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Evidence for Textiles in Loma Negra, Peru, as Recorded in Copper Corrosion

Introduction

Between 1979 and 1987, the Metropolitan Museum of Art acquired nearly 400 metal artefacts said to come from shaft tombs at Loma Negra, a Moche site in the Piura Valley on the North Coast of Peru (Lechtman *et al* 1982; Shaffer 1985; Schorsch *et al.* 1996; Shaffer and Uricheck 1997; Perkins 1997; Schorsch 1998; Centeno and Schorsch 2000). Notable for the excellent quality of their manufacture (Disselhoff 1972; Jones 1975; Jones 2001), the objects were made of hammered unalloyed copper sheet metal, cut to shape and joined mechanically using slotted and crimped tabs. Many were plated with extremely thin layers of silver and gold, using an ingenious electrochemical deposition process found thus far only on artefacts from the Piura Valley (Lechtman 1979; Lechtman *et al.* 1982; Schorsch 1998; Centeno and Schorsch 2000). The corpus includes headdress ornaments, staff heads, ear spools and nose ornaments, as well as hundreds of artefacts of unknown purpose. These objects include three-dimensional representations of insects, spiders, scorpions and crayfish; owl-head rattles; canine heads; representations of human figures in high and low relief; large plaques depicting the "decapitator" figure Ai Apec; human hands and feet; and crescent-shaped objects decorated with depictions of animals and humans. Single objects of an iconographic type are rare: nearly the entire collection can be divided into groups of objects that seem to form pairs or sets.

The shaft tombs at Loma Negra are assigned to the Moche culture (approximately AD 100–800), although the site is geographically isolated from the main Moche centres to the south by the Sechura Desert. During the Early Intermediate period (approximately AD 200–600), when the tombs were constructed, the Moche population shared the Piura Valley with a second indigenous culture, the Vicús. Despite the coexistence of the two groups, the metal artefacts produced by each remained stylistically distinctive.

All of the Moche objects in the Metropolitan Museum associated with Loma Negra are thought to be from the Moche II-III period - roughly contemporaneous with Tombs 1 and 2 (AD 200–300) at the Moche site of Sipán (Alva and Donnan 1993).

Pseudomorphic evidence for lost organic material

Evidence of organic objects deposited with metal objects in burials can be preserved within corrosion in a process similar to fossilisation commonly called pseudomorphism[1]. As the corrosion layers develop on metal artefacts, organic materials in direct contact with the metal are surrounded by or impregnated with corrosion products, sometimes resulting in negative "moulds" and three-dimensional replicas of the organic materials. The organics may subsequently degrade and disappear, but a record of the organic material remains.

Due to the fragile plating, corrosion layers on most of the Metropolitan Museum's Loma Negra artefacts have never been removed. As a result, numerous associated textile fragments remain extant on the surfaces of the metal objects, attached to corrosion layers. However, a large amount of mineralised organic material and pseudomorphic structures also remain intact within those layers. The corrosion primarily documents

textiles, but information about feathers, cordage, plant fibres and other material survives as well.

In addition to pseudomorphs that preserve the same three-dimensional forms as the original organic material, the collection contains abundant examples of two-dimensional corrosion patterns also produced as a result of prolonged contact with textiles. On first glance, it may not be obvious that some of these corrosion patterns are textile evidence. In many cases, they do not resemble textiles. Nonetheless, textile-produced corrosion patterns can contribute useful textile data. That data includes evidence of weave pattern (Fig. 1); dots of corrosion in rows or grids indicating the position of threads (Fig. 2); stripes, striations, or dashes corresponding to threads or cords (Fig. 3); and additional elements preserving information about thread diameters and twist directions. The majority of the Loma Negra objects exhibit outstanding examples of these sorts of textile-related corrosion structures, as well as three-dimensional pseudomorphic structures and remains of actual textiles.

The textile corrosion structures on the Loma Negra metalwork have been previously examined by Anne-Louise Shaffer (1985). However, Shaffer's focus was on reconstructing burial relationships between artefacts rather than on the textiles as artefacts themselves. In particular, the possibility of using the less obvious two-dimensional corrosion patterns to obtain information about ancient textiles has not yet been fully explored. Worldwide, textile-produced patterns in corrosion remain an untapped archaeological resource.

One reason for the under-utilization of corrosion data is that many questions remain about how to correctly interpret corrosion patterns. Little information is available about the analysis of less well-defined corrosion structures in general. Textile-produced corrosion patterns can preserve many of the diagnostic features of textiles, and that data can contribute, as actual textiles do, to the compilation of a set of culturally-defined textile characteristics. However, unlike textiles, corrosion structures cannot be turned over, weaves cannot be manipulated and individual yarns cannot be separated. Even more basic issues include questions such as: does the pseudomorphic replacement process desiccate the yarns or cause them to swell, and do "tracks" in corrosion produced by yarns provide an accurate estimation of yarn diameter? If one is trying to obtain thread counts from rows of dots, exactly what part of the textile is a dot? Does a grid pattern really indicate the weave structure? As yet, protocols for the study of textile corrosion structures have not been established, and therefore, the retrieval of corrosion pattern data is not standard archaeological procedure.

