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ALL FOR ONE? THE PRODUCTION OF BLACK BURNISHED POTTERY AND STATE FORMATION IN THE EARLY KOREAN POLITY OF BAEKJE*

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*This paper tests whether the distinctive black burnished pottery from the early Korean state of Baekje (*c.*250–660 CE) was, as is commonly assumed, under the control of a centralized authority. We employ an integrated approach, combining typological, petrographic and elemental composition data, to reconstruct the organization of production for this prestige ware. Clear heterogeneity in both clay sources and technical styles indicates a decentralized production pattern. The Baekje polity may thus have emerged as a distributed network rather than a centralized entity, with local communities choosing to engage with the political centre and not be subservient to it.*

KEYWORDS: KOREAN ARCHAEOLOGY, BAEKJE, BLACK BURNISHED POTTERY, ORGANIZATION OF PRODUCTION, STATE FORMATION, CERAMIC PETROGRAPHY, NEUTRON ACTIVATION ANALYSIS (NAA)

INTRODUCTION

The emergence of the early Korean state of Baekje in the late third–early fourth centuries CE was accompanied by the appearance and spread of so-called Baekje pottery, including several new ceramic styles and a novel ware: black burnished pottery (BBP) (Fig. 1). BBP has been posited as ware of the social elite (Park 1992, 2001; Choi 2008), with production controlled by the political centre, where leaders used it in gift exchange to secure alliances and the loyalty of regional leaders (Park 2001, 115). The present study tests the proposal that BBP production was centrally organized, being the first application of integrated typological, petrographic and elemental analyses specifically to this ware. This study therefore also contributes to wider debates about the links between the organization of crafting and broader socio-political organization, including a discussion of bottom-up processes, which have recently seen some notable theoretical developments (for a review, see DeMarrais and Earle 2017).

Baekje was one of three states that arose on the Korean Peninsula during the early first millennium, alongside Goguryeo and Silla, culminating in the Three Kingdoms Period (*c*.300–668 CE).

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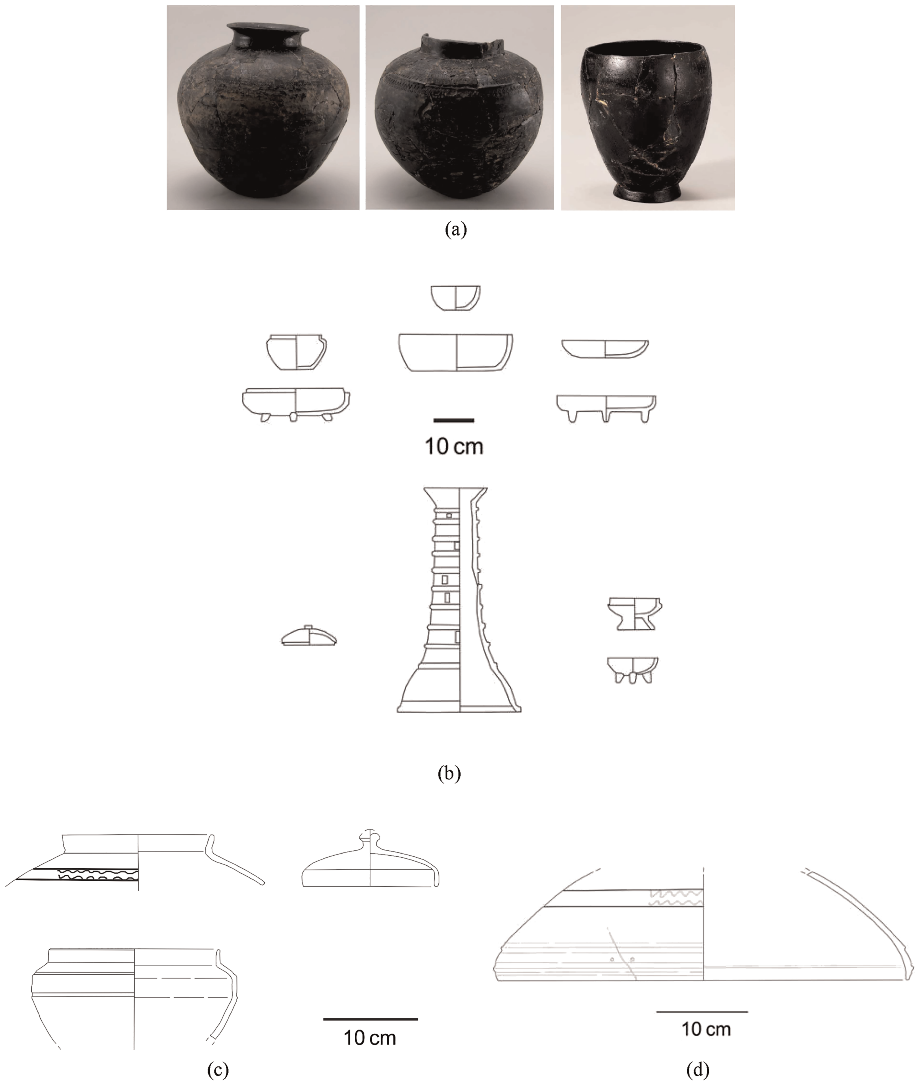

Figure 1 *(a) Examples of black burnished pottery (BBP) (not to scale) from Stone Mound 1 at Seokchondong tombs (from Yi and Cho 2015); (b) types of Baekje serving pottery, including bowls, plates, dishes, footed and tripod bowls/plates/dishes, lids, and pot stand (redrawn after Kim et al. 2016); (c) the most common forms of BBP in the study sample: jar (redrawn from NRICH 2012), lid (redrawn from NRICH 2012) and lidded bowl (redrawn from Lee et al. 2003); and (d) repaired BBP lid (note the crack and two drilled holes on the bottom end) (redrawn from Kwon et al. 2004). [Colour figure can be viewed at wileyonlinelibrary.com]*

Baekje existed through three periods: Hanseong (*c*.250–475), Ungjin (475–538) and Sabi (538–660) (Kwon 2008; Park 2010). It is the earliest period that concerns us here. The Hanseong phase centred on Pungnab fortress, located on the Han River (Fig. 2). The sister fortress of Mongchon, and monumental tombs at nearby Seokchondong, were built in the later fourth century, forming a complex that acted as the political centre of Baekje (Fig. 2, c) (see also Kwon 2008; Park 2010). Park (2001, 2007) has highlighted an area of around 30 km radius as

