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THE GORDION WOODEN OBJECTS  
VOLUME I



THE FURNITURE FROM TUMULUS MM

Elizabeth Simpson

TEXT

With contributions by

Harry Alden	Benjamin Held
Burhan Aytuğ	Walter Hopwood
Mary W. Ballard	Joseph Koles
Robert A. Blanchette	Patrick E. McGovern
Roland Cunningham	Lynn E. Roller
Laure Dussubieux	Krycia Spirydowicz



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## APPENDIX 8

### PRELIMINARY ANALYSES OF TEXTILES ASSOCIATED WITH THE WOODEN FURNITURE FROM TUMULUS MM

MARY W. BALLARD, HARRY ALDEN, ROLAND H. CUNNINGHAM,  
WALTER HOPWOOD, JOSEPH KOLES, AND LAURE DUSSUBIEUX

*Museum Conservation Institute  
Smithsonian Institution*

#### *Introduction*

Many things happen to textiles when they are entombed. Instead of static "time capsules," reflecting their state at the time of burial, textiles are generally found to be degraded physically, chemically, and biologically. Decorative hangings can be pulled apart by their own weight, contact with metals can corrode fabrics, and enzymatic activity from microbes can dissolve textile fibers. It is fascinating to observe the results of these changes and attempt to deduce or reconstruct the original state of the fabrics, decorative furnishings, and textile regalia. As a group, the textiles themselves may be "animal, vegetable, or mineral"—protein, like silk or sheep's wool; cellulosic, like cotton or flax; or even mineral, like asbestos. Each group has its own susceptibilities for destruction.

Over the years, archaeologists and scientists have found intact textiles at frozen sites, but cellulose especially are subject to many degradative soil bacteria.<sup>1</sup> Occasionally fibers will survive, especially when adjacent to antibacterial materials like copper.<sup>2</sup> However, metals can leach into fabric and transform the chemical structure into a metallic one. If the transformation occurs slowly, the surface or morphology of the fibers can re-

main intact, giving the appearance of the fabric, but now in a copper complex.<sup>3</sup> These are termed "pseudomorphs" since the identity of the fabric is retained, while its chemical structure has metamorphosed.<sup>4</sup> If the leaching occurs more quickly, the surface may be degraded, though the shape and volume of the space that the textile occupied survives.<sup>5</sup> Often wool textiles will disintegrate along with the flesh of the corpse (also protein); usually this enzymatic activity will also degrade a colorant. Interactions among decomposition systems can also produce unique synergies.<sup>6</sup>

Along with its own bacterial and chemical susceptibilities, each natural textile fiber has its own surface characteristics, chemical structure, working properties, methods of processing, and technology. Different fiber types lend themselves to different fabric structures, uses, and looms. Thus, identifying the fiber can provide circumstantial evidence for the science and technology, work habits, trade networks, and culture of a people. In her 1962 study of the Gordion textiles, Louisa Bellinger used this descriptive concatenation to assume that the matted compressed materials from Tumulus MM must be napped woolen fabrics or even felts.<sup>7</sup> Although this is technologically and culturally consistent with local tradition,<sup>8</sup> Bellinger's "felt" cannot be substantiated.

<sup>1</sup> The Pazyryk site is the best-known example. Siu, *Microbial Decomposition of Cellulose*, 129-147; Peacock, "Biodegradation and Characterization of Water-Degraded Archaeological Textiles," 52.

<sup>2</sup> See Wessel, "Textiles and Cordage," 424-445.

<sup>3</sup> See Jakes and Howard, "Formation of Textile Fabric Pseudomorphs."

<sup>4</sup> Ibid. See also Chen, Jakes, and Foreman, "Preservation of Archaeological Textiles through Fibre Mineralization," 1016.

<sup>5</sup> Gillard and Hardman, "Investigation of Fiber Mineralization Using Fourier Transform Infrared Microscopy," 180-181.

<sup>6</sup> See Filley, Blanchette, Simpson, and Fogel, "Nitrogen Cycling."

<sup>7</sup> Bellinger, "Textiles from Gordion," 12-13.

<sup>8</sup> See Gervers and Gervers, "Felt-making Craftsmen of the Anatolian and Iranian Plateaux"; Steinkeller, "Mattresses and Felt in Early Mesopotamia."

In another case, fabrics classified by Bellinger as “golden-brown goats-wool, probably mohair,” were restudied in 1977–1978 by Richard Ellis, who used equally convincing structural similarities to conclude that these plain weave (tabby) fabrics from the tomb were “vegetable in appearance.”<sup>9</sup>

Deductions based on simple observations can lead in contrary directions; analytical data can often clarify matters. Neither Bellinger nor Ellis was able to take advantage of modern optical microscopy or the advanced analytical equipment available today. In 2003, 11 diverse textile fragment groups from Tumulus MM were sent to the Smithsonian Museum Conservation Institute (MCI) for structural and chemical analysis, in conjunction with a review of the textiles recovered from the destruction level of the city mound at Gordion. The Tumulus MM textiles have characteristics quite distinct from those of the city mound and have provided some unexpected challenges.

First and foremost, many of the fragment groups from Tumulus MM have more than one type of textile incorporated in the fragment: the front and back of a fragment may actually reveal two different textiles amalgamated together. The textile on the back may have nothing in common structurally with the textile on the front; they are related only by proximity. For instance, textile fragment 2003-Tx-11 includes numerous unrelated specimens with different fibers and weaves. On the other hand, some of the fragments include only one type of textile, such as textile fragments 2003-Tx-1 and 2003-Tx-10, each of which has homologous, multiple layers or pieces of a single type. Second, the textiles have been biologically degraded in various ways: some remain visually intact but lack the physical and chemical properties associated with natural fiber textiles; others have disintegrated and been laminated together. The microbial activity appears to have been both fiber specific and location specific. In addition, an inorganic mineral coating has been found associated with one weave structure or fiber, and an organic bicomponent has also been identified. Yet two materials and two important fabric structures remain enigmatic. The follow-

ing preliminary report provides some indication of the range of issues relating to the textiles associated with the furniture from Tumulus MM.

#### *Textiles from the Tumulus MM Coffin*

*Textile 2003-Tx-1:* a series of woven fragments.

Plates 153, 154A–B; CD-Figures 1–5 (and see CD-Figures 6–7 for a related sample).

Location: coffin, beneath the purple/red textile on which the body lay.

Fiber: bast plant fiber.

Yarns: 2 Z singles are S plied; this S-plied yarn is used in both warp and weft.

Weave: balanced plain weave (also known as tabby).

Weave count: 18 per centimeter  $\pm 1$  (46.6/inch  $\pm 2.5$ )  $\times$  21 per centimeter  $\pm 2$  (54.2/inch  $\pm 5.1$ ).

Color: an even, level, deep golden color.<sup>10</sup>

The fibers are smooth, processed, and tightly packed longitudinally with diameters in the range of 10–20 microns (Plate 153B). They appear to be the processed stem bundles of bast plant fibers, a group that includes flax (*Linum*) and hemp (*Cannabis sativa*) plants. Chemically, bast vegetable fibers are composed primarily of cellulose. In most ancient societies they were used undyed. These fibers are staple (i.e. not continuous monofilament) and therefore require spinning in order to form yarns or threads (CD-Figure 1). There are no selvages on these fragments, but the warp is presumed to be the more deflected and highly packed direction with 21 yarns per centimeter. Although this set of yarns shows a higher variability, the proportion of thinner yarns is greater. The thinner, more highly twisted spun yarn is stronger and capable of greater tension, a requirement for warp yarns. Thicker, less tightly twisted weft yarns fill more space and would provide a faster weaving pace.

The individual fragments are small, and it is surprising to note the high number of spinning and weaving errors—uneven yarn diameters translate into an uneven weave count and give the fabric an uneven density or cover factor (CD-

<sup>9</sup> Bellinger, “Textiles from Gordion,” 13–14. Ellis, “Textile Remains,” 302. It is difficult to ascertain whether Ellis’s “Fabric A” is Bellinger’s “golden-brown goats-wool,” although this seems to be the case.

<sup>10</sup> The specimen cannot be objectively measured with a

tristimulus colorimeter because of its fragile, brittle surface and small size. This is true of all the specimens in this report. Fortunately, the color rendering in the digital images accompanying this appendix is quite accurate (CD-Figures 1–65).

Table 1. Weight percentage of inorganic elements present on the recto of textile fragment 2003-Tx-1, as analyzed by Scanning Electron Microscopy with Energy Dispersive Spectroscopy (SEM-EDS).

