Preclassic ceramic economy in Belize: neutron activation analysis at Cahal Pech

Claire E. Ebert[1,*], Daniel E. Pierce[2] & Jaime J. Awe[1]

This study uses neutron activation analysis of ceramics to examine economic change and increasing social complexity at the Preclassic Maya site of Cahal Pech in Belize (1200 cal BC–cal AD 300). Seven compositional groups were identified from the site's civic-ceremonial centre and two peripheral residential groups. Analyses indicate that both utilitarian and non-utilitarian ceramics were locally produced as early as 1200 cal BC, and that by c. *700 cal BC, fineware vessels were being exported into neighbouring parts of Guatemala. These results provide direct evidence for economic interaction between Maya lowland communities and for their increasing socio-political complexity.*

Keywords: Preclassic Maya, neutron activation analysis, ceramic economy, craft production, exchange

Introduction

Archaeological studies have long focused on understanding the dynamics of prehistoric economies, as the production, distribution and consumption of resources are embedded within larger social and political processes. Geochemical analyses of ceramics have been applied widely across the world to understand how these processes affected the earliest ceramic economies. In Mesoamerica, studies have focused on regional patterns of production and exchange of decorated ceramics and their implications for the development of the first complex Mesoamerican societies (e.g. Neff & Glascock 2002; Blomster *et al.* 2005; Neff *et al.* 2006; Callaghan *et al.* 2018).

Among various analytical approaches, neutron activation analysis (NAA) has become the primary method for sourcing archaeological ceramics because of straightforward sample

[1] *Department of Anthropology, Northern Arizona University, 5 East McConnell Drive, Flagstaff, AZ 86011-5200, USA*

[2] *Archaeometry Laboratory, University of Missouri Research Reactor, 1513 Research Park Drive, Columbia, MO 65211, USA*

[*] *Author for correspondence (Email: claire.ebert@nau.edu)*

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preparation, high analytical precision and multi-element analytical capacity (Bishop 2014; Minc & Sterba 2016). The results of NAA reflect the elemental composition of ceramic pastes, with distinct groups of ceramics determined by common trace elements (Harbottle 1976; Bishop & Neff 1989; Glascock 1992; Neff 2000). The production locale of ceramics (and their pastes) can then often be linked to specific geographic locations based on raw material types and the frequency of ceramic samples within a particular community (i.e. criterion of abundance; Weigand *et al.* 1977; Bishop *et al.* 1982).

Despite the popularity of NAA in Mesoamerican archaeology, compositional studies have largely neglected ceramic production and exchange among the Preclassic lowland Maya (*c.*1200 BC–AD 300). This critical period of socio-economic transition witnessed the development of sedentary village life, complex economic networks and an increased reliance on maize agriculture, along with the adoption of ceramic technology and the specialised craft required for ceramic production. To examine these changes, Callaghan and colleagues (2017a & b, 2018) have focused on defining the geochemical composition of Middle Preclassic ceramics from Holtun, in the Petén region of north-central Guatemala. Their results identified the local production of utilitarian ceramics, as well as fine-paste Mars Orange serving vessels, which were probably manufactured in and imported from the Belize Valley. At K'axob in northern Belize, Angelini (1998) also used NAA combined with petrographic analyses to investigate local ceramic production through the late Middle and Late Preclassic periods.

Here, we use ceramic compositional data from the site of Cahal Pech, Belize (Figure 1), to examine the relationship between lowland Maya ceramic economies and increasing social complexity during the Preclassic period (Figure 2). In the largest NAA study of Preclassic Maya ceramics to date, a total of 192 sherds of utilitarian and fine ware vessels were sampled to identify diachronic shifts in ceramic usage. These sherds originated from radiocarbon-dated contexts in the monumental centre and two peripheral residential groups at Cahal Pech. All sherds were identified to type:variety-mode classification according to standard classifications for the Belize Valley (Gifford 1976; Awe 1992; Sullivan & Awe 2013). Statistical analyses of NAA data identified four primary compositional groups corresponding to diachronic changes in production patterns.

The Early Preclassic Cunil ceramic assemblage is compositionally distinct from previously analysed Maya lowland ceramics, suggesting local production and consumption of this pottery type by the earliest occupants of Cahal Pech and perhaps of the broader Belize Valley. By the Middle Preclassic period, ceramics associated with elite monumental architecture are compositionally distinct from those found in peripheral residential settlements—although both were produced locally. Comparisons with contemporaneous assemblages from Petén, Guatemala, also reveal that Mars Orange finewares were produced and exported from the Belize Valley throughout the Maya lowlands. These data indicate that socio-political connectivity facilitated economic interactions between communities, possibly allowing for groups to underwrite status and authority within emergent political economies of the Belize Valley. Similar to ceramic studies conducted elsewhere, including Europe, Asia, the Near East and South America (Blackman *et al.* 1993; Hayashida 1995; Day *et al.* 1999; Falabella *et al.* 2013; Grave *et al.* 2015), our results highlight the precision of NAA and its value for the

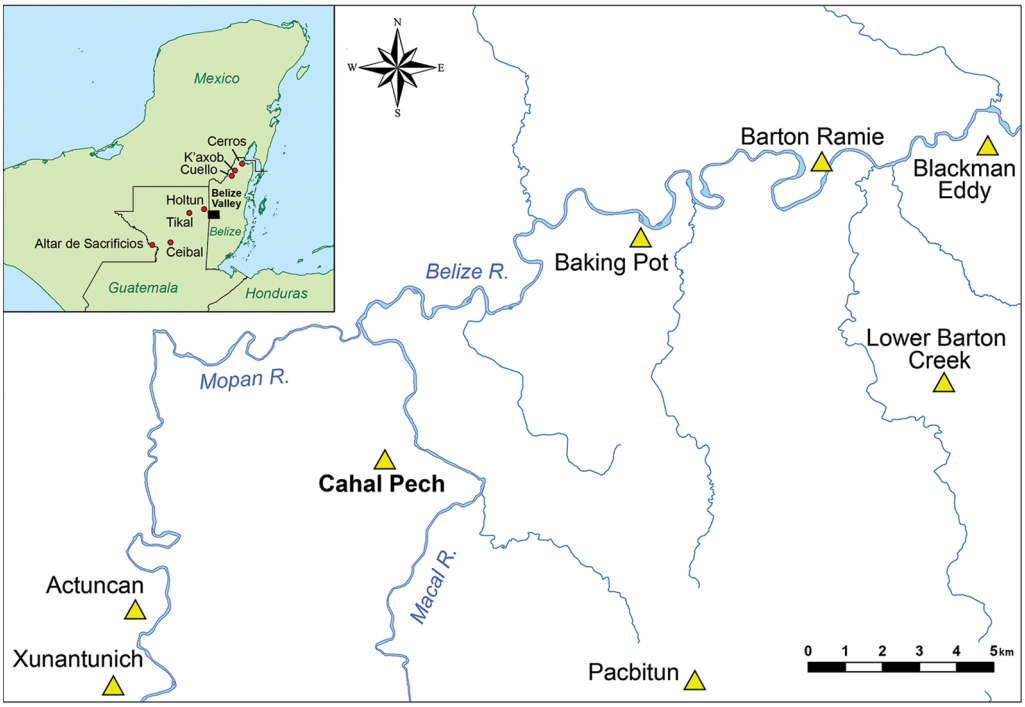

Figure 1. Map of Belize Valley showing the location of Cahal Pech and other major Preclassic sites; inset shows Belize Valley within the Maya lowlands (map by C. Ebert).

study of the development of ceramic craft production and specialisation within a developing complex society.