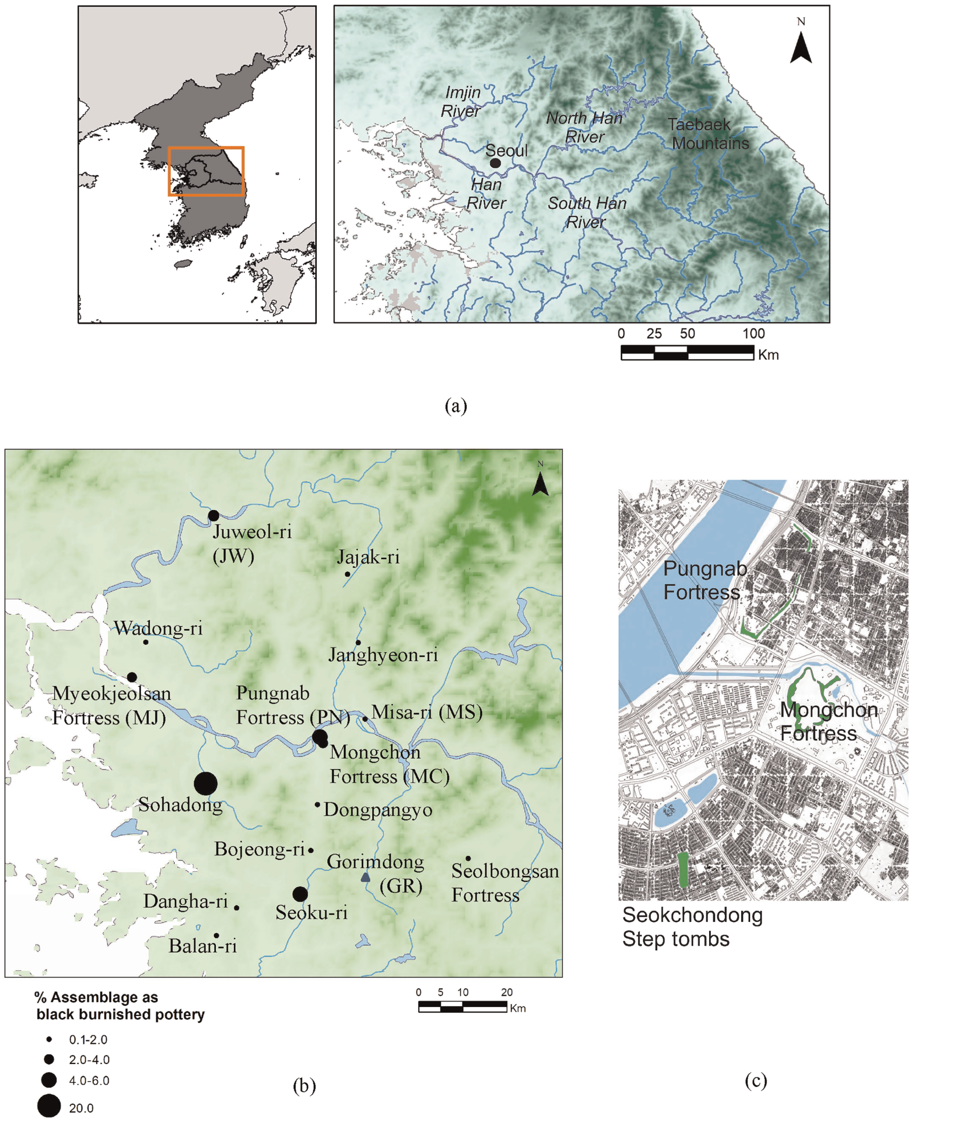

Figure 2 *(a) Geographical overview of Korea's central region; (b) Early Baekje (250–475 CE) settlements and production sites where black burnished pottery (BBP) was found and the proportion of the ceramic assemblage made up by black burnished ware (sites where ceramic samples were taken have site codes indicated in parentheses); and (c) key sites of the Early Baekje centre located adjacent to the Han River (modified from NRICH 2007). [Colour figure can be viewed at wileyonlinelibrary.com]*

the core of Early Baekje, constituting a 'confederate kingdom' led by authorities at Pungnab fortress. We thus focus this study primarily on the lower Han River basin.

BBP has been seen as an utterly novel ceramic type, unrelated to preceding Late Iron Age (LIA) (*c*.100 BCE–300 CE) period wares (Park 1992, 24–25; Park 2001; Lee 2001, 192–193). We use the term LIA here as it is the most inclusive of all peninsular groups and polities. BBP has been characterized as made of fine clay that was burnished in a semi-dry state and fired at a low temperature in a reducing atmosphere (Lee 2001; Kim *et al*. 2016, 132). In contrast, petrographic work presented by Cho (2006), and expanded upon here, shows that BBP was often tempered, and the majority was fired in oxidizing atmospheres of varied temperatures (see also Kim *et al*. 2017). Cho (2006) concluded that, other than the firing procedure, the production process of BBP was consistent with LIA ceramic traditions, using the same raw material sources and coil-building methods. Nam and Kim (2014) also note that clays used for BBP were not particularly different from those used to make other Baekje pottery types. Furthermore, a high relative organic content has been reported for the external surfaces of BBP, indicating either smudging via the burning of organics (Nam and Kim 2014, 7–9, 11–12; also suggested by Lee 2001, 193), or the use of plant ash as a surface colourant (Kim *et al*. 2017).

Influential scholars have often framed the development of Baekje in evolutionary terms, whereby one chiefdom subjugated others to form a state (Pai 2000; Barnes 2001; Park 2001, 34–9). Park (1992, 2001) has explicitly associated BBP with the Baekje political elite, and thus with state formation, the expansion of Early Baekje territory and centralized political control. An association with elite activity seems reasonable considering BBP's association with Baekje pottery (Park 1992, 2001; Choi 2008; Kim *et al*. 2016). However, how far BBP can be used to infer the extent of Baekje's directly controlled territory is unclear, and the hypothesis of state-controlled production is yet to be systematically tested.

Was BBP production closely controlled by the Baekje authorities at (or near) the central fortresses or autonomously produced by multiple actors for use in local social practice? The former would support the hypothesis of controlled gift-giving by Baekje leaders. Clay sources for BBP vessels from all over the study region would therefore have been located near to Pungnab fortress, with standardization in manufacturing techniques and decorative motifs.

Alternatively, were particular raw material sources associated with particular settlements and/or particular technical styles? Different production loci supplying different villages would not indicate central control, while a multitude of independent makers or production units is also likely to have led to a relative heterogeneity in artefact style and decorative motifs (e.g., DeMarrais 2013). Control over BBP production by local leaders or the artisans themselves would indicate local autonomy rather than central political control. A more consensual or alliance-based view of Early Baekje's political structure may thus be needed.

While stylistic analyses alone can yield strong hints about production and distribution patterns, integrating such analyses with combined petrographic and elemental compositional analysis can get to the core of this issue (Tite 1999, 201). Provenance and standardization are clearly key questions. If the production of BBP were funnelled through one centre we may expect high relative standardization and highly concentrated production facilities (Costin 1991, 2005); also, a restriction of source clays to those near that centre (Arnold 1985, 32–57; Arnold 1993, 200–202). Petrography allows an insight into both the local geology of clay and temper sources, and steps taken in the production process (e.g., clay processing, forming, finishing and firing) (Tite 1999; Quinn 2013; Rice 2015). Elemental composition analyses, such as instrumental neutron activation analysis (INAA), allow the identification of distinct compositional chemical groups that are inferred to represent geographically/geologically distinct raw material sources (Arnold 2000, 359–360; Bishop and Blackman 2002, 603–604). An integrated approach therefore allows the model of centralized BBP production and distribution to be scrutinized from multiple angles (e.g., Quinn *et al*. 2010).

MATERIALS AND METHODS

Typological and colour analysis

BBP has been identified at 15 published Hanseong period settlement or production sites in the lower Han River basin (Fig. 2, b). Using published information from those sites, 246 examples of BBP with a clear archaeological context were identified. Typological and colour data were gathered, and their spatial distributions examined. In particular, comparisons were made between BBP of the Pungnab–Mongchon complex and that of the wider region. Information on colour was recorded for over 220 BBP vessels or sherds.