Element	Sample 1	Sample 2	Sample 3	Sample 4	Average <sup>11</sup>
Sodium	0.56 %	0.63 %	0.30 %	0.43 %	0.48 %
Aluminum	0.73	0.60	0.46	0.30	0.52
Silicon	1.52	1.27	0.84	0.84	1.12
Phosphorus	0.78	0.62	0.56	0.44	0.60
Sulfur	—	0.28	0.24	0.21	0.18
Calcium	—	—	0.20	—	—
Iron	96.41	96.60	97.40	97.78	97.05

Figure 2). The loom system had an insufficient shed mechanism: alternate threads were not consistently lifted, so there are occasional mistakes in the weave, and a weaver's knot repairs broken threads. It is not clear at this time whether these errors are the result of a casual treatment. This might have been a utilitarian cloth, not meant to be considered as a fine and uniform fabric, perhaps the clumsier work of a beginning spinner and a beginning weaver. Alternatively, this fabric might have been woven at the limit of fineness for the technological system available. In this case, finer, more consistent yarns would not have been possible, and the weave count was beyond the scope of a more consistent fabric density—hence the repair of breaks with weaver's knots. However, considering the other evidence available regarding Phrygian textiles, the former scenario is more likely.

*Condition:* One side of the fabric appears to be napped, while the other side has no appreciable hairiness. A napped, brushed effect can be purposely induced to achieve a softened surface or be the result of deterioration. In the case of 2003-Tx-1, there is no pattern to the hairiness, and it occurs on the knot (bumpy) side of the fabric. Thus it is presumed to be the result of damage, the simple aggregation of surface yarns broken up during abrasion and caught on one layer, with the density of the fabric acting as a sieve or screen to hold the broken fibers.

On either side of the fabric, as seen in Plate 153B and CD-Figure 2, small white particles are

distributed. These particles are fresh and intact, indicating that they are the result of fungal activity that occurred after the excavation of the tomb. At high magnification (700 diameters, Plate 153B), small white conidia and hyphae can be seen. Larger brown fungal spores are also present. The interior of the fiber is degraded; this would account for the low residual strength and non-plasticity of the fibers, and their tendency to fracture, as well as fractured fiber fragments themselves, observed as "nap." This evaluation is confirmed by the examination of cleaned yarns and fibers (Plate 153C–D).<sup>12</sup> At higher magnifications, it is evident that a hollow sheath of the fiber remains, but the actual fiber itself (Plate 154A–B) has disappeared. A coating or covering has taken on the appearance of the fibers, but the fibers are almost entirely missing.

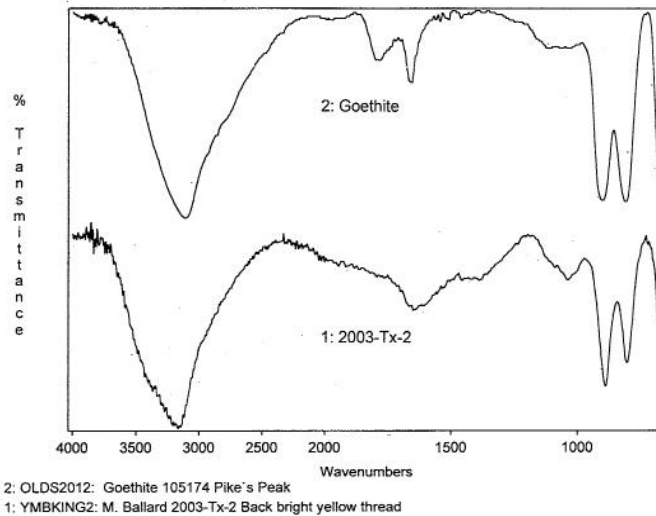
The principal inorganic element of the fibers is iron (96–97 % by weight using energy dispersive spectroscopy in a scanning electron microscope, SEM-EDS; see Table 1). An iron corrosion product ( $\text{Fe}_2\text{O}_3$ ) can impart a dull orange hue to cellulosic fibers. As corrosion occurs, the fibers will be degraded in a pattern often radiating out from a primary source of iron (such as a thumbtack or nail). In this instance, the coloration is consistent, even, and level, as is the concentration of the iron. The textile fragment 2003-Tx-1 is related in weave structure and proximity to 2003-Tx-2 (CD-Figure 6), which was analyzed by Fourier Transform Infrared Spectroscopy (FTIR) for an infrared "chemical fingerprint." Its chief chemical component is goethite,  $\alpha\text{-FeOOH}$ , an iron

<sup>11</sup> Elements with quantities less than 1 % by weight are not always listed. Consequently weight percentage may not total 100 %.

<sup>12</sup> Cleaned with sequential baths of xylene and acrylonitrile on a support of conductive polyester medical fab-

ric. See Ballard, MCI Report #5277, Smithsonian Institution. Unpublished reports, Museum Conservation Institute archives, with contributors including Harry Alden, Roland H. Cunningham, Walter Hopwood, Joseph Koles, Laure Dussubieux, and Amandine Pequignot.





Text Figure 7. Comparison spectra of goethite (source: Pike's Peak, CO) and the gold-colored yarn seen on the "back" of 2003-Tx-2 (CD-Figures 6–7).

oxide hydroxide (Text Figure 7). This is a bacteriostatic, stable, conductive iron coating, of great light-fastness, and gold colored.

*Related textiles:* Textile 2003-Tx-2, back; some fragments of 2003-Tx-11 (see below).

*References:* Richard Ellis described other plain-weave fragments that he examined from the Tumulus MM coffin; he also noted weave errors. He designated this fabric "Fabric A," which he described as "vegetable in appearance."<sup>13</sup> This seems to contradict an earlier conclusion by Bellinger: Ellis identified his "Fabric A" with Bellinger's "golden-brown goats-wool."<sup>14</sup> The fine outside diameter of the fibers (14–18 microns) is comparable to that of cashmere or other fine goat hairs known to be present at other Anatolian sites; this, and the napped appearance of the surface, may have led Bellinger to attribute the fiber to goat. However, no features of goat hairs are present microscopically in textiles 2003-Tx-1 or 2003-Tx-2.

*Textile 2003-Tx-3:* a collapsed laminated mass.

CD-Figures 10–15 (and see Plate 154C–D and CD-Figures 8–9, 16–17 for related samples).

Location: coffin, beneath and adjacent to the body.

Fiber: indeterminate.

Yarns: indeterminate.

Weave: indeterminate.

Color: shades of red and purple.

At first glance this fragment appears to contain no textiles; it looks like a friable, flakey red clay lump of dirt, with white speckles, but the back view shows variegated swirls that might have once been fibrous (CD-Figure 10). On its side (CD-Figure 11) the lump is more clearly laminar, consisting of layers that are more or less porous, compacted, and monochrome. Upon closer examination, the back of the fragment has some extraordinary aspects. For example, there is a circular, spiral-shaped burr (from a burr clover, *Medicago* ssp.) visible at the center of CD-Figures 10 and 13.<sup>15</sup> This burr is dried and loose, but clearly nestled in the debris.

Nearby, fibrous yarn fragments seem to be present, perhaps some even in cross-section (CD-Figure 12). Weave structures that might be twill or some coarse, plain weave may be also present, but the fibers are indistinct and more collagenous than fibrous at higher magnification (CD-Figures 14–15). The degradation of the mass into

<sup>13</sup> Ellis, "Textile Remains," 301.

<sup>14</sup> Bellinger, "Textiles from Gordion," 13–14. *Supra* n. 9.

<sup>15</sup> W.J. Kress, Department of Botany, National Museum

of Natural History, Smithsonian Institution. Personal communication, January 2005.

Table 2. Weight percentage of inorganic elements present in the mixed reddish powder in 2003-Tx-3, as analyzed by SEM-EDS.

Element	Sample 1	Sample 2	Sample 3	Sample 4	Average <sup>16</sup>
Magnesium	2.78 %	3.90 %	3.45 %	3.63 %	3.44 %
Aluminum	8.72	10.64	8.87	11.93	10.04
Silicon	11.29	13.59	10.49	15.93	12.83
Phosphorus	4.24	5.00	4.36	5.16	4.69
Sulfur	10.28	5.57	12.02	8.05	8.98
Potassium	1.99	2.06	1.23	2.59	1.97
Calcium	23.09	17.30	22.69	17.19	20.07
Iron	7.36	5.31	4.37	5.40	5.61
Nickel	1.24	7.52	5.63	3.57	4.49
Copper	29.00	34.42	26.89	26.54	29.21

Table 3. Weight percentage of inorganic elements present in the brightest red powder in 2003-Tx-3, as analyzed by SEM-EDS.

