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Dyes used in pre-Hispanic textiles from the Middle and Late Intermediate periods of San Pedro de Atacama (Northern Chile): new insights into patterns of exchange and mobility

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ABSTRACT

Pre-Hispanic Andean textiles constitute the longest continuous textile record in the world, their structure and design being one of the most significant markers of group identity in Andean populations. Since the Late Formative Period (ca. 100 – 400 AD), the region around San Pedro de Atacama (SPA) in the Atacama desert of northern Chile has been part of a complex and extensive network of interacting polities through which raw materials, agricultural products, goods, people and ideas circulated in the South-Central Andes. The archaeological record in SPA abounds with textiles from various cultures that participated in such network. A study of these textiles would allow intercultural as well as diachronical

comparisons. Numerous studies on textiles found in SPA have focused on their technological and iconographic features. This work addresses the identification of the organic dyes employed in the manufacture of 38 textiles found in funerary contexts in SPA from the Middle (ca. 400 – 1000 A.D.) and the Late Intermediate periods (ca. 1000 – 1450 A.D.), using high performance liquid chromatography with a diode array detector (HPLC-DAD). Purpurin and not alizarin was found in all red dyed fibers and indigotin (IND) and indirubin (INR) in all blue dyed fibers. Natural sources of these dyes are exogenous to SPA; their importation into SPA lasted for nearly a millennium. A positive correlation was found between [IND]/[INR] concentration ratio and the altitude of the place where the fiber was presumably dyed. Overall, the results indicate that finished garments and also raw dyes and ready-to-use dyed fibers were imported into SPA from neighboring regions and that foreign weavers were possibly active at SPA.

1. **Introduction**

Pre-Hispanic Andean textiles constitute the longest continuous textile record in the world (Cardon, 2007). Characteristics of textile structure and design provide one of the most significant markers to group identity in Andean populations, as shown by archaeological, ethnohistorical and ethnographical studies (Agüero et al., 1997, 1999, 2000; Cassman, 2000; Murra, 1962; Oakland Rodman, 1992; Wallace, 1975). The South Central Andes (Figure 1) has been the area of development of a number of long-lasting pre-Hispanic societies. One such society occupied the region around San Pedro de Atacama (SPA) in the Atacama desert of northern Chile. As early as the Late Formative Period (ca. 100 – 400

AD), SPA had become part of a complex and extensive network of interacting polities through which raw materials, agricultural products, goods, people and ideas circulated in the South-Central Andes including the extreme north of Chile, the Pacific coast, the Bolivian altiplano and Northwestern Argentina (Berenguer, 2004; Berenguer and Dauelsberg, 1989; Llagostera, 1996, 2006; Núñez, 1996; Salazar et al., 2014; Tarragó, 2006). The archaeological record in SPA includes textiles from various cultures that participated in such network. Some of these textiles rank among the finest produced in the South Central Andes, with exquisite craftmanship, unique designs and brilliant colors, and appear in a very good state of preservation on account of the extreme aridity of the region (Berenguer, 2004; Blanchette et al., 1990). A study of textiles from SPA would thus allow intercultural as well as diachronical comparisons.

Numerous studies on textiles found in SPA have focused on their technological and iconographic features (Agüero et al., 1997, 1999, 2000; Lindberg, 1963, 1967; Oakland, 1986a, 1986b, 1994; Oakland Rodman, 1992; Oakland Rodman and Cassman, 1995; Uribe and Agüero, 2001, 2004, 2005), and have led to their classification into styles, e.g., Tiwanaku, Bolivian Oriental valleys (BOV), La Aguada from Northwestern Argentina, and SPA (local) styles (Agüero, 2000, 2003, 2012). In this work, we have extended stylistic studies of SPA textiles to encompass raw materials used in their manufacture, thus subscribing the broader concept of style discussed by Chilton (2002), which considers the complete operative chain leading to the finished product, including the materials employed. The ample availability of fiber from camelids in SPA led us to focus the study on the dyes employed. The predominant colors in SPA textiles are shades of yellow, red and blue. Yellow shades usually arise from the use of carotenoid and flavonoid containing plant extracts. These two families of compounds are of widespread occurrence in plants;

distinctive composition profiles in different plant species could be of potential diagnostic value to identify the plants of origin, provided that comparable chemical analyses of plant reference materials were available (Ferreira et al., 2004; Zhang et al., 2008). Unfortunately, this condition is not met by potential sources of yellow dyestuffs in South America. In contradistinction, dyes with shades of reds and blues come from a limited number of sources in pre-Hispanic South America (Cardon, 2007); hence, the identification of the dyes can lead in a straightforward manner to a small set of putative and related plant sources. In the present work, we have analyzed red and blue dyed fibers from pre-Hispanic textiles found in SPA. The dyes were extracted from the fibers and high performance liquid chromatography with diode array detection (HPLC-DAD) was used to separate the components of the organic extract and identify them by comparison of their retention times and UV-visible spectra with those of standard compounds. This methodology has been extensively applied in the study of organic dyes used in textiles (Degano et al., 2009; Rosenberg, 2008), including some from pre-Hispanic cultures of Peru (Degano and Colombini, 2009; Saito et al., 2003; Sousa et al., 2008; Wouters and Rosario-Chirinos, 1992).

2. Materials and Methods

2.1. Objects studied

The basis for this study was a set of textiles from cemeteries at the different oases (or *ayllus*) of San Pedro de Atacama: Catarpe, Coyo, Quitor, Solcor and Solor. All textiles inventoried and stored in the textile deposit of the Museo R.P. Gustavo Le Paige s.j. were

individually examined. From the ca. 550 textiles in the deposit, the 38 textiles chosen were all those which simultaneously contained well preserved red and blue dyed fibers and could be ascribed to the Middle or the Late Intermediate periods. Within the group selected, several forms of textiles were present (bags, embroidered basket, headbands, ritual cloth, mantles, tunics and fragments thereof), both in local and foreign styles (Table 1; Figure 2).

2.2. Local and foreign textiles from SPA

Several studies form the basis upon which textiles have been assigned to styles (see for example: Agüero, 1998; Agüero et al., 1997, 1999; Cases, 1997; Conklin and Conklin, 1996-97; Llagostera, 1995; Oakland, 1986a, 1986b, 1991, Oakland Rodman, 1992; Rydén, 1956; Strömberg, 1956; Uribe and Agüero, 2001, 2004). In general, the style and hence presumed place of manufacture of the textiles was assigned on the basis of iconographical and technological features, contextual evidence of the tomb where they were found, and assignment to cultural period. Thus: i) Tiwanaku style textiles are weft faced and decorated with interlocked tapestry showing figures which have their referents in the Tiwanaku lithic sculpture; or are decorated with embroideries in cross knit loop stitch in side selvedges and openings creating similar icons, or warp faced decorated with stripes with the use of one continuous weft (Oakland, 1986a); ii) La Aguada style baskets ("*tipas*") were made using an intercrossed and wrapped technique (Berenguer, 1984; Llagostera, 1995:11,13) with iconography depicting a feline or individuals throwing darts while tunics show iconography depicting a feline and a 2-headed snake, similar to those found in Aguada engraved ceramics and in a petroglyph in Catamarca, Northwestern Argentina (Llagostera, 1995:20); iii) SPA local style is characterized by rectangular warp faced tunics with satin stitch

embroideries in side selvedges and openings. The stripes can be decorated by floating and transposed warps, always using multiple wefts. These attributes are shared with textiles from the El Loa region and Northwestern Argentina (Agüero, 1998, 2000, 2003, 2012a; Agüero et al., 1997, 1999; Oakland Rodman, 1992; Uribe and Agüero, 2001, 2004); and iv) Bolivian Oriental valleys style shows similar iconographic designs as those of SPA style, using multiple wefts and transposed warps, and sometimes discontinuous warps and wefts. Additionally, while textiles woven at SPA used only camelid fibers, BOV textiles used mainly cotton, generally mixed with camelid fiber and even other local plant fibers.

2.3. Chronology of textiles from SPA

Chronology was determined mainly through correlation with the style of pottery co-occurring in the tomb where the textile was found (Agüero et al., 1997, 1999; Berenguer et al., 1986; Stovel 2013; Tarragó 1968, 1989) or based on dates for other contexts from the same archaeological site where the textile was found (Torres-Rouff and Hubbe, 2013); in the case of a few textiles, dates were available for elements of their funerary context (see Appendix).

2.4. Chemical analysis of textiles

Numerous HPLC-DAD methods have been developed to identify dyes in textiles (Degano et al., 2009; Rosenberg, 2008). Mordant dyes such as anthraquinones are commonly extracted using acidic methanol (Degano and Colombini, 2009) while indigo dyes are conveniently extracted using high-donor number aprotic solvents such as

dimethylsulfoxide (DMSO) (Koren and Verhecken-Lammens, 2013). Red dyed fibers (ca. 1-10 mg) were separated from the textile, cut into small pieces (< 2-mm long) and extracted in a sealed tube with 200 μL 30% HCl and 200 μL methanol for 20 min at 60º C under sonication; the extracts were then filtered (Millipore, PTFE, 0.2 μm, 4 mm-diameter), evaporated to dryness and reconstituted in 30 μL of methanol prior to analysis. Extracts (20 μL) were injected into the column (Merck LiChrospher 100, RP18 - 5 μm, length: 125 mm, diameter: 4 mm) of a high performance liquid chromatograph (Shimadzu LC-20AD) coupled to a diode-array detector (Shimadzu SPD-M20A). Blue dyed fibers (ca. 0.5-5 mg) cut into small pieces (< 2-mm long) were ground using a pellet pestle (Sigma Aldrich), and extracted with 150 μl DMSO for 20 min at 65º C under sonication, and further for 10 min at 135ºC in a block heater (Rocker, Taiwan). The samples were filtered (Millipore, PTFE, 0.2 μm, 4 mm-diameter) and 20 μl of the filtrates directly injected into the HPLC column, as described above. In both cases, the initial elution solvent consisted of 20-80 mixture of solvent A (acetonitrile with 0.1% trifluoroacetic acid) and solvent B (water with 0.1% trifluoroacetic acid); during a 45-min linear gradient, the composition of the mixture changed to pure solvent A. Solvent flow was 0.5 ml/min and column temperature 30ºC.

