two sites, only Non Ban Jak has evidence of pottery production onsite, in the form of kilns with vessels inside.

Costin's production typology was used as a model and applied to the data gathered from the ceramic assemblage and the kilns. This investigation has been able to give a clearer picture of social organisation surrounding pottery production, to identify whether or not it was tied to elite or non-elite production. It is concluded that production at Non

Ban Jak involved individual specialisation, rather than attached specialisation, as potters were not connected to an elite. There were no restrictions on clay sources, and vessels were communally fired. Due to the demand of mortuary vessels as a socially significant means to inter the deceased, production occurred all year round with a high level of skill and standardisation. Finally, production was nucleated, as potters lived close to consumers, other producers, and sources. These findings reflect a ceramic tradition that contrasts greatly to its origins as an elite ware.

9.1.4 The Emulation Hypothesis

The emulation hypothesis, as outlined by Geary (2007; 2010), proposes that Phimai Black started as an elite good which was then imitated, leading to its spread and devaluation, in turn becoming a standardised ceramic tradition across Iron Age sites in the Mun Valley. The assemblage at the site of Non Ban Jak is too late in the sequence to assess this model, but instead looks at the nature of Phimai Black ware as a settled Iron Age ceramic tradition.

Through this research it can be seen that Phimai Black moved from elite ware to common ware, its production carried out by independent specialists who lived with, and catered for, the community. Sources were possibly shared with neighbouring sites, and the techniques of pottery manufacture were known across the Valley. Having said this, Non Ban Jak was its own community; through nucleated production and the assessment of cultural transmission, it can be seen that these people at times slightly differed from the standardised ceramic assemblage used by other Iron Age communities. This is witnessed through innovation of decoration and the variated Form 7 offerings, which indicate individual grief, while the change in vessel forms through time shows a disassociation from the donor settlement in terms of ceramic traditions and the uptake of new forms.

9.2 Summary

The purpose of the Phimai Black ceramic tradition was to symbolise a community-wide goal to associate the deceased with an identity that reflected Iron Age communities across the Mun Valley. Phimai Black through time is seen to be made with a specific clay, showing that originally there was a set of ideals associated with these ceramics, linking to the emulation hypothesis. While vessel forms gradually transcended clay borders throughout the Iron Age, the standardisation of form highlights an effort to hold onto past beliefs, and to the identity of the wider community.

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Appendix A: Results Data

Mortuary Phase	Cat No.	Burial No.	CPCRUs	Form No.	Context	Temper Type	Notes
1A	342	16	1	3	Burial	Chaff	
1A	346	18	1	2B	Burial	Chaff	
1A	440	29	1	3	Burial	Chaff	
1A	444	30	1	1C	Burial	Chaff	
1A	445	30	1	1C	Burial	Chaff	
1A	446	30	1	1B	Burial	Chaff	
1A	454	32	1	2B	Burial	Chaff	Lid to cat. 453
1A	546	41	1	2B	Burial	Chaff	
1A	564	56	1	3	Burial	Chaff	
1A	383	18	2	Unknown	Burial	Chaff	
1A	453	32	2	9	Burial	Chaff	Pot to cat. 454
1A	368	21	3	7A	Burial	Chaff	
1A	356	20	4	7A	Burial	Chaff	
1A	449	29	4	7A	Burial	Chaff	Within cat. 440
1A	452	31	5	Unknown	Burial	Chaff	
1A	525	48	Outlier	7B	Burial	No Chaff	
1B	589	59	1	2A	Burial	Chaff	
1B	600	60	1	2A	Burial	Chaff	
1B	588	59	2	2A	Burial	Chaff	
1B	592	35	3	1B	Burial	Chaff	
1B	463	35	4	7A	Burial	Chaff	
1B	1084	59	4	7A	Burial	Chaff	
1B	580	43	5	7	Burial	Chaff	
2	259	11	1	4	Burial	Chaff	Over Head
2	260	11	1	4	Burial	Chaff	Over Feet
2	302	13	1	3	Burial	Chaff	
2	307	14	1	1B	Burial	Chaff	
2	433	27	1	Unknown	Burial	Chaff	
2	437	28	1	2A	Burial	Chaff	
2	990	95	1	3	Burial	Chaff	
2	1003	99	1	3	Burial	Chaff	
2	1007	101	1	3	Burial	Chaff	
2	1235	124	1	3	Burial	Chaff	
2	1250	127	1	2B	Burial	Chaff	
2	1282	133	1	8	Burial	Chaff	
2	1292	135	1	7B	Burial	Chaff	
2	1333	138	1	Unknown	Burial	Chaff	Lid to cat. 1332

2	1321	137/140	1	7	Burial	Chaff	
2	305		1	Unknown	Around Kiln B2	Chaff	
2	385		1	6	Around Kiln B2	Chaff	
2	387		1	Unknown	Around Kiln B2	Chaff	
2	388		1	1E	Around Kiln B2	Chaff	
2	316		1	1E	Kiln B2	Chaff	
2	317		1	2B	Kiln B2	Chaff	
2	15		1	Unknown	Kiln B2 Rake out	Chaff	Not reconstructed
2	21		1	Unknown	Kiln B2 Rake out	Chaff	Not reconstructed
2	23		1	Unknown	Kiln B2 Rake out	Chaff	Not reconstructed
2	25		1	Unknown	Kiln B2 Rake out	Chaff	Not reconstructed
2	26		1	Unknown	Kiln B2 Rake out	Chaff	Not reconstructed
2	1248		1	1B	Domestic	Chaff	
2	887	84	2	7A	Burial	Chaff	
2	944	91	2	4	Burial	Chaff	
2	1350	141	2	7	Burial	Chaff	
2	1351	141	2	Unknown	Burial	Chaff	Pot to cat. 1361
2	332 A	12	3	1B	Burial	Chaff	
2	885	86	3	Unknown	Burial	Chaff	
2	926	90	3	7A	Burial	Chaff	
2	20		3	Unknown	Kiln B2 Rake out	Chaff	Not reconstructed
2	336	12	4	1B	Burial	Chaff	
2	306	13	4	7A	Burial	Chaff	
2	425	26	4	Unknown	Burial	Chaff	
2	427	26	4	Unknown	Burial	Chaff	
2	582	57	4	1D	Burial	Chaff	Lid on top of cat. 571
2	1023	89	4	2B	Burial	Chaff	Lid to cat. 984
2	962	93	4	1B	Burial	Chaff	
2	993	96	4	7A	Burial	Chaff	
2	985	97	4	Unknown	Burial	Chaff	
2	1086	101	4	7B	Burial	Chaff	
2	1014	103	4	7A	Burial	Chaff	
2	1015	104	4	7B	Burial	Chaff	
2	984	106	4	7A	Burial	Chaff	Pot to cat. 1023
2	1087	107	4	2B	Burial	Chaff	Found inside cat. 1018

2	1268	131	4	Unknown	Burial	Chaff	
2	1314	136	4	7A	Burial	Chaff	
2	1332	138	4	7	Burial	Chaff	Pot to cat. 1333
2	1338	139	4	1B	Burial	Chaff	
2	1339	139	4	7A	Burial	Chaff	
2	1342	139	4	Unknown	Burial	Chaff	
2	1349	141	4	1B	Burial	Chaff	
2	1361	141	4	1B	Burial	Chaff	
2	956	85B	4	7A	Burial	Chaff	
2	256		4	Unknown	Around Kiln B2	Chaff	
2	301		4	7A	Around Kiln B2	Chaff	
2	312		4	4	Kiln B2	Chaff	
2	314		4	1D	Kiln B2	Chaff	
2	320		4	Unknown	Kiln B2	Chaff	
2	17		4	Unknown	Kiln B2 Rake out	Chaff	
2	18		4	Unknown	Kiln B2 Rake out	Chaff	
2	19		4	Unknown	Kiln B2 Rake out	Chaff	
2	255	10	5	4	Burial	Chaff	
2	304	14	5	8	Burial	Chaff	
2	1018	107	5	7A	Burial	Chaff	
2	297		5	1A	Around Kiln B2	Chaff	
2	313		5	1A	Kiln B2	Chaff	
2	16		5	Unknown	Kiln B2 Rake out	Chaff	Not reconstructed
2	22		5	Unknown	Kiln B2 Rake out	Chaff	Not reconstructed
2	24		5	Unknown	Kiln B2 Rake out	Chaff	Not reconstructed
2	1316	136	Outlier	1A	Burial	Chaff	
2	1294		Outlier	1B	Burial	Chaff	
3	405	24	1	4	Burial	Chaff	Over Head
3	406	24	1	4	Burial	Chaff	Over Feet
3	1085	62	1	1D	Burial	Chaff	
3	742	72	1	1E	Burial	Chaff	
3	700	74	1	4	Burial	Chaff	
3	705	75	1	1A	Burial	Chaff	
3	775	76	1	1A	Burial	Chaff	
3	793	78	1	1A	Burial	Chaff	
3	844	80	1	4	Burial	Chaff	
3	845	80	1	7A	Burial	Chaff	
3	833	82	1	Unknown	Burial	Chaff	

3	1159	117	1	4	Burial	Chaff	
3	1160	117	1	4	Burial	Chaff	
3	1161	117	1	8	Burial	Chaff	
3	1162	117	1	1A	Burial	Chaff	
3	1163	118	1	4	Burial	Chaff	Lip to lip
3	1164	118	1	4	Burial	Chaff	Lip to lip
3	1171.1	119	1	8	Burial	Chaff	
3	1208	120	1	1A	Burial	Chaff	
3	1206	121	1	8	Burial	Chaff	
3	1232	123	1	1A	Burial	Chaff	Lid to 1233
3	1233	123	1	7B	Burial	Chaff	Pot to 1232
3	1240	126	1	8	Burial	Chaff	
3	1262	128	1	8	Burial	Chaff	
3	1259		1	Unknown	Kiln West	Chaff	
3	1168		1	1A	Occupation	Chaff	
3	1177		1	7A	Domestic	Chaff	
3	1178		1	8	Domestic	Chaff	
3	1183		1	Unknown	Occupation	Chaff	Found with cat. 1182
3	1231		1	7	Domestic	Chaff	
3	1242		1	7	Domestic	Chaff	
3	1245		1	1B	Domestic	Chaff	
3	1261.1		1	1B	Occupation	Chaff	
3	1263.1		1	1B	Occupation	Chaff	
3	843	81	2	1A	Burial	Chaff	
3	1221	122	2	4	Burial	Chaff	
3	593	62	3	7A	Burial	Chaff	
3	831	82	3	7A	Burial	Chaff	
3	70	7	4	1A	Burial	Chaff	
3	89	9	4	4	Burial	Chaff	Pot over head
3	90	9	4	4	Burial	Chaff	Pot over feet
3	413	25	4	4	Burial	Chaff	Over Head
3	532	49	4	Unknown	Burial	Chaff	
3	533	49	4	7A	Burial	Chaff	
3	543	58	4	Unknown	Burial	Chaff	
3	676	71	4	1A	Burial	Chaff	
3	720	73	4	7A	Burial	Chaff	
3	704	75	4	7A	Burial	Chaff	
3	776	76	4	1A	Burial	Chaff	
3	789	77	4	7A	Burial	Chaff	
3	794	78	4	1A	Burial	Chaff	
3	824	81	4	7A	Burial	Chaff	
3	832	82	4	1D	Burial	Chaff	

