POTS, PEOPLE, AND PILGRIMAGE: ELEMENTAL ANALYSIS OF SURFACE PIGMENTS ON NASCA POLYCHROME VESSELS FROM THE NASCA DRAINAGE

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ABSTRACT

The Nasca (1-700 CE), best known for their monumental geoglyphs, also produced ancient South America's most elaborate polychrome pottery. While changes in the iconographic content of Nasca ceramics have been well documented, less is known about the political and economic organization of ceramic production across the polity. This study aims to assess models of centralized and decentralized production through the analysis of pigment composition across distinct iconographic phases. By closely examining pigments among a widespread sample, inferences can be made about either the homogeneity or heterogeneity of production techniques across vastly different stylistic phases. In addition, this study briefly explores how Nasca polychrome may have served to spread ideology, and the subsequent distribution of these vessels across the Southern Nasca Region, chiefly by spiritual pilgrimages. Using portable X-Ray Fluorescence (pXRF), the pigments of 27 intact polychrome vessels were read and then analyzed using Principal Component Analysis to determine whether compositional changes are concomitant with changes in iconographic phases. The results of this analysis found that though pigments were chemically distinct from each other, there is no significant variation within individual pigments between different iconographic phases. This finding suggests the Nasca potters utilized a rigorous tradition of recipes, sources, and techniques that endured for centuries, but also expanded and morphed over time to create a tradition of incredible visual diversity. This preliminary study sheds some light on production, but additional compositional studies on pigments and clay matrices from Nasca polychrome ware could greatly contribute to the troublingly bare provenances of vessels in museum and university collections.

BIOGRAPHICAL SKETCH

Cristina Juarez is an MA student at Cornell University completing her thesis research on a collection of Nasca polychrome ceramic vessels housed in the Cornell Anthropology collections. Her thesis incorporates both iconographic analysis and the elemental analysis technique of pXRF, which is reflective of her broader research interests of combining art historical and archaeometric methodologies in the study of ceramics. She completed her BA at McDaniel College and majored in Art History and Environmental Studies, where her research spanned topics such as pre-Columbian iconography and indigenous land tenure and conservation efforts. Cristina completed fieldwork at the Moche site of Huaca Colorada in the Jequetepeque Valley, and she plans to continue working in Peru for future research. In May, she will travel to Cusco, Arequipa, and Lima with an Art History faculty member to conduct some preliminary research involving pXRF analysis of colonial paintings censored in the aftermath of the Tupac Amaru revolts.

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1. Introduction

The Nasca, a complex polity located in the southern coastal region of Peru and best known for their monumental geoglyphs were also masterful artisans of ancient South America's most colorful polychrome pottery. The ceramic tradition spans a 700-year period, broken up roughly into four stylistic stages: Monumental Nasca, Transitional Nasca, Proliferous Nasca, and Disjunctive Nasca. Designs range from recognizable and naturalistic motifs to highly abstracted and geometrized iconography that features animals, plants, deities, warriors, and varying amalgamations of the natural and supernatural worlds. Scholars have recently begun to move beyond an iconographic focus to explore the production of these vessels via compositional analysis, both elemental and mineralogical (Eerkens, Bafod, Vaughn, Williams & Lesher 2014; Olivera, Vetter & Petrick 2010; Pappalardo, Masini, Rizzo & Romano 2016; Vaughn, Dussubieux & Williams 2011; Vaughn & Neff 2000). However, few of these studies have attempted to draw connections between compositional groups and stylistic differences, and even fewer have conducted such analyses on whole, intact vessels. For the most part, sherds have been used for chemical analysis, which does not allow for the thorough iconographic classification that whole vessels with complete iconography can provide. Whole vessels are rarer to find outside of private collections, and are not suited for destructive methods of compositional analysis such as XRF and LA-ICP-MS.[1]

This study aims to navigate the technical issues that these more traditional methods have posed by using the non-destructive method of portable X-Ray Fluorescence (pXRF) to analyze variation in the chemical composition of the pigments across a sample of Nasca polychrome

[1] X-Ray Fluorescence and Laser Ablation Inductively Coupled Plasma Mass Spectrometry, respectively. LA-ICP-MS also employs a deeper range of analysis into the matrix of the clay and is thus less useful for thin surface pigments (See Duwe & Neff 2007).

vessels. The composition of these paints, whether homogenous or distinct across different stylistic phases, will potentially offer insight into how ceramic production was organized within the Nasca political economy. Compositional data can address the issue of whether pigments of stylistically distinct vessels show a restricted range of values that may suggest they come from a few mining sources. Alternatively, mining sources may have varied across the stylistic sequence, concomitant with shifts in social, political, or economic organization. In addition, this study will indirectly test the hypothesis that production was largely concentrated at the civic-ceremonial center of Cahuachi (Vaughn & Neff 2000).

The degree to which ceramic production was centralized or standardized carries important implications for the structure of ceremonial life in the Nasca polity, since decorated vessels played a key role in the communication and transportation of religious ideology. This hypothesis also works well with the evidence of Nasca pilgrimages to Cahuachi from all around the Southern Nasca Region; if vessels were the vehicle of ideology, Nasca peoples were the means of transportation and virality. Proof of centralization of production would reflect more broadly on economic and political organization of the Nasca and generate further questions as well: was a restricted group responsible for all aspects of polychrome production, or simply the fabrication stage of production? If raw material resources were abundantly available, why wasn't production more democratized? And critically, is the expansion in colors and diversity of design throughout time a sign of more potters from more regions producing vessels?

To address these questions, a collection of 27 complete Nasca vessels held by the Cornell Anthropology Collections was analyzed using pXRF. Unlike its predecessor technique of XRF, pXRF is non-destructive and portable, permitting the elemental analysis of sensitive or precious materials without destruction or damage of any kind. Its handheld nature permits analysis without the removal of an object from storage or display in collections, which can pose legal and/or administrative difficulties. Though pXRF has been primarily used for more homogenous materials such as obsidian, it has been effectively used for analysis of varying heterogenous matrices such as ceramics, alloys, and pigments (*See* Ferguson, Van Keuren & Bender 2015; Forster, Grave, Vickery, & Kealhofer 2011). The ability to determine elemental composition both without destruction and without removal from institutions represents a significant technological advancement for fields such as archaeology and art history.

In addition to non-destructive pigment analysis, this study also reanalyzes the stylistic classification of the complete vessels, in order to bridge the gap between stylistic and compositional aspects of production. From an archaeological perspective, both of these aspects are links of the *chaîne opératoire*, and it is important to look at them in conjunction with each other to better understand the ceramic tradition of the Nasca, and "the ways in which 'potting communities' are formed and interact" (Duwe & Neff 2007: 404). *Chaîne opératoire* refers to the operational sequence of creating pottery, and includes everything from gathering the materials to create the pot to the eventual discard of the remains by its user. In this framework, every step of production and use history carries social significance, and furthermore, each step directly interacts with and leads to the next. It is important to look at *chaîne opératoire* within its socio-economic context so as not to risk conflating potters' choices with complete independence or freedom; factors such as restricting artistic canons and traditions, environmental resource availability and conditions, and structure of society (who is able and/or expected to craft ceramics, and what is the nature of demand for creation) can all play a role in influencing potters' choices and subsequently restricting or shaping a ceramic tradition.

2. Research Background

2.1. Archaeological Context

In order to understand the context in which this ceramic tradition emerged, a brief overview of the Nasca peoples is necessary. The Nasca civilization was composed of a series of chiefdoms with local leaders sharing a common regional religion and culture (Carmichael 1998; Proulx 2000; Vaughn 2004). The Nasca first created a distinguishable social formation primarily in the Ica and Nasca Valleys along the branches of the river drainages of the same names, although their influence can be seen extending into the Cañete Valley and the Ocoña, Camaná, and Sihuas Valleys in Arequipa, Peru (Proulx 2009). This "loosely allied confederacy" of settlements shared agricultural and pastoral practices, establishing and maintaining self-sufficient subsistence economies in the harsh desert environment (Vaughn 2004: 67). The Nasca and Ica drainages are some of the only fertile areas (and sources of freshwater) for hundreds of kilometers in this intensely arid region of southern Peru (Doyon 2006). Though these rivers provided freshwater, their flow was often unpredictable. During certain parts of the year branches would become completely dry, retreating into vast underground aquifers (Doyon 2006). The agricultural economy of the Nasca depended on tapping these aquifers in the form of springs and wells.