Identification of compounds in the eluates was based on comparisons of retention times (Rt) and UV-visible spectra with those of the standards purpurin, alizarin, carminic acid, indigotin (IND) and indirubin (INR), all from Sigma-Aldrich (Figure 3). Chromatograms of the red fibers were obtained at 430 nm (λ_{max} for alizarin) and at 480 nm (λ_{max} for purpurin and carminic acid), and chromatograms for blue fibers were obtained at 540 nm (λ_{max} for INR) and 600 nm (λ_{max} for IND). Areas under the peaks with maxima at these wavelengths were used to quantitate INR and IND, respectively. These wavelengths were used instead of the frequently used 275 nm because: i) most organic compounds have

strong absorption at 275 nm and potential impurities may distort the measured areas, ii) they provide, over and above the retention time, an element of selectivity to the analysis, and iii) since the absorption coefficient of INR (the compound present in the lowest proportion in extracts of blue fibers) at 540 nm is higher than at 600 nm, the chances of trustworthily quantifying it are enhanced. Full UV-Vis spectra (200 – 700 nm; resolution: 1.4 nm) were recorded for peaks at the retention times of standards in the chromatograms of the fiber extracts (Figure 4).

Quantification of IND and INR in blued dyed fibers was achieved by determining IND_{600nm}/INR_{540nm} ratios - i.e., the ratio between the area under the chromatographic peak for IND measured at 600 nm and the area under the chromatographic peak for INR measured at 540 nm - and extrapolating the concentration ratio [IND]/[INR] from a calibration line made using pure compounds.

The calibration line was constructed as follows: i) DMSO solutions were prepared which contained measured quantities of IND and INR in ratios and concentrations close to the range found in the fiber extracts ([IND]/[INR] = 1.2 to 234; peak areas in extracts ranged from 33,500 for INR_{540nm} to 16.8 million for IND_{600nm} and in standard solutions from 30,000 to 18.7 million, respectively); ii) these solutions were submitted to the same analytical procedure as the fibers, iii) IND_{600nm}/INR_{540nm} ratios were determined, and iv) a regression line through the origin was calculated with initial [IND]/[INR] ratios vs. experimental IND_{600nm}/INR_{540nm} ratios.

Fiber analyses were performed at least in duplicate. The reproducibility of the method was tested with three textiles with low, medium and high mean [IND]/[INR] ratios (7.4, 38.9 and 92.3; see Table 1).

3. Results

All red dyed fibers showed the presence of purpurine at Rt = 33.59 ± 0.88 min (mean ± SD) and the absence of alizarin and carminic acid (Table 1, Figures 4-A and 4-B). All blue dyed fibers showed the simultaneous presence of INR at Rt = 35.21 ± 0.86 min and IND at Rt = 37.00 ± 0.73 min (Table 1, Figures 4-C and 4-D).

The calibration line determined was [IND]/[INR] = 1.74 * IND_{600nm}/INR_{540nm} (R^2 = 0.99; N= 15). Standard errors of the replicated analyses of tissue fibers with low, medium and high [IND]/[INR] ratios were 16.3, 19.2 and 22.0% of the mean, respectively.

A positive and highly significant correlation (Pearson correlation: r = 0.488, N = 38, P = 0.0019) was found between mean [IND]/[INR] values and altitude where the fibers were presumed to have been dyed. The altitudes used in the correlation were: 3900 m.a.s.l. for Tiwanaku style textiles (except for headband from Solcor 3, T132(5),8671 and bag from Quitor 6, T2467, which were presumed to have been dyed at SPA and SPA or BOV, respectively, as discussed below), 2650 m.a.s.l. for local SPA textiles, 1500 m.a.s.l. for La Aguada textiles, and 2650 m.a.s.l. for BOV style textiles (presumed to have been dyed at SPA since they were woven at SPA with camelid fibers, which were used only sparingly in textiles woven in the BOV – see section 2.2). Within the set of textiles woven at SPA, two subsets could be discerned, one with low (< 27) and one with high (>43) [IND]/[INR] ratios (Table 1). Statistical comparisons were performed between the two subsets of locally woven textiles and the Tiwanaku style textiles. Significant differences were found between textile types (Kruskal-Wallis ANOVA: H = 26.473, df = 2, P < 0.001); Dunn *post-hoc* tests showed significant differences (p < 0.05) between local style with low [IND]/[INR] ratio

and Tiwanaku (Q = 4.259) and between local style with low [IND]/[INR] ratio and local style with high [IND]/[INR] ratio (Q = 4.020), and non-significant differences (P > 0.05) between local style with high [IND]/[INR] ratio and Tiwanaku (Q = 0.530) (Figure 5).

3. Discussion

3.1 Red dyes

The main sources of red dyes in the Central Andes during pre-Hispanic times were the cochineal insect *Dactylopius coccus* (Hemiptera: Coccoidea: Dactylopiidae) and plants of genera *Galium* and *Relbunium*, both belonging to the family Rubiaceae (Cardon, 2007). Anthraquinone dyes in extracts of plants from these genera are reliable chemotaxonomical markers; thus, species of the genus *Galium* contain alizarin but not purpurin and species of the genus *Relbunium* contain purpurin but not alizarin (Dutra Moresi and Wouters, 1997; Schweppe, 1986; Thomson 1971). Hence, the likely source of red dyes used in textiles which showed the presence of purpurin and the absence of alizarin are plants belonging to the genus *Relbunium*. In South America, 20 species of *Relbunium* are distributed along the Andes from Guyana to southern Peru, western and southeastern Bolivia, and northwestern Argentina, northeastern Argentina and southeastern Brazil, and southern Chile (Dempster, 1990). With the possible exception of *R. corymbosum*, which has been collected once in the coast south of Antofagasta and once in the western slopes of the Andes opposite Arica (northern Chile), *Relbunium* does not grow in northern Chile, indicating that the red dye used in locally manufactured textiles came from sources exogenous to SPA. The most

abundant and widely distributed species of *Relbunium* in South America are *R. corymbosum* and *R. hypocarpium*, whose distributions include western and southeastern Bolivia and northwestern Argentina. Given the demonstrated interactions between these two regions and SPA during the periods of manufacture of the textiles studied (Stovel, 2008), these two *Relbunium* species are the likely sources of the red dye found in SPA textiles (Roquero, 2008).

It is interesting to note that the same source of red dye was apparently used for nearly a millennium of cultural development at SPA. This situation contrasts with that prevailing in Peru, where *Relbunium*-derived dyes were used predominantly during the Late Formative and Early Middle periods (1100 B.C. – 600 A.D., in Paracas and Nasca cultures), and were gradually substituted by cochineal reds, which became predominant in the Late Middle Period (900-1470 A.D., in Chancay and Moche cultures); in the intervening period (600-900 A.D., in Huari and Tiwanaku cultures), both types of red dyes were used (Claro et al., 2010; Degano and Colombini, 2009; Martoglio et al., 1990; Saito et al., 2003; Salzman, 1992; Schweppe, 1986; Wallert and Boytner, 1996; Wouters and Rosario-Chirinos, 1992).

The question arises as to why cochineal red did not reach SPA. Several factors may have been involved including geographical distribution and abundance of natural dye sources, preferred trade routes and their diachronic change, and cultural identity. Although little is known about pre-Hispanic distribution and abundance of local floras, it can be safely assumed that the impact of collecting *Relbunium* wild plants for the purposes of obtaining the red dye was not great enough to justify a substantial change with respect to the present distribution and abundance which includes western and southeastern Bolivia and northwestern Argentina. On the other hand, cochineal is thought to have originated in

Peru (Rodríguez and Niemeyer, 2001; Rodríguez et al., 2001), its widespread use coinciding with the southern expansion of the Huari culture from the Ayacucho area.

Regarding trade routes and their diachronical change, contextual analysis of funerary offerings at SPA show that during the Middle and Late Intermediate periods local communities interacted with polities located in Northwestern Argentina, the southern altiplano, the Cochabamba area, the circuntiticaca area, as well as the Pacific coast (Llagostera, 1996; Stovel, 2008; Tarrago, 1989). During the Late Formative and early Middle periods, the ceramic record in SPA funerary contexts suggests that trade at SPA occurred principally with Northwestern Argentina while (Stovel, 2008); thus, Northwestern Argentina could have been the preferred area to access the plant-based red dye used in the first textiles dyed at SPA.

During the Middle period, Tiwanaku textiles were dyed with both plant and insect dyes; the absence in SPA of Tiwanaku style textiles dyed with cochineal during such period is intriguing. Given that some of the areas of the Pacific coast and adjacent highlands where cochineal thrives were under Tiwanaku influence during the Middle period, the dye used in Tiwanaku textiles most likely came from such areas; its further exportation to SPA using the caravan route which, surrounding the Uyuni salt lake linked Tiwanaku with SPA, seems uncompetitive in relation to plant-derived red dyes imported via the shorter and more direct route linking SPA with Northwestern Argentina. An alternative direct route for importation of cochineal from the coast of Peru, although possible, has not received support through other materialities.

Even though this interpretation needs future testing, it is interesting to consider that it suggests that certain materials were brought from specific areas in spite of the fact that SPA interacted with other polities which also had access to the same raw materials. In this

regard, cultural options and values seem to be at play in the configuration of Andean exchange (see Nielsen, 2007; Salazar et al., 2014). In fact, the interplay between local availability of raw materials, traffic routes, interregional social connections and local processes of group identity formation were probably responsible for the organization, reproduction and transformation of the multiple interacting spheres simultaneously operating at SPA during the Middle and Late Intermediate periods.

3.2 Blue dyes

Indigo was present in all blue textile samples studied. Main sources of indigo in South America are plants of the genera *Indigofera* (Fabaceae), *Eupatorium* (Asteraceae) and *Yangua* (Bignoniaceae); the only species of these genera which are native to Chile are *Eupatorium glechonophyllum* and *E. salvia* (Marticorena and Quezada, 1985), but neither species grows in the region around SPA; hence, the blue dye used in the textiles analyzed also came from sources exogenous to SPA.