3	835	82	4	1A	Burial	Chaff	
3	1246	125	4	7	Burial	Chaff	
3	1257	129	4	8	Burial	Chaff	
3	1185.1		4	1E	Domestic	Chaff	
3	1186		4	8	Domestic	Chaff	
3	1236.1		4	1A	Occupation	Chaff	
3	517	46	5	7B	Burial	Chaff	
3	774	76	5	7A	Burial	Chaff	
3	836	82	5	1E	Burial	Chaff	
3	1149	116	5	7A	Burial	Chaff	
3	1269		5	8	Occupation	Chaff	
3	1220	122	Outlier	5	Burial	Chaff	
3	1182		Outlier	13	Occupation	Stoneware	Found with cat. 1183
4	33	6	1	1A	Burial	Chaff	
4	481	38	1	1E	Burial	Chaff	
4	487	39	1	4	Burial	Chaff	
4	497	39	1	1E	Burial	Chaff	
4	507	45	1	1A	Burial	Chaff	Lid to cat. 508
4	508	45	1	1A	Burial	Chaff	Pot to cat. 507
4	630	65	1	7B	Burial	Chaff	
4	637	66	1	4	Burial	Chaff	
4	638	66	1	1A	Burial	Chaff	
4	653	69	1	1E	Burial	Chaff	
4	650	70	1	4	Burial	Chaff	
4	1123	112	1	12	Burial	Chaff	
4	1169	112	1	7A	Burial	Chaff	
4	1098		1	1A	Occupation	Chaff	Pot to cat. 1102
4	1112		1	1A	Occupation	Chaff	Pot to cat. 1113
4	1113		1	1A	Occupation	Chaff	Lid to cat. 1112
4	1145.1		1	1A	Occupation	Chaff	Pot to cat. 1146
4	1146		1	1A	Occupation	Chaff	Lid to cat. 1145
4	1155.2		1	1A	Occupation	Chaff	Pot to cat. 1156
4	636	66	3	7B	Burial	Chaff	
4	110	6	4	7B	Burial	Chaff	
4	478	36	4	11	Burial	No Chaff	
4	490	37	4	1A	Burial	Chaff	
4	486	39	4	4	Burial	Chaff	
4	509	45	4	7A	Burial	Chaff	
4	654	69	4	1E	Burial	Chaff	

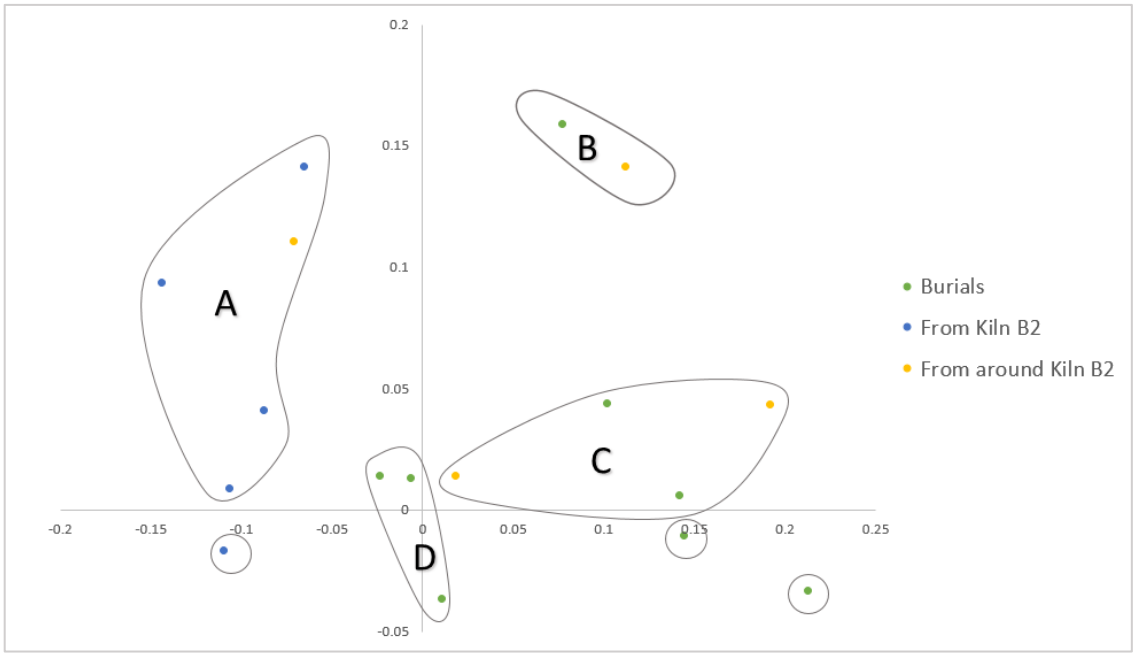
4	1114	113	4	7B	Burial	Chaff	
4	1102		4	1A	Occupation	Chaff	Lid to cat. 1098
4	1156		4	1A	Occupation	Chaff	Lid to cat. 1155

Appendix B

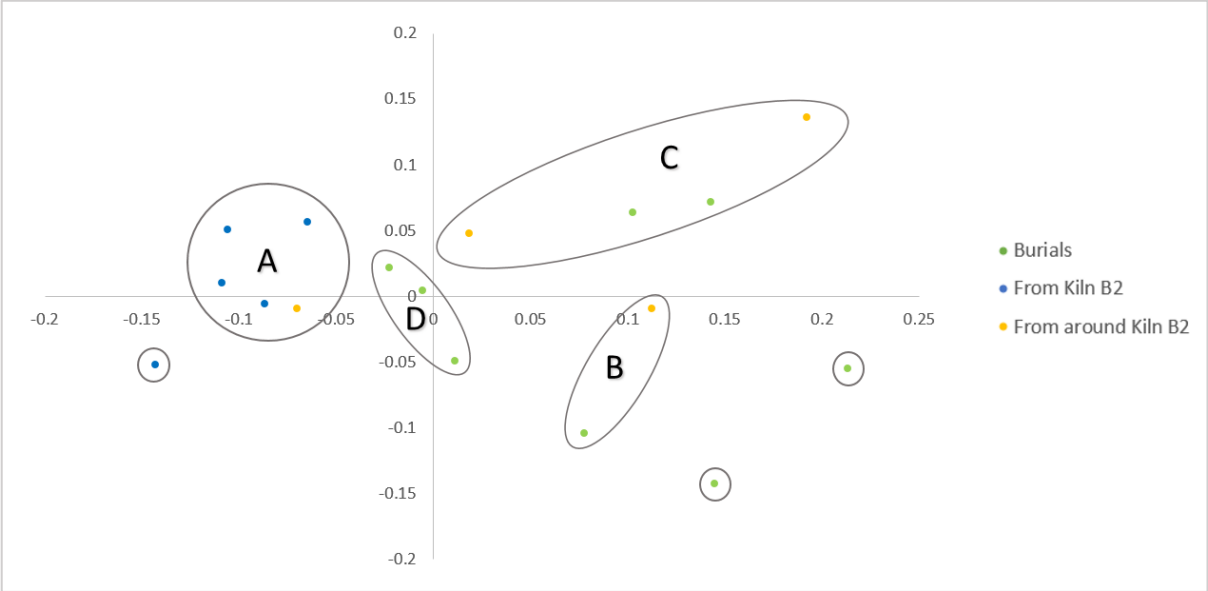
Electron Microprobe Results

A principal component analysis (PCA) was carried out with MVARCH (Wright 1991; Heath 2013) on the 17 samples from the 2014 season at Non Ban Jak subsequently analysed under the EMP. Unfortunately the remainder of the samples could not be analysed due to the decommissioning of the probe, therefore the investigation with the probe changed from clay analysis to temper assessment, to confirm the homogenous nature of the samples for bulk analysis with the pXRF.

The remaining clay data is present here and the following PCAs show that the samples fell into four CPCRUs with three outliers. The elements measured on the EMP were: Na, Mg, Al, Si, K, Ca, Ti, and Fe.



PCA 1&2 of the 17 samples analysed under the EMP

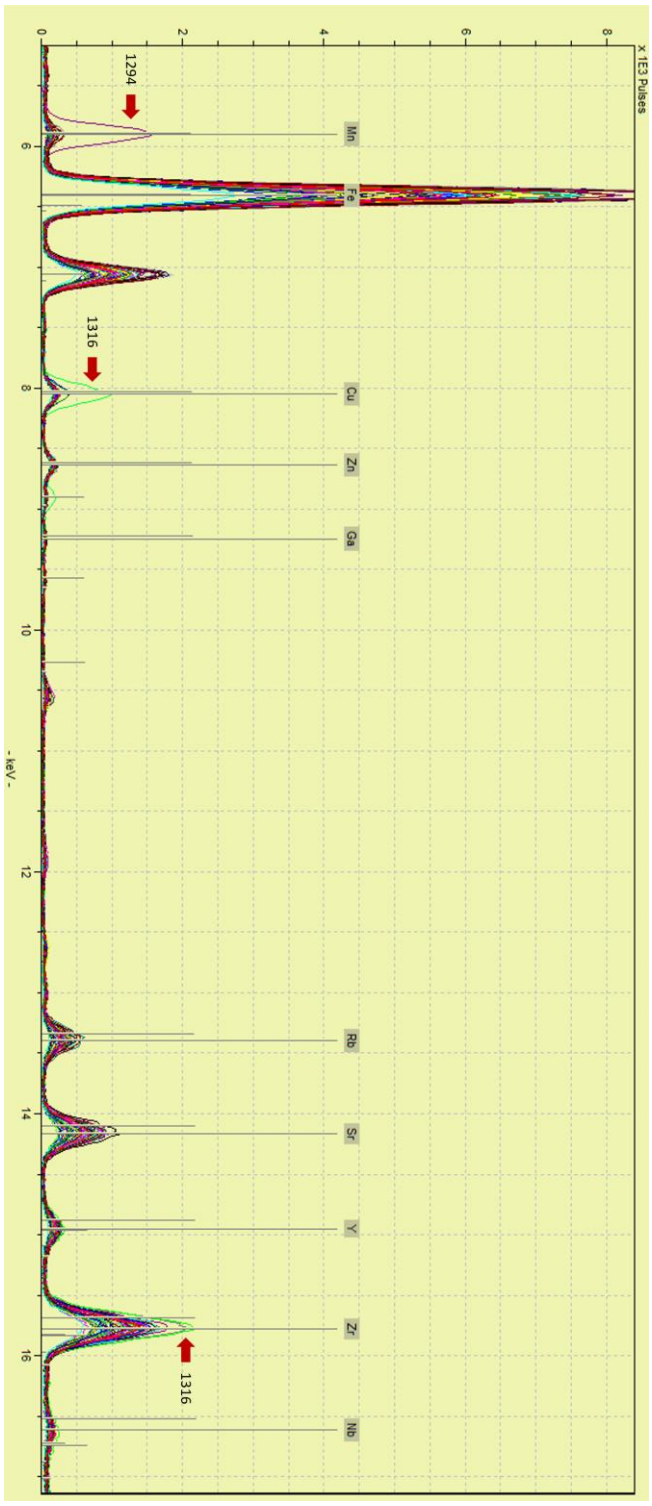


PCA 1&3 of the 17 samples analysed under the EMP

Element Oxide	First Principal component	Second Principal component	Third Principal component
Na_2O	-0.17	-0.10	0.05
MgO	-0.03	0.15	-0.14
Al_2O3	0.01	0.02	0.03
SiO2	0.06	-0.06	0.02
K_2O	**-0.25**	-0.10	0.00
CaO	**0.29**	**-0.13**	-0.12
TiO_2	0.17	0.08	0.20
FeO	-0.07	**0.16**	-0.04

Principal components of the samples analysed under the EMP and the elements measured in oxides. The elements that contributed to the highest and lowest loadings across these samples were K, Ca and Fe, as seen in bold.

