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Rethinking Cultural Hybridity and Technology Transfer: SEM Microstructural Analysis of Lead Glazed Ceramics from Early Colonial Peru

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Abstract:

Through Scanning Electron Microscopy (SEM) microstructural analysis, we examine the firing technology of Early Green Glazed (EGG) Ware – a variety of “hybrid” lead-glazed ceramics produced in Peru’s north coast region during the 16th century CE. Previous scholars have interpreted EGG Ware as the product of indigenous potters who fired ceramics in kilns and learned how to make glazed vessels through direct instruction from Iberian ceramicists. We argue that the production of EGG Ware entailed a more complex process of technological incorporation and innovation. SEM microstructural analysis of 44 refired and unrefired archaeological samples suggests that these ceramics were originally fired under highly variable conditions. Parallel analysis of five samples of lead-glazed ceramics produced in open firings by Peruvian artisans in the 1980’s reveals consistent firing beyond their clays’ maturation temperatures. Based on these results and analysis of whole EGG Ware vessels from museum collections, we suggest that at least some of our EGG Ware samples were produced in open firings. In turn, we argue that EGG Ware reflects the creativity of native potters who adapted indigenous firing technologies and experimented with different technological parameters in the process of forging a new decorative tradition.

Keywords

Ceramic firing technology, Technology transfer, Cultural hybridity, Scanning Electron Microscopy (SEM), Lead Glaze, Refiring, Spanish colonial period, Peru

Highlights

- SEM microstructural analysis of 44 samples of Early Green Glazed Ware from 16th Century Peru
- SEM microstructural analysis of five samples from late 20th century highland Peru
- Results suggest EGG Ware vessels fired in varied conditions, some at temperatures below 890°C
- At least some vessels produced in open firings, rather than kilns
- Simple model of technology transfer rejected to explain EGG Ware production

Introduction

The study of artifacts whose forms and decorations bring together elements from multiple cultural traditions has been a recurring theme in the archaeology of culture contact, colonialism, and imperialism. However, scholars have disagreed sharply about what to call such objects and how to make sense of them – perhaps most saliently, in a series of recent discussions focused on the concept of cultural hybridity and its applications in archaeology and socio-cultural anthropology (Antonaccio, 2003; Card, 2013; Jiménez, 2011; Liebmann, 2015, 2013, Loren, 2015, 2013, Palmié, 2013, 2006, Silliman, 2015, 2013; Stockhammer, 2012; Tronchetti and Van Dommelen, 2005; Van Dommelen, 1997; Van Dommelen and Stein, 2005; van Pelt, 2013; VanValkenburgh, 2013).

Employed in the 19th century to describe biological crosses between wild and domesticated varieties of plants and animals (Warren, 1884), the term “hybrid” – and its derivation, hybridity – became critical keywords in postcolonial studies the 1980’s and 1990’s. Drawing on Bakhtin (1981), Bhabha (1994, 1985) redefined hybridity as the ironic juxtaposition of presumably distinct cultural forms in colonial contexts and highlighted their potential for subverting dominant discourses (see also García Canclini, 1989; Liebmann, 2008; Van Dommelen, 1997; Young, 1995). However, as numerous authors have noted, archaeological scholarship has predominantly employed the words “hybrid” and “hybridity” to refer to an unspecific concept of cultural mixture – what VanValkenburgh (2013) calls the term’s “vernacular” definition – and has treated hybridity as a property that inheres in objects themselves rather than the processes through which they

are produced, used, and understood (see critiques in Dean and Liebsohn 2003; van Dommelen 2005; Liebmann 2013; Silliman 2015; VanValkenburgh 2013).

While Silliman's (2015: 283) witty description of vernacular hybridity as a "Frankenstein creation that lumbers through the discipline" may overstate how pernicious this concept has become, we agree that it retains little analytical potential – except, perhaps, as an object of study itself that may be "symptomatic" of a range of contemporary cultural anxieties (Kohn, 2015; Palmié, 2013; Povinelli, 2016). Yet we continue to be fascinated by objects that are often labeled hybrid because of the potential they hold to reveal processes of technological change and artistic creativity in contact zones (Pratt, 1991).

How, then, do we best make sense of these qualities? Recently, some archaeologists have sought to retool the language through which we describe them, preferring the term "entanglement(s)" (from Thomas, 1991). First used in archaeological literature to describe indirect and long-term processes of cultural exchange in colonial societies (Alexander 1998; Dietler 1998, 2010), the term entanglement has recent been used in a variety of other ways: 1) to label postcolonial cultural forms in a manner that that signals how elements of earlier traditions are not fully erased but are often conserved within them (e.g., Norton, 2017); 2) as a description of step-wise processes by which "foreign" objects and ideas are incorporated into local traditions (Hitchcock and Maeir, 2013; Langin-Hooper, 2013; Stockhammer 2012); and 3) as a metaphor for the affective engagement between people and things (Hodder 2012; Der and Fernandini 2016). In practice, however, we worry that some archaeologists are now

employing the term to refer to the same unspecific notion of mixture that is encoded in the vernacular concept of hybridity – effectively mirroring the process by which earlier terms, including creolization and syncretism, were themselves tabooed and replaced (Dawdy, 2000; Palmié, 2006).

Rather than attempting to coin a new term, we agree with previous authors that our focus should be trained not on objects, *per se*, but on what they have to tell us about the processes of their production, circulation and reception (Dean and Leibsohn, 2003; Silliman, 2013; Tronchetti and Van Dommelen, 2005; van Dommelen, 2006). Studies of the technological properties and “technological style” of colonial artifacts hold particular promise in this regard, because they are explicitly focused on such processes and provoke fine-grained observations of indices that are not revealed in the most salient elements of form and decoration of artifacts (Brezine, 2013; Card, 2013b; Chatfield, 2010; Dietler and Herbich, 1998; Hayes, 2013; Lechtman, 1977; Lemonnier, 2013; Sillar and Tite, 2000).