To probe regional differences in different surface treatments or firing practices, the colours of sherds' inner surfaces, outer surfaces and cores were analysed. Rice (2015, 278–290) has discussed the utility of the Munsell Chart when examining ceramic surface and section colours. Rice notes that the colour of fired ceramic is the product of several variables, firing in particular (time, atmosphere, temperature). Atmosphere is a key factor because only after organic material is oxidized and eliminated can Fe content, a key determinant of colour, play a significant role in colour determination (Rice 2015, 278–282). In a reducing (or not fully oxidizing) atmosphere ceramic section cores remain darker due to carbon deposition, or the entire section appears dark/black. Korean excavation reports often report ceramic colours using Munsell Chart codes, although reportage is patchy in older reports. Where colour codes were reported, colour names from the Munsell colour diagrams were used for classification, and where only colour names were recorded, those names were used. In total, outer surface colours were reported for 235 samples, inner surface colours for 224 and core colours for 222.

Sites and ceramic samples

A total of 22 BBP sherds were collected from six settlement sites for petrographic and elemental analyses (Fig. 2, b). Nine samples were obtained from domestic contexts and an excavated section of the earthen wall at Pungnab Fortress (PN), while three were taken from storage pits and a test pit at Mongchon Fortress (MC). Pungnab was the site of an LIA village, and approximately 3500 m of earthen wall were built during the late third or early fourth centuries. Within the fortress, domestic areas, production evidence (ceramics, metal), storage facilities, roads and a communal/ritual space have been uncovered. The sister fortress of Mongchon (Fig. 2, c) was likely constructed during the late fourth century, and was less densely populated; yet it was the site of at least two artificial ponds, one accompanied by a wooden platform/pavilion, as well as numerous deep storage pits.

The Misa-ri (MS) settlement was located 12 km upstream of the fortresses, and two BBP samples were obtained from one house and one loose find. An area $> 150\,000\ m^2$ was excavated in the early 1990s, and the site likely covered a much greater area that has been lost to modern development projects. Misa-ri was occupied from the LIA to the Early Baekje period, with 39 houses and over 60 other features, including above-ground storage structures.

One sample was obtained from excavation fill at Myeokjeolsan fortress (MJ), which was excavated in 2003. Overlooking the lower reaches of the Han River, this fortress served as a crucial defence base for the Baekje centre during the fourth century.

Juweol-ri (JW) was a settlement site excavated in 1998–99, from which two samples were taken, although their specific contexts are unknown. Over 10 dwelling structures were uncovered, dated to the Early Baekje period. The investigation was carried out as a rescue excavation following flooding, so the actual settlement was likely much larger.

Five samples were taken from Gorimdong settlement site (GR), located about 40 km south of Pungnab and Mongchon fortresses. Regarded as one of the larger scale settlements of the Hanseong Baekje period, and with architectural and ceramic styles very similar to those at Pungnab fortress, recent excavations have revealed 31 subterranean dwellings, dating from the third to fifth centuries. Gorimdong is also the first settlement site in the study area other than Pungnab/Mongchon where Chinese earthenwares have been found.

Ceramic petrography

Standard petrographic thin sections were prepared from each sherd; nine samples were prepared at the Charles McBurney Laboratory for Geoarchaeology, University of Cambridge, while the remaining 13 slides were made at a private laboratory in Kent, UK. After making a fresh section with a circular saw, the sherds were impregnated in epoxy resin and mounted on glass slides. Samples were ground to 30 μm, confirming the thickness via examination of the thin section under cross-polarized light (XP) with a polarizing light microscope.

Thin sections were examined using a polarizing light microscope in the McBurney Laboratory. Thin sections were grouped and described using the method detailed by Quinn (2013). Samples were examined under both plain polarized light and XP, being separated into fabric classes based upon the nature of their aplastic inclusions, clay matrix, voids and textures. Descriptions and interpretations of each fabric's most important characteristics are now given.

Instrumental neutron activation analysis (INAA)

The same 22 samples examined petrographically were characterized chemically via INAA, carried out in the Oregon State University (OSU) Archaeometry Laboratory using its routine procedures (Minc and Sterba 2017). This number of samples is at or above the recommended lower limit for a statistically significant analysis, suggested to be 15–20 samples of the same ceramic type (Tite 1999; Arnold 2000, 366). Following surface cleaning with a tungsten carbide burr, around 1 g of homogenized powder was prepared from each ceramic sample. From this bulk, 250 mg samples were measured into high-purity polyethylene vials and exposed to the OSU TRIGA reactor for irradiation. In every irradiated batch three replicates of standard reference material NIST1633b (coal fly ash) and one of NIST688 (basalt) were included for direct comparison with the samples, allowing the conversion of any sample's γ-radiation emission activity to elemental concentrations (ppm). Single replicates of NIST1633b (coal fly ash) and New Ohio Red Clay (NORC) were also included as standards to assess the accuracy and precision of results.

A total of 29 of the 34 elements for which concentrations (ppm) were detected were used in the subsequent analysis. Potassium (K) was omitted due to a high percentage difference (−10.3%) between the detected concentration of the standard samples and the known concentration. In addition, Sr, Gd, Br and Ni were excluded because at least one sample yielded no result for one or more of those elements. With only 22 samples, it was judged better to omit the elements rather than the samples.

Two methods of standardization and multiple statistical approaches were used to analyse the elemental concentrations. Logarithms ($\log_{10}$) are a common method of standardizing data from INAA (e.g., Arnold *et al*. 1991; Neff 2002, 16–17; Glascock *et al*. 2004), where average concentrations for individual elements may range from 0.1 to $>$ 100 000 ppm. Average-group linkage cluster analysis is often used to differentiate compositional groups (e.g., Quinn *et al*. 2010; also Neff 2002, 21–28), and principal component analysis (PCA) is another frequent tool for identifying compositionally similar groups (Neff 2002, 19–21; Glascock *et al*. 2004). Neff (2002) recommends exploring compositional data through varied avenues, whereby repeated replication of the same results with different approaches solidifies the likely real-world existence of such groups. Therefore, we also employed cluster analysis using Ward's method, which creates the most homogenous groups possible and is thus useful in trace element analysis (Shennan 1997, 241–245). Finally, in addition to $\log_{10}$ data, we standardized each element to its mean, as recommended by Walsh (2017, 47–48), whereby each element is placed on the same scale.

RESULTS

Typological and colour analysis

On Early Baekje sites, 89.4% of all BBP examples were found at three sites: Pungnab fortress (79.3%), the settlement of Seoku-ri (6.1%) and Mongchon fortress (4.5%). Furthermore, these three sites had relatively high proportions of their ceramic assemblage made up by BBP, as did Myeokjeolsan fortress, Juweol-ri and the probable BBP production site of Sohadong, where BBP was found in both kilns and houses/workshops (Fig 2, b).

Among BBP serving vessels, bowls and lidded bowls predominated, while straight short-necked jars were most common overall (other than lids) (Table 1 and Fig. 1, c) (also noted by Lee 2001). Vessel types differed between the Pungnab–Mongchon complex and those sites elsewhere in the study area (Table 1). Bowls and straight short-necked jars were roughly balanced at the former, whereas jars predominated in the wider region.

Sherd colour data were available for Pungnab fortress (one only for Mongchon fortress) and 12 sites outside of the Pungnab–Mongchon area. Surface colours were classified into two categories: (1) black or dark grey and (2) lighter grey or any other colour, and were aggregated to compare Pungnab–Mongchon with the 12 other sites. Chi-squared tests revealed a near significant interaction between colour and region for outer surface (d.f. 1, $n = 235$, Chi = 2.881, $p = 0.090$), and no difference among inner surface colours (d.f. 1, $n = 224$, Chi = 1.547, $p = 0.214$). In other words, outer surface colours differ somewhat between Pungnab and sites in the wider region. In the wider region, BBP sherds were almost exclusively black or dark grey, whereas a significant proportion of examples from Pungnab were grey (in Munsell's terms).