Appendix C



Samples 1294 (peak in Mn) and 1316 (peak in Cu and Zr) green filter

Appendix D

Vacuum (Wt%)

	NaKa1	MgKa1	AlKa1	SiKa1	P Ka1	S Ka1	K Ka1	CaKa1	BaLa1	TiKa1	V Ka1	CrKa1	MnKa1	FeKa1	CoKa1	NiKa1	CuKa1	ZnKa1
BHVO2VAC1	0.395922	0.996788	5.536917	16.78565	0.04714	0.406103	0.355848	6.263724	0.277973	1.291749	0.035097	0.000339	0.061241	3.724059	0.002647	0.005461	-0.0009	0.005123
BHVO2VAC2	0.383409	1.049911	5.606289	16.80191	0.045372	0.404722	0.358354	6.268354	0.283859	1.291951	0.03451	-0.00018	0.061914	3.754276	0.002646	0.005454	-0.00096	0.004937
BHVO2VAC3	0.429576	0.700819	5.103845	15.60104	0.032311	0.398553	0.344891	6.063891	0.310651	1.254109	0.030238	-0.00011	0.059544	3.759059	0.002619	0.00543	-0.00084	0.005438
BHVO2VAC4	0.410879	0.623927	5.110202	15.78386	0.03889	0.399156	0.339131	6.081944	0.262648	1.268927	0.029431	0.000413	0.058238	3.801053	0.002611	0.0055	-0.00099	0.004776
BHVO2VAC5	0.400171	0.925833	5.547167	16.68852	0.046409	0.401674	0.356196	6.234021	0.260954	1.293091	0.034573	0.000156	0.060146	3.772675	0.002633	0.005309	-0.00097	0.00526
BHVO2VAC6	0.410042	0.591701	4.99417	15.49309	0.037646	0.402459	0.340738	6.049694	0.259772	1.25793	0.030871	0.000212	0.058538	3.909924	0.002597	0.005296	-0.00093	0.005469
BHVO2VAC7	0.421257	0.615727	5.053607	15.55665	0.039355	0.404481	0.336117	6.087052	0.308959	1.258382	0.032479	-0.00013	0.059156	3.826107	0.002615	0.005125	-0.00093	0.005793
BHVO2VAC8	0.357057	0.736527	5.132613	15.59911	0.038812	0.413464	0.340191	6.05069	0.228731	1.273862	0.033884	6.92E-05	0.059139	3.829016	0.002595	0.005173	-0.00101	0.005523
BHVO2VAC9	0.378768	0.820962	5.091353	15.59569	0.044005	0.402364	0.350418	6.080648	0.233244	1.278926	0.032131	0.000536	0.060751	3.793844	0.002607	0.005358	-0.0009	0.005425
BHVO2VAC10	0.385954	0.806352	5.09645	15.55746	0.045649	0.407044	0.347257	6.057542	0.228254	1.268414	0.032702	0.000707	0.058761	3.80535	0.002586	0.005165	-0.00101	0.005461
BHVO2VAC11	0.390131	0.872632	5.131018	15.67127	0.043612	0.415318	0.339317	6.08231	0.210864	1.281168	0.034897	2.96E-05	0.059377	3.774603	0.0026	0.005058	-0.00113	0.005432
BHVO2VAC12	0.394338	0.628985	4.899696	15.2049	0.034155	0.412545	0.341812	5.999975	0.23872	1.254167	0.028999	0.000151	0.058238	3.852426	0.002581	0.005147	-0.0011	0.005299
BHVO2VAC13	0.430958	0.561125	4.801846	15.04558	0.035333	0.408603	0.330288	5.929803	0.189534	1.257674	0.032079	4.61E-05	0.057419	3.869343	0.002549	0.005035	-0.0012	0.005316
BHVO2VAC14	0.418839	0.543581	4.848861	15.10515	0.039255	0.42941	0.336868	6.018005	0.221032	1.264547	0.031163	0.000262	0.057948	3.833476	0.002589	0.00521	-0.00093	0.005669
BHVO2VAC15	0.444335	0.421038	4.681487	14.77554	0.037918	0.433173	0.326884	5.904442	0.207578	1.245812	0.029566	0.000248	0.05721	3.822101	0.002559	0.004833	-0.00109	0.006009
BHVO2VAC16	0.424677	0.649547	5.074833	15.56362	0.042119	0.443664	0.342165	6.069285	0.23815	1.269806	0.030705	0.000367	0.058141	3.805803	0.002603	0.00528	-0.00086	0.005686
BHVO2VAC17	0.430639	0.626599	5.067015	15.60052	0.04176	0.447547	0.340449	6.072489	0.229496	1.281241	0.032936	0.000127	0.05836	3.811602	0.002601	0.005128	-0.00098	0.005762
BHVO2VAC18	0.367846	0.699508	5.069362	15.50668	0.041416	0.40652	0.342368	6.015047	0.203934	1.263982	0.032074	0.00058	0.059475	3.827548	0.002567	0.004823	-0.00123	0.005583
BHVO2VAC19	0.395895	0.694456	4.893297	15.23915	0.04657	0.437065	0.335864	5.926784	0.193713	1.247078	0.029038	0.000144	0.056573	3.863386	0.002543	0.004524	-0.00133	0.006003
BHVO2VAC20	0.392938	0.6315	5.01043	15.4497	0.049203	0.443035	0.342307	6.050302	0.167578	1.287419	0.034834	0.000281	0.058363	3.807165	0.002593	0.0053	-0.00089	0.005553
BHVO2VAC21	0.366426	0.768218	4.972168	15.43017	0.05361	0.441084	0.336486	5.97987	0.176072	1.268351	0.034301	0.000354	0.05759	3.788251	0.002569	0.004899	-0.00123	0.00548
BHVO2VAC22	0.424666	0.444738	4.587627	14.65933	0.04423	0.436178	0.320532	5.816764	0.182714	1.231514	0.027288	-0.00034	0.055335	3.873598	0.002523	0.004667	-0.0013	0.005835
BHVO2VAC23	0.387484	0.663543	4.927313	15.42536	0.048626	0.439382	0.341676	6.014535	0.194766	1.267539	0.033047	6.51E-05	0.05798	3.884239	0.002573	0.005058	-0.00099	0.005811
BHVO2VAC24	0.38384	0.644579	4.910926	15.37171	0.050676	0.432115	0.340232	5.974939	0.195603	1.255889	0.031451	-6.4E-05	0.057071	3.855999	0.002554	0.004727	-0.0013	0.005679
BHVO2VAC25	0.385527	0.674516	4.940015	15.34202	0.047752	0.448329	0.339029	5.993047	0.192045	1.261256	0.030137	0.000473	0.058135	3.856625	0.002565	0.004912	-0.00108	0.005883
BHVO2VAC26	0.370406	0.6963	5.08234	15.48228	0.051973	0.452087	0.339159	6.017598	0.255763	1.252161	0.030743	0.000349	0.058047	3.775786	0.002579	0.004786	-0.0012	0.005815
BHVO2VAC27	0.393359	0.744067	4.963846	15.43323	0.050749	0.441733	0.340791	6.027349	0.268395	1.252929	0.028645	0.000249	0.05843	3.744543	0.002579	0.004972	-0.00114	0.00556
BHVO2VAC28	0.408149	0.609582	4.938642	15.32718	0.047514	0.44368	0.337236	5.988074	0.164054	1.276088	0.033697	3.66E-05	0.057208	3.85592	0.002568	0.004923	-0.00105	0.00595
BHVO2VAC29	0.395455	0.744862	4.901126	15.46642	0.053389	0.455889	0.346177	6.028695	0.229871	1.269102	0.030627	5.68E-06	0.058387	3.761372	0.002584	0.004958	-0.00096	0.006129
BHVO2VAC30	0.429569	0.643796	4.88578	15.34022	0.048389	0.462788	0.338455	5.992741	0.197456	1.263357	0.032113	4.68E-08	0.058348	3.808443	0.00258	0.004835	-0.00118	0.005728
BHVO2VAC31	0.380963	0.663936	4.941484	15.38975	0.049652	0.448165	0.34202	6.007442	0.212915	1.263392	0.030741	0.000371	0.058761	3.786856	0.002579	0.005079	-0.00106	0.00559