To demonstrate how the archaeometric study of ceramics can contribute understanding of colonial social life and cultural practice, this paper discusses the firing technology of a variety of ceramics called Early Green Glazed (EGG) Ware – the earliest known example of glazed pottery produced in Spanish colonial Peru. Held in museum collections and found in 16th century archaeological contexts between the Lambayeque and Chao Valleys in Peru’s north coast region, EGG ware vessels have forms that are typically similar to those of the Prehispanic Chimu-Inka tradition but are covered with a thin, lead-based glaze in varying shades of green and yellow (figure 1) (VanValkenburgh et

al., 2015a). No glazed ceramics have been recovered from pre-Columbian archaeological contexts in the Andes, and it has therefore been reasonably suggested that the glazing on EGG ware vessels was in some way inspired by the arrival of glazed ceramics and perhaps Iberian ceramicists to the Andean region after the Spanish invasion (Bushnell, 1959; Mayer, 1984).

However, the mechanics of this process of technological change and the manner in which it reflects colonial social relations are poorly understood – in part because no empirical study of EGG ware technology has ever been conducted and no sites of EGG Ware production have been discovered. Instead, scholars have speculated that EGG ware was produced by native artisans who were directly instructed by Iberian ceramicists but chose to continue to produce pottery with indigenous forms (Acevedo Basurto et al., 2004; Bushnell, 1959; Hecker and Hecker, 1988; Mayer, 1984; Mogrovejo Rosales, 1996; Stastny and Acevedo, 1986).

In this paper, we infer the conditions under which EGG ware was fired through microstructural analysis using scanning electron microscopy (SEM). We examine 44 archaeological samples of the type and compare them to five samples of lead-glazed ceramics produced by modern potters in southern Peru. Our results suggest that EGG Ware vessels were fired under diverse circumstances that included both oxidizing and reducing conditions, different maximum temperatures, and variable temperature profiles.

We argue that EGG Ware's production was spurred on not by straightforward technology transfer between Iberian ceramicists and native

artisans, but a more complex process of technological incorporation and emulation, in which native potters experimented with the production of glazes and, at least in some cases, fired their vessels in open firings. In our estimation, EGG ware's artisans had a great deal of control over the terms of their artistic production. Based on these findings, we suggest that the study of the technological properties of colonial material culture can, in some cases, allow scholars to push beyond the vernacular definition of hybridity and provide substantial insights into social process and cultural expression in contact zones.

[Insert Figure 1 here]

1. 2. Background

2.1 *Early Green Glazed Ware*^f

EGG ware vessels have two defining characteristics: they are decorated with a thin glaze that ranges from yellow-green to green in color and have forms that, in many cases, are similar to ceramics of the short-lived Chimu-Inka (ca. 1470-1532) tradition. Of the twenty-five whole vessels that we have observed in museum collections or existing publications, twelve are Chimu-Inka style double-bodied whistling pots (e.g., Figure 1b, 1c) and three are flat-bottomed pitchers with no clear Precolumbian precedents (e.g., Figure 1a). Both whole vessels and fragments bear common evidence of firing errors, including pinholing, crazing, crawling and discoloration (Figure 2) – characteristics that are also frequently found on lead-glazed ceramics fired in unstable conditions.

^f In this section, we draw on a previous discussion (VanValkenburgh et al 2015) of EGG Ware's key features and chemical characterization of the samples studied here. We refer readers to this earlier publication for additional details, which are not repeated here for reasons of space.

[Insert Figure 2 here]

While the presence of European forms among EGG Ware vessels make it possible that type was employed in non-indigenous households, every EGG Ware fragment recovered to date through systematic archaeological excavations has been found in the remains of houses, middens, and mortuary contexts associated with people of indigenous descent (see VanValkenburgh et al 2015). Moreover, it is likely that complete (or nearly complete) EGG Ware vessels held in museum collections – such as those Rafael Larco Hoyle reports excavating in the Chao valley in the 1930's (ML Cuaderno 3) – were used as grave goods within local burials.

The 44 samples studied here comprise almost 100% of the EGG ware recovered prior to 2014 from VanValkenburgh's excavations in the Zaña valley and Quilter's excavations at Magdalena de Cao Viejo (see map in figure 3). Analysis of data recovered via instrumental neutron activation analysis (INAA) of these samples' ceramic bodies and laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) of their glazes outlines contrasting patterns of composition. Pastes are highly diverse, suggesting multiple recipes and/or source materials (VanValkenburgh et al 2015). Glaze composition, however, falls into two groups, which largely separate by valley (Zaña and Chicama). VanValkenburgh et al (2015) argue that these results reflect 1) the production of EGG Ware pastes using multiple recipes (perhaps in multiple workshops), and 2) the collection of raw materials for glazing from two distinct sources.

[Insert Figure 3 here]

Analysis of LA-ICP-MS results also indicates that the chemical composition of glazes on EGG Ware samples ranges from 63 to 84% lead oxide, which would have reduced their melting points in comparison to glazes containing significant proportions of tin. Lead oxide is a flux that fuses around 800 °C in its pure form and combines with silica to form glazes. It may fuse at 700 °C or lower in the presence of other fluxes. Observations under SEM demonstrate uneven glaze thickness on our samples was uneven, varying from approximately 200µm to 1.2mm, which may be the result of uneven application of glaze to vessel surfaces and/or running and pooling during firing.