Archaeological background

Cahal Pech is a medium-sized Maya centre in the Belize Valley, located approximately 2km south of the confluence of the Macal and Mopan Rivers (Figure 3). Radiocarbon dates from the site's centre indicate initial settlement during the Early Preclassic period, *c.* 1200 cal BC, in the form of a small farming village of relatively egalitarian and economically autonomous households (Awe 1992; Awe & Healy 1994; Ebert *et al.* 2017; see Table S1 in the online supplementary material (OSM) for radiocarbon dates). Early occupation was associated with Cunil-complex ceramics, which include unslipped utilitarian wares, such as large jars, bowls and gourd-shaped *tecomates* (Sullivan & Awe 2013; Sullivan *et al.* 2018). The Cunil complex also includes slipped bichrome serving vessels incised with symbols that connect them to widespread Mesoamerican iconography (Figure 4; Garber & Awe 2009). Excavations at peripheral residential settlements and at other Belize Valley sites, such as Xunantunich, Actuncan and Blackman Eddy, provide further evidence for Cunil-phase occupation within small village settlements (Brown 2003; Garber *et al.* 2004; LeCount *et al.* 2017).

Early Middle Preclassic (900–600 cal BC) population expansion and economic growth across the southern lowlands was accompanied by the adoption of more standardised

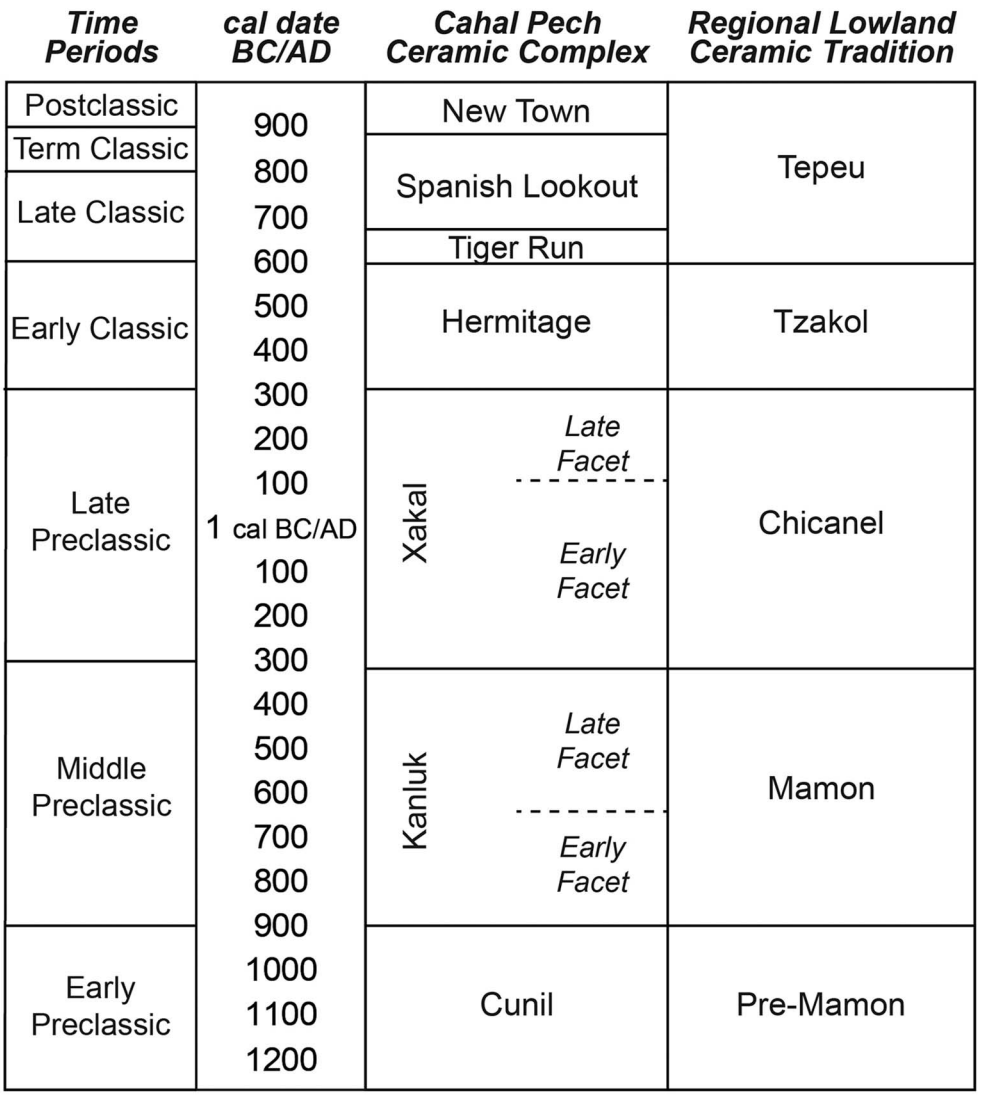

Figure 2. Cahal Pech chronological periods and associated ceramic complexes (figure by C. Ebert).

Mamon-tradition ceramics, which are characterised by monochrome, red-slipped pottery (Willey *et al.* 1965; Gifford 1976; Rice 2015). The contemporaneous Kanluk ceramic complex at Cahal Pech primarily comprises coarse-paste utilitarian ceramics and fine-paste Mars Orange wares, the latter including red-slipped Savana Orange and Reforma Incised types (Figure 5; Gifford 1976; Awe 1992). The construction of large ritual architecture and elaborate residences at Cahal Pech first began between 900 and 650 cal BC, suggesting the development of socio-economic differentiation within the community, and the formalisation of religious institutions (Awe 1992; Horn 2015; Peniche May 2016; Ebert *et al.* 2017).