	NaKa1	MgKa1	AlKa1	SiKa1	P Ka1	S Ka1	K Ka1	CaKa1	BaLa1	TiKa1	V Ka1	CrKa1	MnKa1	FeKa1	CoKa1	NiKa1	CuKa1	ZnKa1
BHVO2VAC32	0.367364	0.717786	4.971735	15.40692	0.049579	0.462514	0.334628	5.972823	0.251333	1.247106	0.030048	0.000207	0.058364	3.779868	0.002568	0.004837	-0.00109	0.006048
BHVO2VAC33	0.393135	0.678207	4.927575	15.3801	0.049557	0.460545	0.340767	6.019332	0.287358	1.248491	0.029111	0.000197	0.059023	3.699021	0.002603	0.005095	-0.00103	0.00564
BHVO2VAC34	0.400116	0.539347	4.705496	14.89156	0.046471	0.520657	0.345346	5.921441	0.276583	1.222331	0.024555	0.000189	0.056453	3.793628	0.002562	0.004623	-0.00113	0.006437
BHVO2VAC35	0.360969	0.782829	4.949315	15.4609	0.049784	0.455711	0.338269	5.99335	0.25807	1.251415	0.029107	0.000652	0.059412	3.702064	0.002578	0.004961	-0.00111	0.00562
BHVO2VAC36	0.392115	0.650321	4.669129	14.88078	0.059102	0.563132	0.343368	5.94969	0.274574	1.233539	0.027864	0.000227	0.056597	3.688946	0.002588	0.004868	-0.00097	0.006412
BHVO2VAC37	0.414133	0.52913	4.599382	14.81256	0.05662	0.555552	0.341102	5.91489	0.283125	1.226529	0.027066	3.15E-05	0.056153	3.72567	0.002564	0.004638	-0.00104	0.006692
BHVO2VAC38	0.374406	0.643788	4.742216	14.94015	0.062033	0.54407	0.344267	5.913709	0.16846	1.249021	0.029504	0.000316	0.056735	3.828486	0.00253	0.004622	-0.00114	0.006414
BHVO2VAC39	0.395032	0.536008	4.622669	14.79148	0.05951	0.560072	0.344573	5.896216	0.295792	1.214888	0.024846	-5.6E-05	0.05739	3.692678	0.002566	0.004714	-0.0011	0.006386
BHVO2VAC40	0.373782	0.489108	4.602011	14.67424	0.057282	0.546645	0.335936	5.865258	0.304698	1.209536	0.024054	-0.00019	0.056727	3.655498	0.002568	0.004705	-0.00114	0.00625
BHVO2VAC41	0.409469	0.571627	4.632361	14.81697	0.060419	0.554908	0.340357	5.911598	0.303681	1.222549	0.024649	-0.0001	0.058054	3.686859	0.002575	0.004693	-0.00093	0.00694
BHVO2VAC42	0.402066	0.593348	4.583058	14.80108	0.060153	0.559849	0.341168	5.868806	0.357943	1.200003	0.020339	-3.3E-05	0.056658	3.625447	0.002561	0.004368	-0.00129	0.006559
BHVO2VAC43	0.368155	0.806679	4.877603	15.41123	0.070849	0.537871	0.355293	5.996669	0.273838	1.248308	0.029242	0.000221	0.058176	3.733704	0.002573	0.004751	-0.00091	0.006885
BHVO2VAC44	0.380651	0.63749	4.633507	14.80549	0.065356	0.534343	0.345417	5.867648	0.195285	1.232386	0.028305	-0.00013	0.056074	3.867427	0.00253	0.004549	-0.00106	0.006882
BHVO2VAC45	0.389714	0.529275	4.551875	14.75256	0.060841	0.550364	0.35271	5.900374	0.161682	1.247196	0.03021	-0.00046	0.056865	3.884673	0.002531	0.004325	-0.00109	0.007301
BHVO2VAC46	0.391524	0.438054	4.497808	14.56679	0.064092	0.558543	0.343136	5.881491	0.153906	1.248248	0.029517	-1.9E-05	0.056407	3.862528	0.002536	0.004651	-0.00099	0.006868
BHVO2VAC47	0.390188	0.481173	4.544589	14.62803	0.063762	0.542333	0.344786	5.848955	0.204003	1.223963	0.027323	-2.2E-05	0.056191	3.806825	0.002523	0.004397	-0.00113	0.007041
BHVO2VAC48	0.424956	0.442575	4.550614	14.75219	0.062352	0.563716	0.345292	5.865026	0.187045	1.235576	0.030109	-0.00018	0.055795	3.867802	0.002529	0.004543	-0.00099	0.00717
BHVO2VAC49	0.407335	0.608131	4.691998	14.41558	0.026338	0.476153	0.324209	5.865553	0.23598	1.232996	0.027793	0.000289	0.058694	3.761979	0.002566	0.004981	-0.00088	0.006335
BHVO2VAC50	0.402854	0.396067	4.499552	14.07651	0.032138	0.476535	0.320062	5.838625	0.183574	1.246789	0.029937	-7E-05	0.057028	3.817241	0.002557	0.004919	-0.00089	0.006498
BHVO2VAC51	0.434889	0.382509	4.352957	13.68662	0.021369	0.486743	0.314439	5.773742	0.173891	1.227933	0.030014	-6.4E-05	0.057313	3.89976	0.00254	0.004966	-0.00096	0.006183
BHVO2VAC52	0.357589	0.943288	5.215375	15.55133	0.050427	0.480599	0.347122	6.045115	0.24015	1.261734	0.03105	0.000641	0.060077	3.775826	0.002604	0.005249	-0.00075	0.006086
BHVO2VAC53	0.380105	0.781151	5.07189	15.46972	0.043483	0.492016	0.33668	6.030996	0.304935	1.24616	0.027469	0.000614	0.060127	3.713097	0.002596	0.004935	-0.00099	0.006081
BHVO2VAC54	0.385878	0.844669	5.222246	15.84091	0.048365	0.487153	0.343447	6.09145	0.271868	1.265017	0.030585	0.000637	0.06155	3.736602	0.002628	0.005471	-0.00055	0.006235
BHVO2VAC55	0.408407	0.696661	4.970002	15.66486	0.057622	0.496594	0.34706	6.067122	0.26252	1.259241	0.032976	4.74E-07	0.059156	3.702086	0.002612	0.005375	-0.00051	0.006633
BHVO2VAC56	0.410972	0.865248	5.451769	16.1571	0.042202	0.448369	0.344792	6.190127	0.279321	1.286735	0.034145	0.000647	0.061767	3.65672	0.002659	0.005758	-0.00042	0.006007
BHVO2VAC57	0.388574	0.994248	5.559951	16.44394	0.041778	0.445225	0.353786	6.21861	0.273613	1.291644	0.035685	0.000265	0.061262	3.661725	0.002655	0.005523	-0.00047	0.006317
BHVO2VAC58	0.417075	0.82683	5.332817	16.16237	0.040305	0.462101	0.35189	6.17896	0.203065	1.29781	0.038529	0.000146	0.062131	3.751208	0.002647	0.005639	-0.00046	0.006123
BHVO2VAC59	0.415447	0.771655	5.289188	16.03673	0.040349	0.465449	0.351589	6.152219	0.238255	1.290468	0.034012	0.000204	0.061299	3.705175	0.002645	0.00567	-0.00043	0.006225
AVERAGE	0.397057	0.672421	4.934244	15.33172	0.047722	0.466205	0.341369	6.003167	0.236099	1.256261	0.03056	0.000168	0.058395	3.785034	0.002583	0.005004	-0.00099	0.005987
STD	0.02103	0.152408	0.288731	0.598217	0.009972	0.053206	0.008542	0.111157	0.046655	0.022478	0.003242	0.000262	0.001668	0.069078	3.46E-05	0.000341	0.000214	0.000564
RSD	5.296442	22.66554	5.851576	3.901828	20.89564	11.41256	2.502163	1.851639	19.76087	1.789265	10.60854	155.9996	2.857255	1.825025	1.341451	6.822598	-21.7065	9.424173
USGS	1.64	4.63	7.16	23.3	0.12		0.43	8.17	0.013	1.63		0.028	0.129	8.63	0.0045		0.0127	

Green Filter (ppm)

	MnKa1	FeKa1	CoKa1	CuKa1	ZnKa1	GaKa1	ThLa1	RbKa1	SrKa1	Y Ka1	ZrKa1	NbKa1	RhKa1
BHVO2FIL1	1008.452	73210.88	54.24713	369.5314	188.9554	21.33696	1.592796	7.95776	335.8257	25.57968	141.1148	15.29773	0
BHVO2FIL2	971.6296	77908.58	70.37294	422.3408	205.8854	19.84435	2.619559	6.832685	344.402	25.67555	144.706	15.35325	0
BHVO2FIL3	950.3989	75565.15	58.23068	377.6638	193.4083	18.77444	1.87634	7.085653	338.7346	24.23255	142.7708	15.56692	0
BHVO2FIL4	994.5423	76684.6	65.16873	498.3779	190.5452	19.0909	1.189659	8.770355	341.3951	24.93203	145.4204	15.03217	0
BHVO2FIL5	958.3552	72677.69	54.40941	292.0816	198.1369	19.02201	0.880332	6.88243	334.0713	23.44795	140.1737	15.74634	0
BHVO2FIL6	990.2873	74774.38	68.21453	310.8662	188.8615	20.06157	3.384094	8.262732	321.4001	25.10553	134.007	16.36608	0
BHVO2FIL7	929.3908	72370.75	52.72946	330.8428	187.6577	19.61225	0.8328	7.328405	329.4697	23.45875	140.826	15.09739	0
BHVO2FIL8	999.7378	74445.31	66.24191	333.3455	192.5227	18.38344	0.991308	7.796529	332.4286	24.75342	135.8086	14.87483	0
BHVO2FIL9	915.0032	75796.32	61.89358	434.1482	199.5109	19.94901	1.954885	6.922994	341.9282	24.75115	145.5059	15.54666	0
BHVO2FIL10	985.2204	76716.97	64.83484	472.2382	192.2869	20.30363	1.671421	7.484744	342.7408	24.72483	143.3188	16.46692	0
BHVO2FIL11	943.8633	76790.39	64.69831	410.1289	194.1941	19.34873	1.890517	8.601916	342.2247	25.13639	143.5849	15.73331	0
BHVO2FIL12	969.8934	74866.92	65.28384	322.7014	186.7547	19.46991	0.181142	8.077201	335.4675	24.43168	141.3014	15.79787	0
BHVO2FIL13	917.2529	71280.08	46.69356	318.969	187.9143	20.34706	1.620097	6.128113	323.6201	23.45687	141.0072	15.46802	0
BHVO2FIL14	940.8497	73218.12	57.77125	294.9133	185.0595	19.70045	2.286345	7.022058	332.403	24.09189	139.3207	14.98753	0
BHVO2FIL15	999.7715	71080.25	47.494	266.6025	179.2145	19.03613	1.92408	6.885396	329.0306	25.54572	140.6793	14.09282	0
BHVO2FIL16	980.5252	77046.39	67.19547	509.9591	203.416	19.76044	0.60842	8.676388	337.3803	25.14057	141.6879	14.24695	0
BHVO2FIL17	991.6489	74263.76	55.07831	471.0458	200.6129	21.51963	1.586994	8.141085	334.7837	25.93781	139.5085	15.94642	0
BHVO2FIL18	955.2038	75507.13	55.16957	307.8873	177.6457	21.28439	1.518573	8.098836	341.8725	25.19274	144.4191	16.17177	0
BHVO2FIL19	934.087	75728.52	60.92372	419.8619	195.0296	20.20153	1.049715	7.023779	338.4623	26.05758	143.8946	16.55883	0
BHVO2FIL20	909.4586	76730.08	64.51589	461.4522	202.3647	19.31835	2.445052	8.573014	337.1776	25.20859	141.1178	14.28945	0

	MnKa1	FeKa1	CoKa1	CuKa1	ZnKa1	GaKa1	ThLa1	RbKa1	SrKa1	Y Ka1	ZrKa1	NbKa1	RhKa1
BHVO2FIL21	985.3308	76670.72	67.1008	467.9889	204.1876	20.22949	2.936752	7.848661	339.6526	24.29582	143.6926	15.55917	0
BHVO2FIL22	978.7137	74762.02	54.06138	442.5964	198.6503	20.68642	0.576294	7.793519	341.615	25.30964	143.8932	15.67844	0
BHVO2FIL23	1012.609	78014.38	75.45896	414.5231	193.0301	19.93692	1.013271	8.216092	330.3067	23.32004	140.7471	15.06106	0
BHVO2FIL24	973.3866	78052.6	74.05722	432.8036	197.2886	19.01469	2.194883	7.331089	335.8613	23.96901	144.4894	15.59784	0
BHVO2FIL25	933.9796	74797.33	55.8872	393.4362	202.115	20.255	1.171154	8.074757	342.143	24.36752	143.496	15.15587	0
BHVO2FIL26	978.6756	74068.82	56.71942	507.6503	201.8171	19.56293	2.182584	7.445241	336.6818	24.46207	137.9519	15.38594	0
BHVO2FIL27	963.9853	74252.29	53.2728	489.9408	206.0684	19.96824	1.455882	8.556944	341.2337	26.13634	142.046	14.64711	0
BHVO2FIL28	965.5305	73747.54	51.40259	460.8767	199.5575	21.41672	1.812257	8.436192	339.8628	25.5962	143.2805	15.40717	0
BHVO2FIL29	961.1405	73460.54	57.49766	477.0657	195.5365	19.459	1.610686	8.214497	322.6545	23.941	137.7179	13.79696	0
BHVO2FIL30	974.3917	71704.89	42.88987	425.5407	207.7908	18.17836	1.551201	6.855254	330.6673	23.8113	144.783	14.80129	0
BHVO2FIL31	943.4732	75998.02	62.18294	421.9701	197.4406	18.52091	0.992424	7.358267	339.3722	26.03885	140.3131	16.39591	0
BHVO2FIL32	903.5279	75874.59	62.12142	402.1233	203.6617	21.04443	1.184108	8.012028	340.5226	24.84106	140.2821	15.63965	0
BHVO2FIL33	961.7047	74565.19	56.84979	495.3461	204.5939	19.56225	3.224804	8.140889	340.9186	23.90687	138.5811	16.04194	0
BHVO2FIL34	1003.262	75976.37	66.50898	436.1961	197.0886	19.39575	3.046678	8.189445	337.9379	23.98166	138.2958	14.55722	0
BHVO2FIL35	992.1261	73638.24	54.81857	382.2853	197.7212	19.84863	2.896795	8.566344	329.7858	24.03132	138.5552	16.29679	0
BHVO2FIL36	912.0444	71931.94	44.82262	367.9557	194.9879	19.00669	1.16979	8.103774	332.2036	24.96529	140.2583	15.07827	0
BHVO2FIL37	950.2373	75398.12	59.86952	381.8802	200.751	20.19743	1.498351	8.785948	340.4131	24.81377	140.6953	15.95036	0
BHVO2FIL38	941.9003	74959.49	60.2407	368.9105	186.3644	19.77816	1.453416	7.68294	334.9839	24.76819	139.8624	15.4942	0
Average	960.4873	74740.18	59.08559	403.7098	195.8775	19.80531	1.670503	7.809338	335.6258	24.67639	141.0324	15.40989	0
STD	29.74929	1824.996	7.755853	69.03564	7.4615	0.801567	0.790115	0.653354	5.89013	0.799414	2.64867	0.712079	0
RSD	3.097313	2.441787	13.12647	17.10031	3.809269	4.047231	47.29801	8.366314	1.754969	3.23959	1.878057	4.620921	0