The green hues of EGG Ware vessels are virtually without precedent in Andean pottery and attest to the presence of copper in their glazes. Copper is commonly found in lead ores, and its concentration varies both within primary sulfides buried beneath the surface and in secondary surface deposits. EGG Ware potters may have specifically sought out ores with visible green hues for their glazes, but high variation in Cu concentration within our sample glazes (between .02% and .3%) makes it clear that their recipes did not call for a fixed amount of copper (VanValkenburgh et al 2015, table 2).

2.2. *2.2 Variation in ceramic firing conditions*

Archaeological discussions of ceramic production often draw a broad distinction between “closed” firing in kilns and “open” firings (Rice, 1987, pp. 152–163), sometimes complemented by the additional category of “mixed” firings in pits (Rice 2015: 172-175). Archaeometric and ethnoarchaeological studies

register a great deal of variation within these categories, based on the type of fuel employed and the configuration of fuel and vessels (Gosselain, 1992; Livingstone Smith, 2001; Maggetti et al., 2011; Maniatis and Tite, 1981; Pool, 2000; Shepard, 1956; Sillar, 2000).

Contrary to popular belief, temperatures in traditional kilns are not categorically higher than those in open firings. Gosselain's (1992) survey of open firings across the globe notes average high temperatures of 800-940°C – comparable to those in traditional kilns (Shepard, 1956, p. 218). Livingstone-Smith's (2001) extensive survey of firing practices in West Africa found no statistically significant differences in the maximum temperatures, soaking times, heating rates or total firing times of open and kiln firings. However, he reports significantly higher variation and standard deviation in these parameters (particularly heating rates and firing/soaking times) within his sample of open firings than within his sample of kiln firings.

In most cases, temperatures in open firings also peak more quickly, hold their temperature for less time, and fall off more quickly than those in kiln firings (Arnold, 1988, p. 213; Rice, 1987, p. 157; Shepard, 1956, p. 89; Tite, 2008, pp. 219–220). These characteristics (particularly slower heating rates) mean that rates of thermal shock in kiln firings are generally lower (Tite, 2008, p. 220). In addition to holding in heat, kilns protect pots from sudden spikes in temperature caused by wind, and the internal temperatures they achieve are generally more consistent across the kiln chamber than in open firings – though this depends on the type of fuel employed (Rice, 1987, p.155; Sillar 2000a). Rice (2015, p. 174)

suggests that there is often a great deal variability in atmospheric conditions during the course of even a single open firing, “as fresh fuel is added and irregularly consumed, as smoke is produced, as gases are released from the fuel and the pottery itself, and as wind gusts touch the fire.” Furthermore, the separation of fuel and pots in kilns allows fires to be continually stoked, further facilitating the control of firing temperatures. In firings where fuel is separated from vessels – i.e., in updraft and downdraft kilns, but not in pit kilns – potters can also achieve greater consistency in surface treatments, by preventing contact between vessel surfaces and burning embers.

Indeed, Rice (1987, p. 155) suggests that the challenge of protecting the surfaces of pots from fuel in open firings explains why glazed wares are “almost never” produced using such technology – with the notable exception of glazed pots produced in highland Guatemala during Reina and Hill’s (1978) fieldwork in the 1970’s. In the Andes, Sillar (2000a; 2000b) has also documented the production of glazed ceramics in open firings. In the community of Charamoray (Cuzco, Peru) in 1987, he observed artisans producing pottery with a lead-sulfide glaze, made from lead ore mined in small amounts near the village. The ore was ground into a fine powder and mixed with water to form a slurry that was wiped onto the surface of the vessels (Sillar 2000a: 54). Potters fired these vessels in carefully constructed open firings that lasted 1-2 hours, using dung as a primary fuel (see figure 4). Dung is a relatively slow burning fuel which leaves an insulating layer of ash over the pottery, permitting a more gradual rise and fall in temperature and relatively homogenous temperature across the firing. While

precise temperature readings were not registered, it is clear that fires at Charamoray grew hot enough to melt the lead mixture applied to vessel surfaces. Below, based on SEM analysis of samples that Sillar collected from Charamoray, we also demonstrate that they fired clays beyond their maturation temperatures.

[Insert figure 4 here]

It is therefore clear that while glazed vessels produced in open firings are relatively rare in the historical and ethnographic records, the temperatures achieved through open firings are quite sufficient for melting lead oxide, though many open firing configurations may not be advantageous for maintaining unblemished glazed surfaces. Based on empirical evidence of firing states among our samples and observations of whole EGG Ware vessels in museum collections, we argue below that at least some – if not all – known EGG Ware vessels were fired in some variety of open firing. Based on observed surface conditions of EGG Ware vessels and samples, we argue that many were in direct contact with fuel during firings, though not with the level of smudging expected had they been fired in pit kilns.

2.3. *2.3 Precolumbian Ceramic Technology in Peru's North Coast Region*

EGG Ware was produced in a region – the North Coast of Peru – with a vibrant tradition of ceramic production that employed a range of firing technologies, including pit kilns. Within a few centuries of the earliest appearance of ceramics in the region circa 1800BCE (Alva, 1986), potters of the Cupisnique tradition produced both lustrous, burnished blackwares and delicate oxidized

ceramics (Castillo Butters, 2009; Elera, 1998; Larco Hoyle, 1941). In the Early Intermediate Period, Moche (0-750 CE) ceramicists continued to produce both oxidized and reduced pottery and began using molds to produce their wares *en masse*.