In addition to agriculture, their economy was bolstered by some trade with highland cultures, evidenced by camelid depictions in iconography (Proulx 2009). They also had interactions of a less peaceful nature; as time passed, the Nasca became increasingly militaristic, and iconographic evidence suggests more interaction with Wari peoples. Vaughn et al. (2011) argue that during the Late Nasca period the Southern Nasca Region also became less integrated; the peoples of the drainage amassed in more isolated and well-defended settlements as the Wari state united north of the Ica-Nasca region and began to influence and invade the territory around

550 CE (Silverman & Proulx 2002). After approximately 750 CE there is no more culturally distinguishable evidence of the Nasca, likely in part due to the unsuitability of the desert environment which “did not allow dense population aggregates” for extended periods of time (Carmichael 1998: 216). The eventual conquest of the Nasca people and their integration with the Wari may have contributed to the collapse of their society due to additional environmental stressors put on the region. At the very least, the acculturation of the Nasca people to Wari culture was complete enough that evidence of the Nasca as a separate and distinct culture vanishes.

Despite the harsh environmental conditions for organic life, the southern coastal region of Peru is an ideal climate for pottery production (Carmichael 1998). The weather is warm and sunny throughout the majority of the year, with very little precipitation; in addition, clay and mineral sources are available in abundance (Carmichael 1998). The geology of the Nasca region is composed of mainly Paleozoic igneous rocks, with vast mineral deposits from the desert alluvial basin (Eerkens, Barfod, Vaughn, Williams, and Lesher 2014). Most of the metal ores that were utilized in the region came from Cretaceous rock formations in the Coastal Batholith and Bella Union complex, but similar geological features in the Southern Nasca region allowed for ore-mining farther south in the Ingenio Valley (Eerkens et al. 2014). Hematite and other iron oxides are most prevalent in this region due to the abundance of iron deposits and their oxidization in silicate materials (Eerkens et al. 2014). Recent research shows the prolific use of one particular mine in the Ingenio Valley, Mina Primavera, throughout the Nasca chronology for hematite extraction (Eerkens et al. 2014). Hematite, limonite, and other iron oxides were used abundantly by the Nasca for the creation of their mineral pigments, and heavier extraction in some mines over others reveals crucial data about sourcing in terms of production (Carmichael

1998). If Nasca potters were choosing to extract heavily from some mines over centuries it could indicate that the source had some significance beyond simple practicality, since there is an abundance of mineral resources in the region. Eerkens at al. (2014) believe that the Nasca may have been deliberately selecting particular types or strains of minerals from the same source for their color or luster. The relative uniformity of colors used in Nasca polychrome ware (despite the diversity of pigment hues eventually achieved) would suggest that if particular parts of raw mineral sources were being used, this must have been somehow communicated to all of the potters producing these vessels. Similar themes and motifs in iconography across a variety of vessels suggest close communication of potting traditions as well.

2.2. Social and Religious Context

The Nasca polychrome ceramic tradition is particularly well known for this decorative phase of production. Iconography of the polychrome ware typically featured natural motifs such as plants and animals, sometimes depicted as supernatural creatures or with trophy heads. Motifs of water and agriculture are prevalent in Nasca iconography in every phase of production, likely due to the proximity of the ocean, and the shifting presence and importance of the rivers (Vaughn 2004). Themes of vitality and fertility played a large role in the iconography; events both mundane and special such as "planting and harvesting, preparation for war, and the primary rites of passage such as birth, adolescence, marriage, and death" are prevalent and were likely cause for major ritual practices in Nasca society (Proulx 2009: 9). Proulx (2009) adds that the greatest concern of Nasca peoples was dependable food and water in their inhospitable landscape and consequently their spiritual lives and lifestyles in general were greatly influenced by this need. That the iconography of polychrome pottery may have served as a vehicle for the ideology of Nasca peoples is further evidenced by archaeological patterns of ceramic use and distribution.

Though little is known about who in Nasca society was producing polychrome ware, its remains are found in all strata of society – both in elite graves and domestic habitation sites. Excavation of tombs has revealed that Nasca society was at least somewhat stratified, with evidence of an 'elite' class; certain individuals were buried with an abundance of polychrome vessels, spondylus shells, and gold (Vaughn 2004). However, an excavation conducted in the small village site of Marcaya revealed that all houses, regardless of status, had access to some form of polychrome ware – though high-status houses had more and a larger variety of vessel shapes and types (Vaughn & Neff 2000).

Polychrome fine ware was specifically used for serving and consuming food and drink, not storage or preparation (Vaughn & Neff 2000). A large proportion (55%, n = 232) of the pottery sherds recovered at Marcaya was polychrome fine ware, and significant midden heaps were found near higher status habitations indicating that feasting regularly took place in this small village context (Vaughn 2004). Vaughn and Neff (2000) theorize that the pottery was used by local elites who hosted feasts to build status and connect themselves with more important and distant religious powers. The consumption of polychrome ware for religious and ceremonial purposes rather than food storage or preparation could explain its ubiquitous presence throughout Nasca society as well as the common motifs of fecundity and supernatural beings. Though it is difficult to speak with certainty on the structure and content of Nasca religion, polychrome ware appears to have aided the spread of a common ideology, suggesting a more centralized religion than the dispersed chiefdom structure of the Nasca society would indicate.

One explanation for such a seemingly uniform and centralized religion despite the scattered nature of Nasca settlement is the site of Cahuachi. Now a series of mostly eroded mounds that blend in with the natural desert landscape, Cahuachi is located 18 km from modern-day Nasca in a 500 meter wide section of the Nasca Valley (Silverman 1993). Situated upon the southern bank of the Nasca River, it faces the pampas to the north, and the monumental geoglyphs to the south (Silverman 1993). Previously thought to be a large domestic site, Cahuachi is now believed to be a dual civic-ceremonial site for pilgrimage and possibly ceramic production that was unoccupied for most of the year (Carmichael 1998; Silverman 1993; Vaughn 2000). There is no evidence of long-term habitation at Cahuachi, and a wealth of ceremonial remains indicate that activities were likely ritual but not domestic (Silverman 1993). Among the artifacts discovered during excavations in the 1980s were various burials, hundreds of panpipes, a ceremonial drum, and elaborate pottery (Silverman 1993).

Archaeological evidence for Cahuachi as a production center is demonstrated by the chemical uniformity of formulas and mineral sources for Early or Monumental Nasca polychrome sherds and vessels, which have been recovered and studied in abundance in comparison to Transitional and Proliferous Nasca ceramics (Vaughn, Dussubieux, and Williams 2011: 3561). In addition, the compositional study published by Vaughn et al. (2011: 3561) stated that archaeological excavations at the site of Cahuachi "have revealed substantial evidence for ceramic production" such as "potter's plates, caches of pigments, raw clay, paint brushes, and polishing stones" (3561). Using the compositional analysis method LA-ICP-MS (Laser Ablation Inductively Coupled Plasma Mass Spectrometry) and drawing on previous results from INAA (Instrumental Neutron Activation Analysis) of Nasca polychrome, they found that not only could the majority of the Monumental Nasca sherds tested – 20 samples from the Southern Nasca Region – be traced to Cahuachi, but the sherds from later phases all included samples that matched the chemical composition of the Monumental Nasca sherds. Earlier studies of relative chronological phasing via type-frequency seriation also confirmed a majority of Nasca 3

(Monumental Nasca) vessels, with Nasca 1, 2, and 4 present but less common, and later phases virtually absent at Cahuachi (Silverman 1993).[2] The surge in production in Nasca 3, as opposed to the other subphases of Monumental Nasca (Nasca 2 and Nasca 4) as well as proto-Nasca (Nasca 1) may suggest a peak production period near the end of the early Nasca period that tapered off by the beginning of the Middle or Transitional period. Vaughn et al. believe that construction at Cahuachi terminated by the end of the Monumental Nasca period, which may explain not only the abundance of Monumental Nasca vessels and sherds, but also their heterogeneity. It is thought that the decline of Cahuachi could be attributed to a "fairly substantial drought" followed by a shift of the limited central power to the north in Palpa (Vaughn et al. 2011: 3561).