Appendix E

Logged Base 10

Samples	NaKa1	AlKa1	SiKa1	K Ka1	CaKa1	TiKa1	CoKa1	NiKa1	MnKa1	FeKa1	CuKa1	ZnKa1	RbKa1	Y Ka1	ZrKa1	NbKa1
1	3.986347	4.667699	5.3222	3.916351	3.935572	3.400163	0.992179	2.015143	3.129587	4.351562	3.06643	2.269031	1.760233	1.209643	2.430261	0.989556
2	3.92905	4.793924	5.390185	4.240861	3.741841	3.563399	1.034632	1.758809	2.548753	4.348272	2.028886	2.073273	1.962081	1.462008	2.213069	1.118144
3	4.061654	4.60937	5.248048	3.852135	3.625535	3.378333	0.929653	1.380514	2.770493	4.3693	2.698036	2.294771	1.909136	1.329982	2.249332	1.031671
4	3.834739	4.779191	5.458235	4.078797	3.943941	3.646394	1.074132	1.91184	2.799736	4.344878	2.143354	2.176786	1.930637	1.456959	2.278781	1.128712
5	4.01384	4.541534	5.271701	3.968709	3.86942	3.452344	0.945234	1.357606	2.869008	4.366773	2.607518	2.25483	1.740141	1.401832	2.252963	1.063019
6	3.876417	4.790322	5.444073	3.964159	3.8913	3.706667	1.051443	2.041694	2.817682	4.280219	2.439626	2.12116	1.804939	1.552204	2.317738	1.203224
8	4.227819	4.417553	4.988404	3.809136	3.583336	3.195541	0.692801	0.0001	2.237646	4.35343	2.411634	2.224675	1.856317	1.459759	2.136653	1.098076
9	3.95517	4.763782	5.337608	4.226274	3.691886	3.525868	1.078751	1.622758	3.001257	4.446567	2.17163	2.139188	1.903844	1.373037	2.192837	1.08672
10	3.884367	4.739409	5.349066	4.200156	3.476951	3.531121	1.198058	1.685824	2.481737	4.558087	2.033963	2.143364	1.869336	1.447828	2.279588	1.091705
11	3.963156	4.685641	5.313689	4.157958	3.564062	3.521677	1.092843	1.574398	2.735055	4.48623	2.150732	2.183867	1.95611	1.362953	2.28682	1.094133
12	3.873926	4.864125	5.33902	4.241448	3.780821	3.563468	1.160381	1.83785	2.525885	4.461471	2.114746	2.146329	1.887166	1.449665	2.26766	1.089553
13	4.076736	4.651472	5.265215	4.104749	3.533762	3.313772	0.867175	0.0001	2.808234	4.333986	2.599585	2.303963	1.822043	1.229912	2.133963	1.012963
14	3.980689	4.685288	5.403761	4.1117	3.603826	3.549217	0.885159	1.717676	2.655179	4.188883	2.379904	2.182122	1.748561	1.422352	2.267261	1.171789
15	4.107993	4.557255	5.262975	3.474147	3.588855	3.471636	0.861084	0.0001	2.794578	4.359108	2.581641	2.24123	1.789448	1.397954	2.361773	1.169177
17	3.900503	4.831729	5.362247	3.766746	3.671609	3.683335	1.162045	1.983746	2.442407	4.452557	2.401765	2.298834	1.871135	1.556761	2.408702	1.218468
18	3.917004	4.734625	5.357219	4.033648	3.83116	3.57574	1.096822	1.687237	2.604802	4.44992	2.26362	2.138505	1.959284	1.436121	2.210051	1.116951
19	3.884925	4.809548	5.360352	4.296664	3.8004	3.581779	1.156584	1.728607	2.992371	4.471244	2.08968	2.163863	1.909574	1.362724	2.218913	1.099675
20	3.872722	4.773563	5.428739	3.937806	3.880855	3.698969	1.051405	1.971813	2.76433	4.298966	2.140852	2.110174	1.809413	1.540936	2.330828	1.24719
21	3.897917	4.874393	5.324171	4.072913	3.91697	3.646223	1.158053	1.885935	2.692996	4.501825	2.629625	2.377248	1.905206	1.49026	2.284272	1.212653
22	3.884228	4.862485	5.362868	4.259781	3.727296	3.641398	1.044962	1.919907	2.508771	4.332223	1.978257	2.085973	1.792445	1.453062	2.260367	1.146732
23	4.134217	4.597645	5.206728	3.916167	3.646136	3.445755	0.769626	0.0001	2.659514	4.273338	1.949987	2.055493	1.742358	1.431353	2.260135	1.19479
24	3.97791	4.71968	5.308602	4.180628	3.716424	3.474802	0.998734	1.464766	2.765179	4.377524	2.32021	2.172967	1.856736	1.293219	2.212044	1.074853
25	3.970573	4.750338	5.308681	4.261417	3.71458	3.503788	1.071267	1.400178	2.952886	4.428961	1.960857	2.122091	1.931048	1.416727	2.233387	1.07283
26	3.984222	4.746371	5.334382	4.077856	3.682102	3.554311	0.901114	1.655692	2.092943	4.2467	2.123377	2.096903	1.708748	1.529988	2.387161	1.155893
27	4.032471	4.643092	5.265303	3.982941	3.653273	3.457375	0.88214	1.113164	2.534402	4.242021	2.162753	2.115686	1.752335	1.364087	2.312021	1.108554
28	3.917472	4.666068	5.38153	4.057938	3.661405	3.531245	1.05413	1.764798	2.672991	4.395798	2.241047	2.166196	1.917999	1.398187	2.373594	1.059797
29	4.068023	4.561388	5.211695	3.887931	3.708354	3.383566	0.937195	0.0001	2.645093	4.451869	2.39862	2.2195	1.983387	1.411352	2.216008	1.068547
30	3.858485	4.754105	5.403214	4.092398	3.790303	3.694781	1.09902	1.928847	2.543443	4.352533	1.838278	2.003019	1.596954	1.527527	2.31251	1.167106
31	4.137585	4.512215	5.229315	3.712215	3.583356	3.52002	0.783062	0.0001	2.903899	4.327155	1.957043	2.039913	1.699196	1.642361	2.358649	1.31812

Samples	NaKa1	AlKa1	SiKa1	K Ka1	CaKa1	TiKa1	CoKa1	NiKa1	MnKa1	FeKa1	CuKa1	ZnKa1	RbKa1	Y Ka1	ZrKa1	NbKa1
32	3.937018	4.825366	5.343908	4.169778	3.715928	3.571727	1.035743	1.683741	2.288603	4.364103	1.844652	2.042521	1.719151	1.448305	2.237919	1.143911
33	3.830552	4.825462	5.371074	4.130959	3.852467	3.635657	1.201668	1.813056	2.85273	4.514558	2.127359	2.161233	1.984856	1.452944	2.282735	1.12294
34	4.018991	4.689103	5.25385	4.048764	3.664106	3.417769	1.054131	0.0001	3.269105	4.668184	2.638965	2.345401	1.971543	1.448975	2.16234	1.104221
35	3.907533	4.800757	5.368779	4.032199	4.013429	3.59217	0.992687	1.822331	2.715139	4.280193	2.341793	2.16679	1.733269	1.44852	2.332669	1.136904
36	3.891842	4.647902	5.405971	4.18543	3.8347	3.643218	1.01092	1.907312	2.570756	4.281942	1.958429	2.053937	1.767642	1.446867	2.311179	1.151156
37	3.930413	4.750114	5.322607	4.217505	3.715594	3.475978	1.06373	1.534517	2.700792	4.427047	2.465572	2.274942	1.930849	1.335085	2.140704	1.07588
38	3.862442	4.825301	5.349763	4.03432	3.734858	3.601051	1.187363	1.782375	3.221622	4.542187	2.443251	2.278084	1.995434	1.392264	2.226815	1.144411
39	3.836443	4.762864	5.404363	4.036066	3.889027	3.610094	1.103237	1.918802	2.786083	4.383379	2.210591	2.124567	1.774947	1.377388	2.309489	1.074857
40	3.985161	4.686493	5.325389	3.529307	3.643075	3.615869	1.003724	1.383211	2.391368	4.446814	2.73293	2.310164	1.833927	1.491912	2.358052	1.2337
41	3.936245	4.805138	5.274753	3.736158	3.882072	3.594798	1.087802	1.590269	2.482329	4.505571	2.604366	2.302376	1.961134	1.483691	2.210174	1.190171
42	3.899353	4.69061	5.314137	3.964407	3.968796	3.516796	1.131392	1.605507	3.077692	4.499719	2.320097	2.208734	1.874668	1.421925	2.244737	1.066154
43	3.801393	4.709519	5.417297	3.810468	3.969561	3.75754	1.165801	2.060512	3.401554	4.401258	2.350611	2.134245	1.88867	1.484847	2.349273	1.206542
44	3.927172	4.687376	5.358669	3.795868	3.644396	3.503591	1.056839	1.636125	2.709435	4.432645	2.57151	2.21688	1.893122	1.394359	2.344831	1.047276
45	4.038859	4.643116	5.301779	4.111875	3.486609	3.377332	0.816271	1.085318	2.365199	4.224803	2.66879	2.307431	1.784493	1.244768	2.173928	1.015596
47	3.886834	4.757513	5.390845	4.001588	3.92732	3.646273	1.04803	1.845711	2.599783	4.347072	2.168942	2.110879	1.71022	1.496125	2.37599	1.159625
48	4.020974	4.618157	5.275255	3.302004	3.631651	3.569223	0.979469	1.43062	2.679024	4.418311	2.765246	2.274138	1.822466	1.438768	2.327086	1.202364
49	3.974898	4.670356	5.368483	4.097473	3.783061	3.510285	0.889444	1.536409	2.619246	4.256954	2.519534	2.214234	1.814042	1.385059	2.238242	1.134956
50	4.067963	4.548718	5.270323	3.907733	3.562516	3.408899	0.83161	1.204595	2.621113	4.282955	2.659343	2.293634	1.785934	1.38825	2.234614	1.143748
51	4.066693	4.63874	5.212241	3.725105	3.555131	3.421571	0.904481	0.750943	2.524084	4.391642	2.69501	2.296136	1.945224	1.43487	2.196624	1.052303
52	3.973191	4.640571	5.354012	3.956622	3.906537	3.46797	0.914378	1.658989	3.015086	4.261849	2.409688	2.238909	1.814505	1.354919	2.134917	1.026667
53	3.783346	4.817236	5.386206	4.127043	3.722217	3.711709	1.263376	1.930759	2.986788	4.585391	2.071963	2.185454	1.978248	1.486912	2.244891	1.167705
54	3.948004	4.67159	5.331885	3.794837	4.001385	3.520698	1.05554	1.759898	3.297218	4.378714	2.302261	2.160601	1.693123	1.339506	2.207075	1.082881
55	3.848512	4.794499	5.359254	3.989381	3.944737	3.603628	1.185774	1.896832	3.347534	4.467058	2.108566	2.131736	1.89057	1.327089	2.19785	1.050944
56	3.899869	4.720904	5.362152	3.855672	3.925472	3.537079	1.050201	1.771377	2.938958	4.379999	2.357711	2.175935	1.774647	1.439812	2.343453	1.133506
57	4.041912	4.54685	5.236261	3.463517	3.640817	3.595963	0.941621	1.459852	2.768229	4.397812	2.621375	2.280701	1.804658	1.482701	2.36777	1.27121
58	3.92006	4.716495	5.376221	3.979673	4.012262	3.544013	1.022975	1.763607	2.378282	4.332527	2.311129	2.189214	1.81885	1.406776	2.213425	1.079649
59	3.982103	4.654576	5.34396	3.929954	3.805789	3.499678	0.94542	1.642342	2.821211	4.319422	2.603105	2.243691	1.924326	1.462837	2.265378	1.123691
60	3.799057	4.734284	5.448286	4.076197	4.062686	3.630409	1.063794	1.991323	2.873239	4.29311	2.057195	2.10384	1.81042	1.455822	2.235715	1.125839
61	3.982699	4.63692	5.376907	3.718336	3.867668	3.509045	0.92364	1.645161	2.904379	4.227524	2.382181	2.172311	1.682494	1.382003	2.199533	1.074055
62	3.941309	4.665718	5.34776	3.895134	4.024912	3.521445	0.990939	1.75469	2.558211	4.301073	2.29787	2.155255	1.808766	1.373319	2.184166	1.017182