Finewares produced during the subsequent Transitional or Early Lambayeque period (750-900CE) showed an increasing emphasis on reduction-fired blackwares (Rucabado and Castillo, 2003). Lambayeque utilitarian ceramics tended to be either oxidized or inconsistently fired, with careful reduction reserved for the finest pottery. Potters continued to produce both relatively coarse paddle-stamped wares and finer blackwares in the late 14th and 15th centuries CE, even as the region was incorporated into the expanding Chimu and Inka polities. During the Inka period, new state organized centers were set up to produce authorized imperial pottery forms; at the same time, local artisans synthesized innovative pottery that brought together elements of multiple traditions.

Among the remains of ceramic workshops dating to the Inka period, archaeologists have discovered multiple styles of decorative pottery alongside each other, including both blackware and provincial Inka polychrome vessels, as well as Chimu-Inka burnished blackware vessels with Inka forms – a ceramic style that has sometimes been labeled “hybrid” (Donnan, 1997; Hayashida, 1999; Mackey, 2010; Tschauer, 2001). Inka imperial policies may have had a direct impact on the crafting environment in which these vessels were produced, through the resettlement of Lambayeque artisans from distinct residential

communities into state workshops (Hayashida, 1999, 1995; Mackey, 2010; Mackey and Jauregui, 2002).

It is also quite clear that the products of these workshops were traded or redistributed far beyond the north coast, as they have been recovered in distant corners of the empire, including Machu Picchu and the Chachapoyas region (Costin, 2016; D'Altroy, 2002, p. 307). Indeed, Ramón (2013, 2017) argues that there were extensive networks of ceramic exchange in the northern Andes during colonial (and likely, late prehispanic) times, in which potters themselves were often responsible for transporting their wares.

The north coast also shares the distinction of being one of the very few places in the Americas with evidence for Precolumbian kilns, alongside those identified in the Veracruz and Oaxaca regions of Mexico (Balkansky et al., 1997; Payne, 1982; Pool, 2000, 1997). Shimada et al's (1998) excavations near that Poma Canal at the site of Batán Grande unearthed 57 simple updraft kilns dating to 1000-800BCE – keyhole-shaped pits dug into the ground, with an open firing box or antechamber at one end and a chimney at the other. Their inward curving walls would have favored reducing atmospheres when covered by fuel and/or large waster sherds (Wagner et al 1999, 1994). Based on experimental testing and Mossbauer spectroscopy, Shimada et al (1998) suggest that these kilns would have been capable of maintaining sustained heat up to 800°C.

Shimada's excavations at Batán Grande also uncovered a Middle Sicán (950-1050 CE) workshop near Huaca Sialupe, containing ovoid kilns built of adobe bricks lined with clay, which the excavators suggest would have been

used to create oxidizing conditions for firing large jars (Shimada et al., 2003; Shimada and Wagner, 2001). Alongside these facilities, they found pit kilns not unlike those at the Poma Canal. Firing experiments employing replicas of the former type of kilns demonstrated peak temperatures around 800 °C, which were generally held for a short time (10-15 minutes). Mössbauer spectroscopy on archaeologically recovered sherds from Huaca Sialupe estimated firing at temperatures up to 900 °C, but only on waster sherds that may have been either improperly fired or used as covers on kilns themselves.

Finally, Hayashida et al. (2003a; 2003b) identify possible open firing pits at the Inka site of La Viña. Mossbauer spectroscopy on diverse samples from La Viña and another nearby Inka site (Tambo Real) suggest a range of different firing practices, including both reducing and oxidizing conditions and maximum temperatures ranging between 450°C and 1000°C (see Hayashida et al. 2003b: 161).

In sum, ceramic technology in the North Coast region on the eve of the Spanish invasion was diverse and innovative. North coast potters had previously mastered the art of producing reduction fired blackwares. Under Inka hegemony, they had begun to produce both authorized imperial forms and creative renderings of Inka vessel types using local technological styles. Kilns were employed in isolated circumstances at least as early as Formative times and as late as the Middle Sicán period. However, there is no evidence of a continuous tradition of kiln firing in the region or for the production of glazed ceramics before the Spanish invasion.

2.4 Iberian Ceramic Firing Technology and Glazed Ceramics in 16th Century

Peru

Iberian firing technology also encompassed multiple traditions. The *horno arabe* (Arab kiln) was employed after the Umayyad conquest of Hispania in 711 CE and consisted of a two-chambered structure with a square or beehive-shaped compartment erected over a firing chamber (Lister and Lister, 1987, pp. 51–52). Holes at the top maintained an oxidizing atmosphere within the kiln. In the second half of the 16th century, Andalusian potters began to employ *hornos cuadrados* (square ovens) – two-chambered updraft kilns based on Italian precedents, which may have been used in parallel to the *horno arabe* (Lister and Lister, 1987, pp. 147–48). The technical properties of these two kiln types are poorly known, but the latter may have been employed for glaze firings after its introduction, with the *horno arabe* retained for bisque firings (Lister and Lister 1974).

There is unfortunately little empirical evidence that attests to the employment of these technologies in the early colonial Spanish Americas. Lister and Lister (1987: 220) suggest that native peoples in the viceroyalty of New Spain adopted some of their elements relatively quickly, employing both rock-lined pit kilns and above ground chambers by the mid-16th century. However, no archaeological or documentary evidence of these structures survives. Similarly, clear evidence of glazed ceramic production facilities has never been recovered from 16th century Peruvian sites, and the dates and loci of production of Andean

tin-enameled ceramics are still being identified (Harth Terré and Márquez 1958; Mogrovejo Rosales, 1996; Rice, 2013).

