SPINDLE WHORLS FROM EL PURGATORIO, PERU, AND THEIR SOCIOECONOMIC IMPLICATIONS

Melissa Vogel, Kristin Buhrow, and Caroline Cornish

In the Andean region, spindle whorls have been the subject of archaeological analysis less often than other artifact classes, such as pottery. Nevertheless, spindle whorls may have much more to contribute to archaeological interpretations of production, status, and exchange patterns than previously acknowledged. The case study presented here examines the spindle whorl collection from the site of El Purgatorio, Peru, the capital city of the Casma polity (ca. A.D. 700–1400). Spindle whorls were not only expertly crafted utilitarian tools for spinning yarn, but also items of personal adornment, symbols of wealth or status, and possible indicators of intra-polity exchange patterns. The analysis of spindle whorls in regard to form and function provides insight into Casma social and economic organization. The spindle whorls discovered at El Purgatorio also reflect varying degrees of standardization and technical knowledge, suggesting that at least some may have been manufactured by specialists in metallurgical and ceramic workshops.

En los Andes, los torteros han sido analizados arqueológicamente con menor frecuencia que otras clases de artefactos, como por ejemplo la cerámica. Pero estas herramientas podrían haber sido mucho más importantes de lo que fue reconocido anteriormente, principalmente para las interpretaciones arqueológicas sobre la producción, el estatus y los patrones de intercambio. En este trabajo presentamos la muestra de torteros procedente del sitio El Purgatorio, la ciudad capital del estado de Casma, en Perú (ca. 700–1400 d.C.). La intención de este análisis es entender a estos artefactos, no sólo como herramientas utilitarias diseñadas por expertos para el hilado, sino también como elementos de adorno personal, símbolos de la abundancia o el estatus y posibles indicadores de patrones de intercambio. Los torteros fueron analizados tanto por su forma como por su función, lo que generó un nuevo entendimiento de la organización social y económica del estado Casma. Los torteros descubiertos en El Purgatorio también reflejan diferentes grados de estandarización y conocimiento técnico, lo que sugiere que al menos algunos de ellos pueden haber sido fabricados por especialistas en talleres metalúrgicos y cerámicos.

Compared to other regions in the Americas, spindle whorls in archaeological assemblages in the Andes have received relatively little attention. Spindle whorls are sometimes included in descriptions of grave goods, but other artifacts, such as pottery, are often given preference in discussions of style, social organization and identity, and economics. Although spindle whorls have been documented at many Andean sites, they are rarely analyzed beyond basic descriptions. This is rather surprising, given their ubiquitous presence and considering the importance of textiles and the production of yarn in the prehispanic Andes. Ethnohistorical accounts document the central role of textiles in late Andean political economy; textiles were the primary means by which the Inca state taxed women (e.g., Costin 1993, 1995, 1998; Murra 1962; Silverblatt 1987). Nonetheless, archaeological studies that have focused on whorls in the Andes and elsewhere in the Americas demonstrate the importance of textiles for investigating functionality, production, specialization, and symbolism (e.g., Carpenter et al. 2012; Chapdelaine et al. 2001; Edwards et al. 2008; Inomata et al. 2002; Loughran-Delahunt 1996; McCafferty and McCafferty 2008; McMeekin 1992; O'Neil 1974; Rivera 2014; Smith and Hirth 1988).

Textile production begins with the spinning of raw fiber into yarn, which in the coastal Andes was primarily made from cotton and accomplished using a drop-spinning technique (Moseley

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2001:74). The weight of the spindle (and the spindle whorl) controls the thickness of the yarn produced. The analysis of spindle whorls and their archaeological contexts can reveal information about the spinning process itself and provide insights into gender roles and the political economies of prehispanic Andean states (Costin 1993, 1995, 1998). We present the study of a collection of 75 spindle whorls excavated at the site of El Purgatorio. Following a brief description of the site and sample, we present the results of the formal (shape and iconography) and functional (weight and inertia) analyses of the sample. Situating the results within the context of the existing literature, we examine the socioeconomic implications of our findings for the political economy and present our interpretations of the meaning of these objects as grave goods in regard to gender and status in Casma society. Because the majority of whorls were uncovered in graves of women and children, we conclude that spindle whorls were indicative of social status (both ascribed and achieved), and possibly of femininity.

Existing studies of spindle whorl assemblages from archaeological sites in the Andes, especially the Moche capital on the north coast of Peru, offer insights into the variety of materials, forms, and contexts associated with the manufacture and use of these objects that can be applied to the sample from El Purgatorio. At Huacas de Moche, Chapdelaine and colleagues (2001) found whorls in a variety of contexts, including urban residences, public administrative structures adjacent to the Huaca del Sol, ceramic workshops, and a cemetery (Chapdelaine et al. 2001:797). The authors concluded that spinning of cotton was ubiquitous and often done in places of social gathering or in domestic areas (Chapdelaine et al. 2001:799). Using neutron activation analysis to investigate spindle whorl production at Huacas de Moche, Chapdelaine and colleagues were able to confirm that the spindle whorls were manufactured in local ceramic workshops. There may have been several specialized workshops at Huacas de Moche, each focused on whorls of differing types (e.g., quality, shape, decoration, etc.; Chapdelaine et al. 2001:802–803), a possibility discussed below for El Purgatorio. They reasoned that Moche women could have selected spindle whorls of differing styles and shapes produced at multiple workshops (Chapdelaine et al. 2001:803–804).

Donnan and Mackey's (1978) sample of Moche and Chimú spindle whorls from female burials revealed formal and design variability similar to those found in the sample from El Purgatorio. Shapes included disks, ollas, trumpet bells (here referred to as conical), and biconical whorls. The metal whorls made from copper were found in various states of decay. Whorls made from different colored stone (green, white, and black) and fired clay were painted and incised with patterns resembling flowers, intersecting dots and lines, and circles (Donnan and Mackey 1978:369).

Drawing on a large sample of sites across highland Bolivia spanning the Late Archaic through Late Horizon periods, Rivera (2014:242) noted the increased standardization of spinning and weaving tools associated with the rise of Tiwanaku state control (see also Costin 1993, 1995). The correlation of state control and craft production standardization observed in highland Bolivia does not seem to apply to textile production and the rise of the Casma state (as discussed below). Rivera (2014:253–254) also asserts that the status and identity of the textile producers probably contributed to the value of their products, either as everyday or prestige objects. This idea is relevant to the data from El Purgatorio discussed below.