Dyeing with indigo, in spite of being a highly complex chemical-biochemical technology, has been mastered and performed by numerous ancient civilizations of Asia, the Middle East, Europe, Africa and the Americas (Balfour-Paul, 2006: 11ff). Although a wide variety of traditional recipes have been developed by different cultures (Cardon, 2000), two basic dyeing processes can be distinguished which use either leaves or purified dye obtained from leaf extracts (the so called indigo “balls” or “cakes”), respectively (Cardon, 2000: 240ff). As of last century, synthetic dye has also been used.

In the first process, the fibers are soaked in the plant extract and are then aereated, exposing them to atmospheric oxygen, whereby the blue indigo dye is produced *in situ*, on

the fiber. Chemically, the process involves the enzymatic hydrolysis of the colorless glycosidic precursor naturally present in the plant, indican or isatans depending on the species, to produce the colorless aglycone, indoxyl, a compound which suffers oxidative condensation upon exposure to air to give IND. In oxygen-rich environments, indoxyl may be further oxidized to isatin, whose condensation with indoxyl gives INR (Clark et al., 1993; Maugard et al., 2001; Muruganandam and Bhattacharya, 2000; Figure 3); in fact, high INR amounts may be obtained by manufacturing processes favoring the oxidation of indoxyl to isatin (Eastaugh et al., 2000). Hence, provided the oxidation to indoxyl is the rate-limiting step in the production of INR, a higher relative yield of INR may be obtained through technological differences in the dyeing process favoring the oxidation of indoxyl to isatin (Garcia-Macias and John, 2004; Kohama et al., 2005; Wouters and Rosario-Chirinos, 1992).

In the second process, the dyeing vat is produced by dissolving the indigo cake with the help of natural antioxidants and/or a reducing agent in basic medium (traditionally, reducing bacteria fed with various natural sources of nutrients or, in modern times thiourea dioxide) whereby a colorless form of the dye is produced; the fibers are soaked in this vat and are then aereated, whereby the reduction process is reversed and the blue indigo dye is produced *in situ*, on the fiber. Chemically, the reduction of indigo produces *leuco*-indigo which is later reoxidized to indigo by atmospheric oxygen when the fibers are aereated (Figure 3).

Little is known of the method used for dyeing with indigo in pre-Hispanic America. However, it seems likely that the first of the processes described was used since ecofacts such as indigo cakes have never been found in archaeological sites in spite of their high chemical stability.

The analysis of textiles showed the presence of both IND and INR (Figures 4-C and 4-D); their concentration ratio, [IND]/[INR], showed satisfactory levels of analytical reproducibility and a large dispersion within each of the groups (styles) of textiles analyzed. This dispersion can be accounted for by several factors, such as: i) differences in the dyeing process; for example, different textiles may have been dyed using extracts from plants belonging to different populations and/or collected at different places and times of the year - hence with different composition of co-adyuvant substances and/or leading to different pH in the dyeing vat (Kohama et al., 2005); ii) processing by different artisans in a time when methods for accurately measuring and dosing the components of a dyeing vat were either inaccurate or not available; iii) dyeing under different environmental conditions such as temperature, humidity, etc. thus affecting the reactions producing the dyes and bonding the dyes to the tissue fibers; and iv) although indigo is a rather stable molecule when protected from light and kept in a dry environment (Sousa et al., 2008), differential thermal or photodecomposition of the dyes may have occurred while the fiber was dyed, or the textile was manufactured, used, deposited, excavated, cleaned, stored, exhibited or analyzed.

It is apparent from the data in Table 1 that the [IND]/[INR] ratio is highest for most Tiwanaku style textiles, whose fibers were presumably dyed at the high altitude altiplano, and lowest for La Aguada, BOV and some SPA textiles, whose fibers were presumably dyed at lower altitudes. In fact, a positive and significant correlation was found between [IND]/[INR] values and altitude where the fibers were presumed to have been dyed. On the basis of the nature of the dyeing process and the chemistry involved, and notwithstanding the possible sources of variations noted above, we hypothesize that dyeing a fiber at lower altitude (higher oxygen availability) leads to the production of more INR relative to IND

and hence to the incorporation in the fiber of a higher proportion of INR; thus, a lower [IND]/[INR] ratio will be obtained when fibers are dyed at lower than at higher altitude.

This hypothesis was tested with the scanty data available in the literature. Sousa et al. (2008) reported the percentages of IND and INR found in 17 samples of blue fibers (one datum was excluded because INR was not found in the fiber) from 11 textiles of the Paracas Necropolis and Nasca cultures of southern Peru and encompassing the period from 200 B.C. to 300 A.D. (some textiles are specified as Paracas/Nasca) from the Boston Museum of Fine Arts; these quantities can be directly transformed into [IND]/[INR] ratios. Two sets of textiles could be clearly discerned (and statistically proven to be different: one-way ANOVA, H = 7.0, d.f. = 1, P = 0.008) with mean [IND]/[INR] ratios of 4.5 (N = 14) and 30.6 (N = 3), respectively. These sets may be associated with fibers dyed near the coast and lower valleys, and upper valleys of central Peru, respectively, the main regions occupied by these cultures (Proulx, 2008).

IND and INR were also reported in blue-dyed fibers from tombs of the Necropolis of Ancón (1040 – 1260 A.D.) and corresponding to the transition from Wari to Chancay cultures in the central coast of Peru (Degano and Colombini, 2009). The results reported are not straightforward to convert into [IND]/[INR] ratios because only chromatograms at 275 nm are shown in the paper. If absorption coefficients at 275 nm were similar for both dyes, a mean [IND]/[INR] ratio of 2.5 (range = 1.3 - 4.5, N = 3) may be estimated by measuring the areas under the peaks in the figure of the paper, consistent with fibers dyed at locations near the coast.

IND has been found in extracts made from blue fibers (Pawlak et al., 2006; Puchalska et al., 2004), sometimes accompanied by INR (e.g., Karapanagiotis et al., 2011; Liu et al., 2011; Novik et al., 2005; Vanden Berghe et al., 2009; Zhang et al., 2008);

however, very seldom are these two compounds quantified. For example, Koren (2008) reported a high IND/INR ratio in a textile from the Judean desert outside Jerusalem, Abdel-Kareem et al. (2010) reported an IND/INR ratio of 1 in a Coptic textile, and Sanz et al. (2011) studied Chinese textiles of two shades of blue and found mean IND/INR ratios of ca. 9 and 1. The causative factors of these widely different IND/INR ratios have not been addressed; it is not unlikely that dyeing techniques and dyeing environment are major factors affecting them (Garcia-Macias and John, 2004; Kohama et al., 2005).

The two subsets of textiles woven at SPA distinguished on the basis of their [IND]/[INR] ratios (Figure 5) suggests that imports to SPA may have included fibers dyed in the northern highlands which were locally used to weave textiles in the local and BOV styles, as well as raw dyeing materials which were used to dye fibers locally; both types of imports were taking place during both the Middle and Late Intermediate periods (Table 1), consistent with the known patterns of diachronic interaction of SPA with neighboring areas (Llagostera, 1996; Stovel, 2008).

Some of the textiles analyzed deserve further comment. The Tiwanaku style headband from the Solcor 3 tomb T132(5) #8671 (Figure 2-A) gave an [IND]/[INR] value of 1.7, outside the range found in textiles presumably dyed at the Tiwanaku highlands. Various anthropological studies have shown that during the Middle period the human biological diversity at SPA increased (Knudson, 2007; Nado et al., 2012; Torres-Rouff and Knudson, 2007; Torres-Rouff et al., 2014; Varela and Cocilovo, 2009), in part due to immigrants from Tiwanaku (Torres-Rouff et al., 2014); some of these immigrants may have been weavers who brought from Tiwanaku the skills and instruments to produce Tiwanaku style textiles at SPA with locally dyed fibers. Alternatively, local artisans could have

copied foreign styles in locally-produced textiles, similarly to what has been observed in other materialities (Salazar et al., 2014: 146-147).

Along similar lines of reasoning, the Coyo Oriente tunic 4185-89 textile (Figure 2-G) represents a particularly interesting case. Oakland (1986b:106-108) assigned it to the Tiwanaku style but suggested the likelihood that it was of provincial manufacture mainly based on the low quality yarn (unevenly spun and plied with large variations in diameter), the low yarn counts, and the variations within motifs, both in design and in color, and their asymmetrical distribution (see however Uribe and Agüero 2001:400). Consistent with this view, the comparatively low IND/INR of 23.7 suggests the use of fiber dyed (and possibly spun) at low altitude and hence the involvement of weavers not living in Tiwanaku. Again, this textile may have been woven by weavers among the population of Tiwanaku origin settled in SPA (Knudson and Torres-Rouff, 2014) or by local artisans copying elements of the Tiwanaku style in the textiles they manufactured; in either case, the artisans were unable to reproduce the exquisite craftmanship exhibited by original Tiwanaku tunics.

The bag covering the skull of the individual in tomb T 2467 from Quitor 6 (Figure 2-E) exhibits a mixture of styles, partly BOV and partly Tiwanaku. The low IND/INR values of 3.6 suggests it was made with fibers dyed at a low altitude, either at the BOV or SPA. However, this and other textiles in the BOV style found in SPA were made with camelid fibers, whereas cotton was mainly used when they were manufactured in the BOV (Agüero, 2007). As proposed and argumented above, it appears this textile was woven in SPA, either by local or foreign artisans. This latter possibility is not inconsistent with a recent report which describes the presence of five women buried in the Coyo Oriente cemetery during the Middle period who were determined to be of foreign origin based on

being diagnosed leischmaniasis, a disease prevailing in the eastern slopes of the Andes (Costa and Llagostera, 2014).