The recovery of EGG Ware in 16th century contexts leaves little doubt that native peoples of Peru's north coast were producing lead glazed ceramics by the last 30 years of the 16th century. Documentary evidence suggests that at least some north coast potters were highly mobile during this period. One group from the Lambayeque region petitioned a colonial official for the right to travel and sell their wares in 1567 (Ramón 2017; Rostworowski 1977a: 232). In 1613, five potters from the north coast (two from the city of Trujillo, two from Túcume and one from Zaña) figured among Lima's community of *olleros* (Ramón 2017). While the types of ceramics that these artisans produced for the market appear to have been predominantly large jars and cooking pots, it is quite possible that some EGG Ware was also distributed by mobile producers.

2.4. 2.5 The Samples

The EGG ware samples studied here were collected from archaeological excavations and surface collections at six sites – 25 samples from sites in the Zaña valley and 19 from excavations in the lowest levels of occupation at Magdalena de Cao Viejo (Chicama valley, occupied ca. 1578-1720). Of the Zaña samples, eleven were collected at the *reducción* of Mocupe Viejo (C74, occupied ca.1572-1650 CE), eight from the *reducción* of Carrizales (C123, occupied ca.1572-1600 CE), two from an isolated mortuary site (C271), two from a midden associated with a colonial canal (C216), and one from the remains of the colonial

port of Chérrepe (C142, occupied ca.1563-1792) (BNL A310; AGN Ucupe 30: 26r-26v) (Table 1; Figure 3). This final sample is typologically identical to EGG Ware excavated in our other, more secure 16th century contexts.

At Carrizales and C271, EGG ware was recovered in direct association with human remains; elsewhere, fragments were recovered from middens and domestic contexts. Samples from Magdalena de Cao Viejo were recovered in the lowest colonial levels at the site, in the town sector, which date to the late 16th century (Quilter 2010). Within sites, samples were chosen from widely separated contexts in order to minimize the probability of analyzing multiple sherds from the same vessel. Additional details concerning the contexts of recovery are discussed in VanValkenburgh et al (2015). All of the samples derive from “end products” and are not associated with kiln wasters or dumps.

A variety of vessel types are represented among the EGG Ware samples – bottles with necks of <5cm diameter (40-019 and 123-30-01), bottles with wider necks (02-48, 209-12, MDC2011-36-03), a flat-bottomed vessel (05-19 - figure 2d), and pitchers or jugs (684-01, 44-023; figure 2c). The majority, however, are small body sherds – necessary inclusions in the sample set given that the total population of EGG ware samples recovered from archaeological contexts to date is so low.

The final five samples derived from Sillar’s ethnoarchaeological research in Charamoray Peru. All are covered with a thin lead glaze that is green to dark green in color. Pinholing and running is common on their surfaces. Two samples (C3 and C18) are body sherds, while one sample (C13) is a cord-shaped handle

from a jug, and two samples (C12 and C15) come from pots with ear-shaped handles (figure 5).

[Insert Figure 5 here]

3. Methodology:

Previous studies have demonstrated the utility of examining ceramic microstructure through scanning electron microscopy (SEM) for observing firing states and inferring production temperatures (Buxeda i Garrigós, 1999; Buxeda i Garrigós et al., 2003; Chatfield, 2010; Maniatis and Tite, 1981). We analyzed 44 sherds via SEM, breaking each into two subsamples – one of which was analyzed as-is, the other of which was refired before analysis. Following breakage, we assigned each subsample a new laboratory code (see “Refired Samples” listed in Table 1), giving all refired subsamples the suffix “R.”

We refired samples under oxidizing or reducing conditions based on visual assessment of their original firing atmospheres. No organic matter was observed in the samples, and so we interpreted black bodies as evidence of reduction firing. We refired red-bodied sherds and samples that showed a mixture of original firing atmospheres in an oxidizing atmosphere and all samples with black/grey bodies in a reducing atmosphere.

We matched refiring conditions (including temperature and duration of refiring) to those employed by Chatfield (2010), in order to facilitate direct comparisons with that previous study. Oxidized and mixed samples were refired at 890 °C for 30 minutes in a muffle furnace. The reduced samples were buried

in corn flour and placed in an argon atmosphere furnace, ramped up at a rate of 200 °C/hour to a peak temperature of 890 °C and then maintained for 30 minutes before cooling. Following refiring, we made fresh breaks in the refired samples. All subsamples were then ultrasonically cleaned in deionized water for one minute, then dried in an oven for 1 hour at 100 °C. Dried samples were then mounted on stubs using carbon tape and dried again overnight at 60°C before being sputter coated with gold (~25nm).

The samples were analyzed using a Hitachi S-3400N SEM at high vacuum, operating at 15kV. Sample surfaces were surveyed in detail and a minimum of four representative areas per sample were imaged. In order to ensure accurate characterization of each sample, three fields of view (approximately 120, 65 and 24 microns in width) were imaged for each area (figure 6)⁹.

We then categorized sherds based on observations of their stages of paste vitrification and bloating pores, following Maniatis and Tite (1981) and Chatfield (2007, 2010). In Table 1, the term Initial Vitrification (IV) describes samples with isolated areas of smooth surface, while Extensive Vitrification (EV) describes samples in which we observed a notable increase in the extent of smooth areas. The term Continuous Vitrification (CV) describes samples with continuous, smooth vitrification layers over the entire sample break.

Where the microstructure appeared to be intermediate between two descriptive categories, it was assigned a label corresponding to the lesser of the

⁹ See supplementary material to access one set of SEM imagery for each sample.

two vitrified states, followed by a “plus” sign (+). For example, sherds with both EV and CV structures were labeled EV+. Samples with bloating pores were additionally labeled based on pore size – “fbp” (fine bloating pores), “mbp” (medium bloating pores), or “lbp” (large bloating pores). Figures 5 and 6 present examples of these microstructural states.