In the Chibcha territory of northern South America, Dennis O'Neil (1974) focused on the manufacturing techniques of stone spindle whorls. Based on examination of flake scars and abrasions, he deduced nine manufacturing stages. First a large, coarse flake was removed from the original slate using a percussion blow. The edges of the blunt disk-flake were trimmed with heavy blows until the desired diameter and roundness was reached. The craggy edges and sides were smoothed and rounded again by more grinding until the sides were flat and parallel. After this, one side of the disk was formed into a concave shape and the other a convex one using a gouging and grinding tool. The domed hat of the convex side was destroyed as a hole was drilled through the center of the whorl. The disk was then ground to a symmetrical shape and smoothed and polished to its desired form, removing all scratches in the process. Lastly, incisions were made on the con-

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cave (and occasionally convex) sides using an especially solid and sharp instrument (O'Neil 1974:482). Although O'Neil could not be sure of the exact tools used, he assumed the need for a stationary abrading surface (boulder), granular abrading stones of variable size, a gouging tool (small and hard rock), a stone drill, and a manipulative sharp instrument for incising were all included in this supposed tool kit (O'Neil 1974:482–483). This case study is an especially useful analogy because we have not yet discovered whorl manufacture workshops at El Purgatorio.

In terms of decoration and iconographic analysis, Dorothy McMeekin (1992) argued that Mesoamerican and South American reverence for agriculture and plants was expressed in spindle whorl decoration. In particular, she used spindle whorls displaying detailed floral and fruit anatomy to demonstrate the depth of this tradition (McMeekin 1992:172). Peppers, tomatoes, and squash fruits were commonly featured, as well as domesticated cotton in western South America (McMeekin 1992:172).

Beyond the Andes, Carpenter and colleagues (2012:395) examine Classic-period residences in El Palmillo, Oaxaca, Mexico. These authors postulate that the economic production of spun cotton and maguey largely took place in domestic residences. Their sample of 188 whorls provides evidence for the spinning of a mix of fibers and variable participation in the steps of textile-production process across households. This suggests a fluid economic model of middle-class domestic production using local resources in multicrafting activity areas (Carpenter et al. 2012:395). An Andean study conducted by Edwards et al. (2008) produced similar results. Based on spindle whorl provenience and sample size, the authors determine that production of cotton yarn was ubiquitous and often took place during social gathering or in domestic residence (Edwards et al. 2008:99). These findings can be used to interpret the provenience and implications of the whorl sample from El Purgatorio, as well.

Inomata and colleagues (2002) excavated at the Maya site of Aguateca (ca. A.D. 800) and recovered 39 spindle whorls from several compounds (Inomata et al. 2002:310). Seven were found in a room that also contained ceramic vessels, storage jars, and a *mano* and *metate*. This suggests that the room was used for food preparation and storage (Inomata et al. 2002:308). Other assemblages included several whorls grouped together, indicating rooms for textile production located near those for food preparation (Inomata et al. 2002:324). Most notable was the concentration of spindle whorls found in a room previously thought of as a "stage for interactions and display" (Inomata et al. 2002:326) or political activities. Inomata and colleagues propose that the purpose of the room may have changed before abandonment of the site or that women had been present here, perhaps participating in political activities (Inomata et al. 2002:326).

Finally, McCafferty and McCafferty (2008) examined a sample of 73 whorls from the site of Santa Isabel in Nicaragua, measuring height, diameter, weight, shape, and hole size (McCafferty and McCafferty 2008:144). Their sample included both modeled whorls and perforated ceramic disks. Interestingly, these whorls were fairly evenly distributed across the excavation locations, with no great distinction between the locations of modeled versus perforated disks (McCafferty and McCafferty 2008:153). They interpret this evidence as showing no functional specialization in spinning technique or quality of thread (McCafferty and McCafferty 2008:153). As described below, the results of our study paint quite a different picture for yarn production and specialization at El Purgatorio.

El Purgatorio and the Casma State

El Purgatorio (Figures 1 and 2) was an important urban center and the capital city of the Casma state (ca. A.D. 700–1400), a large coastal polity that stretched over a distance of approximately 300 km along the north coast of Peru. The archaeological understanding of the Casma state has grown significantly over the last decades through excavations conducted at El Purgatorio (e.g., Cárdenas 1976, 1978; Collier 1962; Przadka and Giersz 2003; Silva 1992; Tello 1956; Thompson 1964, 1974; Vogel 2003, 2011, 2012; Vogel and Pacifico 2011) and the secondary sites of Cerro la Cruz (Silva 1992; Vogel 2003, 2012) and Ten Ten (Przadka 2009). The Casma state emerged following the

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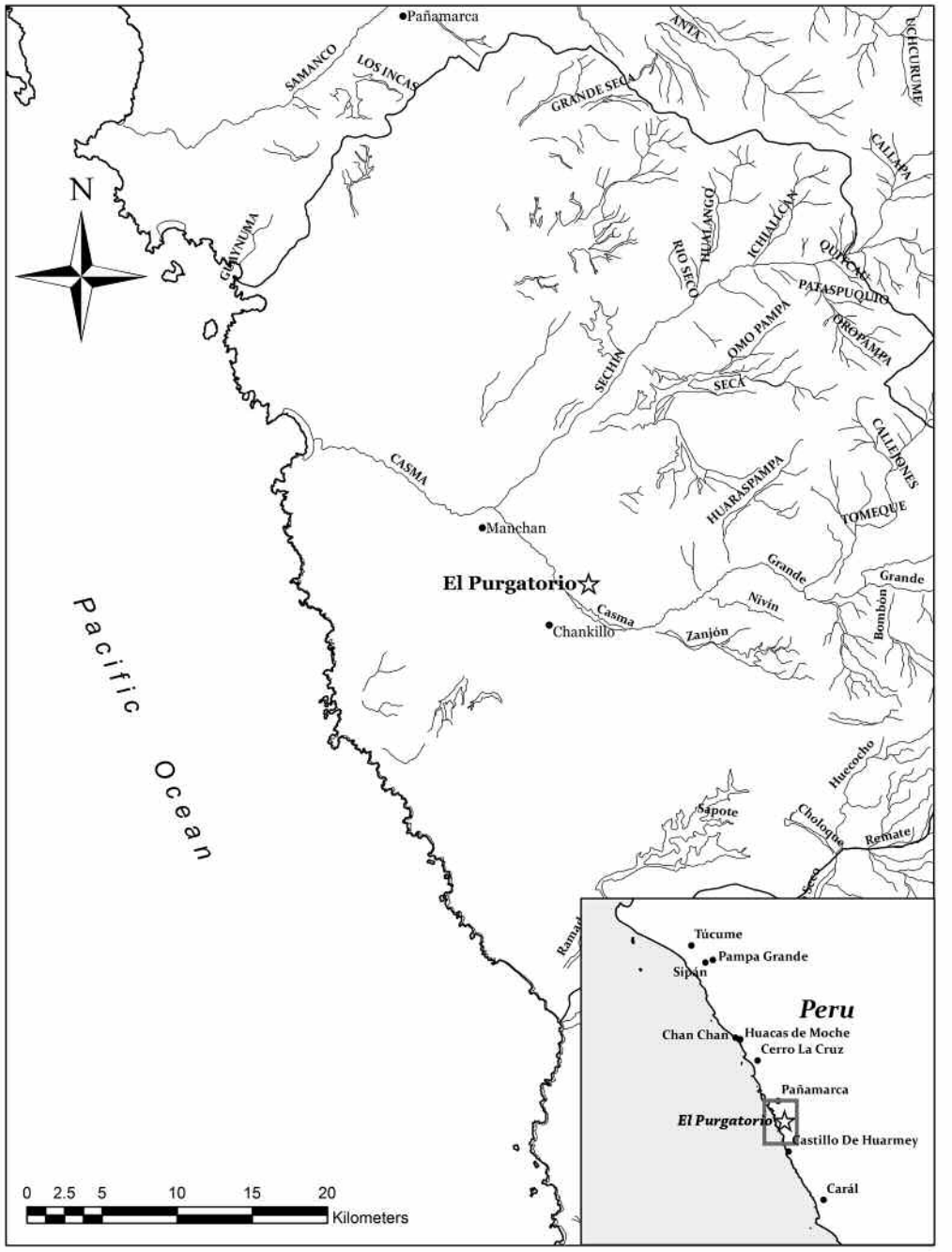