After the fall of Cahuachi and during the Late Nasca period, the Southern Nasca Region became significantly less unified. The previously connected network of chiefdoms aggregated into a smaller number of "towns" with larger populations as a means of defense against invaders to the region (Vaughn et al. 2011: 3562). In their study, Vaughn et al. (2011) note that the naturalistic depictions of Monumental Nasca become abstract during Transitional Nasca. They cite Carmichael's argument that these abrupt changes may have resulted from a larger pool of potters and mounting competition among them after the decline of Cahuachi as a production center (Vaughn et al. 2011). The archaeological record seems to suggest the importance of the civic-ceremonial site in the religious practice of the Nasca, and their subsequent creation of polychrome ware for the spread of said ideology.

In addition to the Monumental Nasca vessels found at Cahuachi, a number of late Paracas ceramics were also discovered (Silverman & Proulx 2002). The Nasca artistic style is believed to

[2] See table 1 for explanation of how stylistic phases used in this study relate to other proposed chronological classifications.

be derived from Paracas ceramic style. In addition to the great artistic influence the Paracas people had on the Nasca, it is also very likely that the Nasca were direct cultural descendants of Paracas people living in the Ica Valley and parts of the Rio Grande de Nasca drainage. How precisely the Nasca culture came to be distinguished from Paracas may very well have to do with technological advances of the Nasca, most directly evidenced by their ceramic production.

2.3. Production

Although the Nasca artistic style was derived from the Paracas, their cultural predecessors in the Ica and Nasca drainages, the two traditions can be distinguished by techniques of production. Paracas sherds are often found amongst Monumental Nasca sherds in the Ica Valley and parts of the Rio Grande de Nasca drainage, and are referred to as Ocucaje to distinguish them (Silverman & Proulx 2002). References to the Ocucaje style can be seen within the Nasca polychrome ceramic tradition, particularly in Nasca 1 (proto-Nasca) where incised lines were still used to separate color just as was common in Ocucaje production (Silverman & Proulx 2002). The most significant change was the technological shift from “post-fire resin painting” to “pre-fire slip painting” with mineral pigments suspended in slip to create a longer-lasting design that was fired onto the vessel (Silverman & Proulx 2002: 17).

The colorful polychrome vessels of the Nasca were created from local clays with natural mica inclusions that add luster to unpainted portions of the vessel. Apart from these natural inclusions, no additional temper was used in the fragile, thin-walled polychrome vessels, as opposed to the thicker-walled utilitarian vessels tempered with sand and crushed quartz (Proulx 2000). The fine, smooth paste was typically worked into vessels using a combination of coiling and pinching, along with direct shaping, paddling, and scraping until walls reached an average width of 3-4 millimeters (Carmichael 1986; 1998). Direct shaping was primarily used for creating the bases of vessels and molding appliques such as the facial features on facepots (Carmichael, 1986). Differing combinations of these methods were used on different vessels with seemingly no correlation to different phases; molds, however, were never used (Carmichael 1986; Proulx, 2009). Carmichael notes that this is particularly impressive concerning the double or bridge spout bottles that required much skill to make; the enclosed spherical shape and narrow spouts not only made them particularly useful in the desert for keeping liquids cool, but also would have proven very difficult to mold by hand without the use of a wheel (Carmichael 1998: 220).

The production of slips for these vessels was no less complex. Paints consisted primarily of iron oxides such as limonite, hematite, and magnetite, as well as manganese oxides and white kaolin clay (Proulx 2000). Pigments were created by crushing these minerals and mixing them with clay slips and occasionally deflocculants such as wood ash or sea salt to keep the mixture suspended (Proulx 2009). Experimentation with differing combinations and varying ratios of ingredients and variations in firing temperatures in the Monumental Nasca phase resulted in an extensive range of colors by the Transitional and Proliferous phases (Carmichael 1998). On average, polychrome vessels created after the Monumental Nasca phase exhibit 8-12 distinct colors, making Nasca polychromes the most abundant in color variety of any ancient ceramic production style in Peru (Proulx 2009). Though black, red, and white pigments seem to appear with the most abundance in the archaeological record, the full range of color used by the Nasca consisted of pigments of black, white, purple, red, dark red, light red, orange, light orange, yellow, gray, brown, violet, pink, and light blue hues (Proulx 2009).

Paints were applied to ceramics using brushes made from human or llama/alpaca hair, and were created in various widths for different parts of designs (Proux 2009). Incising was also occasionally used, though largely during the period of early production (Carmichael 1998). To decorate vessels, ground color was applied first, and then bands (Carmichael 1998). If the design was simple, a black outline was then added and filled with color, but on many complex designs color was added first and an outline was painted on top (Carmichael 1998). Designs were often present on multiple registers, though the interior of vessels was rarely painted (Proulx 2009). Application of color was followed by burnishing of the painted surface with a small stone, which Carmichael states "[compacted] mineral paints, making them more permanent and giving the exterior an attractive high gloss" (1998: 221). Though little is known of the firing methods used by the Nasca due to a lack of archaeological evidence, analysis of the vessels shows that they were fired in an oxidizing environment – likely shallow pits – with cameloid dung and the wood of local huarango or algorrobo trees as the most probable sources of fuel (Proulx 2009). Additionally, evidence of "ghosting" – or faded imprints of designs and pigments not originally intended for a vessel on its surface – has been found on some ceramics, indicating that it may have been common practice to stack pots while firing (Carmichael 1998).

3. Materials

The sample used for this study includes 27 intact polychrome Nasca vessels currently housed in the Cornell Anthropology Collections in McGraw Hall. These vessels span the Nasca iconographic sequence from Monumental to Disjunctive phases (see section 4.2). The only provenience information available on the vessels is the general location of the Nasca River drainage basin on the south Coast of Peru. All vessels were the result of a donation to the collections by Ernest L. Frank, and were first catalogued in 1987. Due to the large chronological and stylistic range of these vessels, it is likely that they came from multiple sites, though the exact provenience information is missing.

4. Methodology

4.1. Portable X-Ray Fluorescence

PXRF or portable X-ray fluorescence is a useful tool for determining elemental composition of materials. It is analytical technique that operates by releasing an X-ray beam that disturbs the electrons in the material being tested from their orbital atomic position, which in turn releases a burst of energy specific to each individual element present in the matrix of a sample. A spectrum of elements is produced as a result, in the form of peaks that represent the concentrations of each element present for that particular 'shot' of the sample. Though its use in homogenous materials such as obsidian is more commonplace, there have been a growing number of studies on its function as a tool for examining heterogenous matrices such as ceramics. Even rarer (though not unprecedented) is its use for surface analysis of paints on ceramics (*See* Ferguson, Van Keuren, & Bender 2015). Though experimentation with pXRF technology in this capacity is uncommon, its usefulness in this context is demonstrable. As previously mentioned, pXRF is handheld and portable, and completely nondestructive. For a collection of whole Nasca vessels that could not be removed from their primary location, these attributes were indispensable.

Before readings were taken with the pXRF, each distinct color on each of the 27 vessels was categorized using Munsell color charts in consistent lighting. Twenty visually distinct pigments were identified, but in order to strengthen the sample size, the six pigments that occurred most frequently across all vessels were utilized for elemental analysis. These pigments were two shades of red (10R 3/3 and 10R 3/4), black (5YR 2.5/1), red-orange (10R 4/6), white (10YR 7-3) and yellow-white (10YR 7-4). The most commonly occurring pigment was black, used largely for outlines in the figures represented in the iconography.

To take readings of the pigments, the pXRF was put on a tripod and the aperture was positioned to read different sections of the vessel. Readings were recorded in the S1PXRF program. For each pigment, the instrument settings were 15 kV and 20 µA, and readings were taken in triplicate. For a few of the pigments on 3 of the vessels (986.1.11, 986.1.13, and 986.1.14) readings of some colors were noted as likely inaccurate because the lines were too thin for the sensor to read without including data from surrounding pigments. These readings were excluded from the study. One vessel in the collection, 986.1.15, was excluded entirely from the study because the intricate designs were too small to allow for accurate readings of any of the pigments used, leaving the sample size at 26 vessels. Among all other vessels, this problem was encountered most regularly with the white (10YR 7/3) pigment as it was frequently used for outlines and thin-line motifs. It was present in enough vessels as a background color that this did not significantly lower the number of readings taken across all vessels in proportion to the other pigments.