4. 4. Results:

Table 1 presents observations of the state of vitrification/ceramic microstructure of each subsample based on SEM analysis as well as inferences of original firing atmospheres, based on ceramic body color. Our analysis of unrefired EGG ware samples found that 55% (n=24) exhibited a state of CV, indicating that they were initially fired beyond the maturation temperature of their clays (“over-fired” in conventional terms – e.g., Kingery et al 1976: 507). The remainder (n=20) of the samples were initially fired to either the EV stage or somewhat beyond this point, but short of CV. Of these latter samples, ten exhibited a microstructural change to a higher state of vitrification following their refiring at 890°C for 30 minutes. In contrast, the other ten samples exhibited no change in their microstructures. Bloating pores were observed in seven samples before refiring and eight samples after refiring; however, only samples 7 and 7R contained pores in extensive areas. In seven samples (7R, 11R, 14R, 16R, 37R, 28R and 42R), we observed increased sizes of bloating pores following refiring, even though their vitrification state (CR) was not altered. All five of the

ethnoarchaeological samples from Charamoray exhibit continuous vitrification, with no bloating pores.

[Insert Table 1 here]

Following Chatfield (2010), we interpret changes in the firing state of samples after refiring as an indication that they were originally fired either below 890°C or for less than 30 minutes. However, our methodology does not allow us to determine whether or not sherds with an initial state of CV were fired above or below 890°C or for more or less than 30 minutes.

We also find minor differences in the prevalence of certain firing characteristics among samples from the Zaña valley sites and Magdalena de Cao Viejo. Among the Zaña Valley samples, 38% (n=10) were fired in reduced atmospheres, while 27% (n=7) were fired in oxidizing conditions. In contrast, only 11% (n=2) of the samples from Magdalena de Cao were fired in oxidizing atmospheres, while 56% (n=10) were fired in reducing conditions. Similarly, the un-refired Zaña valley samples contain a higher proportion of CV sherds (64%, n=16) and lower proportion of EV sherds (8%, n=2) than the samples from Magdalena de Cao Viejo (CV 45%, n=8; EV 22%, n=4). We also observed that a greater proportion of the sherds from Magdalena de Cao Viejo (33%, n=6) changed their vitrification state following refiring than samples from the Zaña valley sites (16%, n=4). However, none of the z or P values of comparisons of these proportions satisfy the criteria for statistical significance, and we hesitate to draw strong distinctions between firing practices among the two sample sets.

[Insert Figure 6 here.]

While the focus of this study is paste microstructure, SEM imaging also provided qualitative information about the production sequences of EGG Ware. The boundary between glaze and vessel bodies appears irregular across all samples (figure 7), indicating that potters did not extensively smooth the surface of their ceramics prior to glazing – or that they may have forcefully pressed glaze into the surface employing a brush or other stiff implement. The presence of a great amount of ceramic body material mixed into the glaze layer in sample 6 seems to indicate that the glaze on that vessel was brushed on in this manner. However, glaze layers on a subset of our archaeological samples do not exhibit mixing between glaze and ceramic bodies or that the ceramics were prefired, and samples from Charamoray similarly demonstrate no similar evidence of mixing between glaze and body material.

[Insert Figure 7 here]

[Insert Figure 8 here]

5. 5. Discussion and Conclusion

6. 5.1. EGG Ware Firing Characteristics and Regional Comparisons

Our results indicate that the 44 samples of EGG ware studied here were fired under diverse conditions. Observed differences in paste color, states of vitrification, and alteration following refiring suggest that atmospheres, maximum temperatures, and thermal profiles of original firings all varied across the sample. In contrast, the five samples from Charamoray display more consistent characteristics: all were fired to the CV state, beyond the maturation temperatures of their clays, above 890°C. Alongside Sillar's (2000a) previous

research, these results demonstrate that lead glazed ceramics can be produced using open firing.

We make two interpretations based on these trends and the archaeological and historical research outlined above: 1) that our EGG Ware samples (and therefore, the type more generally) was likely not produced using a single, introduced Iberian firing technology; and 2) that at least some EGG Ware vessels were produced in open firings. If – as previous authors have speculated – EGG Ware were fired in Iberian-style kilns that were uniformly incorporated into north coastal potting traditions, we would expect to find relatively consistent firing characteristics across our samples. Instead, we find the opposite – high variability.

Observed variation in inferred firing states and atmospheres among our samples may also be directly related to their production in open firings. As we outline above, ethnoarchaeological and experimental studies have underscored the diversity of conditions in so-called “open” and “closed” firings and cautioned against making categorical distinctions between them (Gosselain, 1992; Livingstone Smith, 2001; Shepard, 1956). However, evidence suggests that most open firings subsume much greater variation in firing atmospheres and temperatures than typical kiln firings (Nicholson and Patterson 1989; Rice 2015, p. 174; Shepard 1956, p. 86-88).

It is important to note, however, that these patterns are not universal. As the results of our analysis of the Charamoray samples demonstrates, open firings can be constructed in ways that permit more stable firing atmospheres and more

sustained firing temperatures (Sillar 2000a), and some kilns have been shown to have significant temperature differences across their firing spaces (Nicholson and Patterson 1989). Inferred variation in firing states and atmospheres among our EGG Ware samples may also reflect the use of different clay recipes, with different maturation temperatures. Previous INAA characterization of these samples' pastes revealed a high level of compositional diversity among them, which was interpreted as evidence of production in dispersed workshops (VanValkenburgh et al 2015). Dispersed production may have also entailed localized distinctions in firing practices.