Figure 1. Map of the Casma Valley.

collapse of the southern Moche polity during a time of rapid population increase in the Casma, Nepeña, and Santa Valleys during the late Middle Horizon (e.g., Mackey and Klymyshyn 1990; Proulx 1973, 1993; Wilson 1988, 1995). The Casma polity was contemporaneous with other regional states on the north coast of Peru, such as the Lambayeque and the Chimú, which controlled the coastal desert and low-altitude Andean river valleys (Vogel 2016). There is also clear evidence for interaction with highland polities, such as the Wari and Recuay (Vogel 2011).

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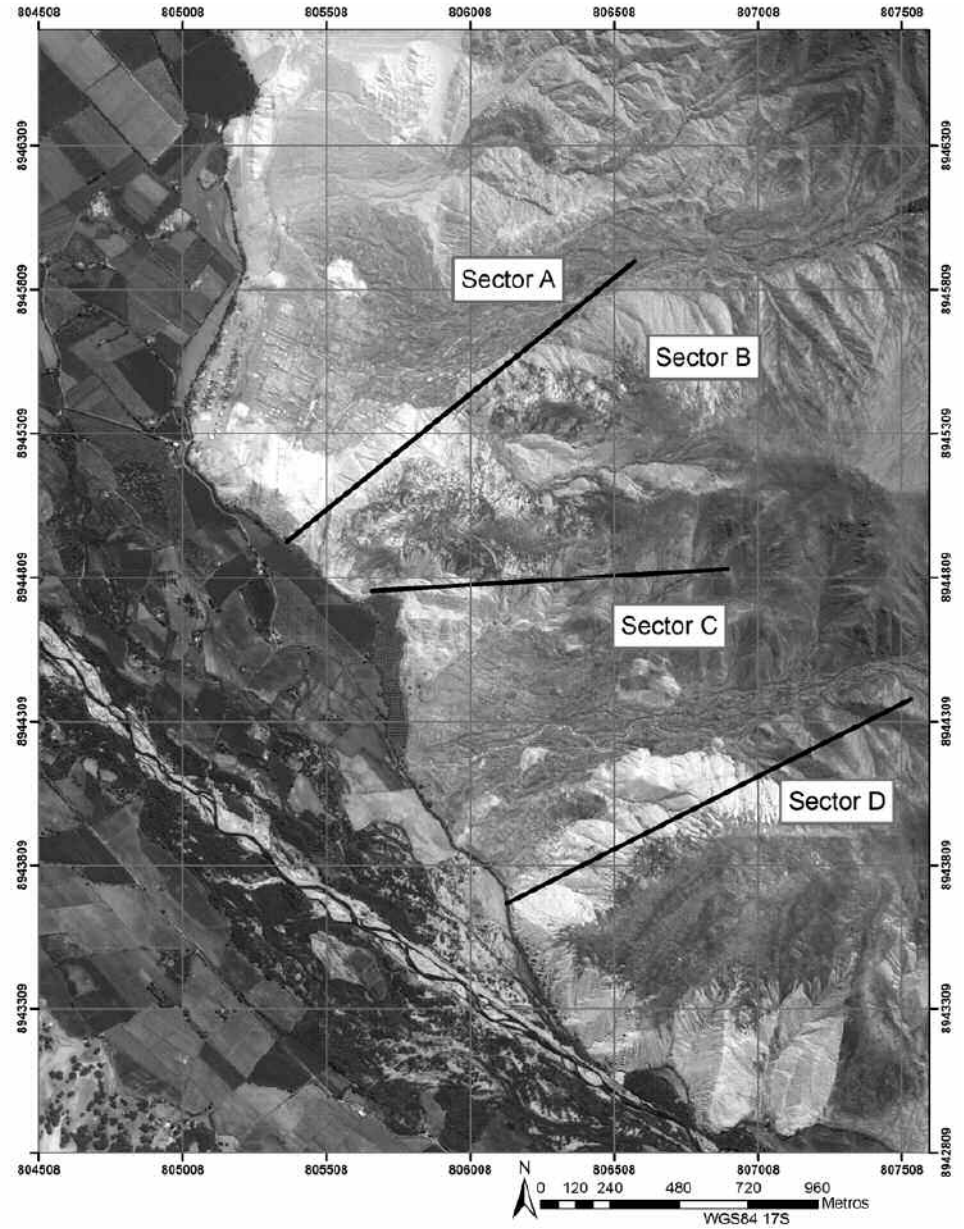


Figure 2. Google Earth photograph of the site of El Purgatorio, Peru (QuickBird/Digital Globe, Inc. 2007 Image 07MAY26155810-S2AS-005726208010_01_P001. Courtesy of Digital Globe, Inc. and the Center for Ancient Middle Eastern Landscapes, Oriental Institute, University of Chicago).