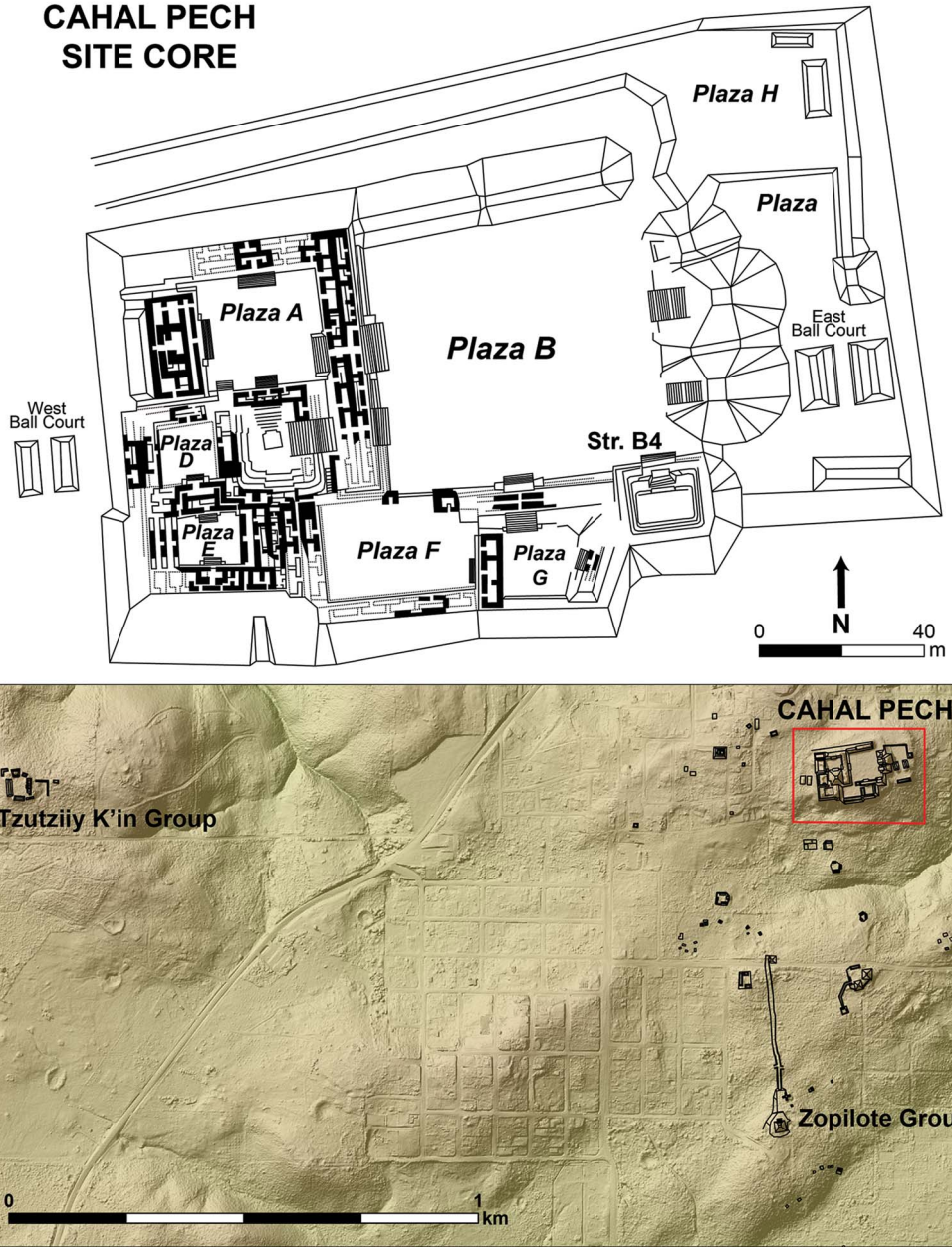

Figure 3. Cahal Pech centre (top) and peripheral settlements examined in this study (bottom; maps by C. Ebert).

Cahal Pech and other Belize Valley centres experienced settlement growth during the end of the late Middle Preclassic period (600–300 cal BC; Garber *et al.* 2004; Brown *et al.* 2013). This study includes samples from two settlements peripheral to Cahal Pech: the Tzutziiy K'in and Zopilote Groups. Located 1.8km west of Cahal Pech, the Tzutziiy K'in Group was initially settled as a single farming household by *c.* 300 cal BC. Within this settlement group, evidence

Figure 4. Incised Cunil-complex ceramics. From left to right: Baki Red Incised with k'an cross, Kitam Incised with flamed eyebrow motif and refit Zotz Zoned Incised vessel (photographs by J. Awe).

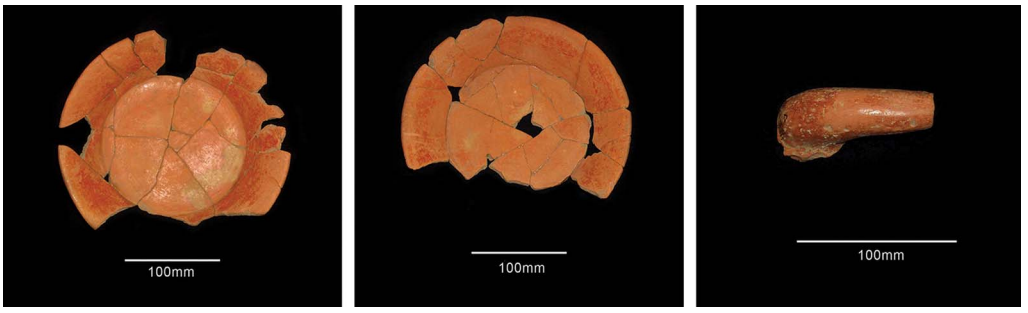

Figure 5. Mars Orange serving vessels from Cahal Pech including large dishes and a chocolate pot spout (photographs by J. Awe).

for social stratification emerges after 350 cal BC in the form of differential house sizes. This was followed by the construction of multiple masonry platforms in the group's main plaza, which probably functioned as domestic architecture for a higher-status family (Ebert *et al.* 2016). At the Zopilote Group, located approximately 0.75km south of the centre of Cahal Pech, the earliest occupation is associated with materials from the Early Preclassic period (Ebert *et al.* 2017). During the Late Preclassic period, several low masonry platforms were constructed. These were associated with the Xakal ceramic complex (300 cal BC–cal AD 300) and probably served as public temple buildings associated with nearby domestic structures. The contemporaneous construction of large public plazas and monumental temples containing elaborate tombs within Cahal Pech's monumental centre signals the development of a royal lineage (Awe 1992; Garber & Awe 2009; Ebert 2017). Diagnostic ceramics and direct dates from burials and several large house groups suggest that this pattern of social, economic and spatial growth occurred throughout the hinterlands of Cahal Pech during the Late Preclassic period (Ebert *et al.* 2016, 2017; Awe *et al.* 2017; Ebert 2017).

Materials and methods

Sample selection

To document diachronic changes in ceramic production and consumption at Preclassic Cahal Pech, we sampled common diagnostic ceramics for NAA. Samples were restricted to

radiocarbon-dated contexts to facilitate comparisons. Sherds were first identified by type: variety-mode classification, according to standard classifications for the Belize Valley (Gifford 1976; Awe 1992; Sullivan & Awe 2013). A sample of 192 sherds representing all type:varieties was then chosen, based on preservation and type. When available, multiple specimens from each ceramic type and context were analysed in order to capture assemblage diversity.

A total of 125 ceramics from Structure B4 and Plaza B within Cahal Pech's centre, previously radiocarbon-dated to the Cunil ($n = 47$) and Kanluk ($n = 78$) contexts, were included in the sample (see the OSM & Table S2). While the Early Preclassic Cunil contexts suggest the remodelling of a series of superimposed living surfaces supporting wattle-and-daub domestic structures (Awe 1992; Peniche May 2016), Middle Preclassic Kanluk contexts display evidence for the construction of several large masonry platforms that probably functioned as public buildings and high-status residences (Horn 2015; Peniche May 2016). To assess this transition, samples of at least 20 per cent of every ceramic type within each directly dated context were sought.

Samples were also chosen from Middle and Late Preclassic contexts at two peripheral residential groups: the Tzutziiy K'in ($n = 40$) and Zopilote ($n = 27$) Groups. Zopilote sherds originated from domestic late facet Kanluk and early/late facet Xakal contexts of Structure 1 (*c.* 600 cal BC–cal AD 300; Ebert 2017), which were later covered by a series of Late Preclassic temple platforms. Samples from Tzutziiy K'in derive from domestic contexts at Structures 2 and 3, and date to the early/late facets of the Late Preclassic Xakal ceramic complex (300 cal BC–cal AD 300; Ebert 2017). Although Preclassic household contexts often possess few diagnostic ceramics, our samples included all diagnostic sherds from directly dated contexts, comprising both utilitarian (bowls and jars) and non-utilitarian wares that may have functioned as serving vessels.

NAA preparation and data interpretation

All ceramic samples were prepared for NAA using standard procedures at the Archaeometry Laboratory at the University of Missouri Research Reactor (MURR) (Glascock 1992; Neff 2000). Multivariate statistical routines, such as cluster analyses, principal component analyses and Mahalanobis distance, were used to identify compositional groups, in coordination with visual inspection of bivariate elemental plots depicting the results of NAA and the calculation of mean, standard deviation and coefficient of variation for each element per group. These methods were combined to identify seven distinct compositional groups in the Cahal Pech ceramic sample (Figure 6). Finally, a canonical discriminant analysis was applied to the identified groups to define the primary dimensions of chemical variation.

Twenty-two sherds spread across context locations (elite *vs* non-elite) were left unassigned to any compositional group. These represent ceramics from unknown source locations, have unique compositions ('paste recipes'), or are similar to more than one compositional group. The Cahal Pech sample was also compared to archived data from previous NAA analyses conducted by MURR (n>12 000) using multivariate Euclidian distance to identify similarities with other individual specimens and identified geochemical compositional groups in Mesoamerica (MURR Archaeometry Laboratory Database n.d.).