Element	Sample 1	Sample 2	Sample 3	Sample 4	Average <sup>17</sup>
Magnesium	2.87 %	5.49 %	3.33 %	—	2.92 %
Aluminum	11.38	12.15	10.57	5.97 %	10.02
Silicon	16.64	15.57	14.78	16.06	15.76
Phosphorus	5.50	5.08	4.43	4.92	4.98
Sulfur	7.19	6.63	6.03	8.45	7.08
Potassium	2.22	1.85	2.22	2.65	2.24
Calcium	17.02	17.31	17.03	21.26	18.16
Iron	6.12	5.91	8.53	8.44	7.25
Nickel	—	—	—	—	—
Copper	30.20	30.00	33.09	32.26	31.39

these indistinct shreds prevents standard microscopic identification of the fiber class. In addition, the ratios of the weight percentages of any inorganic elements present may be distorted by microbial deterioration or chemical degradation. Still, Tables 2 and 3 provide some indication of the nature of the red coloration.

As averaged, the inorganic content includes a high weight percentage of copper (29–31 %) and iron (5.6–7.3 %) as well as high levels of aluminum (10 %), silicon (12.8–15.8 %), and especially calcium (18–20 %). While these latter are often associated with soil and dirt, they may be indicative here of an inorganic complex associated with the coloration. The sulfur content (7 % to almost 9 %) is far too low for that of hair fibers or wool in an unmineralized, undegraded state, and too high for silk or leather, which inherently have no sulfur

content. The sulfur may be associated with the colorant. The material represented by this fragment has been described by Bellinger and Ellis as a “felt,” the non-woven amalgam of wool or hair fibers as processed with heat, pressure, moisture, and alkali. Such processing might account for the high level of calcium shown in Tables 2 and 3, but not the low sulfur content. Even a shearling—fur left on leather—might not explain the data in these tables.

A white powder also exists on the surface of this textile fragment in discrete spots and in a laminar manner (CD-Figures 10–11). By weight percentage, this soft whitish powder contains significantly more sulfur (25.2 %), more calcium (36.9 %), and significantly less copper (8.4 %) than the reddish materials (see Table 4).

<sup>16</sup> Elements with quantities less than 1 % by weight are not always listed. Consequently weight percentage may not total 100 %.

<sup>17</sup> Elements with quantities less than 1 % by weight are not always listed. Consequently weight percentage may not total 100 %.

Table 4. Weight percentage of inorganic elements present in the white powder, 2003-Tx-3, front, as analyzed by SEM-EDS.

Element	Sample 1	Sample 2	Sample 3	Sample 4	Average <sup>18</sup>
Magnesium	1.08 %	1.75 %	0.46 %	1.17 %	1.12 %
Aluminum	6.44	8.25	2.68	6.31	5.92
Silicon	14.36	18.35	6.00	13.73	13.11
Phosphorus	2.08	2.49	0.83	1.59	1.75
Sulfur	22.35	17.77	36.28	24.45	25.21
Potassium	1.70	2.29	—	1.73	1.43
Calcium	35.94	27.66	47.62	36.35	36.89
Iron	6.66	8.36	2.89	6.55	6.12
Copper	9.39	13.07	3.24	7.75	8.36

An organic analysis for the white powder and for the red colorants remains to be completed. Nonetheless, the lack of the halogen bromine in the inorganic analysis by SEM-EDS indicates that the red coloration of the fragment is not caused by a residue of Tyrian purple (6,6'-dibromoindigo), a dyestuff associated with royalty from antiquity.

*Related textiles:* 2003-Tx-2, front; 2003-Tx-6, underside.

*Reference:* Ellis described "Fabric K," found on the remains of the Tumulus MM coffin, as felt; he also noted an interspersions of spun yarns in the "felt" fragments he examined.<sup>19</sup>

*Textile 2003-Tx-5:* A collapsed laminated mass with residual twining(?)

Plates 154C–D, CD-Figures 19–24.  
Location: coffin.

**Fabric #1**

Fiber: indeterminate.

Yarn structure: none, matted.

Weave structure: none.

Color: shades of red, purple, and light brown with white specks.

**Fabric #2**

Fiber: indeterminate.

Yarns: Z twist(?)

Weave: twining.

Color: shades of red, purple, and light brown with white specks.

This textile fragment, along with 2003-Tx-4, yielded indistinct images. Textile 2003-Tx-5 includes two types of materials. One is the amorphous layer (Fabric #1) seen in the scanning electron microscope (SEM) images of Plate 154C–D; the other (Fabric #2) is a vague image of a twined textile with a horizontal thread running perpendicular to the twisting elements.

Both are covered and enveloped with an irregular, powdery white matter that interferes with visual analysis, optical imaging, and elemental analysis. Table 5 below shows a great inconsistency in the quantities of calcium, sulfur, silicon, aluminum, and iron found on various parts of the surface of the fibrous mass illustrated in Plates 154C–D. There may be uneven levels of contamination, alteration, or degradation, but the underlying fibrous "mattress" may also not have been homogeneous.

This fragment and others of similar appearance from the Tumulus MM coffin (2003-Tx-3 and 4) are associated with those identified as "mattress" or "felt" by Young,<sup>20</sup> Bellinger,<sup>21</sup> and Ellis.<sup>22</sup> Historically, it is quite evident that wool and goat (mohair) felts were produced in this time period and cultural milieu. At present, however, this sample cannot be identified unequivocally as "felt."

<sup>18</sup> Elements with quantities less than 1 % by weight are not always listed. Consequently weight percentage may not total 100 %.

<sup>19</sup> Ellis, "Textile Remains," 309. See also 2003-Tx-5,

below.

<sup>20</sup> Young, *Gordion I*, 189–190.

<sup>21</sup> Bellinger, "Textiles from Gordion," 12–13.

<sup>22</sup> Ellis, "Textile Remains," 309.

Table 5. Weight percentage of inorganic elements present in the fibers on the surface of 2003-Tx-5, as analyzed by SEM-EDS.

Element	Sample 1	Sample 2	Sample 3	Sample 4	"Average" <sup>22,3</sup>
Sodium	0.99 %	1.11 %	1.08 %	1.19 %	1.09 %
Magnesium	2.10	5.34	4.80	3.72	3.99
Aluminum	6.64	11.92	11.74	8.70	9.75
Silicon	20.52	40.07	36.19	25.89	30.67
Phosphorus	1.38	2.45	2.15	2.29	2.07
Sulfur	25.37	9.39	12.75	20.20	16.93
Potassium	1.89	4.13	3.80	2.51	3.08
Calcium	34.39	13.85	16.78	25.89	22.73
Iron	6.72	11.12	10.12	6.84	8.70
Titanium	—	0.63	0.58	0.54	0.44/0.58

Table 6. Weight percentage of inorganic elements present in the fiber residue of 2003-Tx-5, as analyzed by SEM-EDS.

Element	Sample 1	Sample 2	Sample 3	Sample 4	Average <sup>24</sup>
Sodium	0.87 %	1.08 %	0.62 %	1.41 %	1.00 %
Magnesium	2.10	1.81	2.02	2.85	2.20
Aluminum	8.18	8.90	8.72	11.94	9.44
Silicon	19.69	22.59	22.67	31.96	28.41
Phosphorus	1.37	1.76	1.63	2.13	1.72
Sulfur	25.45	21.97	22.44	16.45	21.58
Potassium	2.23	3.05	2.68	3.77	2.93
Calcium	33.29	30.24	29.78	20.84	28.53
Iron	5.96	8.07	6.81	8.39	7.31
Zinc	0.86	—	0.79	—	—
Titanium	—	0.53	—	—	—
Copper	—	—	1.82	—	—
Manganese	—	—	—	0.27	—

For Fabric #2, the fiber's inorganic residue has more consistency, as seen in Table 6. There is some birefringence associated with the fiber, as seen in CD-Figures 21–24. However, it is not clear whether this constitutes some residual, original optical property of the fiber or the effect of a subsequent absorption of a particular compound. The fibers of 2003-Tx-4 seen magnified under an optical microscope (CD-Figure 18) also show some ambiguity.

Fabric #2 of 2003-Tx-5 is a twined structure, visible in the left fragment of CD-Figure 19 and shown in detail in CD-Figure 20. A detail of its counterpart in 2003-Tx-4 can be seen at the upper left central edge of CD-Figure 17. The twining is not very clear, but a horizontal yarn may be distinguished running under angled and, per-

haps, counter-angled, vertical yarns, as is visible in the detail of CD-Figure 20. This is not a plain weave fabric. It was not mentioned by either Bellinger or Ellis in their reviews of the fabrics present in Tumulus MM. There are several types of twined textiles that appear in antiquity: two-strand weft twining, tablet weaving, soumak wrapping, and gauze weave all produce a twined or twisted appearance, as seen in Text Figure 8 below.