4.2. Iconographic Classification – Phases & Chronology

After each reading was taken with the pXRF, each vessel was categorized into one of four major stylistic phases by closely examining its designs. Lawrence Dawson is responsible for creating the first categorization of Nasca polychrome into a 9-phase seriation, but for the purpose of creating relatively equal sample sizes for each category, the vessels used in this experiment were divided into the larger iconographic classes of Monumental or Early Nasca, which encompasses phases 2-4, Transitional/Middle Nasca or phase 5, Proliferous or Late Nasca, comprised of phases 6-7, and Disjunctive Nasca (phases 8-9). This more contemporary categorization makes an important separation of phase 1, now believed to be heavily influenced by the preceding Paracas culture or "proto" Nasca, and phases 8-9 which encompass ceramics that are no longer associated directly with the Nasca culture, dating to the Middle Horizon (600 – 1000 CE) (Carmichael 2013). The assignment of each vessel to Monumental, Transitional, Proliferous, and Disjunctive Nasca was based on consultation of Richard Paul Roark's detailed 1965 publication outlining themes and motifs of each phase of Nasca pottery, in conjunction with Donald Proulx's 2009 *Sourcebook of Nasca Iconography* (Paul Roark 1965; Proulx 2009).

The first of these phases, Monumental Nasca, characteristically consists of naturalistic depictions of birds, plants, sea creatures, and various other animals (Proulx 2000). This is the period of Nasca style in which the most animals appear predominantly over supernatural or militaristic content. They are depicted naturalistically, especially in contrast to later periods (Proulx, 2000). This period of Nasca ceramic production seems to be largely one of establishing a distinguishable style, and accurately depicting the natural world. Figure 1a shows a vessel from the sample categorized as Monumental.

The second major phase, Transitional Nasca, is a liminal period of production that demonstrates experimentation in its expansion of colors and the beginnings of a more abstract style. The motifs of Transitional Nasca were still similar in content to Monumental Nasca with many naturalistic themes, but they become more abstracted and geometric with added "rays and tassels" that fill the space of the composition with busier designs (Proulx 2000). In addition, Transitional Nasca phase sees more theriomorphic figures with combined human and animal, or multi-animal features [Figure 1b]. This combination of different elements represents a shift in the

Nasca artistic culture from simply recording the natural world around them to experimenting with more complex depictions of multiple elements of different creatures.

The last phase of Nasca pottery, Proliferous, is named as such because of its seemingly infinite compounding elements that unfold into dizzying geometric motifs that bear little similarity to the simple, thick-lined animal motifs of the Monumental Nasca period (Proulx 2000). Additionally, the content of the iconography seems decidedly more supernatural and militaristic in theme than Monumental or Transitional Nasca (Proulx 2000). Trophy heads, though common before, show up on nearly every ceramic vessel, sometimes multiple times on a single piece (Proulx 2009). The style is highly abstract, and in addition to the accumulation of rays and tassels on the design, figures become "disproportionate with the heads of supernatural figures becoming the center of attention, and the remainder of the bodies much abbreviated" (Proulx 2000: 3). The faces of these figures also become highly elaborated, nearly "baroque" in the intricate weaving detail they develop (Proulx 2000: 3). Face neck jars are predominate during this period and often feature attributes of trophy heads, such as the sutured lips that can be seen in other depictions [Figure 1c].

By examining the attributes of each phase, previously assigned vessel categorizations in the collections catalog were either accepted or rejected, and all unidentified vessels were assigned to a phase. Vessels were classified using a combination of visual analysis of motifs, colors present, and vessel shapes. Some shapes, such as double-spout jars, face neck jars, and woman-form bottles were unique to particular phases, and thus, were easy to diagnose in combination with iconographic analysis. Other shapes and particular motifs, such as geometric designs, were common throughout all phases and more difficult to assign. For these vessels, Dr. Donald Proulx was consulted personally for his interpretation and classification.

After the 26 remaining vessels were divided into each phase for comparison with their chemical matrices, the Disjunctive category was eliminated from the experiment due to its small sample size (n=2). The final sample of 24 vessels were relatively evenly distributed among Monumental (n=8), Transitional (n=10), and Proliferous (n=6). Original catalog classifications were mostly correct, though five vessels were reassigned from their original categories.

4.3. Statistical Analysis

In order to analyze the data acquired through S1PXRF, results were uploaded into the computer program Artax. Once all spectra, a total of 273 PDZ files, were uploaded into the program, the spectra were visualized as a set of peaks. Elements were identified using the identification tab on the program in tandem with a matching Bayesian deconvolution line for each spectrum. For each spectrum file, this step was completed independently and elements were labeled on every spectrum. 'Artifacts' or false peaks caused by an unusually high concentration of one element appearing as a small peak of another, non-present element, were checked for in each spectrum. After identification of the elements detected for each reading of the pXRF, Bayesian deconvolution analysis was completed by the program using the identified peaks.

All of the elements identified for the spectra combined were aluminum, silicon, phosphorous, sulfur, argon, potassium, calcium, titanium, chromium, manganese, iron, nickel, copper, zinc, rhodium, palladium, and lead. Initially, chlorine and barium were identified as well, but chlorine was excluded as part of the L-line for rhodium, and barium has a nearly overlapping peak with titanium due to very similar energy values and was subsequently eliminated. After review of these counts, argon was excluded because it was likely only a result of the surrounding air (because the readings were not taken in a vacuum). The rhodium and palladium columns were also eliminated because they are emitted by the instrument itself during readings and are not indicative of the sample matrix.

Counts for each element and pigment were then divided into groups for statistical analysis according to parameters of color and phase. For each pigment, three groups were created to represent readings for that pigment for Monumental, Transitional and Proliferous Nasca periods (Ex.: Black Monumental, Black Transitional, Black Proliferous, etc.). In total, with six distinct pigments and three phases per pigment, 18 groups were created. Table 2 displays the exact number of 'shots' or variables that fell into each group for analysis. An excel spreadsheet of each shot was created with columns for pigment, phase, and the concentrations of each of the 14 elements remaining in the study. Because the values ranged so widely even among the same shot, log 10 values were created for each photon count. The spreadsheet with these values was then loaded into the statistical analysis program, IBM-SPSS. To assess changes in elemental composition, a table was created that grouped the values by pigment with each divided into three phases, and the mean, standard deviation, and numeric count for each element. This allowed an easier visual comparison to assess if there were any major differences between phases within pigments.

Next, a Principal Components Analysis was completed to determine which elements grouped with the most frequency across the entire sample. The analysis was completed across the entire sample, rather than by individual pigment, because of the relatively small sample size of each pigment. The PCA created an ANOVA table with the main components/factors that were extracted for analysis, or correlative groups of elements across the sample [Table 3]. The analysis was set to Varimax rotation, which produced an output table of variables in addition to the original component matrix; the rotated component matrix estimates not only the correlation between the variables themselves, but also the correlation between the variables and the components. All possible values are represented between -1 (representing negative correlation) and +1 (positive correlation). In Table 3, elements with the highest values or associations with that factor are highlighted. This means that these elements, where dominant in the sample, tend to group together.

After the main components or groups of elements were extracted, the next step was to look at each of these components individually to see how they correlated with each individual phase within each pigment. To look at each component in depth, a general linear model (univariate) was created for each principal component, one at a time. This analysis was run with the individual component as the dependent variable, and pigment and phase as the fixed factors. Under EM means, phase and pigment were set to interact so that the factor being tested (the dependent variable) could be compared to phase *within* pigment. This created an “estimates” output table of mean-differences, or standardized variables that represent how closely correlated each phase (within each pigment) is with the principal component being tested. These values are averages of each value in the original 18 groups, which have their mean subtracted from them and then are divided by their standard deviation. The same analysis was run in a second iteration, but this time without interaction between phase and pigment, to see if there were statistically significant differences between these variables on their own (i.e. is the difference between individual pigments across the entire sample statistically significant regardless of phase, and vice versa). Finally, a bar graph was created from each of the Phase*Pigment interaction EM means outputs (for each individual component) to visualize the frequency of each principal component within each phase and pigment.