Samples	NaKa1	AlKa1	SiKa1	K Ka1	CaKa1	TiKa1	CoKa1	NiKa1	MnKa1	FeKa1	CuKa1	ZnKa1	RbKa1	Y Ka1	ZrKa1	NbKa1
63	3.928103	4.670237	5.360978	3.92297	4.011193	3.529867	1.008409	1.773981	2.632057	4.318842	2.281499	2.171861	1.8054	1.450377	2.210166	1.086394
64	4.057361	4.628689	5.173561	3.79855	3.70375	3.344424	0.909068	0.0001	2.555723	4.423059	2.927396	2.395317	1.921957	1.345325	2.167502	1.09056
65	3.820041	4.783288	5.365683	4.079351	3.97216	3.658021	1.17187	1.867109	3.212492	4.476058	2.323421	2.195441	1.947498	1.413921	2.167826	1.09
66	3.963873	4.721717	5.327757	3.894703	3.845155	3.472304	0.963476	1.563016	2.840546	4.332513	2.432433	2.202685	1.814817	1.397579	2.225592	1.065822
67	3.982909	4.687698	5.319192	4.051027	3.69033	3.454916	0.987789	1.496494	2.734973	4.382146	2.326433	2.21409	1.91925	1.351344	2.206665	1.045469
68	4.140188	4.487263	5.181782	3.713839	3.552795	3.297409	0.729645	0.0001	2.897721	4.264868	2.661414	2.250345	1.792754	1.379013	2.225987	1.070218
69	4.011465	4.61527	5.29363	3.303228	3.901323	3.560007	0.970191	1.371151	2.781949	4.428049	2.690502	2.265694	1.813401	1.475664	2.384586	1.211233
70	3.952474	4.701485	5.313851	4.007793	3.985756	3.514792	1.067549	1.774403	2.889338	4.419404	2.377748	2.238862	1.845003	1.311846	2.186624	1.072606
71	3.84502	4.791281	5.388965	4.149377	4.10484	3.60105	1.140826	1.932557	2.988118	4.428705	2.06006	2.183109	1.896104	1.305247	2.183957	1.095359
72	3.801675	4.78433	5.400853	4.064037	4.138891	3.613862	1.240694	1.953524	3.192811	4.508547	2.196547	2.178589	1.864674	1.460749	2.221448	1.080671
73	4.05803	4.550847	5.205353	3.517378	3.623602	3.58812	1.001032	1.480629	2.932902	4.477212	2.473825	2.211276	1.846322	1.513193	2.382759	1.279402
74	3.974097	4.746565	5.358076	3.928724	3.331329	3.488	1.059469	1.523349	2.129027	4.467714	2.508449	2.258282	1.989658	1.367014	2.303082	1.068391
75	3.954355	4.705636	5.376891	4.029125	3.89149	3.577916	0.992415	1.787961	3.010986	4.298472	2.427499	2.234897	1.870862	1.439007	2.276637	1.118352
76	4.041886	4.609741	5.320131	3.594224	3.732253	3.511432	0.930667	1.390482	2.703336	4.340224	2.633513	2.298406	1.746777	1.401881	2.311724	1.164639
77	3.992744	4.655642	5.343595	3.740966	3.683579	3.614176	1.029216	1.715125	2.882606	4.380669	2.61775	2.258366	1.840193	1.432668	2.274549	1.185363
78	3.873042	4.755123	5.368907	4.118173	4.040074	3.589718	1.111589	1.982031	3.049955	4.362929	2.294504	2.196997	1.889307	1.429684	2.146962	1.071777
79	3.869155	4.740587	5.420708	3.945595	3.709529	3.604074	1.140937	2.054044	3.416323	4.435686	2.762549	2.212961	1.905902	1.379657	2.330425	1.043605
80	4.038545	4.435927	5.142626	3.814575	3.868567	3.299034	0.899399	0.795336	3.384543	4.327501	2.649877	2.266221	1.811555	1.27445	2.152887	0.977898
81	4.097654	4.473479	5.183225	3.677465	3.697455	3.319774	0.842291	0.731381	3.096481	4.314092	2.755816	2.321761	1.729296	1.294645	2.155897	1.037055
82	3.805038	4.781207	5.419986	3.925113	3.864724	3.694981	1.239649	2.030913	3.072493	4.506852	2.358399	2.160279	1.854628	1.488698	2.314465	1.151764
83	3.966425	4.717234	5.369286	3.880385	3.833529	3.503381	0.970615	1.711372	2.438889	4.293651	2.339965	2.201849	1.746203	1.354454	2.217477	1.02685
84	3.964695	4.687469	5.3996	3.725448	3.785044	3.582861	0.951637	1.711898	2.578523	4.275107	2.46873	2.201664	1.628387	1.464676	2.34341	1.142251
85	4.042461	4.636242	5.310002	3.912504	3.996244	3.398995	0.853168	1.326375	2.59832	4.267134	2.714266	2.332524	1.778124	1.402939	2.17947	1.072503
86	3.851301	4.741692	5.45754	4.11462	3.81153	3.66363	1.077183	1.967074	2.634676	4.28755	2.003521	2.056532	1.793028	1.422326	2.229577	1.118026
87	3.887501	4.76533	5.425575	4.170325	3.598668	3.557549	1.069196	1.879035	2.786117	4.357833	2.03242	2.16712	1.874195	1.363938	2.163415	1.015868
88	4.05579	4.616592	5.28762	3.932606	3.590175	3.422973	0.900743	1.418055	2.875865	4.319421	2.365372	2.246932	1.932845	1.347868	2.187703	1.120651
89	4.037475	4.632578	5.339448	3.7592	3.74628	3.469056	0.871608	1.548139	2.910257	4.247148	2.500483	2.222209	1.590674	1.39955	2.347475	1.141428
90	3.883696	4.817136	5.365623	4.151743	3.759914	3.610487	1.22701	1.784109	2.9433	4.581092	2.27208	2.240303	2.018557	1.405641	2.217926	1.122389
91	3.962056	4.706161	5.354302	3.656996	3.613713	3.670252	1.077444	1.58861	2.949387	4.479149	2.597549	2.284671	1.843848	1.488858	2.365642	1.242175
93	4.061365	4.374208	5.079449	3.608145	3.926443	3.257263	0.91862	1.572994	3.38216	4.421746	3.296135	2.365201	1.762539	1.269726	2.108307	0.965982

Samples	NaKa1	AlKa1	SiKa1	K Ka1	CaKa1	TiKa1	CoKa1	NiKa1	MnKa1	FeKa1	CuKa1	ZnKa1	RbKa1	Y Ka1	ZrKa1	NbKa1
96	3.814812	4.799122	5.423969	4.052351	3.88649	3.655115	1.112669	1.896371	2.84546	4.397775	2.102762	2.203088	1.964409	1.493051	2.30569	1.178928
97	3.948872	4.64238	5.329247	4.054494	3.866232	3.474765	0.973712	1.671963	2.637934	4.295725	2.252314	2.211048	1.870156	1.372727	2.139633	1.080288
98	3.782889	4.731067	5.444431	4.114292	3.950001	3.613529	1.081136	1.94901	2.50655	4.294034	1.895388	2.090211	1.744939	1.424252	2.236363	1.142453
99	3.985897	4.618674	5.299777	3.43775	3.784122	3.600517	0.981903	1.475431	2.935693	4.387117	2.4631	2.254527	1.827008	1.466001	2.32065	1.226035
100	3.990381	4.543643	5.302698	3.709202	3.729463	3.519183	0.960686	1.45717	2.715828	4.346789	2.367575	2.210391	1.650093	1.370259	2.256033	1.14089
102	3.965956	4.644813	5.342272	3.925168	3.813157	3.449353	0.949695	1.670936	2.667515	4.248522	2.199069	2.168367	1.759541	1.379672	2.254366	1.055508
103	4.105808	4.448402	5.099472	3.617029	3.393886	3.243119	0.816104	0.0001	2.535189	4.340749	3.047426	2.425674	1.904788	1.30985	2.214705	0.940457
104	3.936655	4.628084	5.357566	3.928824	3.835643	3.488918	0.953671	1.69938	2.531132	4.289936	2.176297	2.176094	1.727849	1.392893	2.234288	1.097132
105	3.964216	4.652996	5.346373	3.915614	3.768295	3.499736	0.948197	1.592929	2.755125	4.322052	2.395418	2.235696	1.83218	1.390447	2.243752	1.104703
106	3.989655	4.689929	5.289474	3.993974	3.669658	3.454849	0.943262	1.332008	2.960021	4.35169	2.493772	2.297016	1.895818	1.436605	2.162167	1.063428
107	4.042044	4.635688	5.266893	3.877365	3.623029	3.400482	0.891381	1.139043	2.457177	4.322712	2.670796	2.308954	1.839318	1.405209	2.169237	1.050761
109	3.966072	4.583816	5.291193	3.947498	4.240134	3.449765	0.887888	1.362255	2.8064	4.275602	2.373843	2.226476	1.836505	1.351507	2.221914	1.098827
110	3.861559	4.720226	5.357401	4.023922	3.772678	3.539897	1.129979	1.824397	2.793022	4.46964	2.212577	2.145986	1.842365	1.269055	2.34392	1.012544
111	4.054822	4.611117	5.204018	3.766909	3.516071	3.332451	0.84723	1.549762	2.808073	4.317986	3.026213	2.324561	1.832423	1.309299	2.164915	1.043316
112	4.072994	4.515808	5.197228	3.755709	3.50742	3.303335	0.895639	0.625234	2.727556	4.395662	2.821886	2.33311	1.938368	1.301586	2.295625	0.98988
113	4.010458	4.549902	5.296024	3.831593	3.57279	3.377916	0.89681	1.276899	2.79339	4.277482	2.393266	2.188374	1.688562	1.298766	2.192383	0.971162
114	3.861534	4.775933	5.343106	4.123782	3.690662	3.568791	1.177208	1.780095	2.876488	4.484279	1.923403	2.182256	1.960969	1.506639	2.288836	1.125415
116	4.040773	4.551854	5.254701	3.552268	3.550398	3.486578	0.904567	1.269461	2.752474	4.343516	2.607672	2.29168	1.764445	1.461305	2.260584	1.1468
117	3.871356	4.760278	5.361365	4.010773	3.789779	3.583422	1.145891	1.829372	2.913049	4.412324	1.745074	2.073522	1.873629	1.36788	2.36301	1.099622
119	4.030565	4.634734	5.264392	3.578738	3.525968	3.513854	0.918505	1.437902	2.307072	4.342495	2.551061	2.264748	1.776776	1.446304	2.293586	1.184135
120	4.059339	4.590427	5.222801	3.857752	3.587245	3.42451	0.971529	0.0001	3.137864	4.406735	2.23883	2.202092	1.914319	1.449004	2.185056	1.105071
121	3.971829	4.669762	5.285301	4.045132	3.754257	3.449969	1.043895	1.463148	2.878121	4.442574	2.274244	2.249562	1.868003	1.396393	2.231616	1.025629
122	3.853254	4.669776	5.344154	4.177851	3.997071	3.506258	1.141625	1.773774	3.036796	4.43526	1.938397	2.120918	1.842061	1.31935	2.253672	0.986433
124	4.048461	4.417724	5.134726	3.618431	4.021334	3.235662	0.886245	0.0001	3.199426	4.413158	2.567764	2.292061	1.759426	1.361761	2.093192	0.983266
126	4.086399	4.414755	5.135069	3.493125	3.767649	3.471012	0.888954	0.0001	3.258829	4.398841	2.661434	2.300634	1.75659	1.432406	2.277864	1.223695
127	3.843034	4.618858	5.359626	3.976712	3.867313	3.539361	1.157136	1.841259	3.289184	4.464253	1.949529	2.104033	1.834724	1.341704	2.329146	1.081267
128	3.905711	4.634045	5.30091	3.514035	4.058035	3.642049	1.074947	1.74436	2.708711	4.409832	2.154573	2.145472	1.664558	1.431255	2.284111	1.171647
129	4.043609	4.55229	5.208013	3.571248	3.824526	3.497997	0.931518	1.063238	2.807693	4.398962	2.511757	2.23821	1.6773	1.426305	2.221393	1.126288
131	3.941554	4.599055	5.360283	3.972631	3.949769	3.567278	0.974397	1.76403	2.587758	4.27498	2.079813	2.135892	1.730208	1.436636	2.264775	1.16215
134	3.966788	4.688151	5.320739	3.830256	3.782891	3.515741	0.967339	1.55244	3.043684	4.359534	2.49126	2.204929	1.689467	1.386215	2.288373	1.107176