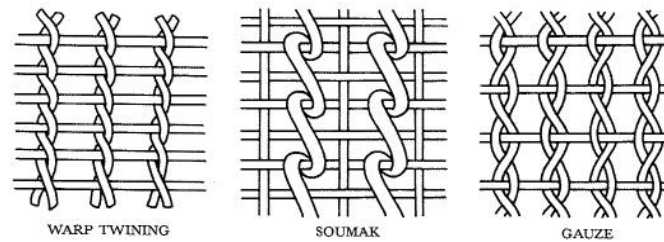
By encircling the perpendicular yarns, the final woven structure tends to be more stable and less able to shift out of alignment.<sup>25</sup> Two-strand weft twining (or warp twining) can be used to produce bags and containers. Designs can be created by alternating the direction of the twining (Text Figure 8, left, is S twined), by

<sup>23</sup> Elements with quantities less than 1 % by weight are not always listed. Consequently weight percentage may not total 100 %.

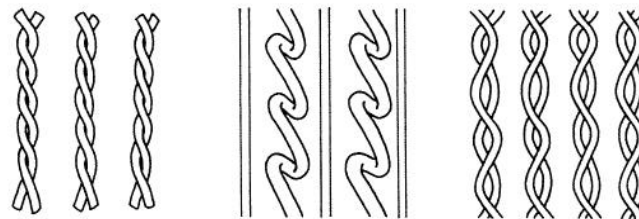
<sup>24</sup> Elements with quantities less than 1 % by weight are

not always listed. Consequently weight percentage may not total 100 %.

<sup>25</sup> Seiler-Baldinger, *Textiles: A Classification of Techniques*, 100.



Text Figure 8. Left: two-strand weft twining, shifted clockwise 90 degrees, or two-strand warp twining. Center: wrapped soumak substituting for a weft shed (i.e. a weft yarn), shifted clockwise 90 degrees. Right: simple gauze weave (after Crowfoot and subsequently Forbes).<sup>26</sup>



Text Figure 9. Left: twined yarns retain their twist. Center: wrapped soumak and adjacent yarns become loose threads. Right: gauze yarns are also detached (after Crowfoot and Forbes).<sup>27</sup>

adding strands, or by switching the position of strand pairs.<sup>28</sup> When the organization is systematized by using pattern cards or tablets with a series of spaced holes, the technology is known as tablet weaving.<sup>29</sup> Soumak wrapping of yarns can be carried out on a loom, as a textile is woven (Text Figure 8, center). Soumak wrapping is much slower than passing a single weft across warps, but it permits the weaver to incorporate color or pattern, as well as producing stability in the finished fabric. Gauze is woven on a loom by manipulating the warps at an angle (Text Figure 8, right): the warps move out of plane; the wefts are not deflected. Of the three types, in their simplest forms, only soumak wrapping will appear different from front or back. Two-strand twining and gauze weave have identical faces.<sup>30</sup>

While these structures can look very similar when they are obscured by dust and dirt, they do not sustain a similar shape when their perpendicular, non-twined elements are damaged. In Text Figure 9, the soumak-wrapped fabric (center) and the gauze fabric (right) both become a series of individual loose strands, entirely disengaged from one another. On the other hand, in the two-strand weft twining shown at the left, the fundamental unit, in this case a pair of yarns, retains its twined relationship. If only a few perpendicular links were left in place, the whole pattern or texture of the textile would be maintained, as is the case in CD-Figure 20. Thus, the fine textile seen indistinctly can be described as a twined textile. This phenomenon is apparently the source of Bellinger's misunderstanding of the structure of her "felt" over a woven base (see below).

<sup>26</sup> Crowfoot, "Textiles, Basketry, and Mats," 430, fig. 271. R. Forbes, *Studies in Ancient Technology* 4, 190, fig. 26. However, in both instances, the simple gauze weave at right was sketched incorrectly, with the lowest (bottom) twining twisted. In Text Figure 8, that mistake has been corrected.

<sup>27</sup> Crowfoot, "Textiles, Basketry, and Mats," 430, figure 271. R. Forbes, *Studies in Ancient Technology* 4, 190, fig. 26. With the sketch of the undamaged gauze weave structure corrected, the degradation or absence of perpendicular el-

ements of the gauze weave produces a consistent uniform result.

<sup>28</sup> Seiler-Baldinger, *Textiles: A Classification of Techniques*, 61-62.

<sup>29</sup> Emery, *Primary Structure of Fabrics*, 199-200. Emery explains that warp twining can be carried out with or without tablet weaving technology. For a full discussion of tablet weaving see Collingwood, *Techniques of Tablet Weaving*.

<sup>30</sup> Emery, *Primary Structure of Fabrics*, 181, 197, 215.

*Related textiles:*

"Felt": 2003-Tx-2, front; 2003-Tx-4; 2003-Tx-6, underside.

Twining: 2003-Tx-4; 2003-Tx-6, back; 2003-Tx-7; 2003-Tx-8, front; 2003-Tx-9, front.

*References:*

"Felt": Ellis refers to this material as "Fabric K."<sup>31</sup> Bellinger also finds "felt" among the Tumulus MM textiles. She describes felt making as the layering of fibrous mats at right angles to each other, but she illustrates this point with a matted sample that bears some resemblance to 2003-Tx-5, illustrated here in Plate 154C.<sup>32</sup>

Twining: Ellis describes a weaving error, a crossing of occasional warps, and he also describes a starting border. Errors do not create a consistent pattern of oblique angles. Weaving errors are noticeable because they introduce irregularity into an otherwise regular pattern. With starting borders, the consistent pattern of warp crossing occurs only once, along one row, at the point of transition from starting border to main weaving.<sup>33</sup> Here the oblique angles of the warps occur repeatedly with several rows of weft. Bellinger illustrates a fragment of "tan wool" that she believes is the mat-like "base" of a felt "blanket" from the coffin; however, this sample seems to be related to the twined textile described above.<sup>34</sup>

*Textiles from the Northeast  
Corner of the Tomb Chamber*

*Textile 2003-Tx-6:* a collapsed laminated mass, cording, and residual twining.

Plate 155A–B, CD-Figures 25–33.

Location: amidst the furniture in the northeast corner of the tomb. The sample was originally labeled "blanketing under bag resting on stool #2."

*Fabric #1*

Fiber: indeterminate.

Yarn structure: floss (imperceptible twist).

Weave structure: twining.

Weave count: rows are 1.5–1.7 mm apart.

Color: dark brown weave on a powdery tan substrate.

*Fabric #2*

Fiber: indeterminate.

Yarns: S-twisted "cords" about 1 mm in diameter.

Yarns: spaced 4–5 mm apart.

Weave: none apparent.

Color: maroon to purple with white specks.

*Other Fabrics*

Fiber: indeterminate.

Yarn structure: none, matted.

Weave structure: none.

Colors: maroon to purple matte areas with white specks.

On the upper side of the fragment (Plate 155A) lies the remnant of a fine twined textile structure, Fabric #1, similar in quality to those twined textiles seen on fragments 2003-Tx-4 and 2003-Tx-5. The remnants are nestled against a white powdery substance (see CD-Figures 29–30). This substance bears the impression of the verso of the textile's structure, along with bits of the fiber, even though the textile has fallen away. Beneath this whitish layer may lie another twined structure, but this cannot be readily ascertained.

Details of a cross-sectional view of the fragment (see CD-Figures 27–28) show a compression of distinct colored layers, voids, and white powder. In the midst of the red layer visible in CD-Figure 28 is an ovoid pit measuring approximately 0.8 mm × 1.4 mm. This void appears to correspond to the S-twisted "cords" of Fabric #2 that are extant elsewhere on the underside of the fragment and shown in Plate 155B. These "cords" or plied materials are spaced 4–5 mm apart in an orderly manner. Where they are no longer extant, raking light shows a slight depression or trough at 4–5 mm intervals.

Between these "cords" are other fabrics, a matted complex, dark in color, as seen in CD-Figure 26. It is possible that this matted complex is evidence of a wool felt. Felts are compacted and condensed matted arrangements of wool or hair fibers; paper is the equivalent for

<sup>31</sup> Ellis, "Textile Remains," 309.

<sup>32</sup> Bellinger, "Textiles from Gordion," 18, plate 3D.

<sup>33</sup> Ellis, "Textile Remains," 298–299; figs. 141, 143. Bel-

linger also discusses starting borders. Bellinger, "Textiles from Gordion," 11–12.

<sup>34</sup> Bellinger, "Textiles from Gordion," 12–13, plate 3D.

Table 7. Weight percentage of inorganic elements present in the reddish/purple powder, 2003-Tx-6, as analyzed by SEM-EDS.