Fig. 1. Grid pattern produced by the undersides of textile yarns in contact with the metal surface. Detail of object 1987.394.133 (© Julie Unruh).

Fig. 2. Rows of dots and dots in a grid pattern indicating the position of yarns in a textile. Detail of object 1979.206.1270 (© Julie Unruh).

Project goals

A study of the Loma Negra textile corrosion patterns was initiated to serve two research goals. First, it was anticipated that the study would provide information about how to correctly read corrosion patterns, and that guidelines for the interpretation of textile-produced corrosion patterns could be proposed. The second goal was to recover a large body of information concerning objects made from organic materials deposited in Loma Negra tombs, in particular the diagnostic features of the textile structures. It was anticipated that a database of the Loma Negra textile corrosion information could form the basis of a Loma Negra textile typology, and by extension, contribute to a Moche textile typology.

Fig. 3. Parallel striations created by thicker yarns in the warp of a faced textile. Detail of object 1980.563.3 (© Julie Unruh).

A further benefit of the project was that the textile data clearly describes depositional relationships between objects made of organic materials and copper objects, a situation originally observed by Shaffer (1985). That facet of the study will not be described in this article.

Methodology

Each Loma Negra copper object was surveyed to assess the presence and location of corrosion structures that indicate lost organic material and the presence of surviving organic material. The survey confirmed that a textile had been in contact with virtually every buried object, and 21 percent of objects exhibited evidence for an association with two or more textiles. In total, 601 textile corrosion "events" were identified on 347 objects. Most of the objects lacking textile corrosion structures also lacked archaeological corrosion, indicative of past cleaning.

From the objects initially surveyed, 129 were chosen for in-depth analysis. This group was selected based on the legibility of the textile corrosion structures, the information to be gained by comparing particular structures, or to include multiples in a typological series. The textile analysis was a straightforward data-collection process and an inquiry into how to accurately read indistinct corrosion patterns that contain recoverable textile information. The methodology for the latter was simple: where preserved textiles or unambiguous textile corrosion structures existed side-by-side with less legible corrosion patterns, the two were compared and differences were tracked.

Insofar as possible, textile corrosion structures were analysed as if they were actual textiles. Weave structures were classified according to Emery (1966). Additional characteristics surveyed were thread count, single and plied yarn diameter, twist direction, number of single yarns in the plied yarn and ply direction. A decision not to record the angle of twist was made for two reasons: 1. it was anticipated that twist angles of corrosion structures could not be accurately measured; 2. hand-spun yarns often have great variability in twist angle, so a measurement of an angle on one yarn at one location is somewhat arbitrary. In retrospect, this decision was unfortunate. As it turned out, about 35 percent of the objects had extant organic yarns from which it would have been possible to record twist angle, and this piece of data might have been useful in indicating warp and weft directions.

Measurements were made using electronic calipers accurate to .01 mm, under appropriate magnification, which included a x3 head loupe, a x10 "thread counter" and a binocular microscope with a range of x10 – x80. Where textile fibres were extant, preliminary fibre identification was possible without sampling. Thirty-two of these identifications were confirmed using polarised light microscopy (PLM). Fourier transform infrared microscopy (FTIR) was performed on four additional samples.[2]

Interpreting textile corrosion structures

The investigation into accurately reading corrosion structures produced some answers about appropriate methodology, and revealed cases in which the textile corrosion structures should be considered untrustworthy. The following tentative guidelines are proposed.

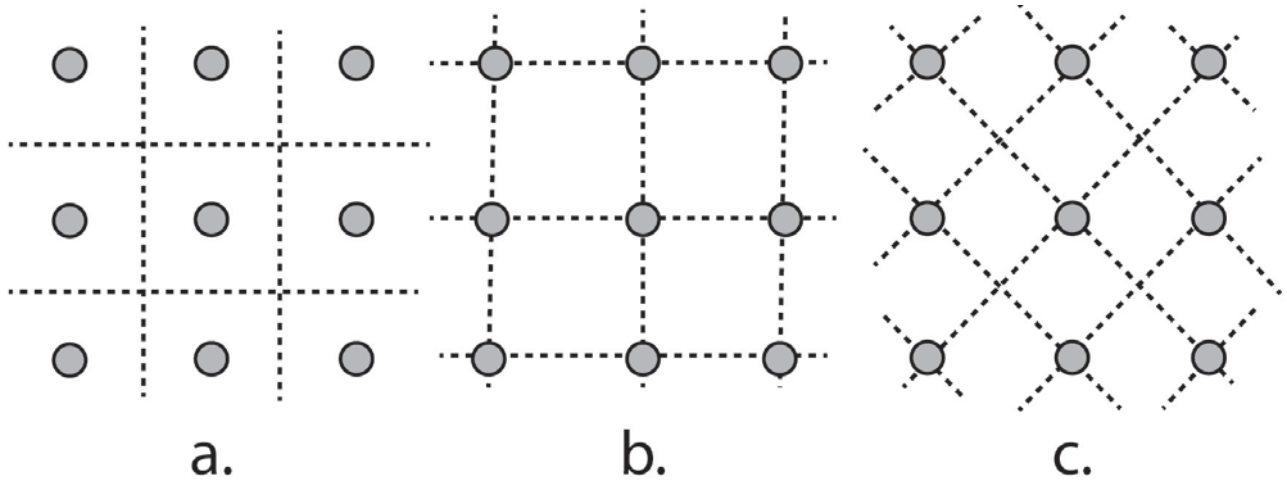

Fig. 4. Three possible interpretations of dots of corrosion: a) spaces between yarns; b) the points of contact of crossing yarns; or c) points of contact of yarns in one system only (Drawing: Julie Unruh).