The headband from Solcor 3, T20 #1356 (Figure 2-D) also shows a mixture of icons associated to BOV (southern viscacha, *Lagidium viscacia* – Rodentia, Chinchillidae) and to Tiwanaku (archer) styles within a textile made with camelid fibers; its relatively high [IND]/[INR] ratio of 42.1, falling outside the range expected for fibers dyed at SPA or BOV ([IND]/[INR] ratio < 27) and within the range expected for fibers dyed at high altitude, suggests that the textile used fibers dyed in the highlands. It may be hypothesized that the textile employed fibers dyed at the highlands and was woven either in Tiwanaku with strong BOV influence and brought ready-made to SPA, or was woven at SPA with strong BOV and Tiwanaku influences. The first hypothesis is supported by the intense interactions between Tiwanaku and the BOV, particularly towards the end of the Middle period (Uribe and Agüero, 2001, 2004), and the second by the immigration of people from the altiplano (Knudson and Torres-Rouff, 2014) and of the eastern lower lands (Costa and Llagostera, 2014) into SPA, which could have included artisans bringing both textiles traditions; additional studies will be needed to distinguish between these hypotheses.

Finally, there are some Tiwanaku style textiles whose IND/INR ratios are in-between the two ranges defined for the local SPA style textiles, i.e., 27 < IND/INR < 43. It seems most parsimonious that these textiles were dyed at a high altitude, albeit using a different technological process than those showing very high IND/INR ratios (60-260) because of the unlikeliness that the center of the Tiwanaku state imported raw materials used in the manufacture of emblemic objects such as textiles.

In summary, the results presented add the raw material dimension to the study of SPA textiles and confirm and complement with new evidence the textile styles that have

been proposed for SPA. The use of exogenous raw materials for the local manufacture of goods at SPA is not restricted to textiles; for example, the raw material for many snuff trays manufactured in a local style at SPA (Horta, 2014) was foreign wood (Niemeyer, 2013; Niemeyer et al., 2013; Riquelme-Toro and Niemeyer, 2014). This underlines the importance of an exchange of goods which took advantage of geographical differences in availability of adequate raw materials. At the same time, the results show that local artisans were able to produce objects of great originality with a markedly local character (textiles: Agüero, 2003, 2012; snuff trays: Horta, 2014), thus pointing to the creativity of pre-Hispanic cultures in the Atacama oases and reasserting their local identity as has been suggested and discussed by several authors and recently summarized and complemented with new evidence by Salazar et al. (2014). Furthermore, our results suggest that even though SPA was interacting with different polities during the Middle and Late Intermediate periods, certain raw materials and certain objects were obtained from specific localities despite the fact that they were more extensively available. Thus, interaction networks seem not to have been limited exclusively by functional or material constraints only, but by cultural options and social relations which privileged certain connections for some objects, and certain others for other types of objects.

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754 Table 1. Textiles analyzed by high performance liquid chromatography with diode array detection (HPLC-DAD).

Object	Site	Tomb/Mummy	Period	Style (a)	Mean [IND]/[INR]
Tunic	Quitor 2	T1983:15; #8	M	La Aguada	4.6
Embroidered basket (*tipa*)	Solcor 3	T113	M	La Aguada	14.0
Bag (*bolsa mizque*)	Solcor 3	T112; #3900A	M	BOV	0.47 b
Bag (*bolsa chuspa*)	Quitor 2	T65:2; #13979	M	BOV	3.1 b
Bag	Solcor 3	T112; #3902	M	BOV	16.5 b
Bag	Solcor 3	T112; #3901	M	BOV	20.9 b
Tunic	Solcor 3	T132, tunic 1 (exterior)	M	Local (low)	3.1
Bag (*talega*)	Catarpe 2	1828; #13947	LI	Local (low)	7.4
Tunic	Solcor 3	T20; #57a1	M	Local (low)	8.9
Tunic	Quitor 1	M1187C	LI	Local (low)	12.4
Fragmented tunic	Coyo Oriente	4012-1	M	Local (low)	17.0
Tunic	Coyo Oriente	5382; #7 tunic 2	M	Local (low)	20.4
Tunic	Quitor 2	T3427.1	M	Local (low)	21.3
Fragmented tunic	Quitor 1	T3438	LI	Local (low)	22.1
Tunic	Solor 3	1983-27	M	Local (low)	22.7
Fragmented tunic	Coyo Oriente	4185-89	M	Local copy of Tiwanaku (low)	23.7 b
Tunic	Solcor 3	T107; tunic 2	M	Local (low)	24.7
Tunic	Coyo Oriente	T4064	M	Local (low)	24.9
Tunic	Solcor 3	T107; tunic 3	M	Local (low)	26.7
Tunic	Coyo Oriente	3978-1	M	Local (high)	43.3
Tunic	Quitor 1	M1187D, #21529	LI	Local (high)	48.3
Tunic	Coyo Oriente	4012-8	M	Local (high)	58.8
Tunic	Quitor 1	M1187B	LI	Local (high)	73.4
Fragmented tunic	Solcor 3	T20, body 1; #57	M	Local (high)	92.3
Tunic	Coyo Oriente	4012-4	M	Local (high)	95.3
Headband	Solcor 3	T132(5) 8671	M	Tiwanaku	1.7 c
Bag	Quitor 6	T2467	M	Tiwanaku + BOV	3.6 d
Mantle	Coyo Oriente	4084-86.1	M	Tiwanaku	33.7
Ritual cloth (*inkuña*)	Coyo Oriente	T5347-1	M	Tiwanaku	34.4
Fragmented tunic or mantle	Coyo Oriente	3935	M	Tiwanaku	38.5

Mantle	Solcor 3	T109; #13149	M	Tiwanaku	38.9
Bag	Quitor 6	T2511; #13959	M	Tiwanaku	40.5
Headband	Solcor 3	T20; #1356	M	Tiwanaku + BOV	42.1 e
Tunic	Coyo Oriente	5382.1	M	Tiwanaku	43.6
Bag (*bolsa chuspa*)	Quitor 2	T65; #3	M	Tiwanaku	63.4
Bag	Solcor 3	T113; #8475	M	Tiwanaku	127.6
Mantle	Coyo Oriente	4012.13	M	Tiwanaku	228.5
Fragmented tunic	Solcor 3	T107; tunic 1	M	Tiwanaku	255.6

a BOV: Bolivian Oriental valleys

b Presumably fibers were dyed at SPA or BOV and textile was woven at SPA – see Discussion.

c Presumably fibers were dyed at SPA – see Discussion.

d Presumably fibers were dyed at SPA or BOV – See Discussion.

e Presumably fibers were dyed at Tiwanaku – See Discussion.

761 Figure captions:

762

763 **Fig. 1.** General map of South-Central Andes.

764

765 **Fig. 2.** Illustrations showing different types and styles of textiles analyzed. A: Headband
766 Tiwanaku style from Solcor 3, T132(5), #8671; B: Mantle Tiwanaku style from Solcor 3,
767 T109, #13149; C: Embroidered basket La Aguada style from Solcor 3, T113; D: Headband
768 mixed Tiwanaku/Bolivian Oriental valleys styles from Solcor 3, T20, #1356: E: Bag with
769 mixed Tiwanaku/Bolivian Oriental valleys from Quitor 6, T2467; F: Tunic Tiwanaku style
770 from Coyo Oriente, T5382.1; G: Tunic fragments local style from Coyo Oriente, T4185-89;
771 H: Ritual cloth Tiwanaku style from Coyo Oriente, T5347-1. Photographs by Carolina
772 Agüero.

773

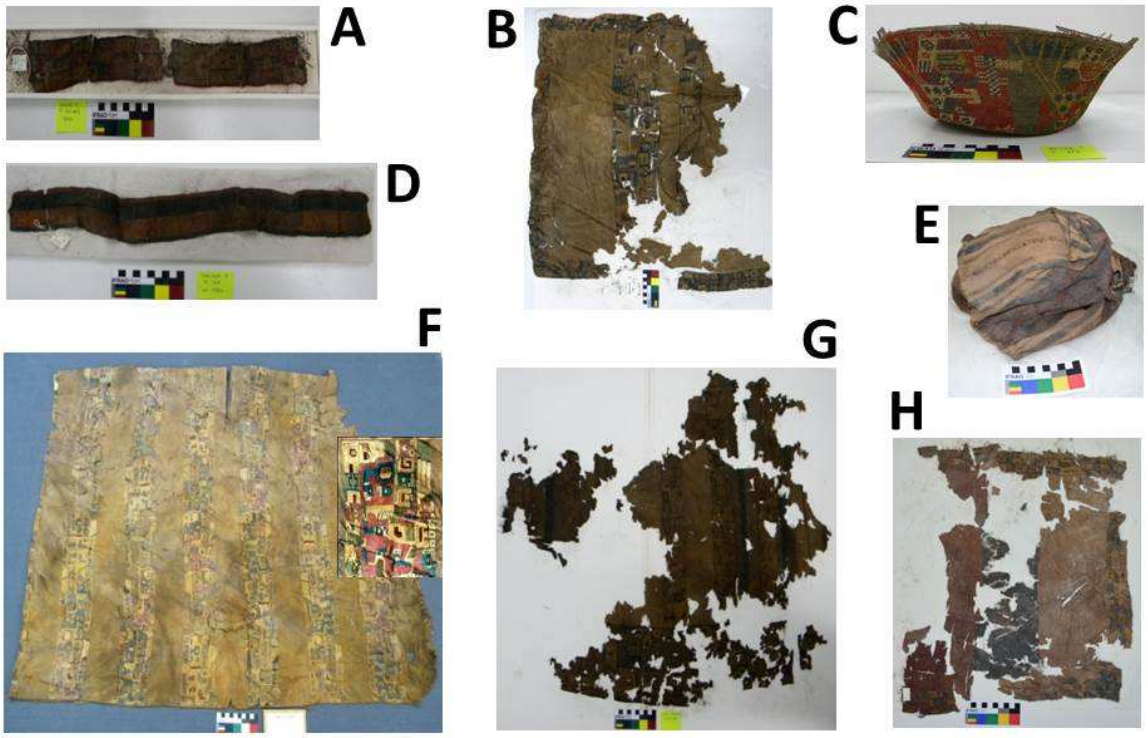
774 **Fig. 3.** Structures of dyes mentioned in the text and some of their precursors. Alizarin,
775 purpurin and carminic acid are frequently found in extracts of red dyed fibers, while indigotin
776 and indirubin are frequently found in extracts of blue dyed fibers.