Element	Sample 1	Sample 2	Sample 3	Average <sup>35</sup>
Magnesium	2.82 %	3.02 %	2.73 %	2.86 %
Aluminum	8.95	8.65	8.66	8.75
Silicon	13.42	14.02	13.84	13.76
Phosphorus	4.06	4.04	4.15	4.08
Sulfur	15.60	14.50	16.72	15.61
Potassium	1.86	2.25	1.79	1.95
Calcium	23.40	22.81	23.98	23.40
Iron	4.13	5.07	5.06	4.75
Copper	25.77	25.64	23.07	24.83

cotton fibers. It has been suggested that sample 2003-Tx-6 represents a cushion or some kind of upholstery padding found on one of the stools placed in the northeast corner of the tomb (stool #2). While such a layer would be practical directly above the tensioned string-course of upholstery, some intermediate layers of uncompacted lofted fibers could be expected. For comfort, a soft, resilient batting would be a reasonable selection. That is, an *uncompacted*, even teased beehive or pillow of fibers might be found, together with intermediary yarns or webs to hold these battings in place. Unlike heavily compacted felts, battings are light, mostly air, and can compact down to 2–3 % of their original thickness. The various striations at the top and bottom rims of the textile fragment seen in CD-Figures 27 and 28, are possible evidence of such lofted battings and their restraints seen in cross-sectional view, now degraded and compacted, as well as the traditional felt.

*Condition:* Thus, it is suggested that the generic “felt” associated with this and the purple and maroon coffin material from Tumulus MM may be divided into actual “felt,” purposely made, in combination with batting or other uncompacted, non-woven, material now compacted due to degradation. Microbial degradation is likely. As regards the reddish coloration, this textile fragment seems to share the lumpish character of textile 2003-Tx-3—a laminated mass with a dark

red coloration, white powdery marks, and indistinguishable textile residues. The reddish purple coloration of sample 2003-Tx-6 (see Table 7) shares with its counterpart, sample 2003-Tx-3, high copper and calcium contents (respectively, 25 % and 23 % by weight), substantial levels of sulfur and silicon (16 % and 14 %), and significant amounts of aluminum and iron (9 % and 5 %).

Again, this reddish purple coloration lacks any bromine. Bromine at the 6 and 6' locations on the indigo molecule are both the cause for the purple hue and a distinguishing chemical feature of Tyrian purple. In the absence of bromine, no Tyrian purple can be associated with this fragment. Indeed, in this instance a sample was analyzed with Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) to determine if any traces of bromine could be found. A 6,6'-dibromoindigo-dyed reference was procured and compared to confirm this finding. The precise cause of the reddish purple coloration has yet to be determined.

The dark, almost twistless fiber associated with the twining on the upper layer was examined by optical microscopy (see CD-Figures 31–33). The fibers are thin, fragmentary, degraded units locked in what appears to be a microbial film.

*Related textiles:*

Twining: 2003-Tx-4; 2003-Tx-5; 2003-Tx-7; 2003-Tx-8, front; 2003-Tx-9, front.

“Felt”: 2003-Tx-2, front; 2003-Tx-4; 2003-Tx-5.

<sup>35</sup> Elements with quantities less than 1 % by weight are not always listed. Consequently weight percentage may not total 100 %.

*References:*

"Felt": Bellinger noted "different consistencies" among the various fragments of felts,<sup>36</sup> and she illustrated the striations and the juxtaposition of "felt" to woven fabric. Ellis observed "spun yarns lying between layers of randomly arranged felted fibers" for his "Fabric K" felt.<sup>37</sup> Associated with his "Fabric K," Ellis found yarns grouped but not spun, lying adjacent to each other, 5–10mm apart, occasionally crossed, but with no apparent weaving intended. Perhaps the textile fragments he examined had less extant twining than the samples analyzed here. In this context, the current study found a fine, reddish, random fibrous amalgam, reminiscent of a collagenous suede, on the front of textile 2003-Tx-2.

Cordage: Cordage is not discussed by either Bellinger or Ellis. No attempt was made during the current study to identify this material, which is now largely evident from impressions left in the textile remains. It should be noted that various reeds, "cat gut," or other membranes might be used as load-bearing, tensioned cords in stool construction. Impressions on one textile sample from the northeast corner were assumed to be "probably rush," according to a 1985 study (unpublished), although this conclusion was based on the observation of a photograph (see above, p. 114, n. 18, and Plate 106B).

*Textiles 2003-Tx-7, 8, and 9:* twined textiles.

*Textile 2003-Tx-7:* fragments of twined textile.

Plate 155C–D, CD-Figures 34–37.

Location: "bag on stool #2, east side, near northeast corner."

Fiber: indeterminate.

Yarns: floss (almost imperceptible S-twist single).

Weave: twining.

Weave count: paired yarns (spirals) are spaced 1.4mm apart; rows (perpendicular to the paired yarns) are 0.5mm apart.

Color: dark brown weave on a powdery tan substrate.

*Textile 2003-Tx-8, front:* fragments of twined textile.

Plate 156A–B, CD-Figures 38, 42.

Location: "bag on stool #2, east side, near northeast corner."

Fiber: indeterminate.

Yarns: floss (almost imperceptible S-twist single).

Weave: twining.

Weave count: paired yarns (spirals) are spaced 1.4mm apart; rows (perpendicular to the paired yarns) are 0.5mm apart.

Color: dark brown weave on a powdery tan substrate.

*Textile 2003-Tx-9:* fragments of twined textile.

CD-Figures 46–51.

Location: "bag mixed with blanketing under it, on stool #2, northeast corner."

Fiber: indeterminate.

Yarns: floss (almost imperceptible S-twist single).

Weave: twining.

Weave count: paired yarns (spirals) are spaced 1.4mm apart; rows (perpendicular to the paired yarns) are 0.5mm apart.

Color: dark brown weave on a powdery tan substrate.

These textiles share the same fiber and weave structure seen above with 2003-Tx-4 and 2003-Tx-5. Whether viewed by scanning electron microscope (Plate 155C–D) or with optical microscopy (see CD-Figures 35–37), textile 2003-Tx-7 also exhibits the same fragmentary damage and coating visible on the fibers. The textiles are made with the same fibers, yarns, and weave structure, although these cannot be precisely classified. Yet the fibers of textile 2003-Tx-7 have a significantly higher iron content than that found in either textile 2003-Tx-8 or textile 2003-Tx-9, as indicated in Tables 8–10 below. The latter two have a high level of copper, while 2003-Tx-7 has none. For all three textiles, the samples have inconsistent levels of iron, copper, potassium, sulfur, and silicon—proportionally changing from a major quantity to a less significant one, varying from sample to sample. This could indicate a capacity of the fiber for absorption, for contamination, or it could indicate a heterogeneous environment in terms of the tomb context. The samples are highly inconsistent.

<sup>36</sup> Bellinger, "Textiles from Gordion," 13; plates 3C–D, 4.

<sup>37</sup> Ellis, "Textile Remains," 309.



Table 8. Weight percentage of inorganic elements present in the dark fiber, 2003-Tx-7, back, as analyzed by SEM-EDS.

Element	Sample 1	Sample 2	Sample 3	Sample 4 <sup>38</sup>
Magnesium	1.85 %	3.00 %	—	1.10 %
Aluminum	14.54	15.82	26.43 %	23.75
Silicon	43.30	42.12	9.92	15.13
Phosphorus	1.77	1.66	5.51	4.19
Sulfur	3.22	4.43	26.85	21.82
Potassium	8.18	6.88	18.00	14.39
Calcium	4.08	1.06	4.91	5.64
Titanium	1.65	1.06	0.68	0.33
Iron	21.41	18.06	7.40	12.47

Table 9. Weight percentage of inorganic elements present in the dark warp, 2003-Tx-8, as analyzed by SEM-EDS.

Element	Sample 1	Sample 2	Sample 3 <sup>39</sup>
Magnesium	0.31 %	3.06 %	2.48 %
Aluminum	0.49	5.48	4.84
Silicon	1.12	13.92	9.84
Phosphorus	—	2.11	2.03
Sulfur	38.06	5.31	19.32
Potassium	—	1.39	1.12
Calcium	50.80	22.95	27.48
Iron	—	3.49	2.73
Copper	9.22	42.30	30.16

Table 10. Weight percentage of inorganic elements present in the dark yarn, 2003-Tx-9, as analyzed by SEM-EDS.