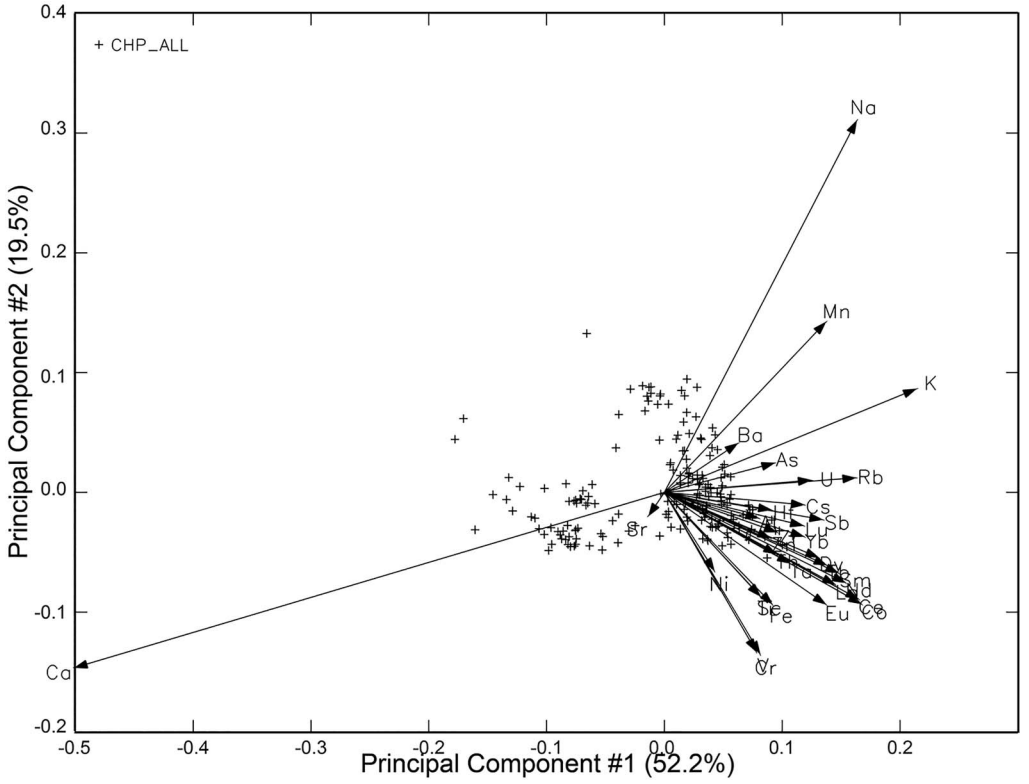

Figure 6. R-Q Mode biplot of the sample on principal components 1 and 2.

Results

The Cahal Pech ceramics divide into seven geochemical compositional groups (Figure 7). The four largest groups (B, C, D & G) correspond generally with type:variety classifications from different temporal and spatial contexts (Figure 8 & Table 1). Three smaller groups were also identified (A, E & F), although they collectively comprise a minor portion of the total analysed sample (4 per cent).

Group A consists of two Cunil-phase sherds of an unspecified type. These ash-tempered sherds share stylistic features with Huetche White ceramics from the Pasión region of western Guatemala, approximately 135km south-west of the Belize Valley (Sabloff 1975: 53–55). Compositionally, however, they more closely resemble pottery from the Pacific Coast of Mexico and Guatemala. Group B (n = 34) features elevated levels of sodium and potassium, and contains all other ash-tempered sherds included in this study, along with some exhibiting fine-texture calcite pastes. Many of the finer Cunil ceramics in this group, such as the Baki Red Incised, Mo Mottled, and Kitam Incised types, are decorated with dull slips and post-slip incision. Euclidean distance searches indicate that these early Cahal Pech specimens are compositionally unique from all archived Maya region samples in the MURR database.

Groups C and D contain samples attributed most frequently to the late facet Kanluk ceramic complex (750–300 cal BC). Group C (n = 13) possesses the most intra-group chemical

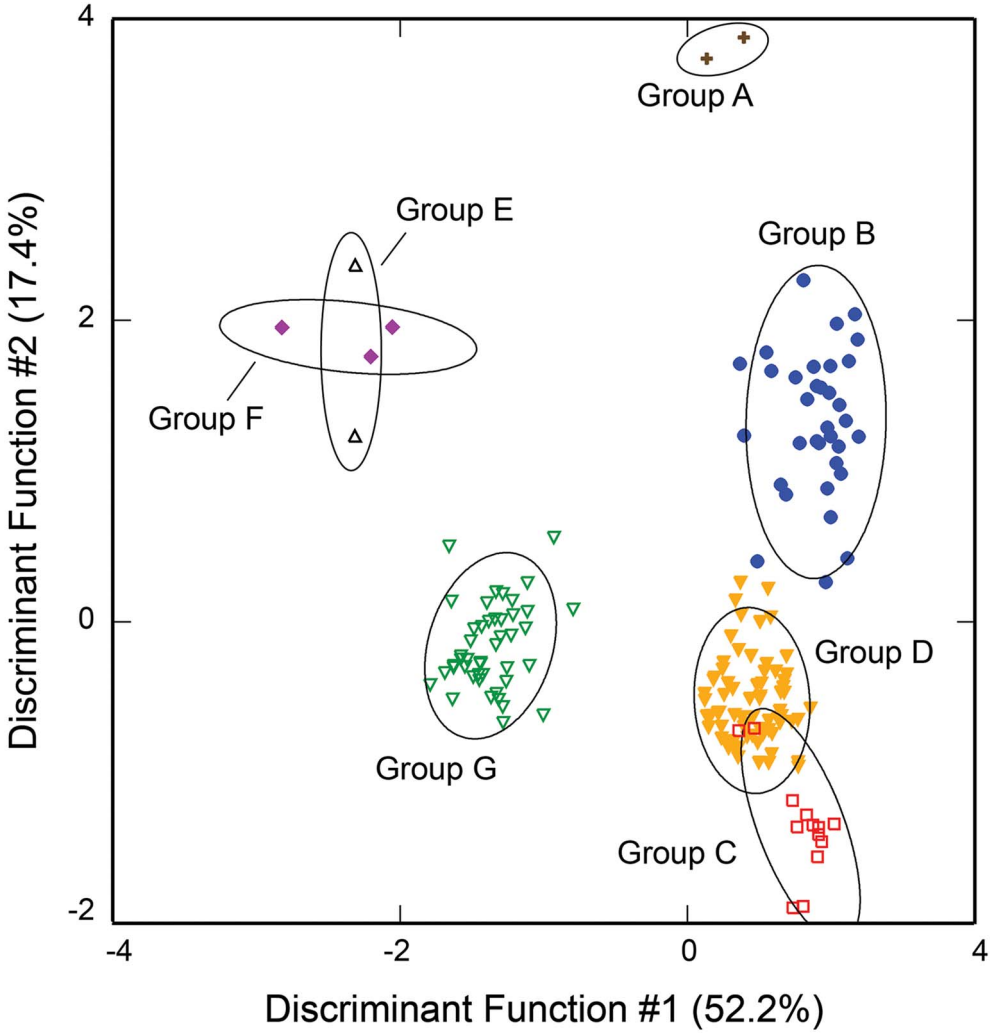

Figure 7. Bivariate plot of neutron activation analysis samples based on discriminant functions #1 and #2; ellipses represent 90 per cent confidence of group membership (figure by D. Pierce).

variability in our sample, exhibiting higher levels of cobalt and cerium and a greater range of manganese compared to other compositional groups. Group C ceramics are primarily Mars Orange wares (92 per cent Savana Orange and Reforma Incised types, see Gifford 1976: 73–76) and were distributed between late Middle Preclassic Cahal Pech site-core (62 per cent) and settlement contexts at the Tzutziiy K'in and Zopilote Groups (38 per cent).