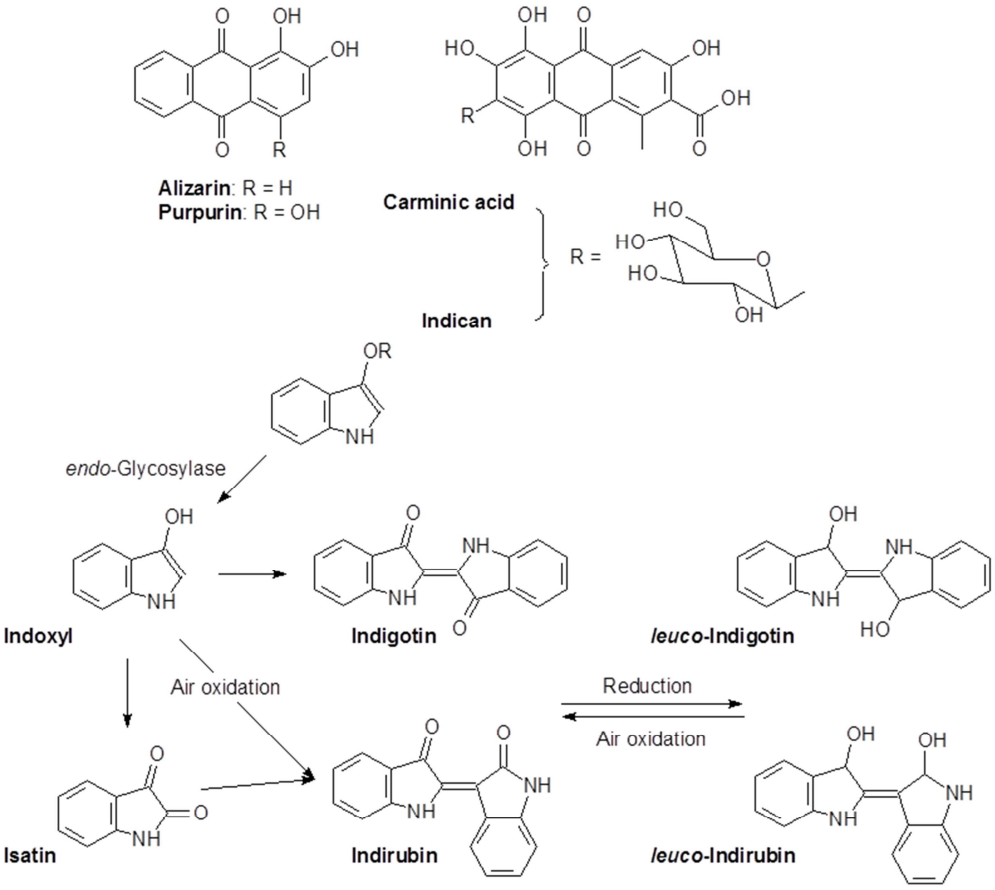
777

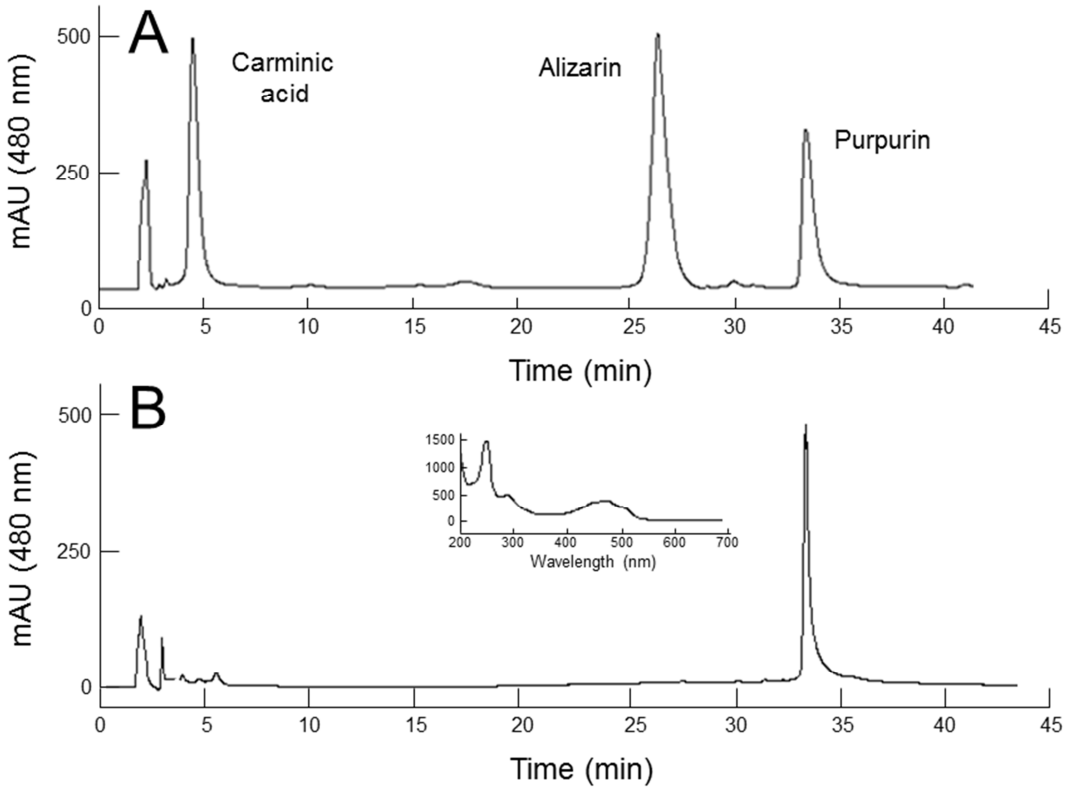
778 **Fig. 4.** HPLC-DAD analysis of dyes in extracts of red and blue fibers from a tunic found in
779 tomb 20 at Solcor 3 site. A: chromatogram of standards of red dyes; B: chromatogram of
780 extract from red fibers and UV-visible spectrum of the purpurin peak; C: chromatogram of
781 extract from blue fibers recorded at 600 nm and UV-visible spectrum of the indigotin peak; D:
782 chromatogram of extract from blue fibers recorded at 540 nm and UV-visible spectrum of the
783 indirubin peak.

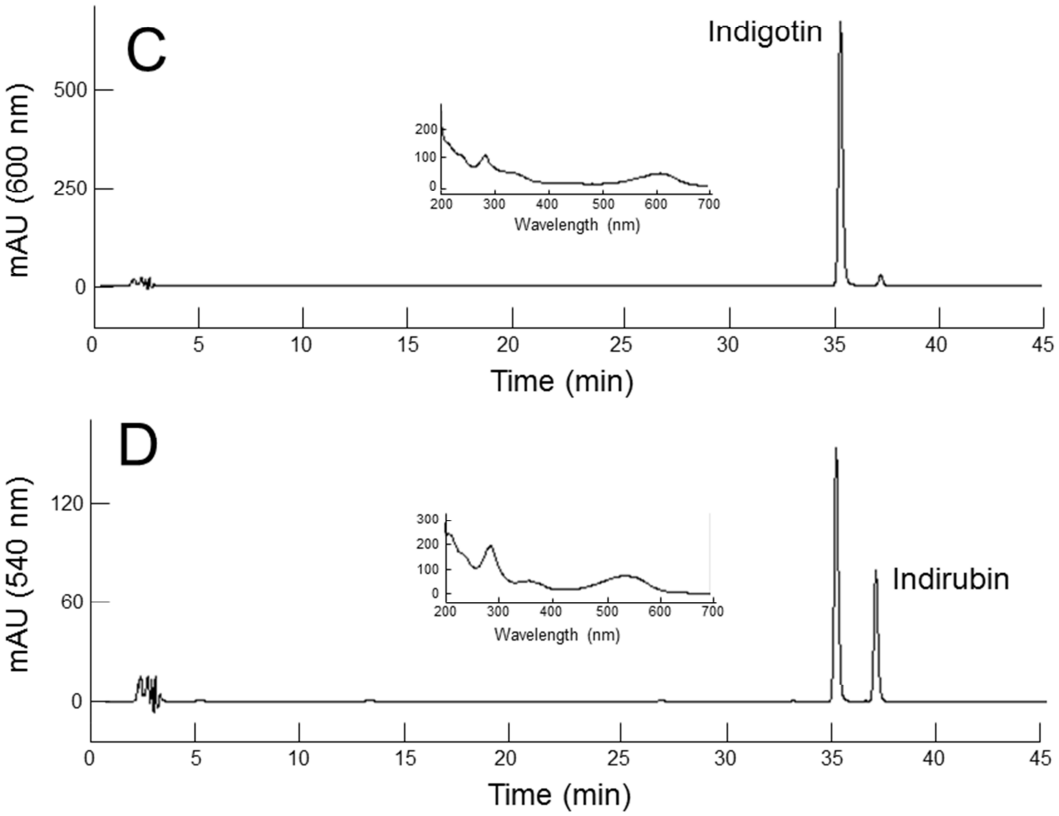
784

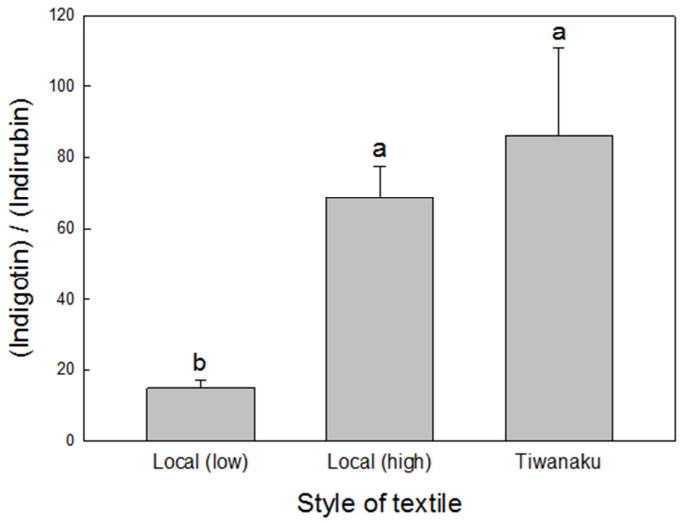
785 **Fig. 5.** Indigotin/indirubin ratios (mean, standard errors) for local and Tiwanaku style textiles
786 found in funerary contexts at San Pedro de Atacama. Results for Kruskal-Wallis ANOVA
787 followed by Dunn tests are shown with letters above the bars: different letters indicate
788 significant differences ($P < 0.05$). Local-low refers to textiles in the lower end (< 27) and
789 Local-high in the higher end (> 43) of the [IND]/[INR] range.
790