Core colours indicating possible reduction firing (black or fully grey section colours) showed no significant difference between Pungnab and regional sites (d.f. 1, $n = 222$, Chi = 2.254, $p =$

Table 1 *Forms and types of black burnished pottery (BBP) found on Early Baekje sites within the study area (250–475* CE*); lids are included for reference*

Vessel type	*Pungnab and Mongchon fortresses (*n *= 205)*	*Other sites (*n *= 41)*
Footed bowl	7 (3.4%)	1 (2.4%)
Tripod bowl/plate	9 (4.4%)	1 (2.4%)
Plate	11 (5.4%)	1 (2.4%)
Bowl, lidded	34 (16.6%)	1 (2.4%)
Pot stand	3 (1.5%)	–
Jars	43 (21.0%)	21 (51.2%)
Lid	98 (47.8%)	17 (41.5%)

0.133). Just over half the sherds were possibly reduction fired, while 20.3% of sherds had black or dark grey cores, where reduction firing can be more securely assumed.

However, there was a significant interaction between region and the likely use of smudging techniques (d.f. 1, $n = 221$, Chi = 4.803, $p = 0.028$), where sherds with black or dark grey exterior surface(s) and grey or lighter core colours offer evidence of smudging. Smudging appears more common for vessels outside of Pungnab.

Ceramic petrography

Four broad ceramic fabrics were identified petrographically. Three of the fabrics could each be split into two or three subgroups: differing porosity; the presence of naturally occurring ferruginous flecks; or as evidence clay mixing underlie these subgroupings (for all photomicrographs, see Blackmore 2020).

Very fine fabric: (i) PN3, PN7; (ii) JW2, JW3; and (iii) GR4, GR5 A very fine paste with no or very rare small to medium-sized inclusions of quartz/recrystallized quartz characterize this fabric. Three subgroups are identified: the first (i) shows firing in a fully reduced atmosphere (Fig. 3, a); the second (i) is porous, showing evidence of clay mixing and firing in an incompletely oxidizing atmosphere (Fig. 3, b); and the third (iii) is porous and was fired in an oxidizing atmosphere, with one sample showing evidence of the plant ash coating discussed above (Fig. 3, c).

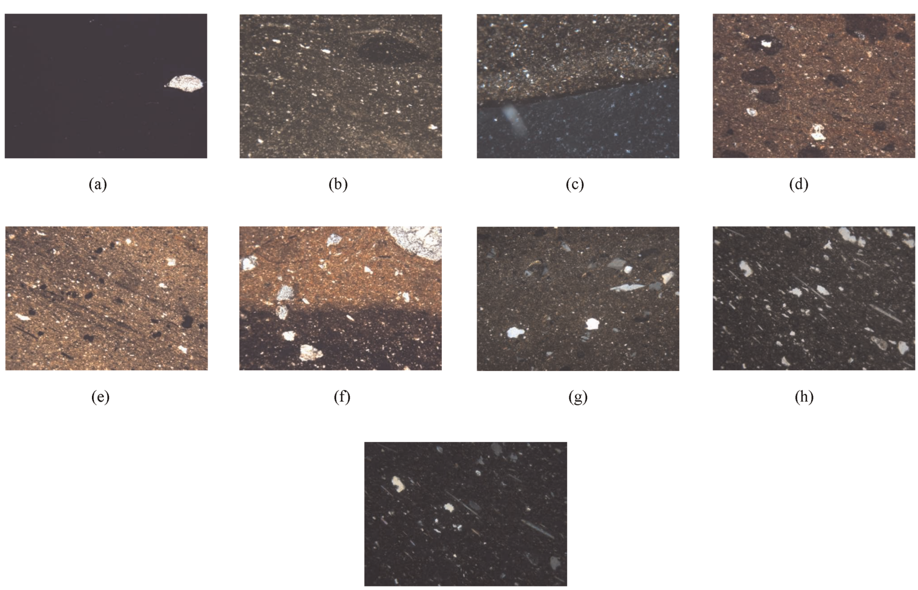

Figure 3 *(a) Very fine fabric, subgroup i—PN7 (plain polarized light (PPL) ×40 magnification); (b) very fine fabric, subgroup ii—JW3 (PPL ×40 magnification); (c) possible plant-ash surface coating—GR5 (cross-polarized light (XP) ×40 magnification); (d) fine fabric with clay pellets—PN1 (PPL ×40 magnification); (e) streaks from clay mixing—PN5 (PPL ×40 magnification); (f) medium to fine gneiss-type fabric, subgroup ii—PN4 (PPL ×40 magnification); (g) medium to fine gneiss-type fabric, subgroup ii—GR1 (XP ×40 magnification); (h) fine mica-rich fabric—GR6 (PPL ×40 magnification); and (i) fine mica-rich fabric—GR6 (XP ×40 magnification). [Colour figure can be viewed at wileyonlinelibrary.com]*

Samples vary in the optical activity of their matrixes; some are weakly active while others are optically inactive. The former were therefore likely fired at < 850°C, while the latter fired at > 850°C (on the relationship between birefringence, i.e., optical activity and firing temperatures, see Quinn 2013, 190–901). Subgroups (ii) and (iii) each have examples of both.

Fine fabric with clay pellets: (i) PN1, PN2, PN5, PN8, MS1; and (ii) MJ1 This group is characterized by a light brown-red matrix that contains relatively abundant small to medium-sized rounded clay pellets. Colour difference indicates these pellets are of a different composition from the matrix (Fig. 3, d). The rounded nature of the clay pellets suggests they are natural occurrences rather than intentionally added as temper (Quinn 2013, 168–171). In all cases there is also a rock component made up of uncommon small to medium-sized subangular quartz/recrystallized grains. Both quartz and clay pellet inclusion types are poorly sorted. Their origin may be from clay mixing, evidenced by clearly visible streaks of clay with a different composition (Fig. 3, e).

The fabric with clay pellets may be divided into two subgroups based on the presence of what appears to be ferruginous material (black flecks in Fig. 3, e). This material is present in subgroup (i) and absent in subgroup (ii). In subgroup (i), a majority of these flecks align with the pots' surface, and thus may be taken as evidence of wheel use during manufacture.

The brown-red matrix indicates firing in an oxidizing atmosphere. Weak to moderate optical activity in the matrix indicates firing at < 850°C.

Medium to fine gneiss-type fabric: (i) PN6, MC2, MC3, MS2, GR1, GR2; and (ii) PN4, PN9, MC1 This fabric is characterized by relatively abundant small to medium-sized inclusions derived from metamorphic rock (Fig. 3, f), most likely gneiss due to the situation of the settlements on the Gyeonggi gneiss complex (for an overview of geology, see Lee 1988). Abundant, poorly sorted angular or subangular small to medium-sized quartz/recrystallized quartz accompany rare elongate subangular biotite mica grains. Rare small, medium or large-sized fragments of metamorphic rock (gneiss) are also present. A moderate abundance of small to medium-sized pores is common.

The angularity and bimodal distribution of the rock-derived inclusions suggests that larger grains were introduced to a paste that had already been filtered or levigated. Introduction may be via addition of temper or through clay mixing, the latter of which characterizes subgroup (ii) (Fig. 3, g). Clay mixing is identified via visible streaks of clay with a different composition. Poorly sorted medium-sized clay pellets are also visible. As with the fabric described above, their irregular shapes suggest these nodules are the result of mixing rather than natural occurrences.