Identification

Good textile pseudomorphs are visually obvious, but it may be necessary to train the eye to recognise the less apparent patterns that also indicate the former presence of a textile. Such patterns include grids, dots or dashes in regular formations, striations, concave impressions of yarns and unusually straight edges. The patterns may be delineated by differences in colour or texture. Unless the structure is a pseudomorphic textile that retains excellent detail, examining corrosion under high magnification is not helpful: at high magnification, patterns cannot be recognised. However, low magnification can assist in recording accurate measurements taken by hand. Raking light is essential for identifying low relief patterns, and a light source that is moveable to different viewpoints and angles is ideal. Positive identification of textile corrosion structure remains frustratingly difficult at times. Caution is necessary. Notably, the regular cellular structure of some wood can mimic a textile grid.

Structure orientation

An initial question was whether dots of corrosion in regular grid patterns represented spaces between yarns (Fig. 4a), or the points at which crossing yarns contacted the metal (Fig. 4b). Moreover, on a backstrap loom, warps are under higher tension than wefts. The result is physically straighter warps and wefts with more pronounced over-and-under contours. If the dots represented yarns in contact with the metal, and the textile was woven on a backstrap loom as expected, it might be possible that only the wefts would contact the metal. In that case, the correct orientation of the textile grid would be diagonal to the grid of dots (Fig. 4c)

In fact, all three situations were observed. However, in most cases, dot patterns were more likely to mark spaces between yarns rather than yarns. If that is the case, the most accurate measurements line up with the grid (Fig. 5). However, there were many instances in which the dots are clearly vestiges of the yarns themselves, as evidenced by somewhat elongated bumps or marks, or as concave impressions of the yarns (occasionally with visible twist directions). Where there was reasonable evidence that the dots designated yarns rather than spaces, the most accurate measurements were usually found to be oriented diagonally to the apparent grid, and thread counts were most accurately measured in a "w" or inverted "w" pattern (Fig. 6). Exceptions did exist.

Thread counts

It may be possible to measure only a few threads in a pattern. In these cases the thread counts per centimeter can be extrapolated (threads/cm = n/d, where n = number of yarns measured, and d = total distance measured in centimetres). Where possible, a useful strategy is to extrapolate thread counts in several locations, and to calculate an average thread count.

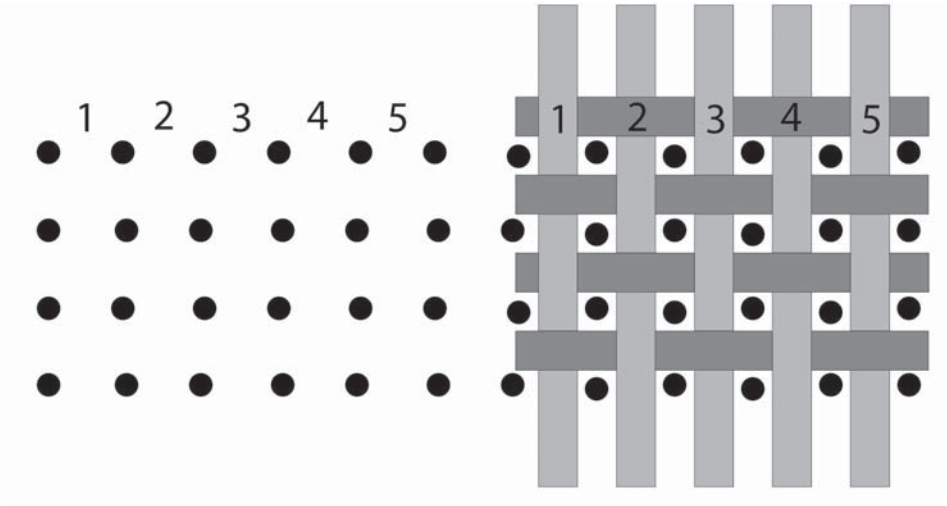

Fig. 5. Measuring a thread count with corrosion dots representing spaces between yarns (Drawing: Julie Unruh).