The site of El Purgatorio is located in the lower Casma Valley (Figure 1), towards the southern end of the north coast of Peru at an altitude of approximately 180 m asl. The site covers an area of approximately 5.32 km^2 (Figure 2) and was occupied between A.D. 700 until the conquest by the Chimú around A.D. 1400. El Purgatorio formed an extensive, complex, urban environment consisting of four contiguous sectors that cover the base and lower western and southern slopes of Cerro Mucho Malo (Figure 3). Located on the western side of the mountain, Sector A contains most of the monumental architecture at the site, including several large compounds with complex internal structures. In Sector B, numerous residential terraces extending up the hill slopes are

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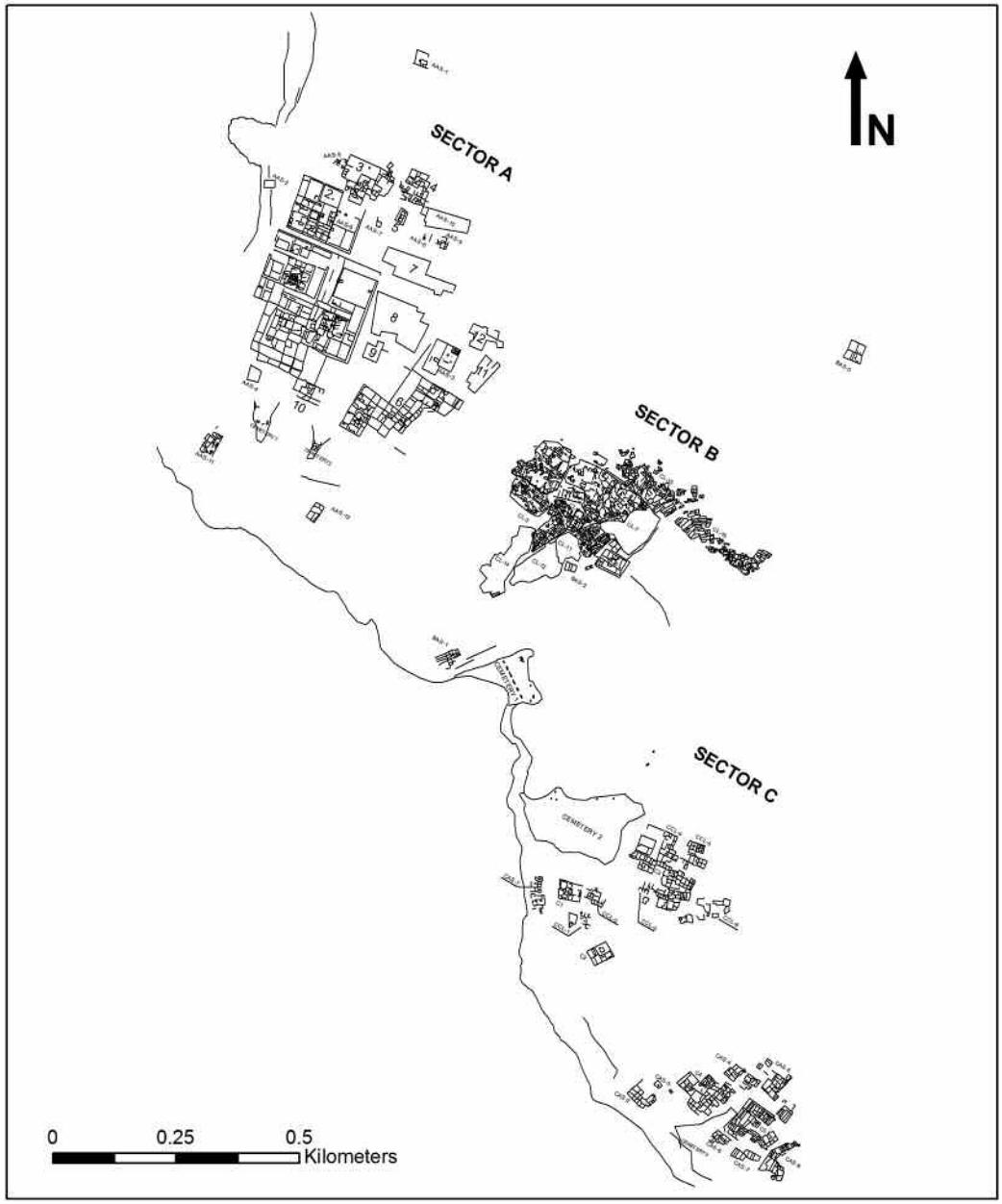


Figure 3. Site map of El Purgatorio Sectors A, B, and C (Sector D is not yet mapped).

covered with densely packed, smaller structures and at least one small cemetery. To the south, Sector C consists of three looted cemeteries, a few residential compounds, several agglutinated room clusters, and smaller associated structures. Finally, Sector D is located on the hilltop above Sector C, filled with smaller stone structures resembling those in Sector B. Based on the spatial organization and variability of archaeological materials present at the site, El Purgatorio may have housed a large and socially stratified population (Vogel and Pacifico 2011).

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Figure 4. Metal and stone whorls still on broken spindle.



Figure 5. Metal whorls and pendant from burial.

Spindle Whorls at El Purgatorio

Between 2006 and 2010, 75 spindle whorls were collected and analyzed from Sectors A, B, and C at El Purgatorio. The whorls, many of them with surface designs, were manufactured from ceramic and lithic material, and metal (Vogel et al. 2015). Ceramic and stone spindle whorls were common in coastal Peru in the Casma and Chimú cultures (e.g., Chapdelaine et al. 2001; Donnan and Mackey 1978; Millaire 1997) and were used to spin cotton and camelid (llama and alpaca) fibers (e.g., Edwards et al. 2008:88). Most spindle whorls found at El Purgatorio were manufactured from stone (n = 42, 56 percent), and only a small percentage were made from fired clay (n = 6, 8 percent). The scarcity of metal spindle whorls in archaeological assemblages in northern Peru may be a result of preservation and targeted looting of metals during later periods. Metal spindle whorls also may have been a late technological development in prehispanic fiber production. Twenty-seven of the 75 spindle whorls (36 percent) were made of metal (various alloys of copper, lead, etc.; see Vogel et al. 2015). Metal spindle whorls were used as tools and personal adornment at El Purgatorio. Most whorls were found in burials (discussed below) strung up on cotton yarn. They may have been worn around the neck, and it was initially thought that these artifacts were beads. In one case, a copper whorl was found on the spindle together with two stone whorls (Figure 4).

Differential preservation of metal spindle whorls found at El Purgatorio affected the sample sizes used for analysis. For example, the corroded state of many metal whorls (Figure 5) limited the reliability of some measurements, such as weight, so that metal spindle whorls were included in our analysis only when feasible. It is worth noting, however, that their overall size and shape in their corroded state remained consistent with that of the stone and ceramic whorls. Based on the condition in which the objects were found, they were included in some analyses but not others. For instance, a broken decorated whorl would be included in the iconographic analysis, but not in the functional analysis. The majority of whorls from El Purgatorio (64 of 75) were found in mortuary contexts. The others were found in both public and domestic areas.