Samples	NaKa1	AlKa1	SiKa1	K Ka1	CaKa1	TiKa1	CoKa1	NiKa1	MnKa1	FeKa1	CuKa1	ZnKa1	RbKa1	Y Ka1	ZrKa1	NbKa1
135	3.958919	4.674038	5.327909	4.086496	3.761146	3.475754	0.992706	1.68224	2.813515	4.322418	2.212025	2.190977	1.913797	1.33569	2.169496	1.011389
137	4.011827	4.566629	5.269655	3.965806	3.667175	3.422953	0.878389	2.090381	2.871419	4.272324	3.369731	2.339026	1.813988	1.326856	2.168451	1.099404
138	3.935534	4.777899	5.344449	4.177036	3.802432	3.531343	1.120478	1.664723	2.841212	4.500371	2.236338	2.257003	1.941186	1.316505	2.234297	1.086873
139	3.990248	4.655079	5.259118	4.038583	3.674058	3.391016	1.013291	0.983855	3.243626	4.510313	2.599528	2.341963	1.925257	1.272692	2.198136	1.022632
142	3.846049	4.763484	5.330667	4.104986	3.749307	3.567273	1.184303	1.991614	3.03124	4.572819	3.072075	2.334868	1.915146	1.422381	2.218553	1.112387
144	3.976157	4.590782	5.311631	3.663951	3.619343	3.546213	0.994304	1.480476	2.955752	4.418782	2.511441	2.269347	1.935859	1.444793	2.325116	1.170811
145	3.99569	4.66742	5.284125	4.022422	3.577542	3.456867	1.019611	1.417973	2.746314	4.419583	2.240489	2.238393	1.849772	1.305803	2.146355	0.997481
146	3.944667	4.622401	5.317745	3.921539	3.600875	3.458119	1.022554	1.570353	2.499182	4.416165	2.390201	2.227815	1.831224	1.315235	2.29984	1.027151
147	3.991137	4.605677	5.310713	3.668678	3.61998	3.571992	1.006592	1.564695	2.885319	4.403801	2.359522	2.236463	1.930767	1.43009	2.320233	1.176571
148	3.969164	4.650506	5.266138	3.98736	3.886875	3.484612	1.05527	1.586911	2.90069	4.424083	2.252287	2.20371	1.832964	1.306369	2.200393	1.106626
150	3.768558	4.694467	5.432133	3.445761	3.934489	3.744912	1.174886	2.008892	3.101214	4.384338	1.640955	1.949044	1.098608	1.409486	2.392755	1.185465
152	3.984425	4.669265	5.253996	4.038209	3.652437	3.505307	1.080086	1.208946	3.073697	4.500995	2.113488	2.287178	1.958235	1.538068	2.226094	1.115394
1098	3.867778	4.718593	5.407351	3.962123	4.103338	3.596621	1.064063	1.922416	2.848119	4.330651	2.122021	2.132358	1.684746	1.427909	2.288697	1.098447
1102	4.013763	4.513293	5.283274	3.743161	3.945037	3.446429	0.910012	1.538471	2.854677	4.256812	2.361542	2.172934	1.625718	1.39512	2.172954	1.025668
1112	3.884801	4.7102	5.432536	4.002285	3.90716	3.574055	1.026611	1.849108	2.54924	4.313818	1.878262	2.086127	1.816059	1.391215	2.243618	1.06848
1113	3.703499	4.791419	5.501721	4.068609	3.952559	3.63064	1.090265	1.97019	2.458643	4.303411	2.037181	2.096441	1.728824	1.460026	2.311542	1.143978
1114	4.039324	4.541804	5.293966	3.573574	3.9303	3.537324	0.923706	1.392281	2.680594	4.312183	2.48488	2.185105	1.551417	1.39724	2.258952	1.149905
1123	3.758605	4.874301	5.38288	4.261194	3.977542	3.683301	1.228864	1.946622	3.074316	4.502778	2.059821	2.12619	2.035988	1.390033	2.23442	1.16869
1145.1	3.875978	4.703608	5.373278	3.950835	4.115148	3.537089	1.005592	1.726447	2.754568	4.29299	2.378438	2.219557	1.789789	1.386063	2.139662	1.050203
1146.11	3.878675	4.767614	5.405742	3.980705	4.048518	3.576068	1.048111	1.841093	2.614783	4.336965	2.197491	2.165992	1.817678	1.371114	2.164578	1.133673
1149	4.111147	4.418735	5.21167	3.567347	3.744401	3.312197	0.793937	0.0001	2.980623	4.285832	2.65561	2.348969	1.636917	1.372144	2.218212	1.076015
1155.2	3.926468	4.683823	5.411724	4.032223	3.915692	3.555758	1.003177	1.745954	2.708568	4.318183	2.192166	2.15748	1.829227	1.374918	2.194952	1.124397
1156	4.00424	4.621634	5.334757	3.934025	3.878704	3.486594	0.925029	1.560105	2.713401	4.298947	2.400397	2.229845	1.805018	1.376737	2.204296	1.087999
1159.16	3.851849	4.680986	5.395209	4.183193	3.862874	3.604599	1.063728	2.088097	2.955004	4.29329	2.191375	2.085409	1.728676	1.386915	2.243756	1.098107
1160.19	3.797971	4.776921	5.379775	4.222633	3.990013	3.623344	1.188717	1.929256	2.953021	4.465775	1.905954	2.107874	1.90692	1.417039	2.294618	1.106338
1161	3.850804	4.671481	5.407147	3.999971	4.085501	3.551645	1.094324	1.903292	2.675192	4.343168	2.077611	2.073868	1.79193	1.369832	2.269934	1.070265
1162	3.769307	4.731529	5.478371	4.046793	3.719379	3.662496	1.042381	1.973026	2.55076	4.278347	2.007878	2.103501	1.808471	1.433475	2.315987	1.172732
1163	3.99753	4.615444	5.368399	3.922987	3.940489	3.438729	0.899641	1.617485	2.723462	4.21217	2.046349	2.115424	1.701357	1.416478	2.203151	1.060759
1164	3.901623	4.701556	5.416641	3.99719	3.734283	3.518089	0.970089	1.7264	2.595886	4.307199	2.20956	2.162517	1.799063	1.402545	2.254261	1.131155
1168	3.885303	4.72686	5.426129	4.131991	3.784445	3.580211	1.036934	1.863585	2.814536	4.299518	2.142952	2.148863	1.814231	1.392098	2.253866	1.102235