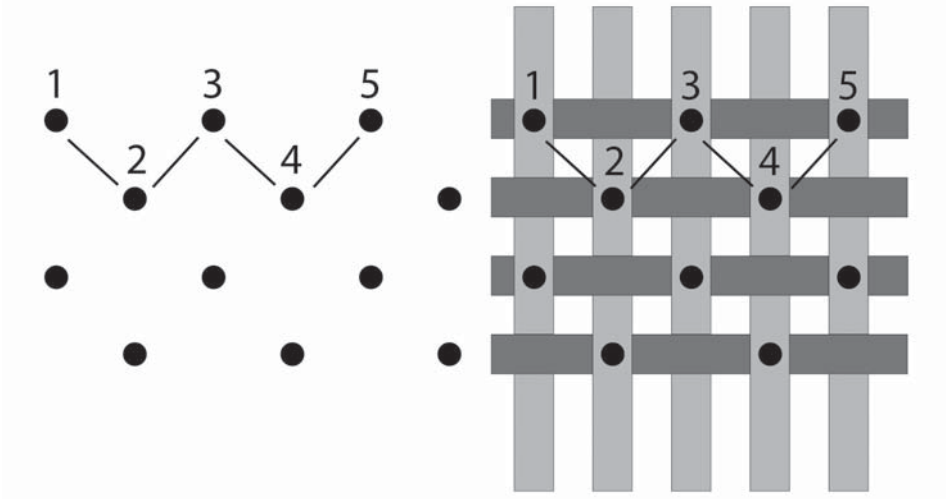

Fig. 6. Measuring a thread count with corrosion dots representing threads in one system only, in a "w" pattern (Drawing: Julie Unruh).

A test was performed to gauge the level of accuracy of thread count extrapolation using two modern basket weave textiles with known thread counts of 23 and 20 threads/cm. Nine measurements of each textile were taken using 4-20 elements. For both textiles, the extrapolated thread counts had between 81 percent and 100 percent accuracy, with accuracies averaging 94 percent. This degree of accuracy was considered satisfactory.

Yarn diameters

The effects of yarn degradation and mineralisation on yarn diameter are not known. In the Loma Negra collection, it was possible to directly compare organic textile remains with corrosion structures produced by the same textile. In this collection, from the particular burial environment of Loma Negra tombs, some trends could be identified, though they were not as consistent as would be wished. Three-dimensional mineralised yarn structures were usually slightly larger in diameter than the corresponding organic yarns. "Tracks" left by yarns in grid patterns generally measured slightly smaller in diameter than the corresponding organic yarns. Differences were in tenths of millimeters; however, since yarn diameters frequently are only tenths of millimeters, that magnitude of error was significant. More work is needed to determine whether these observations indicate consistent relationships, and if so, whether it is possible to identify a likely degree of error for measured diameters of mineralised yarns and two-dimensional marks produced by yarns.

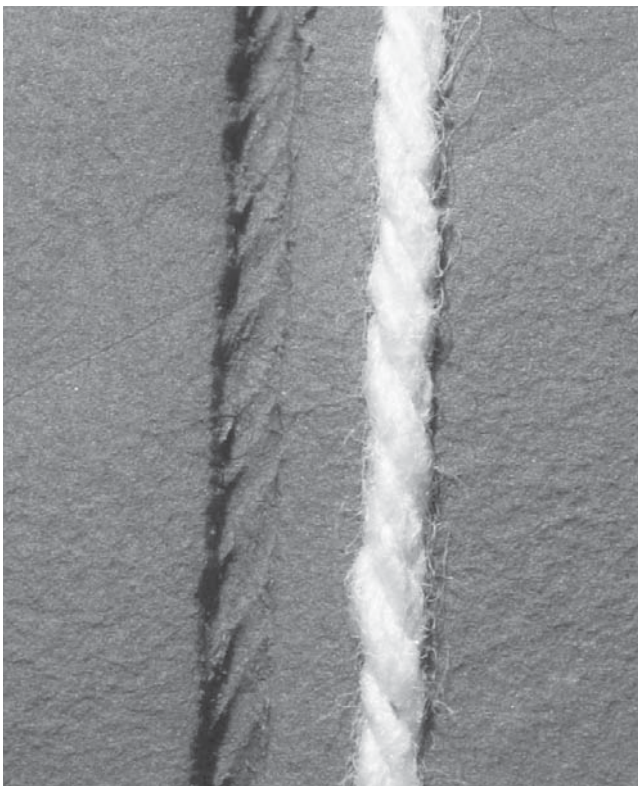

Fig. 7. Reversal of perceived twist direction in an impression (Drawing: Julie Unruh).

Twist direction

If yarn structures are negative impressions, the twist direction will appear as reversed (Fig. 7). If only the lower section of a yarn is extant, either as mineralised or organic material, the twist will also appear reversed. In order to establish the correct twist direction, it is therefore important to first determine whether the corrosion structure is an impression or only the lower section of a yarn. Sometimes this determination is possible; sometimes it is not.

Weave structure

All woven textiles are based on warp and weft systems at right angles to each other. Even complex weaves utilise this basic grid structure, and if only vestiges of complex weaves are preserved, it is the regularity of the grid that is most apparent in the corrosion. The visual dominance of a grid pattern has been observed even in textile corrosion structures produced by twill weaves that might be expected to have a diagonal appearance. It seems that even when other characteristics of a textile can be determined with some accuracy, unless the weave structure can be clearly seen, it may remain in question. The Loma Negra analyses were greatly assisted by the fact that many weave structures of surviving textiles remained intact.

Corrosion products

An in-depth investigation into the process of pseudomorphism was beyond the scope of this study. However, it was possible to do a baseline study of corrosion on Loma Negra artefacts to ascertain whether corrosion products associated with textile structures were random or systematic.