Formal Analysis: Shape and Decoration

The spindle whorls recovered at El Purgatorio were analyzed according to their form and function. Of the 75 total whorls, 53 whorls could be sorted by shape into the following four categories: spherical, conical, biconical, disk, and olla-shaped (resembling a globular cooking pot; Supplemental Figure 1). An additional category was created for shapes outside these categories (Table 1). The remaining 22 whorls were too oxidized to determine their original shape.

The most common form of spindle whorl found at El Purgatorio was a spherical shape, which represented 30 percent of the spindle whorls analyzed (n = 16; Supplemental Figure 2). Spherical whorls have also been recovered at Moche and Chimú sites (e.g., Donnan and Mackey 1978), although their relative popularity at coastal sites is difficult to gauge. All raw materials and surface design options are represented in the analyzed sample of spherical whorls, which suggests that whorl material, decoration, and shape are unrelated stylistic choices.

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Table 1. Frequency of Whorl Shapes at El Purgatorio.

Whorl Shape	Number Found	Percentage of Shape Subgroup
Spherical	16	30.19%
Biconical	14	26.42%
Disk	9	16.98%
Conical	7	13.21%
Ollas	3	5.66%
Unique	4	7.55%
Subgroup Total	53	100%

Conical spindle whorls (Supplemental Figure 3), which resemble a trumpet bell with two circular faces, account for 13 percent of the analyzed spindle whorls at El Purgatorio. Biconical whorls, shaped as though the larger surfaces of two conical whorls had been fused, are the second most common form at El Purgatorio and represent 26 percent of the spindle whorls studied ($n = 14$, Figure 6). Biconical whorls are usually larger and heavier than whorls of other shapes. Although popular at El Purgatorio, biconical whorls are less common in other Andean collections (e.g., Donnan and Mackey 1978).

Designed to be flat and circular, disk-shaped whorls account for 17 percent of the whorls analyzed for shape ($n = 9$). Disk-shaped whorls can be homogeneous in thickness, or taper to a narrow edge with a thicker center (Supplemental Figure 4). The nine disk-shaped whorls were split almost evenly between decorated and plain whorls, and also between metal and nonmetal whorls. These findings suggest that the shape of the whorl is not correlated with a certain design or raw material. Disk whorls are usually smaller and generally weigh less than whorls of other shapes, indicating that they may have been used to create lesser-weight yarn, or may have been added onto a spindle with another whorl to add more weight and produce thicker yarn.

Ollas, large spherical pots with an angled rim used for cooking, may have served as inspiration for the shape of some spindle whorls (Supplemental Figure 1). Olla-shaped whorls accounted for 6 percent ($n = 3$) of the whorl assemblage from El Purgatorio. Although relatively uncommon, olla-shaped whorls are made of both stone and ceramic material and include different surface designs. The last category of whorls includes unique forms, with natural and manmade motifs and elements referencing quotidian Casma life ($n = 4$; 8 percent). One unique ceramic whorl resembles a bird in flight, with the beak and wings jutting out from the top of this biconical whorl (Figure 7). Another ceramic whorl was cut into three terraced levels, similar to the residential terraces at El Purgatorio. A third unique whorl is notched around the edge, much like a small gear. The fourth unique whorl is a variant of the spherical form and made of stone with rims on both the top and bottom and decorated with perforations.

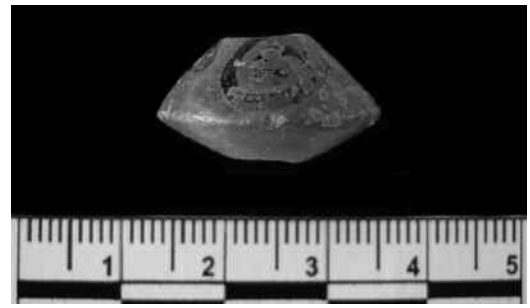


Figure 6. Biconical whorl with painted design.



Figure 7. Bird-shaped whorl.



Figure 8. Tripartite whorl.

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Surface Decoration

From our sample of 75 spindle whorls, surface decorations were observable and studied on 44 whorls. These include the full range of raw materials, proveniences, and designs present at El Purgatorio. This sample was structured to be as representative of the full collection as possible. The whorls are divided into four categories according to their surface decoration: tripartite, quadripartite, unique, and plain. The most common design patterns observed are those using incisions to divide the whorl into a geometric three-part (tripartite; Figure 8) or four-part (quadripartite; Supplemental Figure 5) design. The incised patterns used to divide the whorls also vary between circles, straight lines, and circle-and-dot designs typical of Casma pottery. Examples of tripartite and quadripartite designs are found across all of the shape categories (disks, spheres, conical, and biconical). The remaining spindle whorls exhibit either unique engraved or painted designs, or they are considered plain, with discernible surface decoration (Table 2).

Table 2. Frequency of Whorl Design Types.

Design Type	Number Observed	Percentage of Design Subsample
Decorated	29	65.91%
Tripartite	12	27.27%
Quadripartite	14	31.82%
Unique	3	6.82%
Plain	15	34.09%
Total	44	100%

Quadripartite whorls are the most common in the sample (n = 14, 31 percent). In quadripartite whorls, the central perforation marks the intersection of two perpendicular dividing lines (Supplemental Figure 5). Usually geometric designs fill two of the alternating sections, while the other two are plain. In the case of quadripartite conical and biconical whorls that are decorated on only one side, the perpendicular lines radiate from the center hole until they reach the edge of the whorl, but the bottom of the whorl remains plain.

Twelve of the whorls in the assemblage have a tripartite design (27 percent). This design could be achieved through lines that radiate outward from the central perforation of the whorl, or by placing two evenly spaced, parallel lines on either side of the central perforation. Our sample of tripartite whorls shows an equal number (n = 6) of each variant.

The other whorls in the sample either have unique designs that cover the entire whorl with a uniform pattern such as ridges or chevrons (n = 3, 7 percent), or are not decorated at all (n = 15, 34 percent). The lack of whorls divided any other way, such as into two or five sections, suggests that the numbers three and four may have carried some significance in the context of Casma ideology, iconography, or style.