Samples	NaKa1	AlKa1	SiKa1	K Ka1	CaKa1	TiKa1	CoKa1	NiKa1	MnKa1	FeKa1	CuKa1	ZnKa1	RbKa1	Y Ka1	ZrKa1	NbKa1
1169	3.961486	4.588429	5.363712	3.412049	4.045137	3.602157	1.002131	1.637094	2.546796	4.281006	2.14793	2.122244	1.547982	1.378945	2.231228	1.106043
1171.1	3.846676	4.687307	5.429257	3.86941	3.839721	3.687069	1.145618	1.957723	2.722235	4.4183	2.205746	2.116991	1.876286	1.4444	2.304618	1.201249
1177	3.942969	4.622136	5.358577	3.576181	3.767197	3.610026	1.026306	1.717098	2.634672	4.369546	2.265255	2.126042	1.772184	1.437413	2.331135	1.173431
1178	3.804243	4.630873	5.439475	3.953046	4.034933	3.633269	1.08231	1.968308	2.725076	4.301219	2.01098	2.063581	1.672118	1.373284	2.333976	1.081338
1182	4.016447	4.846506	5.405066	2.240805	3.378665	3.691096	0.797061	1.781912	1.792762	4.041021	1.636746	1.840146	1.036303	1.609921	2.399189	1.293853
1183	3.85576	4.780968	5.320892	4.166494	3.976155	3.605422	1.19721	1.849386	2.832052	4.506271	2.094067	2.194219	1.937462	1.38685	2.197634	1.105361
1185.1	3.939966	4.70998	5.337356	4.052247	3.739361	3.488149	0.986473	1.623248	2.764287	4.315748	2.310701	2.188151	1.842363	1.401339	2.100235	1.013776
1186	3.957554	4.635757	5.338838	3.734612	3.71982	3.601615	1.0234	1.676703	2.449927	4.384007	2.241979	2.107555	1.690693	1.423327	2.261787	1.162592
1206	3.872527	4.822749	5.348336	4.164126	3.785868	3.604317	1.104038	1.776351	2.751125	4.460132	2.063244	2.187542	1.945856	1.429597	2.190602	1.153408
1208	3.897188	4.705629	5.362567	4.231406	3.910101	3.542673	1.026075	1.803652	2.85209	4.317884	2.333379	2.240751	1.944042	1.37392	2.207057	1.084459
1220	3.925488	4.745388	5.409546	3.528906	3.65402	3.737128	1.02123	1.849422	1.880895	4.309591	2.134495	2.062282	1.742156	1.54219	2.396289	1.32977
1221	3.755296	4.719081	5.447512	4.143857	3.95862	3.626726	1.068561	2.057443	2.760653	4.360973	2.799624	2.206322	1.794057	1.506776	2.259463	1.157339
1231	3.900095	4.578204	5.351325	3.946154	4.05523	3.61681	1.061886	1.868887	2.691054	4.348408	1.95105	2.027805	1.761076	1.438781	2.25436	1.160665
1232	3.892053	4.744887	5.360098	4.051224	3.691106	3.551749	1.088654	1.772794	2.774435	4.394441	2.219088	2.139186	1.754806	1.331791	2.332421	1.077997
1233	3.820364	4.765919	5.457869	3.916574	3.765781	3.666089	1.059342	1.884178	2.480115	4.294426	2.387916	2.163602	1.678759	1.444813	2.27593	1.182334
1235	3.824834	4.808512	5.393238	4.186524	3.781477	3.633947	1.212844	1.918396	3.066589	4.511995	2.150846	2.158099	1.998876	1.454247	2.239609	1.11926
1236.1	3.994429	4.710963	5.262393	4.009195	3.628794	3.434639	0.990824	1.488295	2.692335	4.381429	2.536738	2.240835	1.863781	1.343301	2.138269	1.009101
1240	3.83502	4.832571	5.381965	4.072072	3.760489	3.667461	1.191774	1.948552	2.32196	4.447497	1.889861	2.055596	1.81401	1.453791	2.334606	1.172507
1242	3.751892	4.919589	5.405798	3.974471	3.795817	3.642467	1.177884	1.952565	2.903466	4.46204	2.361312	2.259642	2.027532	1.476534	2.25007	1.162021
1245	3.901685	4.666509	5.319237	4.02486	3.970554	3.528734	1.064093	1.739826	2.912859	4.377507	2.290195	2.146244	1.842176	1.356474	2.296204	1.055975
1246	3.972818	4.568343	5.318386	3.884888	3.93589	3.571107	0.996137	1.640539	3.035624	4.358382	2.192724	2.118524	1.722095	1.403737	2.278579	1.195266
1248	3.72522	4.776412	5.421165	4.172661	3.923593	3.632152	1.226702	1.813545	2.83894	4.544748	2.159771	2.143658	1.889834	1.421506	2.209171	1.093996
1250.11	3.790679	4.842108	5.342085	4.111981	3.95248	3.555061	1.133205	1.965279	2.510281	4.394153	1.987116	2.124914	2.028163	1.405592	2.202925	1.070189
1257	4.066346	4.523541	5.253941	3.758009	3.890911	3.313849	0.856809	1.238368	2.896188	4.323628	2.506064	2.23862	1.740927	1.299195	2.196037	1.068861
1259	3.708757	4.948854	5.454231	4.238477	3.838452	3.69999	1.208608	1.968378	2.898215	4.501987	1.786899	2.107285	1.831688	1.46041	2.223286	1.156096
1261.1	3.892835	4.779204	5.368556	4.007632	3.93054	3.663455	1.088629	1.857053	2.185809	4.358321	2.002345	2.02887	1.868471	1.512302	2.27483	1.173579
1262	3.910795	4.776025	5.359743	3.98861	3.757291	3.612519	1.08666	1.770513	2.436272	4.412546	2.144009	2.146174	1.798115	1.447756	2.216548	1.142039
1263.1	3.903716	4.719179	5.375451	3.926001	3.821336	3.712592	1.071451	1.892799	2.409735	4.329059	2.101765	2.092448	1.629566	1.521937	2.313463	1.225396
1268	4.03533	4.461469	5.27821	3.736573	3.607147	3.464709	0.8366	1.596782	2.730593	4.214333	2.504196	2.191093	1.728967	1.355762	2.256723	1.078587
1269	4.101115	4.717891	5.184522	3.852349	3.553192	3.462209	1.006792	0.0001	2.491893	4.542767	2.163243	2.195022	1.912982	1.48432	2.21102	1.151331

Samples	NaKa1	AlKa1	SiKa1	K Ka1	CaKa1	TiKa1	CoKa1	NiKa1	MnKa1	FeKa1	CuKa1	ZnKa1	RbKa1	Y Ka1	ZrKa1	NbKa1
1282.1	3.825593	4.797527	5.373877	4.051152	3.809092	3.660866	1.152002	1.882818	2.881279	4.43411	2.189446	2.103157	1.76736	1.453139	2.175333	1.154048
1292	3.866037	4.755968	5.378531	3.926375	3.771187	3.640497	1.110167	1.944963	2.742501	4.403265	2.080599	2.106522	1.851678	1.484857	2.343552	1.168342
1294	3.819251	4.754463	5.367438	4.141213	4.094875	3.601656	1.176765	1.932872	1.08401	4.389645	2.260038	2.207981	1.860863	1.45459	2.258255	1.10135
1314	3.958481	4.736507	5.301765	4.006787	4.047352	3.566238	1.030882	1.702297	2.243265	4.431629	2.284475	2.151483	1.824204	1.448214	2.189704	1.152574
1316	3.894253	4.734323	5.375797	4.088678	3.81067	3.537508	0.980415	2.458639	2.695961	4.320554	3.9894	2.464036	1.903899	1.386206	2.244642	1.107765
1321	3.781696	4.740633	5.417103	4.060973	3.87049	3.617844	1.197387	1.94526	3.115855	4.461956	2.058263	2.100407	1.894346	1.39557	2.433605	1.08783
1332	3.888302	4.758042	5.294392	4.066348	3.632002	3.553379	1.17056	1.673583	2.682742	4.648446	2.147357	2.157822	1.891147	1.387629	2.18735	1.121053
1333	3.846898	4.753007	5.379606	4.073805	3.762777	3.595607	1.157484	1.851005	2.847043	4.466181	2.155997	2.144204	1.876312	1.436948	2.230157	1.106543
1338	3.980012	4.669399	5.325802	4.003824	3.814519	3.424714	0.949727	1.582522	3.039465	4.328617	2.350815	2.176089	1.824285	1.419191	2.251468	1.047059
1339	4.013788	4.657808	5.367327	3.645919	3.464017	3.538179	0.953634	1.568456	2.809345	4.351915	2.387777	2.168463	1.871128	1.410804	2.312115	1.165928
1342	4.032691	4.572747	5.311757	3.638085	3.583474	3.50076	0.917012	1.347214	2.653008	4.303865	2.336634	2.157311	1.813817	1.396959	2.272294	1.072178
1349	4.046833	4.503716	5.194757	3.889282	3.718247	3.395088	0.933446	1.337355	3.03438	4.352643	2.53269	2.280806	1.77766	1.334932	2.208748	0.999237
1350	4.076564	4.659151	5.227614	3.805408	3.625565	3.386918	0.861146	1.544533	3.065936	4.375467	3.027181	2.347292	1.82525	1.401723	2.18825	1.077325
1351	4.042755	4.581039	5.196653	3.500749	3.822962	3.460983	0.990913	1.938567	3.0934	4.521016	3.531609	2.404033	1.831238	1.559199	2.226736	1.200202
1361	3.983351	4.602315	5.258983	3.974725	3.718435	3.499748	1.041669	1.55267	3.041996	4.434509	2.152289	2.132686	1.791064	1.287497	2.229816	1.046803
BanTaKo ceramic	3.748279	4.827251	5.47039	3.546441	3.633496	3.801793	1.207465	1.930822	2.554034	4.529537	2.064705	2.033226	1.831286	1.572705	2.432641	1.305307
2-Unfired	3.589794	4.414185	5.184141	3.780304	5.186827	3.16277	0.687794	1.578854	2.666457	3.99976	1.86629	1.947774	1.418786	1.135853	2.286994	0.734919
1-1000	3.656392	4.237133	5.332191	3.719031	4.840396	3.243193	0.847609	1.909132	2.985237	4.098536	2.192634	2.042116	1.564354	1.200169	2.501748	0.826674
10-1000	3.64512	4.649594	5.356665	4.155181	4.893552	3.395902	1.05104	1.905982	2.797629	4.352488	2.326714	2.043891	1.800929	1.288492	2.323033	0.973573
10-800	3.663157	4.646563	5.339086	4.173936	4.878316	3.394121	1.040649	1.742896	2.865266	4.361247	2.144846	2.023975	1.803608	1.318988	2.380436	0.935356
8-1000	3.777468	4.476215	5.406288	3.723927	4.688669	3.331067	0.92283	2.083769	2.908579	4.209875	2.251623	1.973166	1.532881	1.256294	2.52013	0.907329
8-800	3.826466	4.527068	5.394512	3.77719	4.694272	3.354165	0.898253	1.919348	2.961682	4.171788	1.994625	1.896938	1.541002	1.228489	2.484575	0.842848
4-1000	3.668671	4.804322	5.37224	4.778935	4.424009	3.340329	1.020411	1.908183	2.517127	4.300128	2.308449	2.009708	2.266837	1.017311	2.16544	1.181512
4-800	3.687677	4.744264	5.311048	4.688048	4.841997	3.200597	0.925553	1.730434	2.538297	4.293417	2.30278	1.983354	2.221898	1.016203	2.19469	1.08809
1-800	3.750342	4.358571	5.437421	3.892152	4.656324	3.318263	0.894795	1.978979	2.994213	4.110533	1.866788	1.995497	1.571037	1.213842	2.498394	0.871519
2-800	3.630375	4.292499	4.99444	3.645249	5.2537	3.020549	0.554728	0.0001	2.676517	4.024256	2.292035	2.05352	1.499532	1.204985	2.340075	0.76852
3-1000	3.774349	4.30382	5.373905	3.62563	4.753432	3.244344	0.799411	1.986711	2.942125	3.961216	1.954047	1.98352	1.369945	1.196649	2.608429	0.820139
3-800	3.808435	4.271111	5.37559	3.633725	4.712776	3.255524	0.778861	1.948931	2.970385	4.00539	1.848351	1.941865	1.389431	1.222485	2.6397	0.86766
5-1000	3.707508	4.61359	5.437941	4.073682	4.538894	3.476711	1.072896	2.16027	2.879982	4.288498	2.025834	1.980824	1.728062	1.263928	2.411515	0.967187
5-800	3.686762	4.636484	5.435506	4.08613	4.579815	3.500193	1.096496	2.089883	2.905482	4.315665	2.216582	1.975586	1.708093	1.256674	2.389698	0.969813

Samples	NaKa1	AlKa1	SiKa1	K Ka1	CaKa1	TiKa1	CoKa1	NiKa1	MnKa1	FeKa1	CuKa1	ZnKa1	RbKa1	Y Ka1	ZrKa1	NbKa1
6-1000	3.770588	4.882963	5.470826	3.559185	3.661828	3.874213	1.21956	2.211185	2.207422	4.427099	2.034563	1.994072	1.80949	1.537174	2.421247	1.264438
6-800	3.79809	4.855575	5.438698	3.542613	3.684266	3.852269	1.211165	2.180209	2.313536	4.514759	2.148325	2.021958	1.814054	1.535781	2.420204	1.266895
7-1000	3.751632	4.88914	5.477668	3.511916	3.598044	3.888105	1.290559	2.190257	2.002386	4.521141	2.329503	2.036461	1.829225	1.521559	2.414162	1.276491
7-800	3.60407	4.756714	5.544219	3.750736	3.618891	3.794767	1.308756	2.176521	1.570256	4.524501	2.016058	2.172383	1.802761	1.491274	2.408985	1.282955
9-1000	3.85794	4.410673	5.487593	3.629335	3.985009	3.370499	0.919528	2.218702	2.858301	4.025596	2.247423	1.964616	1.388692	1.276726	2.583023	0.857196
9-800	3.848416	4.473024	5.495768	3.704768	4.039911	3.389088	0.930671	2.199867	2.818493	4.048088	2.05605	1.908792	1.387061	1.262068	2.60069	0.838776