However, our analysis does not reveal any significant relationship between compositional groups and firing characteristics. Samples from Magdalena de Cao Viejo were relatively uniform in composition, but encompass a great diversity of inferred firing states and atmospheres. In comparison to samples collected from sites in the Zaña valley, they include a higher proportion of samples recovered from that site were fired in reducing atmospheres and to a lower state of vitrification (EV or EV+), but a chi-square test reveals that the difference in these proportions is not statistically significant ($P > .05$).

The observed surface conditions and overall shapes of our EGG Ware samples and whole vessels in museum collections provide other evidence that at least some EGG Ware vessels were produced in open firings – specifically, signs that these vessels came into direct contact with fuel. Concentrations of small, linear, unglazed areas on vessel surfaces, such as those pictured in figure 8, may be the results of contact with burning vegetable matter or the grass

contained in dried animal dung, prior to glaze cooling. Thick accumulations of glaze on the surface of the vessel in figure 1c may be the product of direct contact with more solid fuel, such as wood, or other vessels – a pattern also observed among vessels from Charamoray.

In addition, whole EGG ware vessels held in museum collections often have a “sagging” or deformed appearance, a characteristic that is sometimes observed among ceramics fired beyond the maturation temperatures of clays – and one rarely found among curated examples other types of 16th and 17th century ceramics, such as tin-enameled plates and pitchers fired in Iberian-style kilns (see VanValkenburgh et al 2015: figure 2; Acevedo et al 2004: 60). Because sagging (like any outcome of a ceramic firing) is the product of pairing particular firing parameters and clay recipes, clay selection would also have been a key influence in producing it. To date, however, paste samples from whole, sagging EGG Ware vessels in museum collections have not been available to us for characterization.

Our analytical results outline distinct patterns of technological incorporation to those observed in Chatfield’s (2010) study of Prehispanic and colonial period sherds from the site of Aqnampampa, 70km southeast of Cuzco, Peru. Employing virtually the same parameters in her SEM microstructure analysis, Chatfield found that both colonial period (1600-1800CE) glazed ceramics (tin-glazed and lead-glazed earthenwares) and Killke and Inka style ceramics produced in early colonial times (1532-1600 CE) were predominantly fired to the EV stage, above 890°C and/or for longer than 30 minutes. Of the

glazed sherds in the study, Chatfield observes that two were Andean made and the rest were imported. In contrast, firing temperatures for earlier Late Horizon and Late Intermediate Period sherds (including materials of both the Killke and Inka styles) were generally below 890°C. Chatfield attributes this shift to a change in firing practices – most likely, the introduction of Iberian-style kilns to the region.

While experimental research suggests that we should be cautious in attributing higher firing temperatures to the introduction of kilns alone, and most of the comparative glazed material in Chatfield's study appears to have been imported, her data demonstrate a definite shift in firing characteristics at Aqnapampa in the wake of the Spanish Invasion. If this change was indeed the product of the introduction of Iberian style kilns to the region, it represents a distinct technological trajectory to that outlined by the production of EGG Ware on the north coast during the 16th century. However, the fact that lead glazed ceramics continued to be produced in open firings at Charamoray in the 1980's underscores the diversity of Andean colonial and postcolonial ceramic firing traditions. There, just three valleys to the west of Aqnapampa, potters who had ready access to information about kilns and kiln-fired ceramics produced their own lead-glazed vessels in open firings in the late 20th century.

5.2 EGG Ware, Cultural Hybridity, and Technological Incorporation

These patterns suggest that, like many other Old World technologies (Rodríguez-Alegría 2008; Rogers 1990), Iberian-style kilns did not steamroll

existing traditions when they were first introduced into the Americas. As Sillar (2000a) and Pool (2000) argue, no firing technique is manifestly superior to any other. Rather, as Pool (2000, p. 62) suggests “choosing a particular firing method involves weighing its advantages and disadvantages with respect to specific requirements for using available resources, organising labour and producing the desired range of products.”

On the eve of the Spanish invasion, ceramicists in Peru’s north coast region already had a wealth of different firing technologies available to them, and their ceramic industry was arguably the most diverse on the continent. Evidence at the Inka site of La Viña suggests some were familiar with pit kilns. Variation in the firing states of prehispanic ceramics provides evidence that they made use of distinct open firing configurations to produce both consistent oxidizing and reducing conditions. As indicated by the presence of multiple styles of ceramics in the same workshops, and innovative recombinations of Chimu and Inka styles, late prehispanic north coast potters were already members of a vibrant artistic community that was receptive to the introduction of new forms and decorations.

At the same time, their practices were not infinitely pliable, and they were most likely unfamiliar with updraft kilns. The EGG Ware samples we have analyzed here, as well as whole EGG Ware vessels in museum collections, do not bear the marks of wholesale technology transfer; rather, they manifest significant variation and experimentation with ceramic materials that were incorporated into the local pottery making tradition. This pattern demonstrates that indigenous potters exercised a great deal of control over the basic steps

through which the type was produced. Because open and kiln firings cannot be distinguished strictly based on their maximum temperatures or firing profiles, our SEM microstructural analysis cannot rule out the possibility that some EGG ware artisans employed Iberian style kilns. However, surface evidence of contact between vessels and fuel show that at least some of the EGG Ware vessels were finished in open firings.

As EGG Ware potters adjusted their firing conditions, they may also have experimented with distinct clay and glaze recipes. Earlier chemical characterization of our 44 samples of EGG Ware points to the use of distinct raw materials in the Zaña and Chicama valleys – possibly two sources of lead ore, and divergent clay recipes. Different proportions of reduced vs. oxidized pottery and EV vs. CV firing states among samples from sites in the Zaña valley and Madgalena de Cao Viejo outline the possibility that as potters in distinct workshops procured different raw materials to produce EGG ware, they also employed different firing parameters. In some cases, experimentation led to technically suboptimal results – i.e., sagging forms and surface imperfections. In other cases, such as the formulation of distinct combinations of lead ores with different amounts of copper in them, it led to decorative variation.