Since whorls are placed on the bottom of a spindle, leaving only the top visible when the whorl is in use, it is logical that only one side would be decorated. Of the 44 whorls analyzed for decoration, 16 are plain (36 percent), 17 are decorated on the top, and 11 are decorated on both sides (39 percent and 25 percent, respectively). The decoration of spindle whorls on both top and bottom surfaces may indicate that spindle whorl design also served as an art form or a method of symbolic communication, especially when whorls were used in other contexts, for example, as necklaces. During spinning, whorls were sometimes stacked on top of one another on the spindle to provide more weight (cf. Barber 1991:58), which resulted in only the lateral aspects of the whorls remaining visible. Whorls decorated only on the top surface sometimes have an incised line around the circumference of the whorl separating the top surface from the bottom surface. Typically, this demarcation is observable on biconical whorls, which already have a distinct top and bottom surface. The focal points of designs for the majority of decorated whorls, however, are on the top and bottom surfaces of the whorl, which would be obscured when the whorl is in use. In this way, the designs found on spindle whorls suggest that the primary opportunity for display may not have been in the context of spinning, but under conditions in which the top and bottom surfaces were visible.

The surface decorations described here are mostly incised (n = 28, 64 percent). It is possible that some of the plain whorls may have originally had painted designs that did not preserve. The presence of one whorl (2 percent) with a painted design (Figure 6) suggests that there may have

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been others like it. Fifteen of the 44 whorls analyzed for surface design (34 percent) are categorized as plain, meaning that no decoration is visible. Some plain whorls have polished surfaces, suggesting completion without the need for decoration. Other plain whorls are unpolished, which could be interpreted as unfinished, or perhaps as evidence of a more utilitarian style. Of the 29 decorated whorls, about half are decorated only on the top surface (n = 17; 59 percent). The rest are decorated on both the top and bottom surfaces (n = 12; 41 percent). Spherical whorls are more likely to be decorated all over. Of the 16 whorls identified as spherical in the previous section, seven are decorated all over (44 percent), but no whorls from the biconical and conical categories are decorated on both the top and bottom.

The form and style of whorls, as expressed through their shapes and surface decorations, indicate the existence of a particular Casma artistic style and whorl technology of the late prehistoric era (Vogel 2011, 2012). The variability of whorls in each form indicates that there is little to no correlation between shape, surface decoration, and raw material. The design of spindle whorls at El Purgatorio appears to be a method of creative expression and a display of artistic skill on a necessary, utilitarian object.

Functional Analysis: Weight and Inertia

Variation in functional design of whorls affects the quality of the yarn that is produced. Spindle whorl weights and sizes vary in accordance with their intended use, such as the raw material and the desired thickness of the yarn (Loughran-Delahunt 1996:21). The smaller and lighter the whorl, the thinner the yarn produced. Heavier whorls, without increasing diameter to slow the spin, will stretch the yarn, making it more likely to break (Loughran-Delahunt 1996:55). Spindle whorl weights from around the world range from less than 1 g to 150 g and are used to produce different thicknesses of yarn from different raw materials (Barber 1991). In her study of Aztec women and weaving technology, Brumfiel (1991) classified whorls that weighed 10 g or less as small, and any whorl over 10 g was classified as large. Barber's (1991:51) cross-cultural comparison showed that the standard diameter for spindle whorls usually exceeds 2 cm. Assuming similar weight, the diameter of the whorl determines the thickness and strength of the thread by inducing a faster or slower spin. Larger, slow-spinning whorls create heavy and thick cords with few twists, but faster-spinning whorls with smaller diameters allow for more rotations per spin duration, producing a more tightly spun, thinner yarn (Barber 1991:57). Furthermore, yarn thickness may be altered based on the position of the whorl on the spindle. Low-whorl spindles are spun like a top by flicking the fingers, but high-whorl spindles are rolled up and down the leg with the hand (Barber 1991:43). Spinning conducted at El Purgatorio typically involved the drop-spinning technique with low-whorl spindles.

Spinning can also be completed without the use of a whorl, for example, with a potato or spinning bowl (e.g., Smith and Hirth 1988), but whorls are more efficient. Whorls increase the duration of the spin of a spindle, resulting in a thinner, finer yarn. The use of a spindle whorl also allows for a more constant spinning speed, which can improve the uniformity of tightness across a strand of yarn (Loughran-Delahunt 1996:16). Analysis of the physics and functionality of spindle whorl assemblages can determine the type of yarn produced and its purposes. We therefore conducted a functional analysis of the subsample of whorls from El Purgatorio to examine the weight, diameter, and moment of inertia to determine the kind of yarn produced at the site.

Of the total 75 spindle whorls, 43 ceramic and stone whorls were analyzed with weight measurements to the nearest hundredth of a gram and diameter measurements to the nearest thousandth of a centimeter (Supplemental Figure 6). Metal whorls were excluded from the functional analysis because their high levels of oxidation did not allow for accurate measurements. Due to variability in the copper alloys, similarity or predictability of weight cannot be assumed. PXRF analysis (Vogel et al. 2015) showed that some whorls contained lead. They would have been much heavier at the time of their production. Because lead deteriorates more quickly than copper, these whorls are now lighter than those with higher copper content. Although none of the copper

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whorls could be included in the functional analysis, all five of the ceramic spindle whorls and 38 of the 42 stone whorls were analyzed.

Barber (1991:52) asserted that lightweight spindle whorls are necessary to process short-staple materials, such as cotton. She suggested 8 g as an example of a lightweight spindle whorl, which is .65 g heavier than the heaviest whorl from El Purgatorio. The average weight of the El Purgatorio whorls is 3.25 g (Supplemental Figure 6). It is likely that these whorls were used for spinning short-staple Peruvian cotton as opposed to other, longer-staple materials that would have required a heavier whorl. Abundant evidence of cotton cloth, thread, and raw cotton at El Purgatorio corroborates this assertion (Vogel 2016). Evidence for camelid fiber at the site is rather sparse. The predominance of lightweight spindle whorls indicates a production focus on strong, thin cotton yarn. Nevertheless, multiple whorls have been found together on the same spindle at El Purgatorio, and thicker-staple raw materials may have occasionally been spun using multiple lightweight whorls.

The 43 whorls in the sample appear to be distributed relatively evenly across the different weight categories every .5 g, with the exception of whorls weighing between 5.5 g and 6.5 g. When sorted into smaller weight categories, the sample shows a bimodal distribution with whorl weights favoring both the 1.50–2.24 g and the 4.25–4.49 g ranges (Supplemental Figure 6). The bimodal distribution of whorl weight may indicate that two main types of yarn were produced at El Purgatorio: a thinner, finer thread with whorls around 2 g in weight, and a slightly thicker thread from whorls weighing about 4.5 g. Only three of the 43 whorls (7 percent) weighed 5.5 g or more.

Whorl diameter is another useful indicator of the quality of yarn produced by a spindle (Supplemental Figure 7). The weight pulls the spindle down and ensures rotation, and the whorl diameter influences the speed and duration of the spin. The larger the diameter of the whorl, the farther the weight is distributed from the axis, slowing its spin. At El Purgatorio, whorls measured 2.2 cm in diameter or less, indicating that the spinners produced mostly thin, tightly wound yarn. Although it is possible that heavier whorls existed to produce thicker yarn, such whorls were not recovered in our excavations. Stacking multiple spindle whorls with small diameters could result in the production of a slightly thicker, tightly spun thread. Nonetheless, to spin materials of a longer staple than Peruvian cotton would have required whorls with a larger diameter.