During the initial survey phase, corrosion products associated with textile patterns were classified by colour and type of textile corrosion structure with which they were related. The identification of copper corrosion products via colour is notoriously erroneous, but with no possibility of a large-scale analytical programme, a visual assessment based on colour proved expedient. Subsequently, certain specific corrosion products were identified using open architecture x-ray diffraction (XRD), microdiffraction XRD, open architecture x-ray fluorescence (XRF)[3] and energy dispersive x-ray spectroscopy (EDS)[4]. A programme of XRD and EDS analysis performed in 1997 also contributed additional useful data (Shaffer and Uricheck 1997).

Based on the visual assessment, correspondences were indeed found. A turquoise colour was seen only in association with textile corrosion structures and never in the absence of textile. A corrosion product thought to be paratacamite (a bright, pale green colour) was in association with 68 percent of textile corrosion structures, with probable malachite (dark green) second most common and probable cuprite (bright red) third. The majority of partially mineralised yarns were categorised as turquoise, blue or the pale green "paratacamite". However, the majority of completely mineralised yarns were tagged "malachite" or "cuprite". The majority of the corrosion which had formed two-dimensional patterns under or between yarns also appeared to be malachite or cuprite.

The turquoise product remains unidentified. The best matches to some of the lines in the XRD spectra may be ramsbeckite, a copper sulphate, and langite, a copper sulphide. However, the sample contains additional species or phases that could not be identified. Gillard and Hardman report that in experiments reproducing negative casting with a sodium chloride solution a "blue-green mineral layer is rapidly deposited on the surface of the metal and textile"; the mineral layer, called botallackite, recrystallises to atacamite, and then to paratacamite (1996, 178). The majority of all partially mineralised yarns in the collection are either turquoise or blue, which is consistent with a theory that some of them may be yarns at the initial botallackite stage. Another possibility is that the turquoise colour simply indicates copper-stained organic remains. "Turquoise" may therefore indicate not one product, but a group

of possibilities. Nonetheless, the observation that turquoise occurs only in association with textiles structures is worth further investigation.

A product visually identified as paratacamite was in association with the majority of textile corrosion structures. In instances in which the product was analysed via XRD and by the silver nitrate chemical spot test (Odegaard *et al.* 2000, 108), nearly 50 percent of what was categorised as "paratacamite" was not (an observation of particular interest to conservators, who are frequently required to make visual identifications of paratacamite). Nonetheless, even if only half of the suspected cases are paratacamite, there remains a high correlation of this compound in association with textile corrosion structures, again an observation worth further investigation.

XRD analysis of corrosion products was only possible for 12 textile corrosion and feather samples. A predominance of malachite and cuprite was confirmed in this small sample. The preliminary evidence suggests that despite the availability of a variety of anions, a limited number of corrosion products become pseudomorphic structures. It seems germane that the few textile pseudomorph copper corrosion products reported in the literature are all carbonates, oxides or chlorides (Gillard and Hardman 1996; Gillard *et al*. 1994; Gillard, Hardman and Watkinson 1993; Chen, Jakes and Foreman 1996; Jakes and Sibley 1984; Sibley and Jakes 1982; Carroll 1973). Chen has proposed a fibre mineralisation model in detail (1995). However, her model proceeds from the assumption that malachite and atacamite will be the end products. No published models explain why malachite and atacamite would be thermodynamically preferred products across dissimilar environments. Reasons for the mineralisation of yarns by certain products to the exclusion of others have not been suggested.

Given the small range of corrosion products, it becomes interesting to look at what defines a textile pattern. In some cases, the arrangement of malachite versus cuprite creates the pattern. For example, the textile structure can be delineated by malachite dots on cuprite backgrounds, the dots corresponding to spaces between yarns. This arrangement also appears in reverse: cuprite dots on malachite backgrounds. Cuprite converts to malachite, so in the first scenario, a cuprite layer first developed under the textile, after which malachite developed between the yarns. In the second scenario, a cuprite layer developed under the textile, after which malachite developed under the yarns. There is no obvious determining factor for the position of malachite formation. Nor is it obvious why, if the two products are transposable in the same type of pattern, they remain distinct.

Jakes and Sibley describe the colour differences in a pseudomorphic silk textile composed of green and black corrosion products as caused by differential mineral replacement and attribute the difference to dyed versus undyed fibres (1984, 421–422). A comparable situation exists in the Loma Negra material. In the majority of faced textiles, although both warp and weft appear to have been cotton, the faced yarns are more mineralised, and the unfaced yarns remain more organic. It seems that a difference in the chemistry of the fibres has promoted preferential mineralisation of the faced set. Moche cotton was rarely dyed, but it was deliberately grown in a range of colours (Vreeland 1999). Whether structural differences of naturally pigmented cotton could promote preferential mineralisation has not been investigated.

In some cases, the perceptible pattern is produced by different crystal morphology or "habits".[5] Finer crystals appear lighter; larger crystals appear darker. It seems that specific habits of malachite, in particular, correspond to specific sites with respect to the textile. Malachite under yarns forms as finely divided, pale green, white or grayish crystals, creating pale two-dimensional "tracks" of yarns and grid patterns. Malachite which forms between yarns is dark green, generating a pattern of dark green dots. Mineralised yarns and three-dimensional grid patterns are also dark green, glossy malachite. Malachite within partially mineralised yarns appears pale green.