- Thirty-eight textiles from San Pedro de Atacama were analyzed by HPLC/DAD
- Red fibers contained purpurin and blue fibers a mixture of indigotin and indirubin
- (IND)/(INR) positively corrrelated with altitude where fibers were presumably dyed
- The correlation was explained by the chemistry involved in the dyeing process
- Textiles in Tiwanaku style showed a high (IND)/(INR)
- Low (IND)/(INR) in local style textiles suggests local dyeing of fibers
- High (IND)/(INR) in local style textiles suggests use of fibers dyed at highlands
- Literature data is discussed in relation to the proposed hypothesis

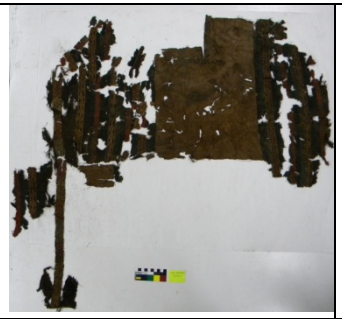
Appendix

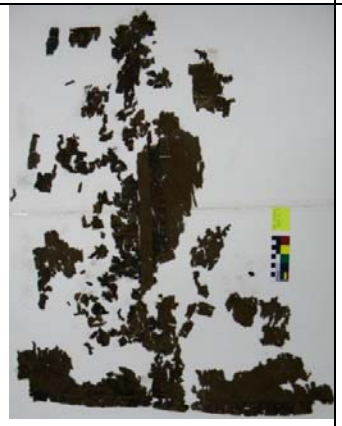
Niemeyer and Agüero

Dyes used in pre-Hispanic textiles from the Middle and Late Intermediate periods of San Pedro de Atacama (Northern Chile): new insights into patterns of exchange and mobility

Site Tomb/ Mummy Object	Whole textile	Detail of textile	Place of fiber extraction	Description	Context	Style	References
Catarpe 2 1828; #13947 Bag (*talega*) containing algarrobo (*Prosopis sp.*) seeds.				Dimension: length 23 cm; width 18 cm. Technique of manufacture: warp faced with multiple wefts. Decorative technique: warp faced. Design: stripes and stripes with checkerboard, in classical local style (Cases 1997).	Another warp faced bag with multiple wefts; semicircular plush hat with geometric designs (hooks and steps).	Local	Cases (1997)
Coyo Oriente 3935 Fragmented tunic or mantle				Dimension: length and width indeterminate. Technique of manufacture: weft faced. Decorative technique: interlocked, eccentric and rough tapestry. Design: one fringe with geometric motifs (hooks and steps) in red, rose-orange, blue, yellow and dark brown.		Tiwanaku	Oakland (1992), Agüero (2003:191)

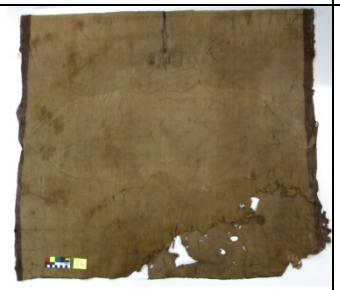
Coyo Oriente 4185-89 Fragmented tunic				Dimension: length and width indeterminate. Technique of manufacture: weft faced. Decorative technique: interlocked tapestry; dovetailed tapestry. Design: vertical stripes between two [interlocked] tapestry bands closest to each lateral edge and the wide tapestry border sewn to the bottom of the tunic [woven in dovetailed tapestry], similar to formative tunics (see Agüero 2012). "Each vertical tapestry would then accommodate five repeats of the Tiahuanaco style human figure whose face with divided and winged eye, and legs and feet, are in profile and whose headdress and body are pictured frontally, a method common to pictorial conventions of Tiahuanaco" (Oakland, 1986b:107). Oakland (1986b:107) suggests this is a provincial copy of a Tiwanaku tapestry tunic: "Yarn counts in both the warp and the weft directions are low, with only 8 warp yarns and 35 weft yarns per cm. The yarns are unevenly spun and plied and vary widely in diameter, which at best is twice the thickness of any yarn in the ….Tiahuanaco textiles"; "Uncommon to Tiahuanaco is the variation within motifs and within both horizontal and vertical rows. In fact, no particular repetition of exact images or coloring can be determined"; "Its originality and the tremendous variety in design would not have been tolerated in the highlands, where repetition of identical images was constant"	In this tomb, five adults were buried together. This tunic was associated with a male individual with a hat with chin strap (Oakland Rodman, 1992). Collectively the tomb included: "1 small mortar, 1 ordinary rape tube, 1 cane piece, 2 baskets with ground corn, 1 plate and 1 flat piece of wood" (Oakland, 1986a:93) "No ceramics were found in this burial" (Oakland, 1986b:107). "A large fragment of an additional tunic woven in warp face with warp stripes near the side selvedges in green, blue-green, gold and maroon was the only other textile preserved and could have been associated with any of the funeral bundles excavated in tomb 4185-89. Characteristic of tunics from many cemeteries of San Pedro de Atacama, elaborate flat stitch embroidery decorated the side selvedges and neck opening. A neck plaque (1.3 x 17 cm) placed just below the neck opening was formed in 13 fine rows of cross knit loop stitch. All designs are geometric with crosses, diagonal lines and concentric squares predominating. Fragments of at least two and possibly three fur hats were also preserved with the remains from tombs 4185-4189" (Oakland, 1986a:93-94).	Tiwanaku (provincial copy)	Oakland, (1986a:92-94; 1986b:106-108), Oakland Rodman (1992), Agüero (2003: fig. 3)

Coyo Oriente 3978-1 Tunic				Dimension: length, 100 cm; width, 95cm. Technique of manufacture: warp faced. Decorative technique: warp face; complementary warps; satin stitch. Design: stripes in both sides of the tunics, some stripes with geometrical designs. Side selvedges are embroidered with geometric motifs (Oakland Rodman 1992: 330, Fig. 7d)	No information.	Local	Oakland Rodman (1992: 330, fig. 7d)
Coyo Oriente 4012-13 Mantle				Dimension: length, 80 cm; width, 150 cm. Technique of manufacture: weft faced. Decorative technique: interlocked tapestry; cross knit loop stitch. Design: Red mantle with Tiwanaku iconography in blue, green, red and yellow. A snake image with stepped fret defining the body is repeated in a simple sequence […]. The bilateral symmetry is exact, so that one half of the motif is a mirror image of itself above and below in the vertical band in 10 separate repeats" (Oakland, 1986b:105). "A beautiful edge finish of four rows of cross knit loop stitch embroidery covers both front and back of all selvedges, creating a completely reversible garment […]. The four rows are only 6 mm in height and contain a repeated image of a condor aligned in profile horizontally with a yellow beak and neck ruff, divided eye in blue and white, and white tail feathers" (Oakland, 1986b, 105).	Date ^{14}C: 677±50 cal. A.D. (Oakland Rodman, 1992, 1994). "Excavated in the collective tomb 4012-4013" (Oakland 1986a:94). Female individual around 40 years old (Oakland, 1986a:94); four Casi Pulida ceramics; a bag with copper stones; a domestic bag contained food, copper stones and *Strophocheillus oblongus* shell. Four tunics, two asymmetrical, one with lateral stripes and one completely beige, two warp faced mantles, "a narrow belt woven with discontinuous warp with simple designs using warps floats and transposed warps" (Oakland, 1986b:105) . "A long mended tear originating near the outer top edge and continuing to the textile center demonstrates that the mantle was used and reused and was not simply a burial fabric" (Oakland, 1986b, 104).	Tiwanaku	Oakland (1986a: 94; 1986b:104, 105), Oakland Rodman (1992; 1994: 115), Agüero (2003: 190)

Coyo Oriente 4012-1 Tunic				The tunic is very fragmented. Dimension: length and width indeterminate. Technique of manufacture: warp faced. Decorative technique: warp faced with multiple wefts.. Design: Asymmetrical beige tunic with stripes yellow, maroon, red, blue, red, blue, red, blue, red, maroon, red, blue, red, blue, maroon (see Oakland 1994: 113, fig 3, c and d).	Date ^{14}C: 677±50 cal. A.D. (Oakland Rodman, 1992, 1994). Context: see above.	Local	Oakland Rodman (1992, 1994:113, fig 3, c and d)
Coyo Oriente 4012-4 Tunic				Dimension: length and width indeterminate. Technique of manufacture: warp faced. Decorative technique: warp faced. Design: Lateral stripes blue, maroon, green, red, yellow, blue, maroon, yellow, red.	Date ^{14}C: 677±50 cal. A.D. (Oakland Rodman, 1992, 1994). Context: see above.	Local	Oakland Rodman (1992, 1994:114)
Coyo Oriente 4012-8 Tunic				Dimension: length and width indeterminate. Technique of manufacture: warp faced. Decorative technique: warp faced. Design: Asymmetrical beige tunic with stripes yellow, blue, maroon, yellow, blue, yellow, blue (see Oakland 1994: 113, fig 3, c and d).	Date ^{14}C: 677±50 cal. A.D. (Oakland Rodman, 1992, 1994). Context: see above	Local	Oakland Rodman (1992:333), Oakland (1994: 113, fig 3, c and d).
Coyo Oriente 4084-86.1 Mantle				Dimension: length, 75 cm; width, 91 cm. Technique of manufacture: weft faced. Decorative technique: interlocked tapestry, dovetailed tapestry. “Two single interlocked tapestry bans, one narrow, the other, wide, were woven near one warp end and were probably mirrored on the other end, on each side of wide plain light brown ground […]. Surrounding all selvedges is a narrow, separately woven tapestry band dovetailed to the main textile on the weft selvedge […]” (Oakland, 1986b:106). Design: profile of bird with divided eye and ‘S’ motif in the neck. “A simple headdress of three concentric squares and a feather motif with two circles on either side is repeated above. The body is defined by a simple step or step fret appended to the bird’s neck” (Oakland, 1986a:136-137).	“It was found in a collective tomb 4084, 4085, 4086, which contained two adults and one fetus […] all three were described together in the excavation notes” (Oakland, 1986b:105). The tomb contains a broken bow; two Negro Pulido ceramics (a bowl and a *puco*); a hafted hammer with doubled handle; two undecorated snuff tablets; a bone tube; a broken bow and a hat (*boina*).	Tiwanaku	Oakland (1986a :136-137, 298; 1986b:105,106,117, 118)