Because the interplay of the weight and diameter of a whorl affects the quality of the yarn, independent measurements of weight and size can be combined to calculate the moment of inertia, which is indicative of whorl efficiency. In her dissertation, Loughran-Delahunt (1996) studies the physics of Northwest Coast Native American spindle whorls by calculating their moments of inertia (the tendency of a body to keep rotating on an axis at a constant speed). Using the same method, the inertia of the whorls in the El Purgatorio sample were calculated using the following formula: $I=MR^2/2$, where I is the moment of inertia, M is the mass of the whorl, and R is its radius. A higher inertia measurement indicates that a whorl can maintain a constant speed for a longer time, that is, it has a greater spin efficiency.

The inertia measurements of the 43 whorls in our sample range from .126 to 3.377 gcm^2 (Supplemental Figure 8). Compared with assemblages featured in other studies (including whorls with inertia measurements up to 16,479 gcm^2 and averaging 4341.4 gcm^2 in Loughran-Delahunt 1996),[1] the level of moment of inertia among whorls from El Purgatorio, which average 1.16 gcm^2, is low across the sample. This low level of moment of inertia suggests that thin, loosely spun yarn was the most popular variety produced at El Purgatorio. Although the whorl diameters alone might suggest a tightly spun yarn, the inertia measurement indicates that the yarn was loosely spun. The inclusion of more variables increases the credibility of the moment of inertia calculation, which should result in a more accurate interpretation. The relatively low inertia of these whorls is consistent with the idea that Casma whorls were meant for spinning short-staple cotton fibers; an unsupported whorl spinning too quickly could result in broken thread when processing shorter-staple fibers, such as short-staple Peruvian cotton. The distribution of inertia measurements in our whorl sample demonstrates that even within the available range of low-inertia whorls, whorls with the lowest in-

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ertia measurements (under 1.2 gcm^2) are still more prevalent. Another consideration necessary for the correct interpretation of these data is that the equation used to calculate inertia assumes the object in question to be a flat disk. Since many spindle whorls included in this subsample are spherical or biconical in shape (with tapered edges), they are not evenly flat disks. This may mean that their true inertia values are actually slightly lower than those provided here (Loughran-Delahunt 1996). The measurements provided here are therefore an approximation of the efficiency of spindle whorls used by the spinners of El Purgatorio.

The narrow ranges of diameters, weights, and inertia measurements indicate little variability in yarn quality between whorls. There appears to be some correlation between whorl material and the type of yarn it was designed to produce. Ceramic whorls produced relatively thin, loose thread, but stone whorls produced a wider variety of threads. Ceramic spindle whorls were found only among the lower half of the inertia measurements, ranging from .184 to 1.883 gcm^2, exhibiting a lower average inertia than their stone counterparts (average inertia of ceramic whorls: .909 gcm^2; average inertia of stone: 1.189 g/cm^2). This variation may be intentional, or it may result from the smaller number of ceramic whorls in our sample (five ceramic as compared to 38 stone whorls). It is difficult to determine whether the choice of whorl material was determined by the desired thread thickness, available resources, or was purely a stylistic decision. Indeed, all of these factors may have played a role in the design of spindle whorls.

In sum, functional analysis revealed a prevalence of lightweight, low-inertia whorls with relatively stable weight and diameter measurements. These results suggest a preference for thin, loosely spun yarn as opposed to tightly wound threads. Nonetheless, it is important to note that the 84 excavation units at El Purgatorio contained almost entirely more elaborate whorls in terms of decoration and quality of raw materials, unlike the plainer whorls found at the site of Cerro la Cruz (Vogel 2012:134, Figure 5.27). It seems likely that the residents of El Purgatorio who used more elaborate whorls produced a more delicate yarn than people using plain whorls at outlying settlements, an intriguing hypothesis that remains to be investigated.

Socioeconomic Implications

The formal and functional analyses presented here, when combined with the whorl contexts and our understanding of prehispanic Andean societies, have new implications for interpreting Casma social identities and economic organization. As mentioned above, spinning is a quotidian activity that often occurred in areas where other activities took place. Elsewhere spindle whorls have been found in domestic areas, public areas, and mortuary contexts. In contrast, at El Purgatorio spindle whorls were found predominantly in burials.

Of the 84 excavation units in sectors A, B, and C, 14 units yielded spindle whorls. Of the total 75 whorls uncovered at El Purgatorio, 64 whorls (85 percent) were found in the Sector C cemeteries as grave goods (Table 3). The other 11 whorls (15 percent) were found in residential and public architectural spaces. Of those 11, only two were found in Sector B, the commoner residential area. The other nine were distributed across seven compounds: A1 ($n = 2$), A3 ($n = 1$), A6 ($n = 2$), AAS3PA1 ($n = 1$), C4 ($n = 1$), C5 ($n = 1$), and CAS5 ($n = 1$). Two whorls were found in areas used for ceremonial purposes, and one was found in the ceramic workshop. The others were found in domestic areas, often associated with food preparation. These varied locations are consistent with data from other sites suggesting that spinning was a ubiquitous activity in the Andes that was often performed while doing other things (e.g., Costin 1993:6; Moseley 2001:74; Silverblatt 1987:9).

The majority of the whorls were found in burial contexts. This highly uneven distribution of whorls between architectural and mortuary contexts suggests that spindle whorls were valued objects. Two of the 11 whorls found in architectural contexts are broken, and one is made of poorly fired clay. This leads us to propose that they were rarely lost and were considered of significant value for inclusion as a grave good. Their presence in burials also suggests that whorls were personal items. Rather than pass them on to children or other loved ones, they were taken to the grave with the deceased. These findings suggest that whorls were so important to spinners that they were often buried with their owner instead of passed down, sold, or traded.

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Table 3. Distribution of Spindle Whorls in Intact Burials.