In short, preliminary observations suggest that mineralisation of textile yarns may involve only a small number of specific corrosion products, and the crystal morphology of those products varies with location in predictable ways. Again, these observations merit further study.

One additional question was whether camelid could be distinguished from cotton via corrosion product. Camelid is a keratin which contains the amino acid cysteine, which contains a disulphide bond. In theory, the sulphur present in cysteine might remain in the corrosion layer as a cuprous sulphide. Feathers, which are also cysteine-containing keratin, might also leave the same marker.

Because camelid was scarce in this collection, feather pseudomorphs were analysed to determine whether the presence of sulphur can be used as a marker for protein. In three trials, feather pseudomorphs were found to be composed of malachite, cuprite and/or atacamite, with no sulphur component in any of the samples. Gillard and Hardman propose a reason: "At pH < 9, the bonding of copper to the wool matrix is predominantly due to green carboxyl/copper (II) complexes. Copper (II) complex formation at

disulphide sites is minimal. Copper (II) ions catalyse the oxidation of the disulphide bond but bind elsewhere, presumably through greater electrostatic attraction" (1996, 179). In fact, only two sulphur-containing corrosion products were identified via XRD: brochantite, from a location in which there were not believed to be any textile corrosion structures at all, and the unidentified turquoise, which is seen in yarns positively identified as cotton. Silver scavenges sulphur, gypsum contains sulphur, and in a tomb, the decomposing body is a source of protein. Accordingly, even if sulphides were found in association with feathers, the presence of so much sulphur not in association with a feather source seems a good indication that in this collection, sulphur-containing corrosion would have to be considered an unreliable marker for keratin.

Textile analysis results and discussion

Two hundred and four instances of textiles, 69 instances of cordage, 39 instances of feathers (12 in clear association with textiles) and seven instances of plant fibres or wood were identified on the 129 artefacts subjected to in-depth analysis. Additionally, 17 of those objects had corrosion patterns indicating lost materials that remain unidentified.

Basket weave: a possible diagnostic for Loma Negra

Textiles have stylistic differences that vary with time and geographical origin. It is therefore possible to construct a cultural and chronological sequence of textiles similar to the ceramic sequences used by archaeologists. As with ceramic chronologies, a textile sequence can demonstrate cross-cultural influences, identify periods of social change, indicate technological developments and provide other information of use in interpreting the archaeological record. At least one textile sequence has been demonstrated to expand the ceramic sequence for coastal Peru (Wallace 1979).

Excavated data is always incomplete data. Moreover, some Moche sites have not yet published their textiles' diagnostic statistics. In general, textiles attributed to the Moche culture have not yet been extensively studied or published. Accordingly, a typology for Moche textiles is in its initial development.

The majority of published Moche textiles, both with and without provenance, are decorated textiles. Weave structures include brocade, tapestry, and double and triple cloth, as well as extraordinarily complex weaves with discontinuous warps, wefts and complementary yarns (Donnan and Donnan 1997; Prümers 1995; Kajitani 1982; Conklin 1979; O'Neale 1947). Excavated Moche textiles do include large numbers of undecorated plain weaves, as well as undecorated twills, plaiting and interlacing; however, only France-Éliane Dumais has studied undecorated textiles in depth (2008). The focus on decorated textiles to the exclusion of the others means that a broad concept of Moche weaving has yet to be formulated. However, several scholars have proposed diagnostic characteristics for both yarn make-up and woven structure for the Peruvian North Coast and Moche. Moche yarns are predominately cotton, s-spun singles. Camelid fibre is typically z-spun, plied and used sparingly in conjunction with cotton yarns. The principal Moche weave structure is a plain weave utilising single (rather than paired) yarns in both warp and weft.

The Loma Negra objects are thought to have been deposited in tombs. Accordingly, the associated textiles do not necessarily typify Moche textiles in general use: they can only be said to represent a group of textiles deposited in a burial context and specifically those in contact with metal objects. Moreover, the corrosion can only record the portion of the textile in direct contact with the metal object's surface: one layer of yarns and one side of the textile. Since Moche weavers created structures which incorporate more than one set of yarns in warp, weft or both, and in which obverse and reverse are dissimilar, it must be assumed that some of the data recorded in the corrosion is incomplete. Accordingly, it must be assumed that the Loma Negra textile corrosion structures present a simplified picture of the textiles in the Loma Negra tombs. Fortunately, the simplification does not negate the usefulness of the data. Even if a complete weave structure is not present or cannot be fully deciphered, as long as basic characteristics can be determined, a typology of diagnostic weaving characteristics for Loma Negra tomb textiles can be generated.

The textile corrosion data indicates that the Metropolitan Museum's Loma Negra textile type is largely consistent with the proposed Moche type described above. It utilises s-spun, single yarns, predominantly cotton, with camelid fibres used to a much lesser extent. 29 % of the Loma Negra textile corrosion weave structures analysed in detail remained unidentified, and 15 % were only tentatively identified; but among those positively identified, plain weave predominated as expected, at 93 %.