The majority of samples have a red-brown or lighter grey-coloured matrix, indicating firing in an oxidizing atmosphere. However, a third of cases were reduced fired. The optical activity of samples' matrixes also varies. As with other fabrics, therefore, firing temperatures appear variable within the group, some > 850°C and others at or below this temperature.

Fine mica-rich fabric: GR6 This fabric is characterized by moderately abundant evenly sorted small inclusions of muscovite mica and relatively rarer biotite mica (Fig. 3, h, j). These inclusions are characteristically elongate and subangular rounded on the edges. Their origin is therefore likely natural, derived from the schists that characterize the geology of the south-western part of the study area (Lee 1988). Rare, small, equant, subrounded quartz/recrystallized quartz inclusions are also present. The matrix is slightly porous, with pores of small to medium size. The very dark brown-red to black matrix suggests the pot was fired in a reducing atmosphere. The matrix remains very weakly optically active, so firing temperature was likely at ≤ 850°C.

INAA

Four cluster analyses were carried out in total, revealing four broadly consistent chemical composition groups; squared Euclidian distance was used as the distance measure because it gives greater weight to elements with high variance (Neff 2002, 21–28). Particular regional and site associations can be identified in each case (Fig. 4, a). Although certain individual members of each group vary, there is a high degree of overlap and regularity among the analyses. Groups 1 and 2 are strongly associated with settlements situated on or north of the Han River, with group 2 consistently dominated by pottery from the Pungnab–Mongchon complex. Group 3 always contained the same four samples from Gorimdong, even when other group members varied. These four samples cluster together tightly even when nested within a broader group (Fig. 4, a). The only group that has consistent membership across all analyses is group 4; considering the presence of the mica-rich fabric in this group it is likely associated with a location in the south/south-west of the study area, away from the Han River basin. Sample PN5 was left ungrouped because it was consistently distinct from all other samples (Fig. 4, a).

PCA carried out on the $\log_{10}$ elemental data reduced to main three axes that cumulatively account for 67.6% of the variation within the data set; factors 1–3 account for 37.3%, 17.8% and 12.5% of that variation, respectively. Factors have significant correlations with particular

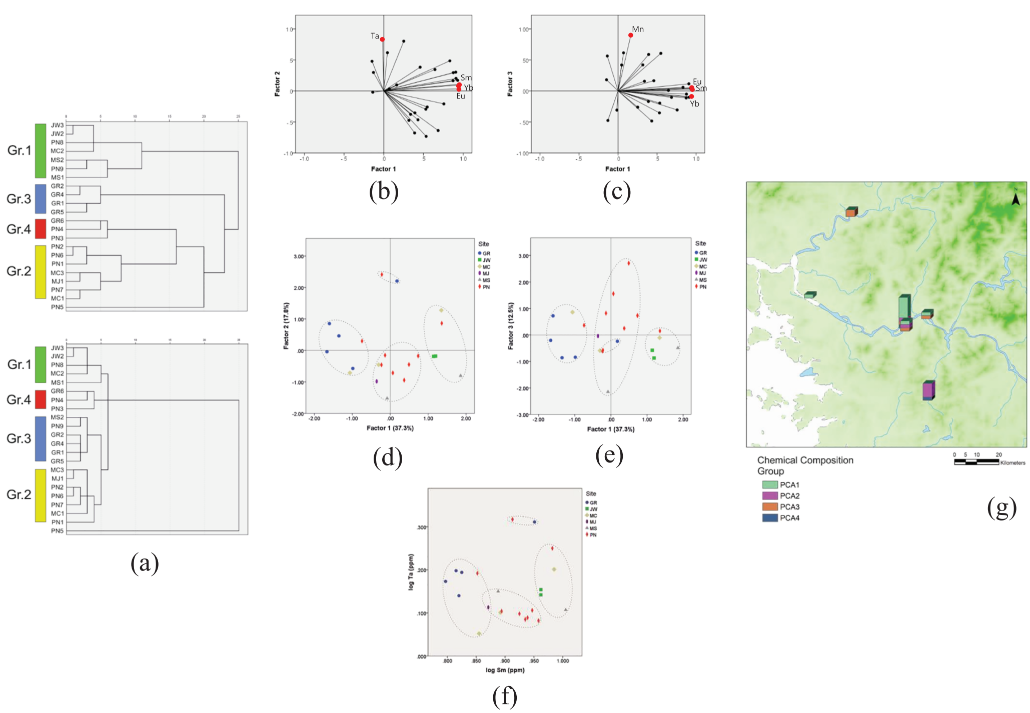

Figure 4 *(a) Two results of cluster analysis on the elemental concentration data: (above) Ward's method on $\log_{10}$data; and (below) average-linkage method on data standardized to elemental means; (b) loading plot of principal component analysis (PCA) factors 1 and 2; (c) loading plot of PCA factors 1 and 3; (d) plot of PCA factors 1 and 2 (suggested chemical groups are circled); (e) plot of PCA factors 1 and 3 (suggested chemical groups are circled); (f) plot showing $\log_{10}$concentrations (ppm) of Sm and Ta (circles represent the suggested PCA groups); and (g) distribution of black burnished pottery (BBP) samples' chemical groups. [Colour figure can be viewed at wileyonlinelibrary.com]*

Table 2 *Collated information on each sample's technical style, including principal component analysis (PCA) groups, cluster analysis group, petrographic fabric and firing strategy*

PCA group	*Sample*	*Cluster analysis group(s)*	*Petrographic group*	*Firing temperature*	*Firing atmosphere*
1	PN1	2	Clay pellets	Lower	Oxidizing
	PN2	2	Clay pellets	Lower	Oxidizing
	PN5	–	Clay pellets	Lower	Oxidizing
	PN6	2	Gneiss type	Lower	Reducing
	PN9	3/1	Gneiss type	Higher	Oxidizing
	PN8	1	Clay pellets	Lower	Reducing
	MJ1	2/3	Clay pellets	Lower	Oxidizing
	MC3	2/3	Gneiss type	Lower	Oxidizing
	MS2	3/1	Gneiss type	Lower	Oxidizing
2	GR1	3	Gneiss type	Higher	Oxidizing
	GR2	3	Gneiss type	Higher	Oxidizing
	GR4	3	Very fine	Lower	Oxidizing
	GR5	3	Very fine	Lower	Oxidizing
	PN7	2	Very fine	Higher	Reducing
	MC1	2	Gneiss type	Higher	Oxidizing
3	JW2	1	Very fine	Higher	Reducing
	JW3	1	Very fine	Lower	Reducing
	MS1	1	Clay pellets	Lower	Oxidizing
	PN3	4	Very fine	Higher	Reducing
	MC2	1	Gneiss type	Higher	Reducing
4	GR6	4	Mica rich	Higher	Reducing
	PN4	4	Gneiss type	Higher	Reducing

elements (Fig. 4, b, c), primarily reflecting variance within those particular elements. Elements with the strongest correlations to each factor have concentrations < 200 ppm, and thus may be considered trace elements. Trace elements in clays are effectively accidental, and so provide the best information for provenance studies (Glascock *et al*. 2004, 96), boding well for the significance of our results. PCA on the elements standardized to their means gave virtually identical results, with three axes accounting for 67.2% of the variation and identical sample groupings.