5. Results

The results of the PCA are displayed in Table 3, which also contains the significance values of individual elements for each factor extracted. For the loadings, only variables with values above .3 were considered significant (these values are highlighted in Table 3). The first component extracted, Factor 1, shows high correlation between Si, Al, K, and P. Factor 2 consisted primarily of Cr, Ti, and Pb. Factor 3 displayed high correlation between Ca, S, and Ni, while the highly correlated elements for Factor 4 were Cu, Mn, and Fe. The final component, Factor 5, shows correlation between Zn and Ni, though this component primarily consists of Zn. The results from the PCA alone revealed which groups of elements were most dominant in each pigment. For example, across the entire sample, black pigments were mainly comprised of iron, manganese, and copper, while dark red showed higher concentrations of chromium, titanium, and lead.

When the univariate general linear models were run for each factor *without* interaction between phase and pigment, it showed that while there are differences between each pigment in terms of which principal components are most dominant, these differences are not statistically significant. A few of the values fall within the $p < .05$ significance range, but because of the small sample size it was necessary to complete a Bonferroni correction to correct for multiple comparisons. This is done by multiplying any significant p-values by 15 (the number of pairwise comparisons) to see if values remain significant, and they did not. There are differences between pigments that were maintained throughout the majority of the production period in this sample, but they are ultimately statistically insignificant.

After the univariate general linear model was run for each principal component *with* interaction between pigment and phase, a bar graph was created from the “means” column of the estimate output table for each component. [Figures 2-6]. Figure 2 shows the bar graph created from the analysis of the first component. The colors along the bottom axis of the chart represent all of the pigments tested, and the blue, orange, and gray clustered columns represent the Monumental, Transitional, and Proliferous phases within each of those pigments. The values on the left axis of the chart represent the range of standardized variables, or EM means, from the output table created. For black, dark red, and light red, regardless of phase, the means are negatively associated with this component, which means that this grouping of elements is unlikely to show up in these pigments. The light red pigment is particularly negatively associated with the first component. Because these values are based on standardized variables, the mean values for the light red pigment are outliers amongst the rest of the sample and fall more than one standard deviation from the average, while all the other pigments fall within one standard deviation, either in a negative or positive direction. In opposition to the light red, black and dark red, the red-orange, white, and yellow-white pigments are all positively associated with the first component, indicating that this grouping of elements is likely to occur within these pigments, regardless of phase. While the clustered bars in the graph show some difference in size, the variation between phases within pigments is not statistically significant.

For the most part, phases within pigments trend in the same direction – either negatively or positively correlated with each particular factor, suggesting that the elemental composition of visually distinct color was consistent throughout time. The exception to this consistency is the light red pigment. In Factors 2, 3, and 4, the light red trends in opposing negative and positive directions between the Monumental and Transitional phases, respectively, while they trend in the same direction and appear more correlated for Factors 1 and 5. Additionally, for factors 1-4, each pigment shows an insignificant amount of variation between the Monumental, Transitional, and Proliferous phases. However, for Factor 5 consisting primarily of Lead and Zinc, the pigment

Yellow-White appears to vary more between the phases of Monumental and Transitional versus Proliferous (as opposed to much less variation in previous components). However, this difference between phases, similarly to the light red pigment, is not statistically significant.

In sum, each graph demonstrates that although there is some difference between the composition of pigments, there does not seem to be consistent significant variation within individual pigments between the Monumental, Transitional, and Proliferous phases.

6. Discussion & Conclusions

The data from this preliminary experiment show that there is heterogeneity between pigments of different colors characterized by higher concentrations of some elements vs. others in the pigment matrix, which corroborates conclusions found from other pigment analysis studies on Nasca polychrome pottery (Romano et al., 2011). Despite expected dissimilarity between pigments, the data also show that there is very little variation between the elemental groups present in each pigment across different phases. What little differentiation does exist between phases seems to be random, and certainly cannot be classified into a pattern that is consistent across pigments. In the case of the Light Red pigment, the larger amount of variation between the only two phases present, Monumental and Transitional, is likely due to the small sample size of this particular pigment (Light Red – Transitional: n=1; see Table 2). In addition, the sole vessel that fell into the "Light Red – Transitional" category was labeled in the original collections catalogue as a potential fake. The iconographic analysis completed for this study also raised suspicions that this vessel was a modern reproduction due to both uncommon stylistic elements as well as a lack of wear or degradation of the paint. Though it is beyond the scope of this experiment to make this claim with certainty, this double spout bottle [Figure 7] shows significant evidence of modern reproduction or alteration. Disregarding this outlier, however, the results show a general trend towards uniformity in chemical groups over time.

These results indicate that despite drastic changes in iconographic style and vessel shape over the course of centuries, there does not seem to be corresponding changes in the chemical composition of pigments. This finding suggests that the mining source for the mineral pigments in this sample may have remained relatively unchanged for centuries. The Eerkens et al. (2014) iron isotope analysis on red and black pigments helps support this argument; the study found evidence for prolonged hematite extraction from the Mina Primavera in the Ingenio Valley, and the iron isotopes from the hematite tested in that study were "indistinguishable" from pigments from Cahuachi. They also concluded that regardless of phase, the iron oxides contained in both the red and black pigments showed a restricted range of isotopic values indicating homogeneity through time (Eerkens et al., 2014). However, Eerkens et al. (2014) note that the similarity they see is not consistent with a natural, greater level of variation between hematite samples from the same source, which may suggest that potters were deliberately picking specific, chemically similar strains of minerals for their color, luster, or properties during firing. This could perhaps make it harder to distinguish between pigments that come from different mineralogical sources because their selected physical properties make them more chemically similar, despite coming from different geographic areas.

These revelations also have significant social implications; the general homogeneity of elemental composition (at least among this sample) indicate that geologically similar sources of raw materials were being selected throughout the major period of production (Monumental through Proliferous) for hundreds of years. This deliberate selection of certain parts of minerals presumably to produce consistent colors suggests a complex level of organization in the Nasca potting tradition. The fact that singular mines show prolonged use despite the abundance of mineral resources in the region could also indicate the importance of specific areas and mines that may go beyond practicality. There is a dearth of provenience data for this particular collection of vessels: they are all catalogued as having come vaguely from the “South Coast, Nasca Drainage.” The collection spans a chronology of approximately 700 years, which suggests that they likely come from at least a few different sites. If this is true, it may suggest an organized method of direct acquisition of raw materials for pigments, as well as a consistency in recipes used to produce consistent colors. This supports the argument for centralized production, at least throughout early phases as a canon was being established.

These results also reveal new information pertinent to the Cahuachi hypothesis. While the data show that there is indeed relative chemical uniformity between phases, the elemental composition of these pigments is only partially consistent with the composition of the pigments present on a group of sherds found at Cahuachi. Romano, Pappalardo, Masini, Pappalardo, and Rizzo (2011) conducted a combined PIXE-alpha and XRD analysis on some painted sherds from Cahuachi, and while that analysis was primarily mineralogical, they shared some of their elemental composition results from the PIXE-alpha analysis. Like this study, the analysis found that the white pigment was characterized by a high calcium content and the red pigment by a high iron content [Figure 8]. However, the spectra produced in that analysis and this one are more dissimilar than expected. There are much higher counts of lighter elements such as Aluminum and Silicon in the Romano et al. study [Figure 9]. In addition, the results from this analysis show a high iron content in the white pigment, while iron levels in the white pigment from the Romano et al. study are negligible [Figure 10].

There could be a number of reasons for these differences. Primarily, the Romano et al. study used a penetration depth of 15 µA, while this analysis used a penetration depth of 20 µA. This analysis might have picked up more of the underlying paste, which would account for high levels of iron. In addition, PIXE-alpha and pXRF are vastly different technologies, and a variety of different settings were used in the Romano et al. study which may have affected how different elements were weighted. There is also no certainty that the shades of red and white tested in both experiments were the same. For this experiment, colors were categorized using a Munsell color chart, but they may not be identical to the pigments found in the sample of the Romano et al. study, considering the many different shades of one color that are often present on Nasca polychrome fine ware. Based on the results from a compositional analysis performed on Nasca polychrome sherds from the Southern Nasca region conducted by Vaughn, Conlee, Neff, and Shreiber (2005), this may in fact be the case. Their study utilized LA-ICP-MS and found that within one visually homogenous pigment across several samples, black, there actually existed seven chemically-distinct subgroups (Vaughn et al. 2005). This could suggest that the reason for the very slight compositional differences found in the pigments of this experiment versus others are indeed due to experimentation with chemical recipes in an attempt to create more visual diversity in surface decoration. However, it appears that many of these slight changes in concentrations or firing resulted in either very slight or entirely indistinguishable visual differences in colors.