However, excluding faced plain weave (which normally requires single elements in the faced system to achieve the desired effect, and which accounted for 13 % of plain weave), only 25 % of the plain weave uses one yarn in each system. Instead, a majority of the plain weave textiles, at 65 %, utilise paired yarns in both warp and weft – *i.e.* basket weave (or 2/2 plain weave, Fig. 8). The remaining 10 % of plain weaves

Fig. 8. The primary textile type in association with the Loma Negra material: s-spun cotton (unplied) singles in a basket weave. Detail of object 1979.206.1275 (© Julie Unruh).

utilise combinations of singles and pairs (*i.e.* half basket weave).

If tentative identifications are included, increasing the sample size but decreasing the statistical validity, the numbers remain similar. 29 % of the textile corrosion weave structures remained in question, but among those positively identified or tentatively identified, 92 % are in plain weave; 13 % of the plain weave textiles are faced; of the remaining plain weave textiles, 30 % use one thread in each system and 61 % are basket weave.

Even allowing for a degree of error in the corrosion/textile analysis, this is a higher percentage of basket weave than has been reported elsewhere. Paired warps and wefts account for 11.5 % of El Castillo (Moche III) plain weave textiles; 20 % of Guadalupito (Moche IV) plain weave textiles (Dumais 2008); approximately 33 % of the Pacatnamu plain weave textiles (Donnan and Donnan 1997); 26 % of Gallinazo – Moche I fragments from the Virú Valley and Santa Valley (Wallace 1979); 11% of Conklin's Moche III-V sample (1979); and 15 % of the Vicús textiles (AD 250–650) in the collection of the American Museum of Natural History, New York (personal observation, 2007).

As noted earlier, this study only counted occurrences of textile structures, not individual textiles. In several cases what appears to be the same textile can be tracked across several objects. It is therefore possible that there were only a handful of textiles with paired warps and wefts, each in contact with dozens of objects. In fact, this interpretation is reasonable based on excavated precedent and on the textile data. In the Moche tombs excavated at Sipán, large textiles were wrapped around entire burial groups, enclosing multiple assemblages of artefacts (Alva and Donnan 1993; Prümers 1995). In the Loma Negra textile data, the thread counts and yarn diameters of basket weave textiles form a continuum: in both warp and weft, thread counts range from eight to 32 yarns/cm (four to 16 pairs/cm) with yarn diameters ranging from 0.16 mm to 0.9 mm in both sets of yarns. Based on visual characteristics, it seems unlikely that the Loma Negra basket weave textile corrosion structures all represent the same piece of fabric (Christiansen 2005, elaborates on the inability of standard data points to fully describe visually distinctive types). Statistically, the variation in thread counts almost certainly describes more than one textile. But in light of expected variations in hand-woven textiles, the majority of basket weave textile corrosion structures could, in fact, all derive from only a few textiles in contact with multiple objects. As a point of comparison, within one Chimu plain-weave backing on a mantle fragment in the collection of the Metropolitan Museum (33.149.99), the thread counts vary from 12 to 24 threads/cm in the warp, and 5 to 11 threads/cm in the weft, with a variation of yarn diameters from 0.22 mm-1.2 mm.

Nonetheless, paired warps and wefts seem to occur as a feature of Moche tomb textiles more often than previously acknowledged. Five out of the six Moche

weave structures from Moche I and Moche III burials at Huaca del Sol have pairs in both warp and weft (Donnan and Mackay 1978). The Moche IV textiles from Site F in the cemetery at the foot of Huaca de Luna include an unusual number of basket weave textiles (O'Neale 1947). Wallace observes that in general, paired warps and wefts are common in Peruvian North Coast textiles (Wallace 1979, 41; 1975, 110). An informal survey of textiles on view in the Museo Tumbas Reál de Sipán in Lambayeque, Peru identified a basket weave structure in the majority of cases (personal observation, 2007). Additionally, although the weave structures of the textiles from El Brujo have not been published, two textiles from the tomb of "Señora de Cao" which are illustrated in detail appear to be basket weave (Barreda 2007, 230 –231).

It seems that the Loma Negra basket weave textiles are not as anomalous as they first appear. The possibility that a basket weave should be viewed as a diagnostic feature of Moche tomb textiles or perhaps even a widespread Moche type deserves further investigation. In fact, it has been proposed that the basket weave structure was developed as a basic weave on the North Coast (Wallace 1979, 47 and 49). Further, it was proposed that paired wefts, rather than warps, are the *diagnostic* component of this weave structure, a suggestion that is supported by the continuation of paired warps but not paired wefts into the later Chimu period (Rowe 1984).

Donnan and Donnan theorise that "weavers used single warps and wefts when they wanted an open, light-weight fabric, and paired warps and wefts when they wanted a more tightly woven, heavier fabric" (1997, 217). However, the Loma Negra material does include basket weaves that could be characterised as open, indicating that the fabric density was not the sole factor in the choice of weave structure. Many researchers have proposed a deeply embedded principle of dualism that pervades pre-Columbian Peruvian cultures from the Initial through to the Inka periods, manifested in political, religious, aesthetic and mythical arenas (Schorsch 1998; Quilter 1997; Burger and Salazar-Burger 1993; Lechtman 1984; Lechtman 1977; Moore 1995). It is tempting to ascribe the use of not just pairs, but of pairs of pairs, to cultural values relating to dualism and symmetry, particularly in light of the symbolic meaning proposed for paired yarns in textile weave structures from elsewhere in pre-Columbian Peru.