Coyo Oriente 5382.1 Tunic				Dimension: length, 120 cm; width, 105 cm. Technique of manufacture: weft faced. Decorative technique: interlocked tapestry. Design: six wide vertical stripes with seven modules of a condor which is an emblematic Tiwanaku design, known as an "attendant" of the Sun Gate (Agüero et al., 2003), and two narrows stripes at each side. The colours are blue, pink, green, yellow and red. The solid areas are natural beige. A complete description is in Oakland (1986b).	"The bundle was found sitting upright, facing east, and surrounded with a basket and two bags, one containing food and the other containing the objects of the hallucinogenic snuff complex including a plain wooden tablet, a tube, a bone spatula, and a leather bag; and copper stones, a green stone hammer with a handle and a broken bow with three arrows. A single black polished [Negro Pulido] ceramic fragment possibly places the tunic and burial in the period of San Pedro II or Tiahuanaco III or IV" (Oakland, 1986b). Two types [of furry hats] were excavated with the bundle. The first, a fine red pile hat [with a chin strap] placed on the head […]" (Oakland, 1986b). "An additional furry hat was found near the body […] (Oakland, 1986b). Also, the bundle contains a wooden spoon, a basket with maiz and algarrobo, and a wooden spoon; a malaquita collar and cords.	Tiwanaku	Agüero (2003), Oakland (1986a:136-137, 294, 295; 1986b:102, 103, 113), Oakland Rodman (1992:325; 1994:116), Torres and Conklin (1995: 90-91).
Coyo Oriente 5382; #7 Tunic 2				Dimension: length, 100 cm; width, 90 cm. Technique of manufacture: warp faced. Decorative technique: warp faced. Design: a wide yellow lateral stripe, and tree stripes, blue, red and blue. The center of the tunic (or *pampa*) is natural beige.	Context: See above.	Local	Oakland Rodman (1992)

Coyo Oriente T4064 Tunic				Dimension: length, 100 cm; width, 120 cm. Technique of manufacture: warp faced with multiple wefts. Decorative technique: warp faced; satin stitch. Design: stripes in blue, black, red, green and white; geometric embroidered motifs in side selvages and armhole openings.	Date ^{14}C: 677±80 cal. A.D. (Oakland Rodman 1992, 1994). Man with a hat made with plant fiber core, covered with stripes of camelid skin and hair; the center is looped from a central point in a radiating swirl design.	Local	Oakland Rodman (1992:331), (1994)
Coyo Oriente T5347-1 Ritual cloth (*inkuña*)				Dimension: the piece is fragmented, but approximately the length is 45 cm and the width, 55 cm. Technique of manufacture: warp faced. Decorative technique: warp faced; cross knit loop stitch. Design: the center of the piece has a wide stripe, and avian figures around.	Date ^{14}C: 888±100 cal. AD (Oakland Rodman, 1992, 1994).	Tiwanaku	Oakland Rodman (1986a:317a, 1992, 1994)
Quitor 1 M1187 B Tunic				Dimension: length, 76 cm; width, 69 cm. Technique of manufacture: warp faced with multiple wefts. Decorative technique: warp faced with multiple wefts, complementary warps, satin stitch. Design: stripes, and stripes with geometric designs in red, blue, green, yellow, and white. The center of the tunic or *pampa* is red. The tunic is very fragmented. The neck and arms openings, the side selvedges and the bottom of the tunic are embroidered with geometric designs. Corresponds to Group A/Type V of Oakland Rodman (1992).	Typical bag (*talega*) of Quillagua (Cases, 1997) with red, green, blue and yellow stripes; warp face tunic with multiple wefts and camelid hair in the selvedges.	Local	Oakland Rodman (1992)

Quitor 1 M1187C Tunic				Dimension: length, 107 cm; width, 117 cm. Technique of manufacture: warp faced with multiple wefts. Decorative technique: warp faced and satin stitch. Design: one lateral 5-cm wide red stripe; embroidering creates a step fret and crosses that cover the side selvages and openings for the arms and neck.	See above.	Local	
Quitor 1 M1187D #21529 Tunic				Dimension: length, 109 cm; width, 116.5 cm. Technique of manufacture: warp faced with multiple wefts. Decorative technique: warp faced and satin stitch. Design: A red stripe of 4 cm at the side; side selvedges and armhole openings embroidered with crosses white, green, yellow, blue and red.	See above.	Local	
Quitor 1 T3438 Tunic				Dimension: (fragment) length, 73 cm; width, 37 cm. Technique of manufacture: warp faced with multiple wefts. Decorative technique: warp faced; satin stitch. Design: side stripes in pale blue, dark blue, white, red, and maroon red. The side selvedges are embroidered with geometrics motifs.	No information.	Local	

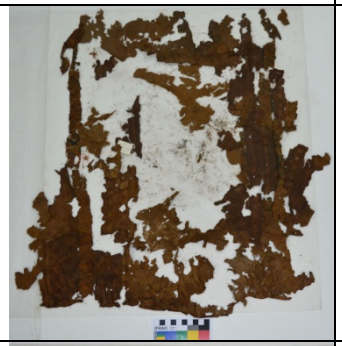
Quitor 2 T1983:15; #8 Tunic			 	Dimension: length 71 cm; width 54 cm. Technique of manufacture: warp faced. Decorative technique: Different techniques: mooring, sewing, probably some clay and even discontinuous warps and wefts to achieve a clear definition of design. Each stripe was stained in red or blue, then assembled so that both sides of the upper and lower garment alternate colour. Design: It consists of four cloths with discontinuous warps. Two of these panels are square and two rectangular, in the bottom of the piece. Jaguar figures on square cloths and headed serpent with serrated jaws in rectangular cloths; both figures have diamonds inside their bodies. Some technical attributes such as the use of multiple wefts and discontinuous warp technique insert it in the Textile Tradition of Atacama during the Middle Period (Agüero *et al.* 1997, 1999; Uribe and Agüero 2004). The design of the tunic closely resembles designs found on Argentinian Aguada ceramics which date approximately 660 A.D. An identical figure of the feline has been described in a rock art block at Catamarca, Argentina (Llagostera 1995:20).	Date: 660 A.D. (Llagostera 1995:20, 33). Covered the head of a 40-year old male individual without cranial deformation; local mantle warp faced with multiple wefts (#2); three monochrome tunics, warp faced with multiple wefts (# 9, #15, #;18); six "saquitos amuletos" (*sensu* Le Paige notes); bag (*chuspa*) (with no number), weaved with discontinuous transposed warps, similar to those of the Argentinian Northwest (see López Campeny, 2000); collar of lapizlázuli.	La Aguada	Llagostera (1995:19), Torres and Conklin (1995:88, 105-107), Conklin and Conklin (1996-97), Ataliva (2000), Cases and Agüero (2004), Knudson and Torres-Rouff (2014:182); Agüero et al. (1997, 1999), Uribe and Agüero (2004), Llagostera (1995)
Quitor 2 T3427.1 Tunic				Dimension: fragmented; length, 50 cm; width 45 cm, approximately. Technique of manufacture: warp faced with multiple wefts. Decorative technique: warp faced. Design: two fringes at the sides of the tunic with double stripes. The center of the tunic is blue, and the sides are red. The stripes are blue, pale yellow, yellow and red.		Local	
Quitor 2 T65:2; #13979 Bag (*chuspa*)				Dimension: length, 28.5 cm; width, 35 cm. Technique of manufacture: warp faced. Decorative technique: discontinuous warp with dovetailed links. Design: two wide stripes with hooks, steps and 'T'; three narrow stripes with hooks and stairs. Colours: beige, green, white, red, pale blue, green, red-maroon, dark brown. Identical to another bag of the same site, without reference. We have seen similar bags from Mojocoya in the Museo de la Universidad Mayor de San Simón, in Cochabamba.	Tunic weaved in discontinuous warps and weft with interlocked link, and steps and crosses yellow, red blue, green and white; two bags (*talegas*) #11A and s/n° with multiple wefts; braided belt #11B; little bag (*chuspa*) #12 with multiple wefts; three polished ceramics.	Bolivian Oriental valleys	