Burial	Sex of individual	Number of whorls
CCM1U2F1	female	2
CCM1U2F2	female	8
CCM1U6F3	female	5
CCM1U8F1	female	8
CCM1U9F10	female	4
CCM1U2F5	male	1
CCM1U2F3	child (indeterminate)	3
CCM1U7F1	child (indeterminate)	4
CCM1U9F5	child (indeterminate)	2

All of the metal whorls were found in mortuary contexts, although burials also contained stone and ceramic whorls. As mentioned above, we argue that whorls may have been used both as spinning weights and as items of personal adornment, at least in death. Of the 64 whorls found in the cemeteries of Sector C, 38 whorls were found in direct association with an intact burial (the rest were in fill) and often showed signs of having been strung together. These 38 whorls were collected from nine graves: five adult females, one adult male, and three children. The male had only one whorl, and it was metal. In contrast, the children had two, three, or four whorls, and the females had as many as eight whorls (Table 3). Because whorls are almost exclusively associated with women and children (whose sex cannot be determined), they appear to have been gendered objects. If grave goods are often a reflection of a person's activities in life, the gender identity of spindle whorl users or consumers can be inferred from the predominant association of whorls with female burials. Ethnographic and ethnohistorical documentation (e.g., Costin 1993, 1995, 1998; Murra 1962; Silverblatt 1987) show that textile production tended to be a female task in the prehispanic Andes, although men did participate in textile production occasionally. Children likely learned to spin, although the presence of whorls in the burials of two infants (CCM1U7F1 and CCM1U9F5) who were clearly too young to spin indicates that one could be buried with spindle whorls before one could actually use them, suggesting that whorls may have been an indicator of status, wealth, or perhaps even of feminine gender (although this idea must remain speculative). The lack of spindle whorls in five out of six adult male burials at El Purgatorio suggests that this artifact type was not strongly associated with men, and supports the assertion that women were the primary recipients of spindle whorls as offerings.

It also seems possible that whorls were an indicator of wealth or status more than age or achievement, since the children have multiple whorls but the adult male had only one. It is difficult to know whether whorls were worn as conspicuous signs of status in daily life or only in death. Since our evidence comes from burials, we cannot say for certain that spindle whorls were worn as necklaces while the owner was alive. The burials at El Purgatorio tend to reflect an intermediate class (rather than the highest elites or truly poor commoners) based on their grave goods. Because whorls interred with burials would be taken out of circulation for productive purposes, we argue that the number and type of whorls (especially metal whorls) may also reflect the wealth or status of the interred. The production of textiles played an important role in Andean economies for thousands of years (as prestige goods and indicators of elite status) (e.g., Costin 1993, 1995; Murra 1962), and there may have been some prestige or status associated with elaborately worked spindle whorls like those found at El Purgatorio.

The spindle whorls from El Purgatorio also offer insight into production practices and economic organization in the Casma polity. Although the narrow range of diameters and weights reflects the predominance of cotton as the raw material for thread in this society, the high variability of whorls in this assemblage in terms of whorl material, shapes, and decorations suggests that there were multiple manufacturers for these whorls. The fact that they are made of three different materials indicates a minimum of three workshops for creating stone, ceramic, and metal implements. The high quality of these whorls also suggests that they were produced by skilled workers, who were able to create low-inertia whorls for spinning cotton. In our view, the plethora of shapes and decorative elements, combined with the range of raw materials, suggests that whorls were likely produced by several different manufacturers, either in household industries or in state-controlled workshops (such as the ceramic workshop found in the monumental Sector A at El Purgatorio; see Vogel 2011, 2016). Relatively little is known about the process of crafting spindle whorls, but O'Neil's

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(1974) study of stone spindle whorls from the Chibcha territory of northern South America highlights the need for an extensive set of tools and considerable technological knowledge to produce whorls in an assortment of shapes and designs. As mentioned above, Chapdelaine et al. (2001) found evidence for Moche whorl production in specialized workshops, as well.

Spindle whorl studies can also give indications of economic structures that regulate or control whorl production and distribution. For example, at Classic period sites in Oaxaca, Carpenter et al. (2012) describe the production of spun cotton and maguey as taking place mostly in domestic residences under a fluid economic model of production using local resources, but marked by interdependence and specialization. Smith and Hirth (1988) also document increased specialization in Mesoamerican cotton textile production, suggesting that the rise in "specially manufactured" spindle whorls during the Epiclassic period in central Mexico indicates an increase in demand and scale of cotton production for finer textiles (Smith and Hirth 1988:355).

In a similar fashion, the data described here may also provide some insights into Casma political economy, at least where spindle whorls are concerned. The lack of standardization of whorls may indicate that their production and distribution were not tightly controlled by elites. In other words, whorls may have been freely traded and circulated amongst the populace without much state oversight. This certainly seems reasonable for stone and ceramic whorls, given the easy accessibility of their raw materials. But access to copper and lead as well as the metallurgical technology to produce the metal whorls may have been more closely attached to state control (Vogel et al. 2015). The presence of copper whorls in burials may indicate a manner of payment or reward to women for their service to the state, perhaps even for their production of textiles (see Vogel 2016 for further discussion of economic organization at El Purgatorio). Of course, the use of artifact frequency as an indicator of economic patterns and transitions is not unique to this analysis. Brumfiel (1991) used the frequency of different Aztec spindle whorls across time periods as evidence for a proposed shift in the traditional economy. The ideas proposed here will need to be investigated further as the study of Casma sites continues.

Conclusion

There is much to be learned from the careful examination of spindle whorls, especially when a large sample from controlled excavations is available. In addition to examining the technical aspects of spindle whorls as tools for making yarn, this study sought to identify the manufacturers and users of the whorls, as well as other meanings or uses of these artifacts. The El Purgatorio sample is especially intriguing for its diversity of materials, shapes, and decorations. In addition to their traditional function of spinning yarn, spindle whorls may indicate gender identities, gendered tasks, expressions of wealth or status, and a lack of state-controlled production. This case study from El Purgatorio is intended as a model for investigating textile production in late prehistoric Peru and as a more holistic way to approach these artifact assemblages around the globe and in varying time periods.

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Data Availability Statement. The results of this research have been disseminated via public presentations and publications in both Peru and the United States, as well as through our project website: http://business.clemson.edu/PAEP/index.html.

Supplemental Materials. Supplemental materials are linked to the online version of this paper, which is accessible via the SAA member login at www.saa.org. These include the following figures:

Supplemental Figure 1. Olla-shaped whorl.
Supplemental Figure 2. Spherical whorl.
Supplemental Figure 3. Conical whorl.
Supplemental Figure 4. Disk-shaped whorl.
Supplemental Figure 5. Quadripartite whorl.
Supplemental Figure 6. Distribution of Whorls by Weight.

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Supplemental Figure 7. Distribution of Whorls by Diameter.
Supplemental Figure 8. Distribution of Whorls by Inertia.

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Note

1. The whorls described by Loughran-Delahunt (1996) for the Pacific Northwest are made of wood rather than ceramic, stone, or metal. Moreover, they are nearly an order of magnitude larger in diameter and can have masses 100 times those of the El Purgatorio samples. Because of the incredible differences in size, a clear distinction in the kind of materials that were spun and the thickness of the product is obvious.

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