Overall, the two studies show that while certain elements remain dominant for certain pigments, there does not appear to be close chemical uniformity between the pigment on Monumental Nasca polychrome sherds found at Cahuachi and whole vessels tested in this experiment. There are not enough data to say with certainty whether or not the two could be considered definitely homogenous or heterogenous; that would require compositional data from a larger sample from Cahuachi. If further research following this experiment shows evidence of production in a variety of locations, it may suggest more communication and interaction between the widely spread Nasca communities than was previously assumed. It would also be useful in further exploration of the Cahuachi hypothesis to test a variety of pigments from different areas of Nasca territory, including Cahuachi, to see if they differ regionally.

From this initial study, there appears to be significant enough difference from sherds produced in Cahuachi to challenge that the civic-ceremonial center served as a major production and distribution center for all of most of the Southern Nasca Region. The pigments tested in this study show different concentrations of dominant elements than the pigments on sherds from Cahuachi tested in the Romano et al. (2011) study. Though access to the data used in the Romano et al. study would better confirm the significance of this difference, elemental peaks are dissimilar enough to suggest either very different sources for the pigments or different recipes of production. In addition, the vessels in the sample from this study range from Monumental to Proliferous and do not show significant variation. Production at Cahuachi ceased around Phase 4/5, roughly at the beginning of the Transitional Period. If the Monumental and Transitional vessels in this sample were produced at Cahuachi, they should show significant chemical dissimilarity to the Proliferous vessels indicating a change in production.

In addition, slight but not statistically significant change in composition of pigments between phases may represent some experimentation with chemical recipes for the pigments, though not in direct correlation with changes in iconography. This would also explain different ratios of the same elements in this study versus the Romano et al. experiment. Thus, it can be suggested that the Nasca experimented with slight alterations to their chemical recipe for pigments over time, but this does not appear to be directly correlated with the distinct iconographic phases, and the changes are slight enough to suggest that mining sources either remained homogenous or the Nasca were deliberately selecting geologically similar sources for raw materials.

7. Future Research

There is a need for more research exploring the challenges and abilities of pXRF to conduct analyses on different matrices and studying its potential as an archaeometric tool. There are a variety of settings and techniques that could be implemented to gain different results based on such factors as varying thickness and porosity of the sample, inclusion of temper, and the amount of 'lighter' or 'heavier' elements present in the matrix. If a more robust version of this experiment were to be performed, taking readings with a variety of settings and filters might provide a more complete dataset. Of the 14 elements analyzed for this study, Silicon, Aluminum and Phosphorous were identified as potentially problematic due to the light atomic mass of these elements. It would be useful in a future study to conduct readings at multiple settings (voltage and amplitude) to better record readings for both high-Z and low-Z spectra.

Another limitation encountered with the pXRF during this experiment was the relatively wide aperture that made obtaining readings on particularly thin lines of pigment difficult. The aperture is approximately half a centimeter wide and tall, and in order to be variable in size would require a material that could simultaneously block the aperture and prevent reflection of the radiation beam back into the device (which would cause skewed results). Having a larger sample size or limiting colors tested to those that can fully fill up the width and height of the aperture would provide less skewed results.

This preliminary study demonstrates the usefulness of pXRF as an archaeometric tool, as well as the importance of considering style as an element of production in ceramic analysis. Use of pXRF analysis represents an important contribution to the field of South American archaeology; being able to analyze ceramics *in situ* and in collections may allow archaeologists to make important discoveries about production, and potentially flesh out the very bare provenances of large collections of South American ceramics that exist in museums throughout Latin America and the United States.

APPENDIX

Figure 1a. A cup bowl with naturalistic leaf designs characteristic of the Monumental Nasca period.

Figure 1c. A face neck jar with sewn lips in the style of a trophy head. This style is common during Proliferous Nasca, particularly in Phase 7.

Figure 1b. A shallow cup bowl with flaring sides depicting a supernatural creature and the "girl head motif." The latter is particularly prominent during Transitional Nasca.

Stylistic Strains	*Dawson's Phases*	*Sawyer's Phases*
Disjunctive	9	Nasca-Wari
Proliferous	8 7	Late Nasca
Transitional	6 5	Middle Nasca
Monumental	4 3 2	Early Nasca
Proto-Nasca	1	Proto-Nasca

Table 1. This table, based on Fig. X in Silverman and Proulx's *The Nasca* (2002) shows the stylistic strains of Nasca polychrome being utilized for this study (i.e. Monumental, Transitional, etc.) compared to other relative chronologies used in classifying Nasca style.

	Monumental (n)	Transitional (n)	Proliferous (n)	All pigments tested (n)
Black	7	10	6	23
Dark Red	5	7	6	18
Light Red	4	1	0	5
Red-Orange	5	6	4	14
White	8	8	4	20
Yellow-White	1	4	4	9

Table 2. This table shows the number of shots utilized (after averaging triplicate shots) for statistical analysis from each of the 18 groups created.

Components

	1	2	3	4	5
Si K 12b	0.960	-0.043	-0.084	0.053	-0.140
Al K12b	0.943	-0.111	-0.136	0.052	-0.036
K K12b	0.892	-0.082	-0.148	0.210	-0.056
P K12b	0.500	-0.367	0.085	-0.184	0.251
Cr K12b	-0.168	0.904	0.055	-0.142	-0.027
Ti K12b	0.002	0.889	-0.123	-0.125	0.204
Pb L1b	-0.346	0.623	0.181	0.244	0.407
Ca K12b	-0.072	-0.156	0.905	-0.130	-0.022
S K12b	-0.299	0.247	0.811	-0.085	-0.180
Ni K12b	0.070	0.035	0.633	-0.574	0.311
Cu K12b	0.129	-0.009	0.024	0.806	0.088
Mn K12b	0.013	-0.304	-0.281	0.747	0.128
Fe K12b	0.110	0.174	-0.560	0.686	-0.150
Zn K12b	-0.091	0.192	-0.071	0.063	0.928

Table 3. An ANOVA table with Varimax rotation displaying the 5 factors extracted from the Principal Component Analysis.

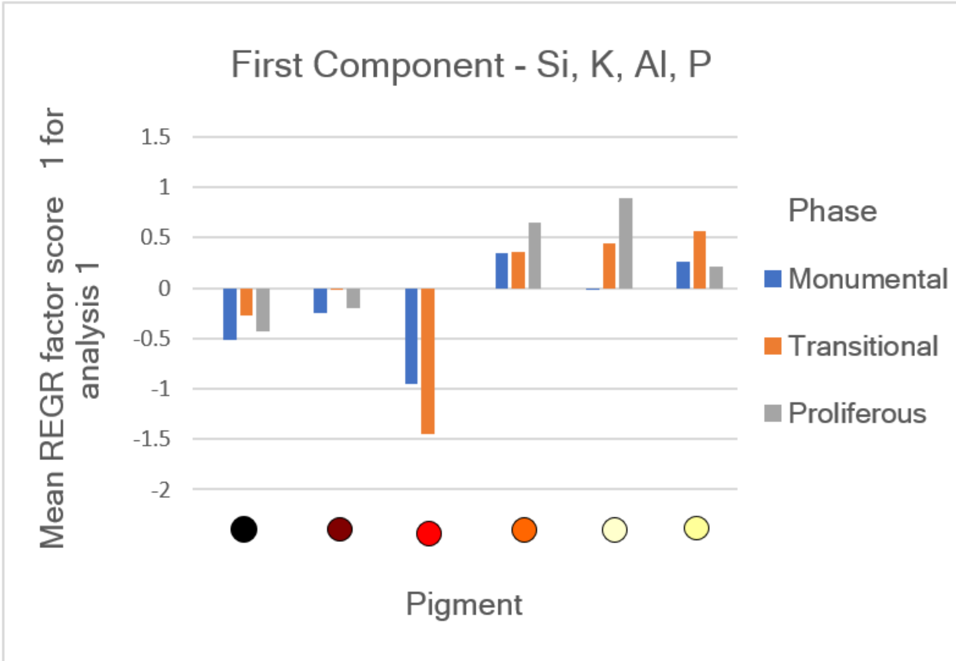

Figure 2. The graph shows the correlation of the 1st Factor with each pigment across the entire sample. The cluster of 3 columns per pigment represents this correlation across phases.