Group D is the largest compositional group ($n = 71$) identified at Cahal Pech and is geochemically distinguishable based on elements including calcium and potassium. Most specimens (87 per cent) come from the site core and are attributed to the Cunil and Kanluk complex, while a smaller number of peripheral settlement samples date to the Late Preclassic

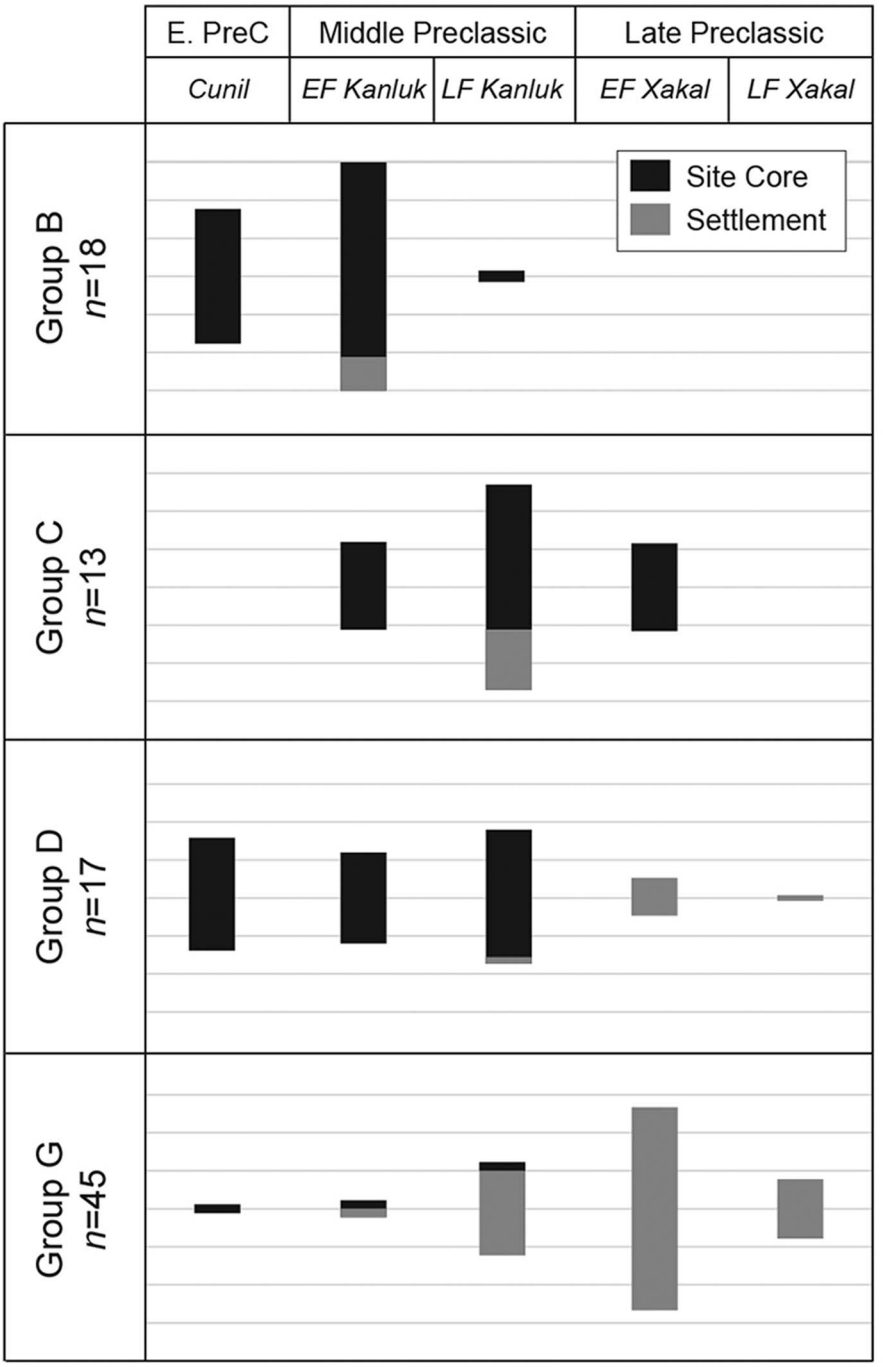

Figure 8. Frequency seriation of compositional groups with samples n>3 showing correspondence with type:variety classifications from site-core and settlement contexts (figure by C. Ebert).

Table 1. Distribution of Cahal Pech compositional groups identified by NAA for each chronological period and ceramic complex. Early facet (EF) and late facet (LF) components of ceramic complexes listed when present.

Compositional groups	Context	Early Preclassic	Middle Preclassic		Late Preclassic	
		Cunil	EF Kanluk	LF Kanluk	EF Xakal	LF Xakal
Group A	Site-core					
n = 2 (1%)	settlement	2				
Group B	Site-core	12	18	1		
n = 34 (18%)	settlement		3			
Group C	Site-core		3	5		
n = 13 (7%)	settlement			2	3	
Group D	Site-core	21	17	24		
n = 71 (37%)	settlement			1	7	1
Group E	Site-core		1			
n = 2 (1%)	settlement					1
Group F	Site-core			3		
n = 3 (2%)	settlement					
Group G	Site-core	1	1	1		
n = 45 (23%)	settlement		1	10	24	7
Unassigned	Site-core	2	4	9		
n = 22 (11%)	settlement		1	2	3	1
Totals by period		**38**	**49**	**58**	**37**	**10**

period. This group is dominated by unslipped coarse utilitarian pottery, such as Sikiya and Jocote types (57 per cent), but also contains high frequencies (37 per cent) of Mars Orange (Savana Orange type) wares. The remaining six per cent of group D includes Ardagh Orange ($n = 7$), Sierra Red ($n = 1$) and cream slipped sherds of an unknown type ($n = 3$). Comparison to the MURR database indicates a compositional similarity to ceramics collected from the Petén Lakes region of Guatemala and Middle Preclassic Mars Orange ceramics from Holtun, Guatemala (see Callaghan *et al.* 2017a & b, 2018).

Groups E ($n = 2$) and F ($n = 3$) ceramics comprise only three per cent of the total Cahal Pech sample. While both groups are compositionally distinct, they exhibit high degrees of internal variability, which indicates slightly different paste recipes for each sherd. Groups E and F are found in both site-core and peripheral settlement contexts, and comprise Joventud Red sherds from the Kanluk ceramic complex.

The second largest group in the assemblage, group G ($n = 45$), is homogeneous and characterised by high levels of calcium and little variation in potassium. Group G comprises approximately two-thirds of the Late Preclassic Xakal-complex (300 cal BC–cal AD 300) sherds, despite only making up 23 per cent of the total Cahal Pech sample. This indicates a preference for this paste recipe within households during later time periods. As securely dated Late Preclassic contexts are lacking in the site core, however, our sampling strategy only focused upon peripheral settlements for this period. It remains unknown how common

this recipe is in ceramics from contemporaneous site-core contexts. Nonetheless, even in Middle Preclassic contexts, group G specimens are found almost exclusively at peripheral households. This contrasts with the other compositional groups, which are only rarely found in settlement contexts. Approximately 74 per cent of sherds sampled from the Tzutziiy K'in and around 65 per cent of the sherds sampled from Zopilote were assigned to group G. The most common ceramic types in group G include Joventud Red (late Middle Preclassic) and Sierra Red (Late Preclassic), with small quantities of Jocote Orange-brown and Sayab Daub Striated unslipped utilitarian wares. Finally, group G is most similar compositionally to samples from other regions of the Maya lowlands, including western Belize. Given the criterion of abundance (Bishop *et al.* 1982)—particularly considering later time periods and in household contexts—the compositional similarities between group G and other western Belizean ceramics probably indicates local production.

Discussion

This study uses NAA to explore the development of local ceramic production and the expansion of exchange networks from the Early to Late Preclassic periods at Cahal Pech. The earliest ceramics (Cunil complex) in the Belize Valley appeared within Early Preclassic domestic contexts in Cahal Pech's core (Awe 1992; Sullivan & Awe 2018), including large storage jars and colanders used to make *nixtamal* (lime-treated maize), signalling an increase in maize agriculture and the first permanent settlement in the Belize Valley (Clark & Cheetham 2002; Ebert *et al.* 2017). We identify three compositional groups (A, B & D) containing Cunil ceramics, indicating a preference for these paste recipes during the Early Preclassic period. Group B contains the highest proportions of slipped and grooved-incised vessels, which were only found in the Cahal Pech site core.