Four broad groups were identified, although certain groups become more or less obvious depending on which PCA factors are examined (Fig. 4, d, e). Groups were defined by eye, using the plots provided. These groups broadly concur with those obtained through the cluster analyses, particularly PCA groups 2–4 (Table 2). Overlap is not full; however, both analyses indicate the presence of four chemical groups, one biased towards Gorimdong, one biased towards Pungnab–Mongchon, and one including sites on the Han River outside of the central complex. Cluster groups and PCA groups each also show heterogeneity in terms of manufacturing practices.

DISCUSSION

Local technical styles or local consumption preferences?

Typological and vessel/sherd colour data both highlight some distinction between BBP from the Pungnab–Mongchon complex and that from settlements throughout the wider study region.

Differences in social practice, production methods and/or distribution processes are thus evident. At Pungnab–Mongchon serving vessels were in relative abundance alongside jars, whereas jars predominated elsewhere (Table 1). Differences in social practice and the social meaning carried by BBP were therefore likely to have existed between the central fortresses and other settlements. Contextual studies of BBP use-contexts are necessary to tease out what this difference means.

The lack of significant difference in core colours between Pungnab–Mongchon and the wider region points to firing atmospheres having been relatively consistent throughout the study area. Almost half the sherds had lighter core colours, so, contrary to suggestions that BBP was typically fired in a reducing atmosphere (e.g., Lee 2001; Kim *et al*. 2016, 132), much was likely fired in an oxidizing atmosphere (see also Nam and Kim 2014).

Probable differences in vessel outer surface colours likely derive from different surface treatments, where smudging was more commonly used on vessels found outside of Pungnab–Mongchon. Darker surface colours were preferred by people who lived in the wider region. Either consumer preferences were different or the authorities at Pungnab–Mongchon were sending only very particular items to regional leaders/allies.

Unequivocal conclusions about the nature of BBP production in Early Baekje cannot be made through an analysis of vessel forms or vessel colours alone, although the available data *do* constrain possible or plausible scenarios. It is certainly possible that production was distributed throughout the study area, with different forms or surface colours having different local significances. Alternatively, centrally organized patronage of production units remains plausible, whereby particular consumer expectations and preferences for certain forms, styles and colours framed the patterns discussed above. In the latter case, regional sites appear unlikely to have been fully subordinate to the leadership of the main fortresses. Regional actors or authorities selected the types they wanted, or the central authorities had to distribute what regional actors preferred rather than gifting standardized items.

Diverse raw sources

Petrographic and compositional analyses strongly suggest that the first of the two scenarios outlined above is more likely. Four broadly consistent chemical groups were identified via multiple statistical approaches, indicating that four distinct sources were used to make the BBP assemblage sampled here. These chemical groups have obvious biases towards particular sites or regions of the study area (Table 2). One group is primarily made up of BBP sherds from Pungnab–Mongchon (PCA group 1, cluster group 2), that is, the centre of Early Baekje communal activity. Another consistently associates four of the five samples from Gorimdong, in the southern part of the study region (PCA group 2, cluster group 3). A third encompasses various sites on or north of the Han River, up to Juweol-ri in the north (PCA group 3, cluster group 1). The fourth group is small and includes sherds from both the centre and Yongin (PCA group 4, cluster group 4); however, as noted, this group includes the mica-rich fabric, probably derived from geology to the south/south-west of the study area.

Plotting the concentrations of elements highly correlated with particular PCA factors (Fig. 4, f) further highlights the presence of multiple source groups. In particular, the difference between the chemistry of BBP at Pungnab and Gorimdong becomes more obvious. Sherds from the latter consistently had lower samarium (Sm), manganese (Mn), europium (Eu) and ytterbium (Yb) concentrations relative to the bulk of those from Pungnab. The group associated with primarily non-Pungnab sites on or north of the Han River has a notably higher Sm concentration than others (Fig. 4, f). Finally, the two examples making up PCA group 4 are characterized primarily via their high concentrations of tantalum (Ta) relative to the rest of the assemblage (Fig. 4, f).

The ability to create discernible and broadly consistent groups demonstrates that compositional analyses have utility for ceramic studies in this region of Korea. Other scholars have expressed some scepticism regarding the resolution of compositional analyses due to the geological and pedological homogeneity of the study area (e.g., Cho 2006; Kim and Kwon 2008). However, this study tentatively indicates that techniques such as INAA can be effective here, offering information on likely source groups and their associations with particular past settlements or geographical areas. Further work with a larger range of ceramic samples from different social contexts would be required to test the resolution and limits of such approaches in this region.

Although the existence of multiple sources can be inferred, the data do not allow us to pinpoint exact locations of production. While chemical groups primarily give information on the geological context of the clay(s) from which a pot was made (Arnold 2000), what that 'source' exactly was may be highly variable. 'Source' may refer to anything from a single clay pit, a widespread clay stratum or all clays in a particular drainage basin (Arnold *et al*. 1991, 70, 87; Bishop and Blackman 2002, 604). Without further work examining production sites and sampling possible raw clay sources it is not possible to identify the precise geographical areas where particular sources were located (Tite 1999).

Even though precise locations cannot be identified, we can conclude that multiple communities were producing BBP, and that they were likely situated in disparate geographical locations. Each source identified here could have been used by a single or multiple communities. Without more direct evidence it is not possible to know the spatial relationships among the various sources and the sampled sites; artisans may have been located nearby to the sampled settlements, at a farther distance, or present within specific other settlements. As Arnold (2000, 368) has noted, pots can often travel much further than clays, and ceramic paste compositions alone do not necessarily give strong information on the distribution of finished vessels, distribution being much more dependent on socio-political relationships. The study area is not particularly large and is characterized by traversable rivers and valleys; thus, any production centres need not have been in close physical proximity to the settlements where their products ended up.

Heterogeneous-making practices

In addition to diverse loci of production, the techniques and technologies used to make BBP were also heterogeneous, varying *within* sources. There is no consistent association between any particular paste recipe (i.e., petrographic fabric) and the identified chemical groups (Table 2). At each source, a range of techniques were used: some artisans added temper, while others likely used levigation to produce very fine pastes. Even within broad paste recipes, heterogeneity in manufacturing techniques is evident, with subgroups differing in porosity, firing conditions or clay mixing.

Specific paste recipes and tempering practices are therefore unlikely to be significantly affecting compositional groupings. An exception is the clay pellet fabric, which almost exclusively occurs in PCA group 1 (with one exception) and shows a relative consistency in firing atmosphere and temperature (Table 2). Four of six samples from this fabric group are from Pungnab fortress, and the other two sites are also located on the Han River (Fig. 4, g).

In fact, this group appears to represent a major supply source for the Pungnab–Mongchon complex. PCA group 1 is exclusively made up of BBP samples recovered from sites on the Han River, and 75% are from Pungnab–Mongchon. The artisans working with clay from this source either had an exclusive relationship with the leaders at Pungnab (with BBP vessels being regifted to contacts along the river) or, due to more intense consumption, simply came to supply Pungnab–Mongchon residents more frequently over time. Either way, the production site was most likely near Pungnab fortress. Leaders within Pungnab–Mongchon may therefore have had a degree of control over the production and distribution of vessels made from this clay source.