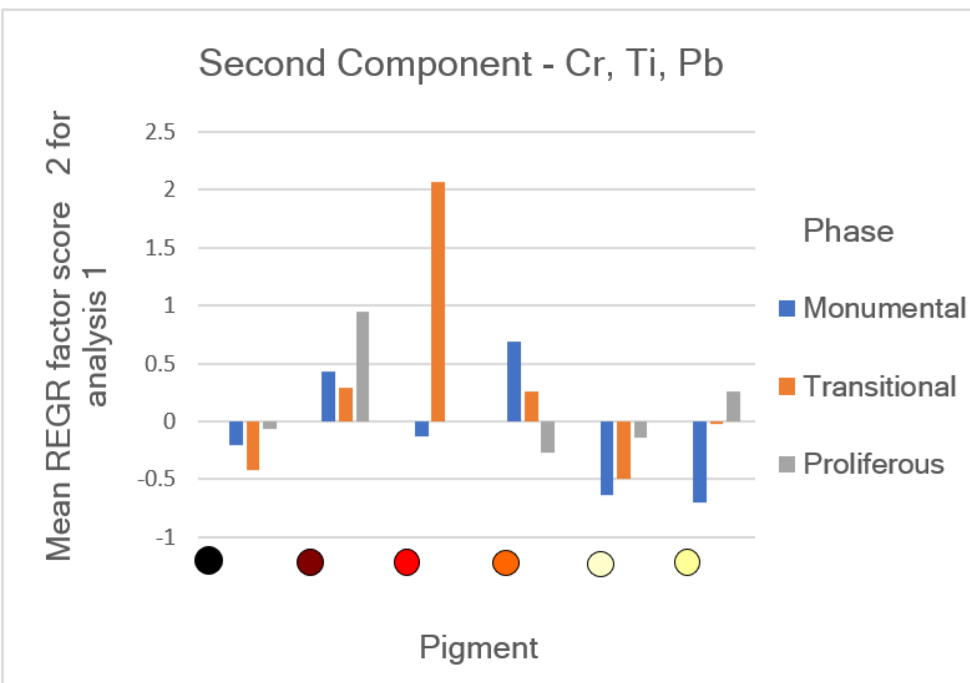

Figure 3. The graph shows the correlation of the 2nd Factor with each pigment across the entire sample. The cluster of 3 columns per pigment represents this correlation across phases.

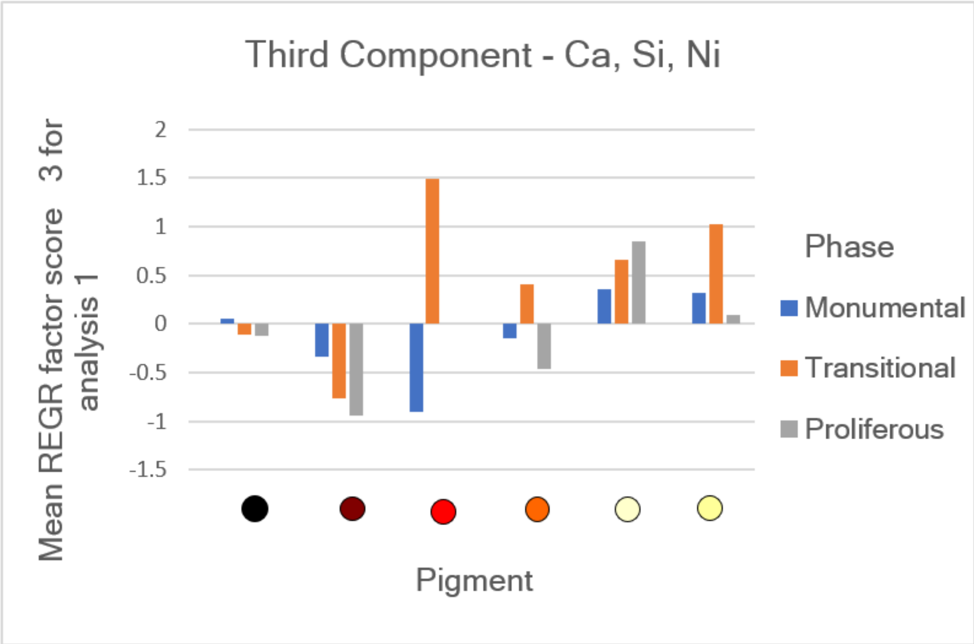

Figure 4. The graph shows the correlation of the 3rd Factor with each pigment across the entire sample. The cluster of 3 columns per pigment represents this correlation across phases.

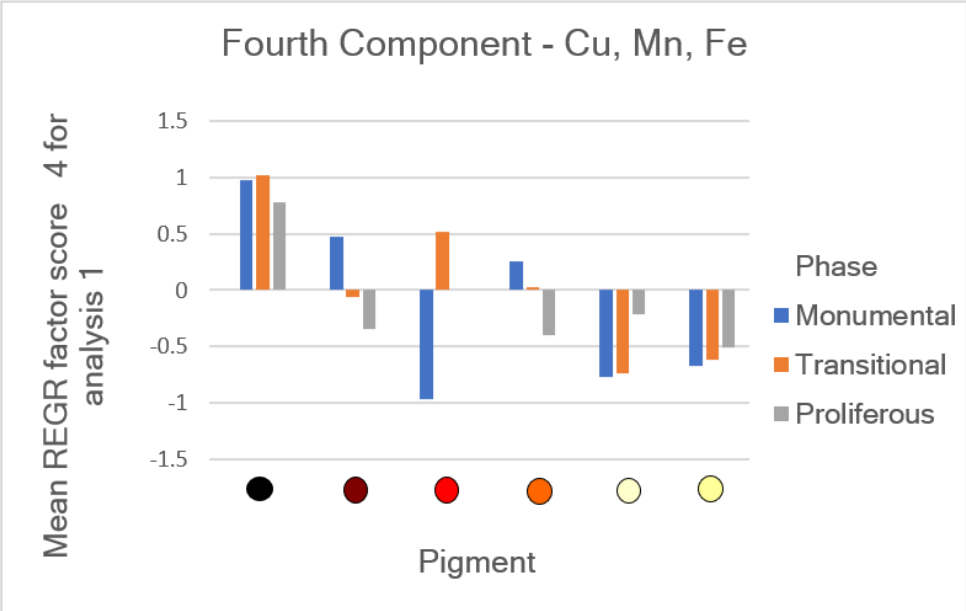

Figure 5. The graph shows the correlation of the 4th Factor with each pigment across the entire sample. The cluster of 3 columns per pigment represents this correlation across phases.

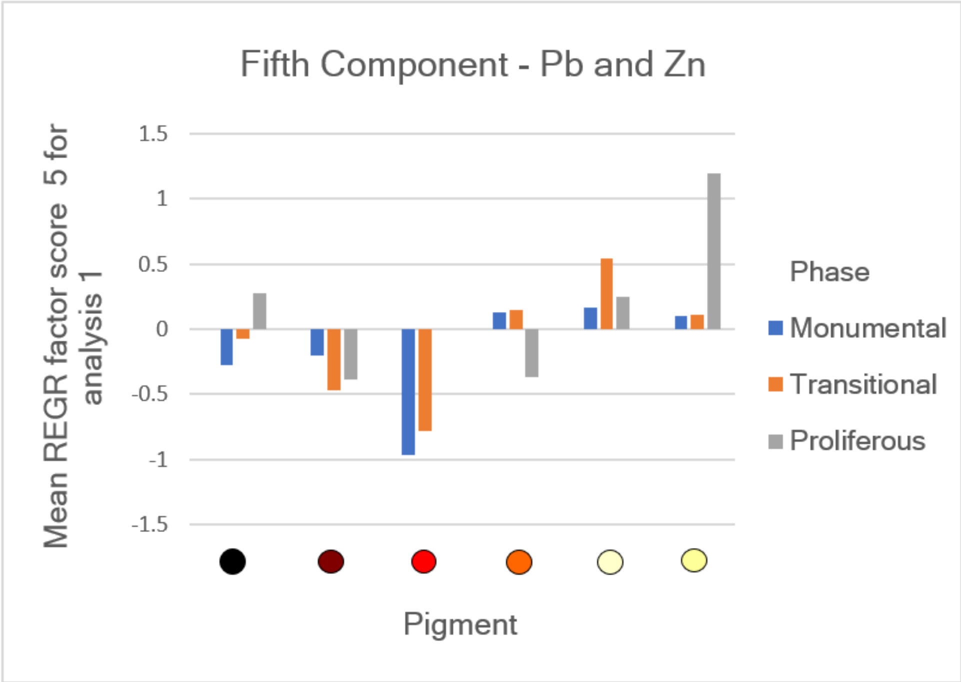

Figure 6. The graph shows the correlation of the 5th Factor with each pigment across the entire sample. The cluster of 3 columns per pigment represents this correlation across phases.