Camelid

Moche weavers used camelid sparingly, but published assemblages of Moche textiles do contain camelid (Conklin 1979; Donnan and Donnan 1997; Dumais 2008; Kajitani 1982; O'Neale 1947; Prümers 1995; Wallace 1979; O'Neale and Kroeber 1930; Kroeber 1944). The Loma Negra collection exhibits an overwhelming preponderance of cotton and a puzzling scarcity of camelid. Thirty fibre samples from 19 textiles were identified using polarised light microscopy: 28 are cotton, and only two are camelid. Fourier transform infrared spectroscopy (FTIR) was performed on four additional samples which seemed likely to be camelid in light of the weave structure, fibre colour or spin direction: three of the four were cellulosic (cotton), and the fourth was indeterminate. A near absence of camelid at Loma Negra is inconsistent and unlikely. One explanation is that the camelid has degraded to the point that it is difficult to identify via microscopy, implying an alkaline environment (Sibley and Jakes 1984). In a number of cases, organic textile remains are associated with a brown or rust-coloured substance which is not obviously burial soil and that sometimes seems to occur in geometric patterns. Although two FTIR trials did not identify protein within this material, it may be the trace of degraded camelid yarns and seems worth more in-depth investigation.

Additional structures

The Metropolitan Museum corrosion/textile structures include double cloth in 2 % of the positively identified weave structures, plaiting or interlacing (1 %) and twill (4 %). Additionally, 8 % of the weaves were suspected to incorporate supplementary yarns, though none of those cases were confirmed. All of these values are likely to be low estimates. Because only one side of a textile is recorded against the surface of the metal, and because only fragments of textiles are preserved, it is very unlikely that all double cloths and textiles with supplementary yarns were identified on the Metropolitan Museum objects. Likewise, the technique of plaiting cannot necessarily be distinguished from weaving in corrosion patterns, and interlacing could only be confirmed if an extant interlaced edge survives, so it is likely that the percentage of plaited or interlaced textiles is actually higher than identified. The 4 % occurrence of twill weave is also lower than expected. Twill is reported in four out of six cases of the textiles from the Moche III Burial M-III at Huaca del Sol (Conklin and Versteylen 1978), accounts for 25 % of textiles at Pacatnamu (Donnan and Donnan 1997) and is proposed by Wallace (1979, 49) and O'Neale (1946) to be characteristic of Moche. However, 29 % of the Loma Negra textile corrosion structures analysed in detail had weaves that remained unidentified, and 15 % were only tentatively identified. Some of these are fragments of complex weaves for which a repeating pattern could not be discerned, but a portion

of the "uncertain" group included structures that were too indefinite to identify, and these may include additional twill.
"Cordage" was defined to include sewing thread, feather attachment threads, cords used to secure the metal objects to unknown substrates, and wrapping cords. Ninety-nine instances of cordage had been identified in the initial survey, and 69 of these were examined in detail. Of those cordages for which twists and number of ply could definitely be discerned, 52% are ss/Z cotton threads. However, z-spun cotton does exist (3 %). The number of ply generally ranges from one to six, though one s-spun cord consists of at least 27 threads plied Z.
Feathers were found on 17 % of the 367 artefacts initially examined. In the 39 occurrences of feathers on the objects examined in detail, the feathers showed evidence of an associated textile in 12 cases. In other words, of the 204 textile events examined in detail, 6 % are believed to have been feathered textiles.
Grassy plant material or wood was identified on only 2 % of the objects. This percentage seems low, based on our understanding of North Coast burial practices, and it seems likely that more thorough inspection of those objects not examined in detail would reveal more instances of plant material.

Conclusion
The information contained in corrosion patterns can be well worth the effort of recovery. The rediscovery of a group of textiles physically absent from the archaeological record is the obvious benefit to documenting information recorded in corrosion. The corrosion textile structures observed on the Museum's Loma Negra collection also provide enough data to expand the textile sequence of North Coast Peru, and raise the possibility that basket weave may be a diagnostic feature of Loma Negra tomb textiles. It is emphasised that the majority of the corrosion structures analysed were not three-dimensional pseudomorphic replicas of textiles. The bulk of useful data was recovered from two-dimensional textile corrosion patterns, which are not usually analysed as part of standard archaeological procedure.

Notes
1. In this article, "pseudomorph" refers to mineral-replaced or partially mineral-replaced textile structures. The term "textile corrosion structures" refers to both mineral-replaced textiles and to the largely two-dimensional corrosion patterns produced on the Loma Negra artefacts by contact with textiles during burial.
2. Fourier transform infrared spectroscopy was performed by Marco Leona, David H. Koch Scientist in Charge, Department of Scientific Research, The Metropolitan Museum of Art.
3. X-ray diffraction and x-ray fluorescence were performed with the assistance of Tony Frantz, Research Scientist, Department of Scientific Research, Metropolitan Museum of Art.
4. Energy dispersive x-ray spectroscopy was performed by Mark T. Wypyski, Research Scientist, Metropolitan Museum of Art.
5. Observation initially made by Ellen Howe, Conservator, Sherman Fairchild Center for Objects Conservation, The Metropolitan Museum of Art (personal communication, 2007).

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