Notably, all Cunil ash-tempered specimens in this study were also assigned to group B. Previous, limited petrographic analyses of 13 Cunil ash-tempered sherds (Sunahara 2003: 123–34; Sunahara *pers. comm.*) suggest that the volcanic ash petrofabrics that constitute these vessels were non-local to the Belize Valley, and that vessels may have even been imported as finished products. Multivariate geochemical comparisons of the specimens examined in this study, however, indicate that group B ceramics are compositionally unique compared to other ceramics in the MURR database (>15 000 specimens). Based on these comparisons, we suggest that Cunil vessels were probably produced and distributed locally in the Belize Valley—including between Cahal Pech and other neighbouring communities. Furthermore, as the group B vessels possess incised motifs representing significant ideological meaning, they may have been intended for public display in order to communicate socioeconomic differences at Early Preclassic Cahal Pech. Although Cunil vessels may have been produced in the Belize Valley using local clay tempered with non-local volcanic ash (Simmons & Brem 1979), ceramic pastes may alternatively be composed of local clay tempered with a local source of ash that has not yet been located, or that was exhausted in antiquity (Ford & Spera 2007; see also Graham 1987: 759). While additional NAA and petrographic analyses are required to test these hypotheses, the current data suggest that the ash-paste tradition for the Early Preclassic and subsequent periods probably originated in western Belize (see also Callaghan *et al.* 2018: 824). While group B vessels (ash-tempered)

were primarily non-utilitarian decorated types, the Cunil-complex sherds in group D were strictly utilitarian. Differential distribution of Cunil utilitarian and decorated serving wares between compositional groups suggests that specialised household production began during the Early Preclassic period.

During the Middle Preclassic period, population expansion and economic growth across the Belize Valley and the broader Maya lowlands were accompanied by the adoption of a more standardised Mamon ceramic tradition, characterised by monochrome, red-slipped pottery (Willey *et al.* 1965; Gifford 1976). At Cahal Pech, the associated Kanluk-complex ceramic assemblage comprised primarily unslipped utilitarian ceramics and fine Mars Orange serving wares, the latter including undecorated and decorated types (Awe 1992; Ball & Taschek 2003). Direct evidence for household production, including the identification of ceramic manufacturing areas or the presence of related tools (e.g. Jordan & Prufer 2017) is absent. A compositional correlation between late Middle Preclassic Jocote vessels and earlier Cunil utilitarian wares, however, suggests that both types were produced locally for domestic consumption. Typological studies from elsewhere in the Belize Valley have also documented high frequencies of Mars Orange ceramics (approximately 18–50 per cent) in Middle Preclassic ceramic assemblages, suggesting production within the region (e.g. Gifford 1976: 73–77; Awe 1992: 236–40; Ball & Taschek 2003: 195; Kosakowsky 2012: 62).

The decreasing frequency in distribution of Mars Orange wares westward into the central Petén region of Guatemala appears to reflect its probable importation from western Belize through down-the-line exchange (Callaghan *et al.* 2017b, 2018). Over 77 per cent of the Mars Orange sherds from Cahal Pech are assigned to compositional groups C and D ($n = 27$ and $n = 35$, respectively). These sherds derive primarily from site-core contexts associated with high-status residences and public architecture, including a series of specialised circular structures and raised masonry platforms that were probably used for public ceremonies within Plaza B (Awe 1992; Peniche May 2016). These platforms are adjacent to an eastern triadic temple structure (Structure B1), which dates to at least the late Middle Preclassic period. Functioning as a ritual architectural complex, the triadic buildings contain some of the earliest and most elaborate caches and high-status burials at Cahal Pech (Awe *et al.* 2017).

A comparison of the Cahal Pech Mars Orange ceramics with archived data identifies compositionally similar ceramics collected from Holtun, in the central Petén region (Figure 9). The Holtun sherds form a distinct compositional group (group 1; Callaghan *et al.* 2017b) and were associated with an ideologically important E-Group architectural complex in the site's civic-ceremonial centre. Although the Holtun and Cahal Pech assemblages exhibit similar paste recipes, higher frequencies of Mars Orange wares in the latter assemblage (77 per cent) *vs* the former (approximately 11 per cent; Callaghan *et al.* 2018) suggest that these vessels originated in the Belize Valley (per the criterion of abundance; Bishop *et al.* 1982). As most of the Mars Orange paste wares from Cahal Pech were recovered from the site core, additional sampling from household contexts is necessary in order to determine whether these ceramic types were produced or consumed primarily by elite individuals, as well as the function of these vessels within specific contexts.

The Late Preclassic (early/late facet Xakal ceramic complex) period saw the local development of a distinctive style of Chicanel ceramics—characterised by waxy-finish red and black slips—at Cahal Pech and throughout the Belize Valley (Awe 1992; Gifford 1976). The

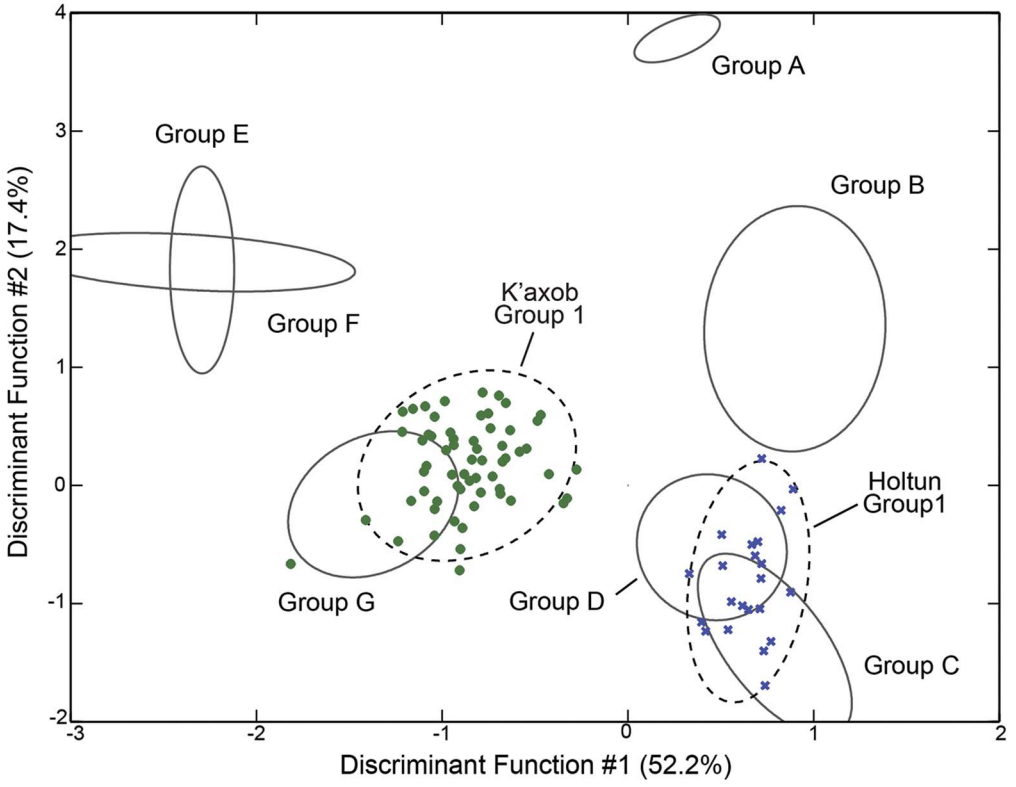

Figure 9. Bivariate plot of compositional groups compared to other Preclassic assemblages. Middle Preclassic group 1 ceramics at Holtun (Guatemala) are plotted in blue, and Late Preclassic group 1 ceramic from K'axob (Belize) are plotted in green. Ellipses represent 90 per cent confidence of group membership (figure by C. Ebert).

development of this regional style corresponds with the rapid growth of major civic-ceremonial centres and the development of shared monumental architectural traditions across the Belize Valley (Ebert *et al.* 2017). Consequentially, incipient elites could now reinforce their authority by acquiring exotic prestige items, such as non-local variants of Chicanel-style ceramics, through long-distance exchange (Awe & Healy 1994; Peniche May 2016). At Cahal Pech, a contemporaneous programme of large-scale monumental construction was initiated in the site centre (Plazas A and B), while peripheral households also expanded. Specifically, radiocarbon and architectural data document the construction of larger-scale residential buildings in at least five house groups on Cahal Pech's periphery—including the Tzutziiy K'in and Zopilote Groups—after *c.* 350 cal BC (Ebert *et al.* 2016, 2017).