Figure 7. Front and rear view of vessel 986.1.137, a double-spout bottle suspected to be a modern reproduction.

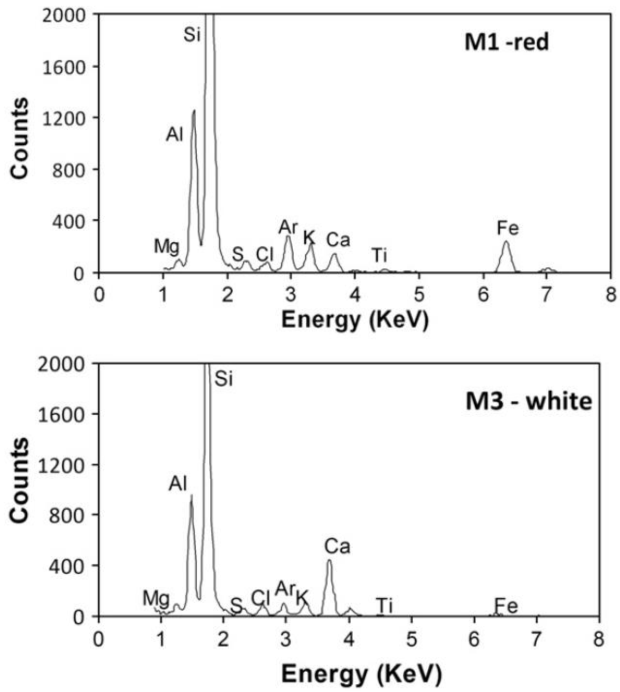

Figure 8. The PIXE-alpha spectrum of a red and white pigment from the Romano et al. study (2011).

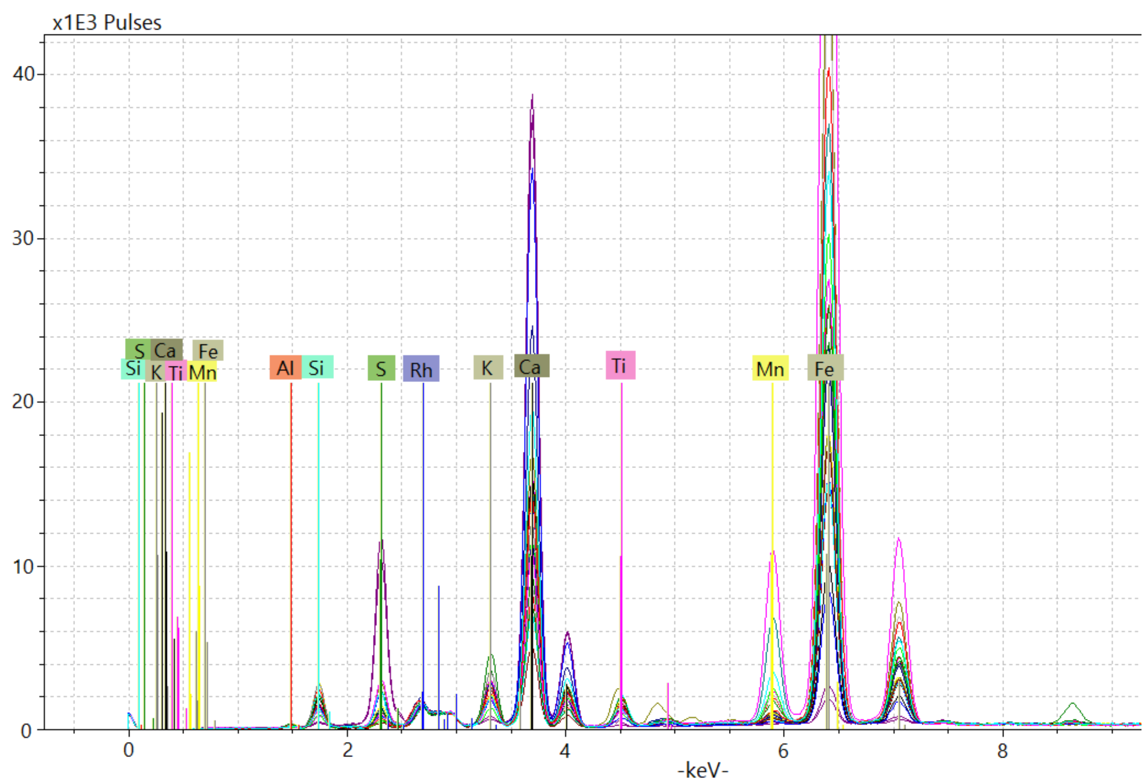

Figure 9. This figure shows pXRF spectra of every shot taken for the White pigment (10YR-7/3) layered on top of each other.

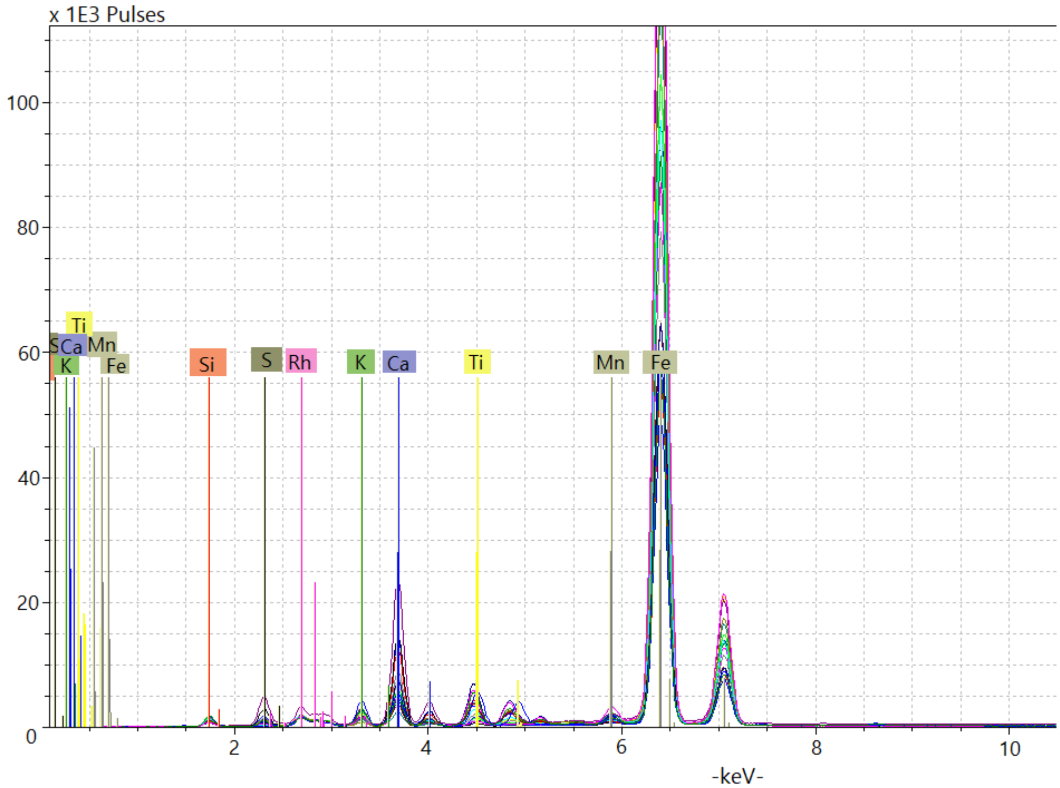

Figure 10. This figure shows pXRF spectra of every shot taken for the Dark Red pigment (10R-3/3) layered on top of each other.

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