A certain consistency in firing techniques also broadly characterizes the identified chemical groups (Table 2), likely derived from differences in local traditions or practice. For example, the majority of PCA group 1 sherds were fired at < 850°C in an oxidizing atmosphere. For PCA group 2, an oxidizing atmosphere was generally used, but the firing temperatures varied. Examples from PCA group 3 also show varied firing temperatures, but they tend towards reducing atmospheres; and group 4 was fired in a reducing atmosphere at > 850°C. Cluster analysis groups show an analogous pattern, although certain group members do vary. Firing conditions may affect the concentrations of volatile elements within a ceramic (Minc and Sterba 2017); however, this effect only significantly relates to bromine (Br) (Cogswell *et al*. 1996), and firing conditions have significantly less impact on elemental concentrations than other technical aspects such as tempering (Sterba *et al*. 2009). Because none of the key elements identified by the above PCA is volatile, variation in firing technology probably did not influence the delineation of chemical groups. In other words, potters using each different source also had particular traditions or preferences regarding firing technologies.

Artisans working with each of the clay sources identified here therefore had their own particular traditions and technological preferences when making BBP, distinct from those using other clay sources. Yet, in certain aspects, such as paste recipes, there was further local diversity. How far this diversity may be due to the presence of multiple artisans using the same source clays but different techniques, or to drift in local paste recipes through time, is hard to say. Migration and population movement is hard to identify, but regional exchange, and therefore movement of people, does appear to have been relatively dynamic.

Decentralized production

BBP-making practices do indeed appear to have been localized and geared towards local concerns and preferences. The stylistic analysis above noted distinction between Pungnab–Mongchon and other settlements in terms of BBP surface treatments and preferred vessel forms. The scenario that these differences derive from preferential central redistribution of certain BBP styles appears highly unlikely in light of the compositional analyses, particularly regarding the distinctive chemical signatures at Gorimdong (and Juweol-ri to a less obvious extent).

The artisans working at any source may have been specialist potters, but evidence from the production site of Sohadong (Fig. 2, b) indicates that communities producing BBP had a wide repertoire of forms and wares. The excavations at Sohadong revealed six domestic or workshop structures and one kiln situated on a low hill less than 2 km from a major tributary of the Han River. BBP was found in both workshops and the kiln. Also, within the kiln were pieces of grey serving and storage vessels. BBP was thus just one type of ceramic among many that Early Baekje artisans manufactured. Sohadong may not be representative of all BBP production, but at least some production was smaller in scale and possibly expedient, made when needed, alongside other types.

Park's (2001) hypothesis that BBP production fell under the direction of the Early Baekje state is therefore implausible. We do not dismiss the centrality of the Pungnab–Mongchon complex, as the bulk of BBP was concentrated here; the importance of BBP would have been heavily mediated through its meaning and use at that political centre. However, the significance of BBP came in terms of emulation and its role in facilitating certain actors' participation in social networks or communities of practice. The centrality of Pungnab–Mongchon to BBP's importance in socio-political relations should not be conflated with central control over, or manipulation of, the distribution of this ware to actors throughout the study area.

With a good degree of confidence, we can say that the organization of Early Baekje BBP production was decentralized in nature. Still, individual artisans or communities that ultimately produced BBP appear to have been in preferential relationships with political authorities in particular settlements; most obviously seen in the cases of PCA group 1 (Pungnab fortress) and PCA group 2 (Gorimdong village). In both cases, and at other settlements, the consumers of BBP were primarily those engaging in public ceremony and/or feasting, where BBP appears alongside other types of Baekje pottery. Yet, details of the relationships remain obscure without further research.

Other evidence supports a model of decentralized production for Baekje pottery in general. People living in various sizes of settlement often obtained ceramics made in multiple source communities (Cho 2006; Walsh 2017), and the large Early Baekje village of Weoncheon-ri, outside the study area (to the east), shows geochemical evidence for the localized production of 'prestige' Baekje pottery styles (Cho 2013). As Costin (1991, 2005) has discussed, the sizes of production loci, their distributions in space and the social relations associated with production activity are reflective of the organization of past production. Evidence presented here and by others highlights a strong tendency towards localized/decentralized production organization for ceramics during the Early Baekje period.

Regional exchange appears to have been quite dynamic and possibly crucial to the political economy and reproduction of authority. BBP made at each source was not only preferentially distributed to people at particular settlements (or made at those settlements), but also distributed widely to other settlements (with certain regional biases). Walsh (2017) found that while the bulk of high fired greyware produced at a site around 80 km south of Pungnab fortress was concentrated at that fortress, it was also distributed widely throughout the Early Baekje region, even on smaller hamlets (see also Walsh *et al*. 2019). It remains difficult to tell the precise nature of exchange, however; producers may have been directly dealing with multiple actors on multiple sites (or shifting in relationships through time), or supplying consumers at particular settlements who subsequently engaged in further exchange relationships.

Both scenarios are plausible, and in both cases exchange relationships and the items mediating those relationships were highly significant. Procuring certain items from, and maintaining relationships with, more distant places may also have played a role in the political economy (Walsh 2017; Walsh *et al*. 2019). Relationships forged by BBP exchange or procurement were highly socially significant and did not simply flow one way. Black burnished vessels from multiple sources were brought to the Early Baekje political centre at Pungnab–Mongchon, as well as possibly being distributed out from there to other sites along the Han River. BBP vessels were also curated, with examples of cracked vessels being repaired (Fig. 1, d). Such curation may have been due to the difficulty of obtaining replacements, or because the life histories of the vessels, and the (real or fictive) relationships they represented, were socially significant. In both cases the relationships involved in the manufacture and/or procurement of BBP were valued.

That BBP and other elite wares were produced by multiple artisans in multiple locations prompts the need for a reconsideration of Baekje formation processes and its early socio-political organization. Rather than being recipients of central patronage, local artisans and leaders were active participants in the manufacture and exchange of prestige products. Even if the Baekje centre were in full control of these production nodes, the manufacturing process was primarily guided by local needs and preferences, not central ones.

Regional communities may therefore not have been wholly subservient to some central Baekje authority, but instead held significant autonomy, making or procuring BBP (and other wares) in order to participate in feasting at Pungnab fortress (after Kim *et al*. 2016) and locally. Baekje's power may have come through its access to international trade routes (Kwon 2008, 78–80), but that alone would not account for the centre having full authority over the hinterlands; rather, local people of authority would be attracted to Pungnab fortress, offering tribute or participating in social exchange. Baekje thus likely emerged as a distributed network, mediated by activities at Pungnab–Mongchon, but not necessarily under centralized control, at least during the earliest phases. The possibility that such bottom-up processes were important factors in Baekje's emergence needs to be explored further in future work. This study thus also underlines the importance of modelling and understanding issues of production and exchange when investigating early polity formation and structure; process cannot be assumed to follow theoretical social evolutionary sequences unless supported by detailed investigation.

PEER REVIEW

The peer review history for this article is available at https://publons.com/publon/10.1111/arcm.12632.

[Correction added on 11 December 2020, after first online publication: URL for peer review history has been corrected.]

REFERENCES

Arnold, D. E., 1985, *Ceramic theory and cultural process*, Cambridge University Press, Cambridge.

Arnold, D. E., 1993, *Ecology and ceramic production in an Andean community*, Cambridge University Press, Cambridge.

Arnold, D. E., 2000, Does the standardization of ceramic pastes really mean specialization? *Journal of Archaeological Method and Theory*, **7**(4), 333–75.

Arnold, D. E., Neff, H., and Bishop, R. L., 1991, Compositional analysis and 'sources' of pottery: An Ethnoarchaeological approach, *American Anthropologist*, **93**, 70–90.