Element	Sample 1	Sample 2	Sample 3 <sup>40</sup>
Magnesium	1.28 %	4.11 %	1.53 %
Aluminum	2.46	8.57	4.34
Silicon	6.45	25.58	11.61
Phosphorus	—	1.57	1.12
Sulfur	34.10	5.58	25.03
Potassium	0.92	3.56	1.47
Calcium	44.68	10.60	33.35
Titanium	—	0.85	0.31
Nickel	—	0.83	—
Iron	2.63	8.22	3.97
Copper	7.46	30.52	17.27

<sup>38</sup> Elements with quantities less than 1 % by weight are not always listed. Consequently weight percentage may not total 100 %.

<sup>39</sup> Elements with quantities less than 1 % by weight are not always listed. Consequently weight percentage may not

total 100 %.

<sup>40</sup> Elements with quantities less than 1 % by weight are not always listed. Consequently weight percentage may not total 100 %.

*Related textiles:*

Twining: 2003-Tx-4, 2003-Tx-5, 2003-Tx-6.

*References:* Twined textiles are a well-defined group, but they can be manufactured by different technological methods. The twined structure of the present samples, like those examined previously, could have been made with or without tablet technology. Several authors provide knowledgeable definitions, examples, and comparative structures, among them: Emery, *Primary Structure of Fabrics*; Burnham, *Warp and Weft: A Dictionary of Textile Terms*; and Seiler-Baldinger, *Textiles: A Classification of Techniques*. A more complicated and decorative format can be carried out with tablets (sometimes referred to as "cards"), which can produce paired warps making confronting S and Z patterns—or other textures, depending upon the threading and holes, as well as the sequence of turning. Collingwood, in *The Techniques of Tablet Weaving*, describes the structural variation and technical intricacies possible. While tablet weaving is generally considered suitable for narrow bands, tapes, and belts, it may be used for wider textiles. Such complexity in a degraded fabric would render the weaving difficult to analyze and to reconstruct. With the current samples, the precise method of weaving is obscure, and tablet weaving offers a possible, but speculative, explanation.

*Textile 2003-Tx-8, back:* plain weave fragment.

Plates 156C–D; CD-Figures 39–41, 43–45.

Location: "bag on stool #2, east side, near northeast corner."

Fiber: bast plant fiber.

Yarns: 2 Z singles are S plied; this S-plied yarn is used in both warp and weft.

Weave: balanced plain weave (also known as tabby).

Weave count: 28 warps/cm × 23 wefts/cm (71/inch × 59/inch).

Color: golden, light tan.

*Textile 2003-Tx-9, back:* plain weave fragment.

Location: "bag mixed with blanketing under it, on stool #2, northeast corner."

Fiber: indeterminate.

Yarns: 2 Z singles are S plied; this S-plied yarn is used in both warp and weft.

Weave: balanced plain weave.

Weave count: perhaps 35 warps/cm × 35 warps/cm (89/inch × 89/inch).

Color: golden, light tan.

*Textile 2003-Tx-10:* plain weave fragment.

CD-Figures 52–55.

Location: "pieces of fine material lifted from fibulae, northeast corner on stool #2."

Fiber: flax (or ramie).

Yarns: 2 Z singles are S plied; this S-plied yarn is used in both warp and weft.

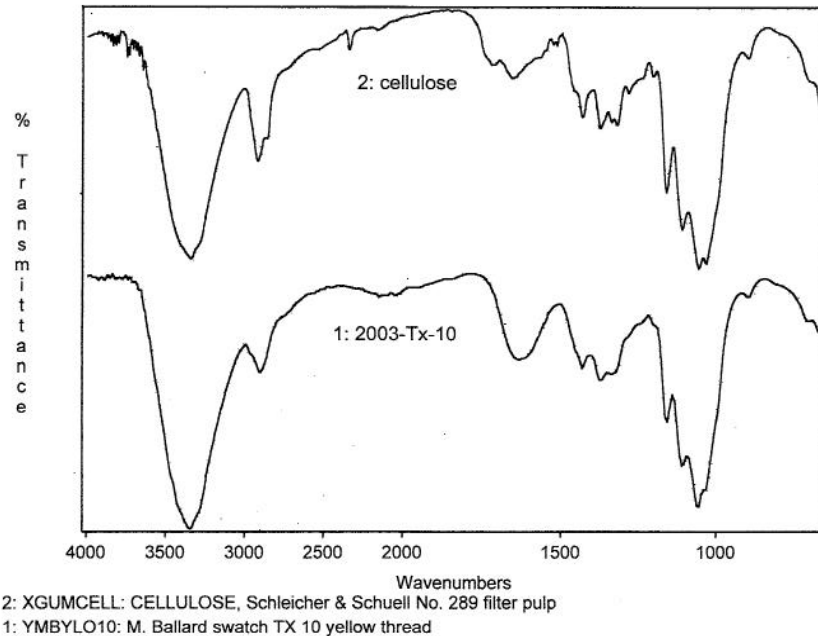
Weave: balanced plain weave.

Weave Count: 35 warps/cm × 35 wefts/cm (89/inch × 89/inch).

Color: brown.

The light tan or gold-colored fabric found on the back of 2003-Tx-8 is a finely woven, lustrous, balanced plain weave. Yet as seen in Plates 156C–D, the fibers are coated and obscured with debris. In part, this is due to a white powdery substance, seen in CD-Figure 41, which was also observed on 2003-Tx-1. Again, this undetermined white material may be a by-product of biological degradation. Microscopically, the fiber is fragmentary and breaks into brittle chunks, with a coated bubbly surface, as seen in CD-Figures 43–45. These images match the optical microscopy of the plain weave textile 2003-Tx-2. Small fragments of balanced plain weave also exist on the back of 2003-Tx-9. The largest is pulled, distorted, and partially covered by other layers of debris.

The case of 2003-Tx-10, the brown plain weave fabric (CD-Figure 52) is anomalous. It is a darker, slightly hairier, finely woven plain weave fabric. It has several layers folded upon each other, crumbled together; the fabric has a tarry (tar-like) coating over parts of it. With polarized light microscopy the fiber was identified as a right-handed bast fiber, flax or ramie (its Far Eastern equivalent), as can be seen in CD-Figures 53–55. Not only was the microscopic character of the fiber intact, the working properties of the yarns remained pliant and flexible. Its cellulosic character is confirmed by Fourier Transform Infrared Spectroscopy (FTIR), as seen in Text Figure 10. FTIR takes the chemical "finger-print" of the major constituent, so that minor components of the bast fiber—lignin or pectins, or even the tarry stain—do not necessarily figure against the dominant component, which, for modern flax, is cellulose. The tarry



Text Figure 10. Comparison of pure cellulose with yarn from 2003-Tx-10, by Fourier Transform Infrared Spectroscopy (FTIR).

substance partly coating textile 2003-Tx-10 has not yet been identified.

*Related textiles:* While the plain weave textiles of 2003-Tx-8 and 2003-Tx-9 share the same weave structure as 2003-Tx-1 and the back of 2003-Tx-2, the quality of their yarns is more lustrous, smoother, and less golden. They resemble more closely the “smooth yarns” found among the fragments of 2003-Tx-11. Textile 2003-Tx-10 is unrelated to the other plain weave fabrics in color and texture, but appears to share its fine weave count with 2003-Tx-9.

*References:* Reference to these fabrics cannot be discerned from Ellis’s descriptions of fabric types that he catalogued from Tumulus MM.<sup>41</sup> Bellinger illustrates four plain weave fabrics of different fibers.<sup>42</sup> The sheen of the fabric illustrated in Bellinger’s plate 17C is reminiscent of that of textile 2003-Tx-8, back. However, she lists it as linen. Of the group of textiles discussed in the current study, 2003-Tx-10 is the firmest candidate for attribution to flax; this textile is a dulled, matte, dark fabric with no sheen.

#### *Textiles Found behind Serving Stand A*

*Textile 2003-Tx-11:* various yarns, plain weave fragments.

Plates 157–158; CD-Figure 56 (overall view of fragments), CD-Figures 57–65.  
Location: floor behind serving stand A.

**Yarn #1**  
Plate 157A–D, Plate 158A.  
Fiber: indeterminate, smooth appearance.  
Yarn: 2 Z singles, S plied.  
Color: gold colored.

**Yarn #2**  
Plate 158B–D.  
Fiber: indeterminate.  
Yarn: 2 Z singles, S plied.  
Color: dark (black).

**Fabric #1**  
CD-Figure 57.  
Fiber: indeterminate.  
Yarn: 2 Z singles, S plied in both directions.

<sup>41</sup> Ellis, “Textile Remains.”

<sup>42</sup> Bellinger, “Textiles from Gordion,” plate 17.

Weave: balanced plain weave (tabby).  
 Weave count: 13 "warps"/cm  $\times$  18 "wefts"/cm  
 (33 "warps"/inch  $\times$  46 "wefts"/inch).  
 Color: gold colored and, in part, green.