The Xakal-complex ceramics sampled in this study derive from two of these peripheral settlement groups, Tzutziiy K'in and Zopilote. Approximately 96 per cent of these ceramics are restricted to compositional group G, which is composed primarily of Sierra Red and Sayab Daub-striated Xakal types with both utilitarian (e.g. large jars, spindle whorls) and more specialised forms (e.g. serving dishes, spouted vessels) present. While most of the later samples derive from household contexts instead of contexts associated with the Cahal Pech

monumental centre, there may yet remain important implications for understanding diachronic patterns in ceramic production and consumption at Cahal Pech and beyond.

Group G paste types dominate later periods, indicating a shift in the recipe used for production for all functional categories of ceramics. As our Late Preclassic sample, however, derives primarily from peripheral Cahal Pech households, group G ceramics may alternatively represent differential production between the households and site core. The shift in paste recipes at Cahal Pech may also correspond to the adoption of Chicanel-style ceramics following the development of regional interaction networks. Additional comparisons to the MURR database indicate that nearly all of the Cahal Pech group G specimens share some compositional similarity to assemblages from the eastern Maya lowlands. When compared to the Late Preclassic assemblages of similar types (e.g. Sierra Red) produced at the site of K'axob in northern Belize (Angelini 1998), the Cahal Pech group G ceramics overlap significantly (see Figure 9). This may indicate broadly shared ceramic production traditions in the eastern periphery of the Maya lowlands. Additional NAA of Late Preclassic ceramics from the Cahal Pech site core and from other Maya sites could better characterise the production and consumption patterns associated with local tradition and status.

Conclusions

The reconstruction of the economic networks that facilitated the movement of key resources, craft items and shared ideological expressions of wealth within and between communities and regions has long been the focus of intensive geochemical provenance investigations in Mesoamerica and beyond (Bishop 2014). The analyses presented here provide new evidence concerning the structure, function and development of Preclassic-period economic systems at the Cahal Pech in the Belize Valley and provides the largest geochemical dataset of Preclassic lowland Maya ceramics to date. Although previous efforts to understand the nature and timing of Preclassic Maya economic exchange have depended upon relative dating of ceramic typologies, samples from radiocarbon-dated contexts now permit a higher-resolution assessment of diachronic patterns of ceramic production and consumption. These results indicate that local production and consumption of specialised ceramic serving vessels bearing ideologically significant designs first appeared at Cahal Pech as early as 1200 cal BC, during the Cunil phase.

By the late Middle Preclassic period, ceramic economic networks became increasingly complex and interconnected. Our results also provide evidence for the inter-regional exchange of specialised Mars Orange pottery between Belize Valley sites such as Cahal Pech and sites in the central Petén region of Guatemala (see also Callaghan *et al.* 2018). Production and distribution of these specialised vessels may have supported networks of high-status individuals within a developing regional economy—although additional research is required to test this hypothesis.

Future research focused on characterising ceramic assemblages from other Preclassic contexts at Cahal Pech, from other Belize Valley sites and throughout the Maya lowlands, will aid in the reconstruction of changing production and exchange systems that were critical to the development of complex societies throughout the Preclassic period. Variation within and between assemblages may reveal the economic strategies that shaped both local and regional economies and contributed to institutionalised socio-economic differentiation.

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Supplementary material

To view supplementary material for this article, please visit https://doi.org/10.15184/aqy.2019.93

References

Angelini, M.L. 1998. The potter's craft: a study of formative Maya ceramic technology at K'axob Belize. Unpublished PhD dissertation, Boston University.

Awe, J.J. 1992. Dawn in the land between the rivers: formative occupation at Cahal Pech, Belize, and its implications for Preclassic development in the central Maya lowlands. Unpublished PhD dissertation, University of London.

Awe, J.J. & P.F. Healy. 1994. Flakes to blades? Middle Formative development of obsidian artifacts in the upper Belize River Valley. *Latin American Antiquity* 54(4): 1–15. https://doi.org/10.2307/971879

Awe, J.J., J.A. Hoggarth & J.J. Aimers. 2017. Of apples and oranges: the case of E-Groups and eastern triadic architectural assemblages in the Belize River Valley, in D.A. Freidel, A.F. Chase, A.S. Dowd & J. Murdock (ed.) *Maya E-Groups: calendars, astronomy, and urbanism in the early lowlands*: 412–49. Gainesville: University Press of Florida.

Ball, J.W. & J.T. Taschek. 2003. Reconsidering the Belize Valley Preclassic: a case for multiethnic interactions in the development of a regional culture tradition. *Ancient Mesoamerica* 14: 179–217. https://doi.org/10.1017/S0956536103142034

Bishop, R.L. 2014. Instrumental approaches to understanding Mesoamerican economy: elusive promises. *Ancient Mesoamerica* 24: 251–69. https://doi.org/10.1017/S0956536114000157

Bishop, R.L. & H. Neff. 1989. Compositional data analysis in archaeology, in R.O. Allen (ed.) *Archaeological Chemistry IV*: 576–86. Washington, D.C.: American Chemical Society. https://doi.org/10.1021/ba-1988-0220.ch004

Bishop, R.L., R.L. Rands & G.R. Holley. 1982. Ceramic compositional analysis in archaeological perspective. *Advances in Archaeological Method and Theory* 5: 275–330. https://doi.org/10.1016/B978-0-12-003105-4.50012-1

Blackman, J.M., G.J. Stein & P.B. Vandiver. 1993. The standardization hypothesis and ceramic mass production: technological, compositional, and metric indexes of craft specialization at Tell Leilan, Syria. *American Antiquity* 58: 60–80. https://doi.org/10.2307/281454

Blomster, J.P., H. Neff & M.D. Glascock. 2005. Olmec pottery production and export in ancient Mexico determined through elemental analysis. *Science* 307: 1068–72. https://doi.org/10.1126/science.1107599

Brown, M.K. 2003. Emerging complexity in the Maya lowlands: a view from Blackman Eddy, Belize. Unpublished PhD dissertation, Southern Methodist University.

Brown, M.K., L. McCurdy, W. Lytle & T. Chapman. 2013. Mopan Valley Preclassic Project: results of the 2011 field season. *Research Reports in Belizean Archaeology* 10: 137–46.

Callaghan, M.G., D.E. Pierce, B. Kovacevich & M.D. Glascock. 2017a. An atlas of paste fabrics and supplemental paste compositional data from late Middle Preclassic-period ceramics at the Maya site of Holtun, Guatemala. *Data Brief* 12: 55–67. https://doi.org/10.1016/j.dib.2017.03.024

– 2017b. Chemical paste characterization of late Middle Preclassic-period ceramics from Holtun, Guatemala and its implications for production and exchange. *Journal of Archaeological Science: Reports* 12: 334–45. https://doi.org/10.1016/j.jasrep.2017.01.040

Callaghan, M.G., D.E. Pierce & W.D. Gilstrap. 2018. The first Maya trade ware? New data on Middle Preclassic-period Mars Orange ware from Holtun, Guatemala. *Latin American Antiquity* 12: 821–27. https://doi.org/10.1017/laq.2018.42

Clark, J.E. & D. Cheetham. 2002. Mesoamerica's tribal foundations, in W.A. Parkinson (ed.) *The archaeology of tribal societies*: 278–339. Ann Arbor: University of Michigan.