Quitor 2 T65; #3 Bag (*chuspa*)				Dimension: length 42 cm; 27 width cm. Technique of manufacture: warp faced with one weft. Decorative technique: warp faced; cross knit loop stitch. Design: stripes yellow, maroon, blue and red. The bag had been very utilized and exhibits repairs. Embroidery in the top creates anthropomorphic heads with a radiated headdress with bird heads, and in the selvedges, geometric motifs.	See above.	Tiwanaku	Oakland (1986a).
Quitor 6 T2467 Bag (*chuspa*) covering skull				Dimension: length, 30 cm; width, 42 cm. Technique of manufacture: warp faced. Decorative technique: warp faced; transposed warps; cross knit loop stitch. Design: stripes, stripes with checkerboard, intercrossed stripes. The bag is placed upside down on the head. We have seen the same situation in skulls from the Cochabamba valleys as well as the technique of transposed warps. The embroidery at the top in cross knit loop stitch is an attribute of Tiwanaku style.	No information.	Tiwanaku and Bolivian Oriental valleys	
Quitor 6 T2511; #13959 Bag				Dimension: length, 23 cm; width 27 cm. Technique of manufacture: warp faced. Decorative technique: warp faced; cross knit loop stitch. Design: stripes red and beige; the top is embroidered with Tiwanaku icons such as geometric motifs and a bird with a crown, flying.	This bag was covering a skull, over a local bag. Originally the skull belonged to a mummy with braids, a wig of human hair, a turban of threads of skin, cord of skin, diadems, a monochrome tunic, another tunic (¿?), a mantle, a carcaj with hallucinogic snuff complex, small bags and sandals (Lindberg, 1963:201).	Tiwanaku	Lindberg, (1963:201)
Solcor 3 T107; Tunic 1				Dimension: length, 100 cm; width, indeterminate. The tunic is very fragmented. Technique of manufacture: weft faced. Decorative technique: interlocked tapestry. Design: narrow side fringes with steps, and two central wide fringes with composite motifs (*sensu* Oakland 1986a) with step frets and profile heads.	Bags #3827 and #3810 with side selvedges and top embroidered with cross knit loop stitch creating avian and geometric motifs; fragments (#3811) of interlocked tapestry with bird heads red, blue, yellow and white; two bags (*wayuña*) #3812 and #3821; bag for snuff kit #3811A; fragmented bag #3827; belt in transposed warp with multiple weft wrapped something (as in Cochabamba valleys); re-	Tiwanaku	Oakland (1986a)

					used Tiwanaku textile as a little bag #3810; tunic put in the neck of the mummy (warp face with multiple wefts); warp faced tunic with side selvedges embroidered in wide satin stitches with geometric (steps) motifs; braided headband #9D; a coiled basket; a wooden spoon.		
Solcor 3 T107; Tunic 2				Dimension: length, 85 cm; width, 80 cm. Technique of manufacture: warp faced with multiple wefts. Decorative technique: warp faced. Design: seven stripes red, blue, yellow, red, yellow, red, blue. The center of the tunic is beige.	See above.	Local	
Solcor 3 T107: Tunic 3				Dimension: length, 88 cm; width, 91 cm. Technique of manufacture: warp faced with multiple wefts. Decorative technique: transposed warps, complementary warps. Design: present in only one side of the tunic, and consists in a central band of diamonds and on each side of it a band with serpentine motifs. Correspond to Group B, Type IV of Oakland Rodman (1992).	See above.	Local	Oakland Rodman (1992)

Solcor 3 T109; #13149 Mantle				Dimension: fragment: length, 69 cm; width, 53 cm. Technique of manufacture: weft faced. Decorative technique: interlocked tapestry. Design: one wide and another thin fringe, with a profile anthropomorphic figure with ornitomorph attributes (with the nose similar to those of the figures of Linares and Kantatayita lintels; see Agüero et al., 1997) in pale blue, blue, red and yellow. Around the mantle we can see the profile of a bird with a crown.	Female individual of 30-34 years old with tabular erect cranial deformation. Aguada *tipa* with diamonds design; warp face mantle with multiple wefts; bag; three coiled baskets; one twined basket; spindle whorls; Tiwanaku style pyroengraved cucurbit (Llagostera 1995:16, 26).	Tiwanaku	Oakland (1986a, 1986b), Torres and Conklin (1995:86), Agüero et al., (1997), Llagostera (1995:16, 26)
Solcor 3 T112; #3900A Bag. Catalogue #3054				Dimension: length, 18 cm; width, 18 cm. Technique of manufacture: weft faced. Decorative technique: interlocked and eccentric tapestry with circular warps. Design: deers, birds and geometric motifs in modules. The colours are red, black, yellow, blue and green. We have seen these patterns in many textiles from Mojocoya in the Museo de la Universidad Mayor de San Simón, in Cochabamba (Yacambi Cave), for example: #3427, #3476, #3370, #3416, s/n°7). Torres and Conklin (1995:85) propose this is an Inca style bag and published it with the wrong number 3054). We think this bag shows local motifs (Mizque) and a mixture of local and Tiwanaku techniques.	The bag is attached with whipping stitches to other local bag (#3900B) with multiple wefts. Originally, both bags contained algarrobo (*Prosopis* sp.) seeds (Torres and Conklin 1995:85). Context: two tunics (#9307 and #9306) weaved in warp face with multiple wefts, with narrow stripes at both sides in red, blue, beige, yellow and blue, and the center or *pampa* is beige; monochrome warp faced tunic (#9304) with multiple wefts; monochrome mantle (#9302-A) with multiple wefts; fragments of a tunic (9032-B); elevated hat (#9301) made with flat braiding with inserted red hair of camelid and the top with a weave of simple looping; red feathers; simple looping bag (#8443) for snuff kit; bag #3900B with multiple wefts; bags #3901, #3902.	Bolivian Oriental valleys	Llagostera (1995:30), Torres and Conklin (1995:85).

Solcor 3 T112; #3901 Bag				Dimension: length, 16 cm; width, 15 cm. Technique of manufacture: warp faced with multiple wefts. Decorative technique: transposed warps. Design: intercrossed maroon, yellow, red, green and blue stripes. We have seen similar bags from Mojocoya in the Museo de la Universidad Mayor de San Simón, in Cochabamba.	See above.	Bolivian Oriental valleys	
Solcor 3 T112; #3902 Bag				Dimension: length, 18 cm; width, 16 cm. Technique of manufacture: warp faced with multiple wefts. Decorative technique: transposed warps. Design: intercrossed maroon, yellow, red, green and blue stripes. We have seen similar bags from Mojocoya in the Museo de la Universidad Mayor de San Simón, in Cochabamba.	See above.	Bolivian Oriental valleys	
Solcor 3 T113 Embroidered basket (*tipa*)				Dimension: diameter, 30 cm; height, 18 cm. Technique of manufacture: "wound intercrossed" (Michieli cited in Llagostera, 1995). Decorative technique: wrapping with threads of camelids. Design: Anthropomorphic figure with propeller and darts.	Female individual, 20-24 years old with tabular erected cranial deformation. Two more *tipas*, one with a similar anthropomorphic figure with propeller and darts, and another with a feline with anthropomorphic body; five coiled baskets; a Tiwanaku style pyroengraved bone; two Gris Pulido Grueso ceramics; a carved spoon with anthropomorphic figure #8473; Tiwanaku bag #8475; bag #8466, similar to others of the Argentinian Northwest (López Campeny 2000); bag (*talega* #8454).	La Aguada	Llagostera (1995:12); López Campeny (2000)
Solcor 3 T113; #8475 Bag				Dimension: length, 34 cm; 42, width cm. Technique of manufacture: warp faced. Decorative technique: warp faced; cross knit loop stitch. Design: completely covered with stripes red, blue, yellow and green. The top and side selvedges are embroidered with Tiwanaku geometric motifs and anthropomorphic faces, profile birds flying and a step fret.	See above.	Tiwanaku	Oakland (1986a).

Solcor 3 T132 Tunic 1 (exterior)			 	Dimension: length, 80 cm; width, 93 cm. Technique of manufacture: warp faced with multiple wefts. Decorative technique: warp faced. Design: nine stripes blue, red, blue, yellow, blue, red, blue, yellow, blue. The center of the tunic (or *pampa*) is natural beige.	Snuff kit; rough tunic # 16; mantle; bag (*chuspa*) 867; two textile bracelets with Tiwanaku motifs 8671 #2; a belt woven in sprang technique #21; a fragmented hat "tipo corona" (*sensu* Le Paige notes) with one braid of vegetable fiber and the top woven in cross knit loop technique; another similar hat with a chin strap.	Local	
Solcor 3 T132(5),# 8671 Headband				Dimension: length, 40 cm; width, 5 cm. Technique of manufacture: weft faced. Decorative technique: interlocked tapestry with strings attached at both ends. Design: Tiwanaku motif: a profile bird flying repeated four times. Under its head is the head of a fish.	See above.	Tiwanaku	Oakland (1986a), Torres and Conklin (1995:101).
Solcor 3 T20, body 1; #57 Fragmented tunic				Dimension: fragmented (length, 82 cm; width, 70 cm). Technique of manufacture: warp faced with multiple wefts. Decorative technique: warp face; complementary warps; satin stitch. Design: stripes, and stripes with geometric designs in red, blue, green, yellow. The center of the tunic or *pampa* is beige. Side selvedges and bottom are embroidered with geometric motifs.		Local	
Solcor 3 T20; #1356 Headband				Dimension: length, 50 cm; width, 5 cm. Technique of manufacture: warp faced with multiple wefts. Decorative technique: complementary warps. Design: Image of Southern viscacha (*Lagidium viscacia*), head of bird and archer, in alternate red, yellow, blue and pale blue. *Lagidium viscacia* appears in many textiles from Mojocoya (Agüero 2001) and the archer is a common motif in Tiwanaku ceramics.		Tiwanaku + Bolivian Oriental valleys	

Solcor 3 T20; #57a2 Tunic				Dimension: length, 70 cm; width, 95 cm. Technique of manufacture: warp faced with multiple wefts. Decorative technique: warp faced; satin stitch. Design: stripes, and stripes with geometric designs in red, blue, green, yellow, and white. The center of the tunic is beige. Side selvedges and bottom are embroidered with geometric motifs.		Local	
Solor 3 1983-27 Tunic	Pictures are not allowed because the textile is covering a mummy.			Dimension: length, 100 cm; width, 106 cm. Technique of manufacture: warp faced with multiple wefts. Decorative technique: warp faced; satin stitch. Design: similar to Quitor 1, M1187C tunic.	Worn by a female mummy.	Local	

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