#### Fabric #2

CD-Figure 60.  
 Fiber: indeterminate.  
 Yarn: filled, 2 Z singles, S plied in both directions.  
 Weave: balanced plain weave.  
 Weave count: 18 yarns/cm  $\times$  17.5 yarns/cm (46 yarns/inch  $\times$  44 yarns/inch).  
 Color: gold colored with dark blue-black S-slanted markings in the yarns.

#### Fabric #3

CD-Figure 59.  
 Fibers: indeterminate.  
 Yarn: "warp" is Z single, gold colored; "weft" is filled, 2 Z single, S plied.  
 Weave: weft-faced plain weave/warp-faced plain weave.  
 Weave count: 14 "warps"/cm  $\times$  24 "wefts"/cm (36 "warps"/inch  $\times$  61 "wefts"/inch).  
 Color: tarry coated tan appearance (predominant yarn).

#### Fabric #4

CD-Figure 58.  
 Fibers: indeterminate.  
 Yarn: "warp" is filled, 2 Z single, S plied; "weft" is Z single, gold colored.  
 Weave: balanced plain weave.  
 Weave count: 20 "warps"/cm  $\times$  23 "wefts"/cm (51 "warps"/inch  $\times$  59 "wefts"/inch).  
 Color: gold colored with mottled darker areas.

A group of diverse textile fragments, including unraveled yarns and woven fabrics, was found near the east wall of the tomb, behind the inlaid serving stand A. Two types of yarns that were recovered did not appear to be associated with any of the woven fabrics. Yarn #1 could be recognized as a smooth, homogeneous spun yarn, once its surface debris was removed by mild solvent cleaning, as seen in Plate 157A.<sup>43</sup> Details of this yarn's fibers reveal an undifferentiated morphology, which at high magnification is seen

to be composed of rows of convex bubbles (see Plates 157C, 158A). These bubbles are punctured at their top with small-diameter "blow-holes" as though for gas to escape. Running longitudinally through these bubbles are fine hairline cracks. In Plate 157D, the bubbled surface is seen to cement the left center fiber to its neighbor, and the fiber itself is hollow. That is, the coating has replaced the fiber, leaving a molten, melted-looking surface that gives a smooth appearance macroscopically.

Dark individual yarns, Yarn #2, were also found in this group. These yarns are especially friable or brittle. They are set with the permanent deflection or undulating wave that arises from ageing in place in a plain weave fabric. Yarn #2's counterpart, perhaps the weft, has disintegrated entirely, leaving these dark yarns disengaged. Once cleaned of debris, the surface of the dark yarn becomes clearer, as seen in Plates 158B-D. Again, this surface is not typical of a natural fiber: it is as though the outer cover of the fiber, whatever its origin, has been dissolved or eaten away. Indeed, the small spheres visible under high magnification are indicative of microbial activity (Plate 158C).

Samples of Yarn #2 were analyzed for their inorganic content. As seen in Table 11, they have a very high iron content (90%), though slightly lower than that found in the gold-colored textile fragments, 2003-Tx-1 (Table 1). Further examination of these yarn fragments may provide a definitive identification of the fabrics and fibers associated with these yarns, and explain the dark coloration.

In addition, four fabric fragments among the many from 2003-Tx-11 are of particular interest. Fabric #1, seen in CD-Figure 57, is a balanced plain weave. It has a tarry red stain near the center, but most peculiarly half of it is green and half of it is gold colored. Some of the yarns have a slight dark mark that follows the angle of the yarn's ply, emphasizing the S direction of the ply. This marking occurs in both warp and weft and is most apparent where the fabric is green. Green coloration on antique fabrics can be due to a combination of dyes, usually a yellow flavonoid mordanted onto a protein fiber and an indigoid vat. In archaeological contexts, copper mineral

<sup>43</sup> Cleaned with sequential baths of xylene and acrylonitrile on a support of conductive polyester medical fabric. See

Ballard, MCI Report #5277, Smithsonian Institution.

Table 11. Weight percentage of inorganic elements present in the dark strands, 2003-Tx-11, Yarn #2, as analyzed by SEM-EDS.

Element	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Average <sup>44</sup>
Magnesium	0.30 %	0.19 %	0.43 %	0.63 %	0.26 %	0.56 %	0.40 %
Aluminum	1.26	0.85	0.78	0.83	0.48	0.59	0.80
Silicon	2.43	1.97	2.77	2.00	1.34	3.16	2.28
Phosphorus	0.43	0.57	0.98	1.29	0.92	0.68	0.81
Sulfur	0.58	0.48	1.00	0.88	0.66	1.52	0.85
Potassium	1.05	0.75	0.23	0.28	0.26	0.50	0.51
Calcium	1.69	0.93	1.43	1.72	1.43	2.41	1.60
Iron	88.89	94.27	90.79	89.43	90.72	86.27	90.06
Nickel	0.71	—	—	—	—	—	—
Copper	2.67	—	1.58	2.94	3.90	4.31	2.56/3.08

salts are well known to produce green staining.<sup>45</sup> Indeed, some of the bronze vessels that had fallen behind the stand were apparently wrapped in or contained 2003-Tx-11 fabrics.<sup>46</sup> However, the FTIR spectrum for Fabric #1 produced an unusual indication of the mineral goethite for the yellow, top-dyed with indigo (see Text Figure 11 below).

It is unusual to find a dyestuff or dyeing better preserved than the fiber with which the dye is associated. The yarns of Fabric #2 (see CD-Figure 60) share the S-direction yarn markings and were also examined. In this instance the classic microchemical reduction test was carried out as well as FTIR on a microscopic scale to confirm the presence of indigo.<sup>47</sup> In this Fabric #2 the indigo has not been vatted; it lies inside the yarns, and it is what forms the dark tiger-stripe, perhaps painted on one of the two Z singles before they were plied. When viewed under the microscope, these stripe markings have a tarry appearance (see CD-Figure 61). A tentative identification of myrrh as the binder for the indigo powder has been made, as the FTIR in Text Figure 12 shows.

Indigo is vatted at about 50° Celsius in a reduced or oxygen-depleted, aqueous bath. In this reduced state, the pigment becomes soluble and can migrate into the fibers of a textile. Once

it reoxidizes in the air, it is no longer soluble and is locked inside the fiber. Early illustrations of the process typically depict plain fabrics being submerged in vats of chemicals and dyes. Yet, there is no logical prohibition to dressing a yarn with the dye matrix, especially in the case of indigo, where the insoluble dyestuff diffuses into a fiber only in its leuco (reduced) state. Vatting a bicomponent fabric like Fabric #2 could easily produce a well-dyed, wash-fast product.

Vatting a plain, unprepared cloth runs the risk—characteristic of modern blue jean manufacture—of having the indigo vat not diffuse well through the fibers, so that the dye lies on the surface. Once poorly dyed indigo re-oxidizes and dries, the dye rubs off or “crops” off as pigment particles. Whether it was more economical to paint yarns prior to spinning them than to dye plain cloth with more chemicals, a longer bath time, etc. is not known. Common reducing agents are odiferous; a smaller quantity might be necessary, or the duration of the bath might be shorter using painted yarns. Such fabrics could be stored as is, unreacted, for a very long time. Finally, it may have been the intention to use the indigo as a blue-black pigment, rather than as a dye. In that case, the texture of the subtle tiger-stripe was the goal, and the indigo was not simply a means to coloration.

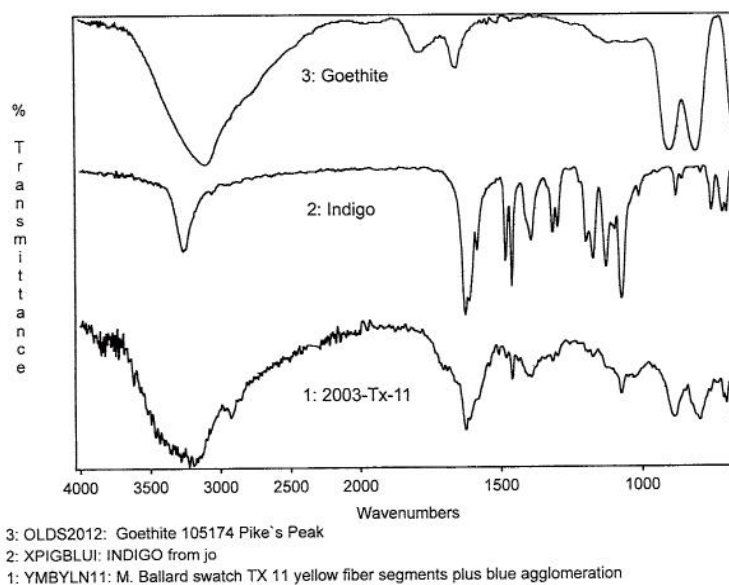
<sup>44</sup> Elements with quantities less than 1% by weight are not always listed. Consequently weight percentage may not total 100%.