Day, P.M., E. Kiriatzi, A. Tsolakidou & V. Kilikoglou. 1999. Group therapy: a comparison between analyses by NAA and thin section petrography of Early Bronze Age pottery from central and east Crete. *Journal of Archaeological Science* 26: 1025–36. https://doi.org/10.1006/jasc.1999.0424

Ebert, C.E. 2017. Preclassic Maya social complexity and origins of inequality at Cahal Pech, Belize. Unpublished PhD dissertation, The Pennsylvania State University.

Ebert, C.E., B.J. Culleton, J.J. Awe & D.J. Kennett. 2016. AMS ^{14}C dating of Preclassic to Classic period household construction in the ancient Maya community of Cahal Pech, Belize. *Radiocarbon* 58: 69–87. https://doi.org/10.1017/RDC.2015.7

Ebert, C.E., N. Peniche May, B.J. Culleton, J.J. Awe & D.J. Kennett. 2017. Regional response to drought during the formation and decline of Preclassic Maya Societies. *Quaternary Science Reviews* 173: 211–35. https://doi.org/10.1016/j.quascirev.2017.08.020

Falabella, F., L. Sanhueza, I. Correa, M.D. Glascock, T.J. Ferguson & E. Fonseca. 2013. Studying technological practices at a local level: neutron activation and petrographic analyses of Early Ceramic period pottery in central Chile. *Archaeometry* 55: 33–53. https://doi.org/10.1111/j.1475-4754.2012.00681.x

Ford, A. & F. Spera. 2007. Fresh volcanic glass shards in the pottery sherds of the Maya lowlands. *Research Reports in Belizean Archaeology* 4: 111–18.

Garber, J.F. & J.J. Awe. 2009. A terminal Early Formative symbol in the Maya lowlands: the iconography of the Cunil phase (1100–900 BC) at Cahal Pech. *Research Reports in Belizean Archaeology* 6: 151–60.

Garber, J.F., M.K. Brown, J.J. Awe & C.J. Hartman. 2004. Middle Formative prehistory of the central Belize Valley: an examination of architecture, material culture, and sociopolitical change at Blackman Eddy, in J.F. Garber (ed.) *The ancient Maya of the Belize Valley: half a century of archaeological research*: 25–47. Gainesville: University Press of Florida.

Gifford, J.C. 1976. *Prehistoric pottery analysis and the ceramics of Barton Ramie in the Belize Valley*. Cambridge (MA): Harvard University.

Glascock, M.D. 1992. Characterization of archaeological ceramics at MURR by neutron activation analysis and multivariate statistics, in H. Neff (ed.) *Chemical characterization of ceramic pastes in archaeology*: 11–26. Madison (WI): Prehistory Press.

Graham, E. 1987. Resource diversity in Belize and its implications for models of lowland trade. *American Antiquity* 52: 753–67. https://doi.org/10.2307/281383

Grave, P., M. Stark, D. Ea, L. Kealhofer, B.S. Han & T. Tin. 2015. Differentiating Khmer stoneware production: an NAA pilot study from Siem Reap Province, Cambodia. *Archaeometry* 59: 13–24. https://doi.org/10.1111/arcm.12220

Harbottle, G. 1976. Activation analysis in archaeology. *Radiochemistry* 3: 33–72. https://doi.org/10.1039/9781847556882-00033

Hayashida, F.M. 1995. State pottery production in the Inka provinces. Unpublished PhD dissertation, University of Michigan.

Horn, S.W. III. 2015. The web of complexity: socioeconomic networks in the Middle Preclassic Belize Valley. Unpublished PhD dissertation, Tulane University.

Jordan, J.M. & K.M. Prufer. 2017. Identifying domestic ceramic production in the Maya lowlands: a case study from Uxbenká, Belize. *Latin American Antiquity* 28: 66–87. https://doi.org/10.1017/laq.2016.3

Kosakowsky, L.J. 2012. Ceramics and chronology at Chan, in C. Robin (ed.) *Chan: an ancient Maya farming community*: 42–70. Gainesville: University Press of Florida.

Lecount, L.J., D.W. Mixter & B.S. Simova. 2017. Preliminary thoughts on ceramic and radiocarbon data from Actuncan's E-Group excavations, in L.J. LeCount & D.W. Mixter (ed.) *The Actuncan Archaeological Project: report of the 2016 field season*: 21–42. Belmopan: Belize Institute of Archaeology.

Minc, L.D. & J. Sterba. 2016. Instrumental neutron activation analysis (NAA) in the study of archaeological ceramics, in A. Hunt (ed.) *The Oxford handbook of archaeological ceramic analysis*: 424–46. Oxford: Oxford University Press.

MURR Archaeometry Laboratory Database n.d. Available at: http://archaeometry.missouri.edu/datasets/datasets.html (accessed 7 June 2019).

Neff, H. 2000. Neutron activation analysis for provenance determination in archaeology, in E. Cilberto & G. Spoto (ed.) *Modern analytical methods in art and archaeology*: 81–134. New York: Wiley & Sons, Inc.

Neff, H. & M.D. Glascock. 2002. *Instrumental neutron activation analysis of Olmec pottery*. Columbia: Research Reactor Center, University of Missouri.

Neff, H., J. Blomster, M.D. Glascock, R.L. Bishop, M.J. Blackman, M.D. Coe, G.L. Cowgill, R.A. Diehl, S. Houston, A.A. Joyce, C.P. Lipo, B.L. Stark & M. Winter. 2006. Methodological issues in the provenance investigation of Early Formative Mesoamerican ceramics. *Latin American Antiquity* 17: 54–76. https://doi.org/10.2307/25063036

Peniche May, N. 2016. Building power: political dynamics in Cahal Pech, Belize during the Middle Preclassic. Unpublished PhD dissertation, University of California, San Diego.

Rice, P.M. 2015. Middle Preclassic interregional interaction and the Maya lowlands. *Journal of Archaeological Research* 23: 1–47. https://doi.org/10.1007/s10814-014-9077-5

Sabloff, J.F. 1975. *Excavations at Seibal: ceramics* (Memoirs of the Peabody Museum of Archaeology and Ethnology 13). Cambridge (MA): Harvard University.

Simmons, M.P. & G.F. Brem. 1979. The analysis and distribution of volcanic ash-tempered pottery in the lowland Maya area. *American Antiquity* 44: 79–91. https://doi.org/10.2307/279191

Sullivan, L.A. & J.J. Awe. 2013. Establishing the Cunil ceramic complex at Cahal Pech, Belize, in J. Aimers (ed.) *Ancient Maya pottery: classification, analysis and interpretation*: 107–20. Gainesville: University Press of Florida. https://doi.org/10.5744/florida/9780813042367.003.0007

Sullivan, L.A., J.J. Awe & M.K. Brown. 2018. The Cunil complex: early villages in Belize, in M.K. Brown & G.J. Bey III (ed.) *Pathways to complexity: a view from the Maya lowlands*: 35–48. Gainesville: University Press of Florida.

Sunahara, K.S. 2003. Ancient Maya ceramic economy in the Belize River Valley region: petrographic analyses. Unpublished PhD dissertation, McMaster University.

Weigand, P.C., G. Harbottle & E.V. Sayre. 1977. Turquoise sources and source analysis: Mesoamerica and the southwestern USA, in T.K. Earle & J.E. Ericson (ed.) *Exchange systems in prehistory*: 15–34. New York: Academic.

Willey, G.R., W.R. Bullard, J.B. Glass & J.C. Gifford. 1965. *Prehistoric Maya settlements in the Belize Valley*. Cambridge: Cambridge University Press.

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