Barnes, G. L., 2001, *State formation in Korea: Historical and archaeological perspectives*, Curzon, Richmond.

Bishop, R. L., and Blackman, M. J., 2002, Instrumental neutron activation analysis of archaeological ceramics: Scale and interpretation, *Accounts of Chemical Research*, **35**(8), 603–10.

Blackmore, H., 2020, Worlds of authority, communities of practice*,* And state formation in early 1st millennium Central Korea, PhD Thesis, University of Cambridge.

Cho, D., 2006, Crafting the state: Analytical approaches to ceramic technology and exchange from the bronze age to Paekche periods in Korea, PhD Thesis, University of Sheffield.

Cho, D., 2013, Scientific analysis of ceramics excavated from the Weoncheon-ri site, Hwacheon, in *Hwacheon Weoncheon-ri site* (ed. Yemaek cultural research institute), 222–33, Yemaek Cultural Research Institute, Chuncheon.

Choi, J., 2008, The development of the Pottery Technologies of the Korean Peninsula and their relationship to neighboring regions, in *Early Korea: Reconsidering early Korean history through archaeology* (ed. M. Byington), 157–98- Early Korea Project, Korea Institute, Harvard University, Seoul.

Costin, C. L., 1991, Craft specialization: Issues in defining, documenting, and explaining the Organization of Production, *Archaeological Method and Theory*, **3**, 1–56.

Costin, C. L., 2005, Craft production, in *Handbook of archaeological methods* (eds. H. D. G. Maschner and C. Chippindale), 1034–107, AltaMira, Oxford.

Cogswell, J. W., Neff, H., and Glascock, M. D., 1996, The Effect of Firing Temperature on the Elemental Characterization of Pottery, *Journal of Archaeological Science*, **23**, 283–7.

DeMarrais, E., 2013, Understanding Heterarchy: Crafting and social projects in pre-Hispanic Northwest Argentina, *Cambridge Archaeological Journal*, **23**(3), 345–62.

DeMarrais, E., and Earle, T., 2017, Collective action theory and the dynamics of complex societies, *Annual Review of Anthropology*, **46**, 183–201.

Glascock, M. D., Neff, H., and Vaughn, K. J., 2004, Instrumental neutron activation analysis and multivariate statistics for pottery provenance, *Hyperfine Interactions*, **154**, 95–105.

Kim, J., and Kwon, O.-Y., 2008, Analysis of the distribution of pottery forms in the Hanseong period, in *Political and social implications of the development and expansion of the Baekje production and distribution system* (ed. Hanshin University academy), 99–144, Hanshin University Press, Seoul.

Kim, M., Shin, H.-N., Kim, J., Roh, K.-j., Ryu, A., Won, H., Kim, J., Oh, S., Noh, H., and Kim, S., 2016, The ins and the outs: Foodways, feasts, and social differentiation in the Baekje kingdom, Korea, *Journal of Anthropological Archaeology*, **43**, 128–39.

Kim, S., Han, M. S., Nam, S. W., and Jang, S., 2017, Manufacturing characteristics of black burnished pottery from Pungnaptoseong, Baekje, *Journal of Conservation Science*, **33**, 417–29.

Kwon, O. Y., 2008, The influence of recent archaeological discoveries on the research of Paekche history, in *Early Korea: Reconsidering early Korean history through archaeology* (ed. M. Byington), 65–112Early Korea Project, Korea Institute, Harvard University, Seoul.

Kwon, O.-Y., Kwon, D., and Han, J., 2004, *Pungnab earthen fortress IV*, Hanshin University Museum, Osan.

Lee, N.-s., 2001, An examination of black burnished pots in Baekje dynasty, *Prehistory and Antiquity*, **16**, 177–99.

Lee, D.-S., 1988, *Geology of Korea*, 2nd edn, geological Society of Korea, Seoul.

Lee, N., Kwon, O.-Y., Lee, K., Lee, M., Shin, S., and Han, J., 2003, *Pungnab earthen fortress III*, Hanshin University Museum, Osan.

Minc, L. D., and Sterba, J. H., 2017, Instrumental neutron activation analysis (INAA) in the study of archaeological ceramics, in *The Oxford handbook of archaeological ceramic analysis* (ed. A. M. W. Hunt), 424–46, Oxford University Press, Oxford.

Nam, S., and Kim, S., 2014, Research on the production Technology of Black-Burnished Pottery in Baekje period from the perspective of experimental archaeology, *The Baekje Hakbo*, **12**, 5–34.

National Research Institute of Cultural Heritage (NRICH), 2007, *Pungnab earthen fortress VIII*, NRICH, Daejeon.

National Research Institute of Cultural Heritage (NRICH), 2012, *Pungnab earthen fortress XIV*, NRICH, Daejeon.

Neff, H., 2002, Quantitative techniques for analyzing ceramic compositional data, in *Ceramic production and circulation in the greater southwest: Source determination by INAA and complimentary mineralogical investigation* (eds. D. M. Glowacki and H. Neff), 15–36, The Cotsen Institute of Archaeology, University of California, Los Angeles.

Pai, H. I., 2000, *Constructing 'Korean' origins: A critical review of archaeology, historiography, and racial myth in Korean state-formation theories*, Harvard University Asia Center, Cambridge, Mass.

Park, S.-b., 1992, The formation process of Baekje pottery, *Baekje Research*, **23**, 21–64.

Park, S.-b., 2001, *A study of the state formation of Paekche*, Seogyeong Munhwasa, Seoul.

Park, S.-b., 2007, Some pattern of early Baekche's local cemetery continuation in view of localization of periphery by political center, *The Journal of Korean Ancient History*, **48**, 155–86.

Quinn, P. S., 2013, *Ceramic petrography: The interpretation of Archaeological Pottery & Related Artefacts in thin section*, Archaeopress, Oxford.

Quinn, P., Day, P., Kilikoglou, V., Faber, E., Katsarou-Tzeveleki, S., and Sampson, A., 2010, Keeping an eye on your pots: The provenance of Neolithic ceramics from the cave of the cyclops, Youra, Greece, *Journal of Archaeological Science*, **37**, 1042–52.

Rice, P. M., 2015, *Pottery analysis: A sourcebook*, 2nd edn, University of Chicago Press, Chicago/London.

Park, S.-b., 2010, *Capital cities of Baekje*, Chungnam University Press, Daejeon.

Shennan, S., 1997, *Quantifying archaeology*, 2nd edn, Edinburgh University Press, Edinburgh.

Sterba, J. H., Mommsen, H., Steinhauser, G., and Bichler, M., 2009, The influence of different tempers on the composition of pottery, *Journal of Archaeological Science*, **36**, 1582–9.

Tite, M. S., 1999, Pottery production, distribution, and consumption – The contribution of the physical sciences, *Journal of Archaeological Method and Theory*, **6**(3), 181–233.

Walsh, R., 2017, Ceramic specialization and exchange in complex societies: A compositional analysis of pottery from Mahan and Baekje in southwestern Korea, PhD Thesis, University of Oregon.

Walsh, R., Lee, G.-A., and Lee, Y.-C., 2019, Ceramics and Society in Mahan and Paekche: A comparison of pottery geochemistry and craft production patterns at the sites of P'ungnap T'osŏng and Kwangju Palsan, *Asian Perspectives*, **58**(1), 149–79.
Yi, S., and Cho, G., 2015, *Seokchondong mound tombs III*, Seoul National University Museum, Seoul.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Data S1. BBP Contexts and Surface Colours

Data S2. BBP INAA data_ppm