Yet even as EGG Ware potters developed a new form of surface treatment for their vessels, with new technological requirements, their technological choices were guided by existing cultural practices. In addition to being employed in domestic contexts, EGG Ware appears to have been quickly incorporated into indigenous burial traditions, appearing alongside human

remains in the looted church at the site of Carrizales, as well as in burials excavated by Rafael Larco Hoyle in the 1930's (ML Cuaderno 3). Moreover, unlike the lead glaze layered onto the interior of some colonial *botijas* (olive jars) to reduce their porosity, the glaze on EGG Ware was employed strictly for decorative purposes. It was applied to vessel exteriors, giving them a glassy feel and shine similar to that of Iberian tablewares, which are found alongside EGG Ware fragments at Magdalena de Cao Viejo and sites in the Zaña valley.

Indeed, in some cases, the initial production of EGG Ware may have been as much inspired by the circulation of Iberian glazed ceramics within indigenous communities (or conversations with Iberian non-specialists) than either direct observation of kiln firing or instruction in its methodologies. Alternatively, like many ethnographically documented potters, EGG Ware artisans they may have been resistant to the adoption of a new technical style of production (kiln firing) even as they were receptive to new forms of decoration (Foster, 1948; Ramón and Bell, 2013, p. 596).

Our analysis suggests that, at a time when the material culture and lifeways of native peoples were becoming an increasingly concrete focus of Catholic missionary and viceregal political discourse (Rostworowski de Diez Canseco, 1975; Toledo, 1986), and as Iberian decorated ceramics were circulated among North coastal indigenous communities that were increasingly tied into trans-oceanic trade networks, some native potters incorporated a new material (lead) and new aesthetic effects (green glaze) into their existing artistic practices. They employed the resulting decoration to both “traditional” forms of

pottery, such as double-bodied whistling vessels, and new forms such as Iberian style pitchers with flat-bases that were most likely designed to be used in concert with flat wooden tables.

Following their production, EGG Ware may have been acquired and used by non-indigenous people, but archaeological evidence suggests that it was preferentially employed in native domestic contexts and mortuary practices – at a time (the late 16th century) when the styles, forms, and locations of burials were becoming increasingly salient targets of Catholic and viceregal projects of conversion, catechism, and *reducción* (Duviols, 1986; Gose, 2003; Mills, 1997; Polo de Ondegardo, 1916). It thus represents a powerful assertion of native creativity and resilience in the midst of overwhelming oppression.

In sum, our SEM microstructural analysis of 44 samples of EGG Ware and observations of whole vessels in museum collections reveal significant new insights into the processes through which indigenous north coast potters created a new variety of ceramics. Merely describing these forms as the “hybrid,” or “entangled” products of cultural encounters runs the risk of obscuring the series of more intricate (and we believe, more interesting) processes by which new technological and aesthetic practices emerge. Here, we have attempted to show that getting beyond the surface of these objects and investigating the technological choices that were made in their production can tell us a great deal more about cultural process than a more restrictive study of form and decoration.

Acknowledgements

Funding for SEM was provided through a grant from the Mark Wainwright Analytical Centre at the University of New South Wales. SEM work was undertaken at the Electron Microscope Unit at the University of New South Wales. Collections from Peru's Zaña valley were obtained via excavations and survey funded by grants to VanValkenburgh from the Social Science Research Council and a Frederick Sheldon traveling fellowship. Excavations at Magdalena de Cao Viejo, directed by Quilter, were supported by grants from the National Science Foundation and National Endowment for the Humanities (RZ5115010) of the USA. Peter van Dommelen and three reviewers provided valuable feedback on this manuscript. Thilo Rehren and Marcos Martiñón Torres offered advice on the presence of copper in our sample glazes. Ulla Holmquist provided access to collections at the Museo Rafael Larco Herrera, where Isabel Collazos provided additional support. Carlos Wester La Torre generously provided access to collections at the Museo Nacional Heinrich Brüning in Lambayeque, Peru. Thanks also to Pramod Koshy (University of New South Wales) for kindly refiring samples.

Figure captions

Figure 1 – Whole EGG Ware vessels from museum collections in Peru. 1a – flat-bottomed pitcher, Museo Larco, Lima, Peru; 1b – double-bodied whistling vessel, Museo Nacional Heinrich Brüning, Lambayeque, Peru; 1c - double-bodied whistling vessel, Museo Larco, Lima, Peru; 1d – pitcher with animal-like mouth, Museo Larco, Lima, Peru (photographs by P. VanValkenburgh)

Figure 2 – Fragments of EGG Ware recovered from archaeological sites in the Zaña valley. 2a - Sample 139-039, 2b - Sample 139-031; 2c - Sample 44-023; 2d - Sample 005-014, 2e -Sample 40-019, 2f – Sample 123-9-19

Figure 3 – Map of sites discussed in text.

Figure 4 – Diagram of second open firing observed by Sillar at Charamoray, Peru in 1987 (after Sillar 2000a: figure 6).

Figure 5 – Samples collected by Sillar at Charamoray, Peru.

Figure 6 – SEM images of analyzed samples, demonstrating different firing states (upper left – sample 40, EV; upper right – sample 25, CV; lower left – sample 7R with medium bloating pores; lower right – sample C3, CV)

Figure 7 – SEM images of the edges of two EGG Ware samples (top – sample 2; bottom - sample 6)

Figure 8 – Close up photograph of the surface of an EGG Ware double-bodied whistling vessel, from the Museo Larco.

Archival Abbreviations

ML – Museo Rafael Larco Herrera

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