<sup>45</sup> See for example, Chen, Jakes and Foreman, “Preservation of Archaeological Textiles through Fibre Mineralization”; Gillard and Hardman, “Investigation of Fiber Mineralization Using Fourier Transform Infrared Microscopy”; Jakes and Howard, “Formation of Textile Fabric Pseudo-

morphs.”

<sup>46</sup> Young, *Gordion I*, 111 (small cauldron, MM 7), 112 (small cauldron, MM 13), and 121 (lion- and ram-headed situlae, MM 45-46). These can be identified with Ellis’s fabrics A and F.

<sup>47</sup> Hofenk de Graaff, “A Simple Method for the Identification of Indigo,” 54-55.



Text Figure 11. Gold-colored Fabric #1 of 2003-Tx-11 and its blue stain (bottom) are compared with the mineral goethite (top) and the spectrum of indigo (center) by FTIR.

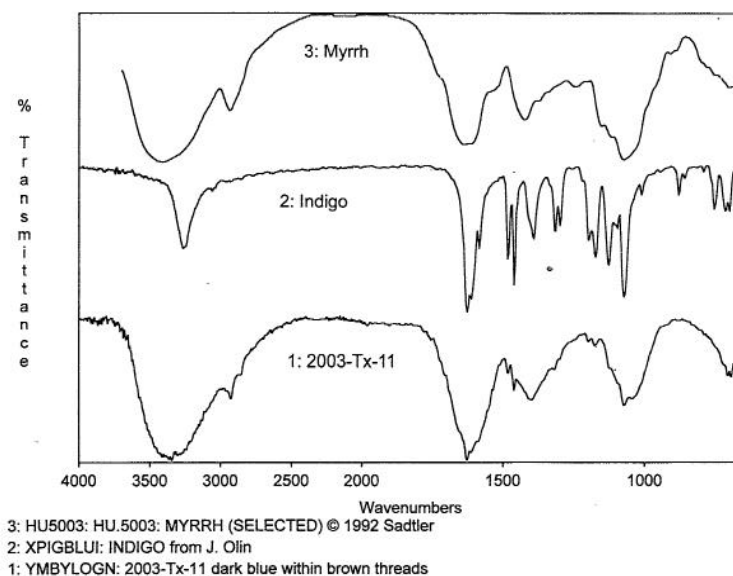
The inorganic elements of the bicomponent yarn were analyzed. In Table 12, the high iron content (63%) is considerably lower than in Yarn #2 or in 2003-Tx-1 (Tables 11 and 1 respectively). In the “bicomponent fabric” there is a higher copper content, a higher phosphorus content, and a higher calcium content. These inorganic elements are not directly related to the myrrh or the indigo, since they are organic in chemical structure, but they may be auxiliaries associated with the binding matrix or chemicals (additives) for subsequent dyeing. The inorganic elements may also represent contamination and migration with microbial decay.

With optical microscopy, the fibers of the bicomponent yarn appear curiously mottled, covered with particulate matter that is translucent but orange or black in color (see CD-Figures 62–63). Individual fragments of fiber do appear to have some birefringence (see CD-Figures 64–65). These characteristics appear related to those seen earlier in textile 2003-Tx-1 (compare with CD-Figures 3, 4, and 5).

Fabric #3, seen in CD-Figure 59, is a mixed fabric or “union cloth”: the fine Z-spun warps do not share the same degree of twist, color, and other fiber characteristics with the larger weft yarns. The wefts are smooth 2 Z-spun singles S plied, with a tar-like filling, somewhat more irregularly coated than in Fabric #2. Upon close

examination, the weft yarns of Fabric #3 appear quite similar to those of Yarn #1 and of textile 2003-Tx-1. The tar-like matrix on the weft yarns does not touch the warps, so the coating was applied prior to weaving. With the goal being to produce a weft-faced closely packed fabric, the weaver could simply have used an untarred, not-yet plied Z single. In weave constructions, a Z-spun yarn nestles on the perpendicular with an S-plied yarn. This weave structure compacts neatly. Yet, an entirely different fiber type was chosen for the Z-spun yarn, perhaps because it was stronger or cheaper. Is this a consciously crafted fabric or a finishing end? Fabric #4 is its plain weave counterpart (see CD-Figure 58, the warps set horizontally). Also a “union cloth,” Fabric #4 is a balanced plain weave in somewhat more deteriorated condition. In this instance, the wefts appear more variegated than tar covered and are thus reminiscent of Fabric #2.

*Related textiles:* Yarn #1 may share its smooth character with textiles 2003-Tx-8 and 2003-Tx-9. Fabric #1 shares appearance and composition with textiles 2003-Tx-1 and 2003-Tx-2. Fabric #2 is linked to Fabric #1 by the presence of indigo and to Fabric #3 and Fabric #4 by the structure and technology of their weft yarns.



Text Figure 12. The FTIR spectra of the dark tiger-stripe components of Fabric #2, 2003-Tx-11 (bottom), compared with those of indigo (center) and of the gum resin, myrrh (top).

*References:* The “union” fabrics, Fabric #3 and Fabric #4, seem to match Ellis’s “Fabric F,” which he describes as having a Z single yarn weft and a 2 Z single S-plied warp yarn of unrelated origin. He suggests that the plied yarn is “vegetable” and that the single is “animal.”<sup>48</sup> His plate 100D shows a starting border, which can provide a tape-like edge or selvage to anchor and space individual warps. This would place the plied yarns as warps and the Z single as weft. If the fibers were respectively bast and wool or mohair, such a choice would be sensible, since the bast fiber would be stronger and capable of sustaining greater tension, as warps must necessarily do.<sup>49</sup> However, the identification of the fibers for Fabric #3 and Fabric #4 remains problematic at this time, due to their degraded character. Ellis noted areas on his samples where the Z single yarn was purple or dark red. This was not seen on Fabrics #3 or #4. He also found areas where the plied yarn was black and somewhat melted in appearance. These dark yarns should not be confused with those described above as Yarn #2 (Plates 158B–D). They would seem to be consistent with the staining seen in Fabric #1.

### Conclusions

The initial purpose of this project was to characterize and identify the fibers and fabrics physically associated with the wooden furniture in Tumulus MM. By achieving a better understanding of the textiles related to the furniture, the role of upholstery or cushioning might also be explored. As the examination of the fragments got underway, the complexity of the extant material became apparent, as did the sophistication of the textile workers of Gordion. The following concluding remarks summarize the samples according to category.

#### *Textiles from the Tumulus MM Coffin*

*2003-Tx-1 and 2003-Tx-2, back:* gold-colored balanced plain weave (tabby).

What appeared to be a straightforward tabby or balanced plain weave from the coffin (2003-Tx-1) is actually mineralized fabric. It is difficult to find any organic material present, except for some adventitious post-excavation surface fungal and bacterial residue. Only with serious searching into the least disturbed fibers could birefrin-

<sup>48</sup> Ellis, “Textile Remains,” 304, plate 100E.

<sup>49</sup> *Ibid.*, 298–299, 304.

Table 12. Weight percentage of inorganic elements present in a single bicomponent yarn, 2003-Tx-11, Fabric #2, as analyzed by SEM-EDS.

Element	Sample 1	Sample 2	Sample 3	Average <sup>50</sup>
Magnesium	1.28 %	1.51 %	1.91 %	1.57 %
Aluminum	1.61	1.33	1.33	1.42
Silicon	3.85	3.15	3.08	3.36
Phosphorus	4.97	5.82	5.83	5.54
Sulfur	1.28	1.37	1.39	1.35
Chlorine	0.60	0.54	0.43	0.52
Potassium	0.87	0.96	0.84	0.89
Calcium	6.98	7.65	7.28	7.30
Iron	64.32	61.82	63.72	63.29
Copper	14.23	15.84	14.20	14.76

gence be found to suggest the anisotropic behavior of flax. Yet, technically, this positive mineralized cast of a fiber does not conform to the image of a "pseudomorph" since the metal is iron, rather than copper. Iron is reputed to produce negative casts and destruction to the preservation of the textile shape.<sup>51</sup> Corroded textile residues might be expected due to the proximity to the iron bars and other reinforcements on the coffin. However, analyses of the extant textiles more closely conform to the results of an intentional coating, which appears to be goethite.<sup>52</sup> Iron oxide hydroxide is also present on the back of another fragment associated with the coffin (2003-Tx-2) and others found behind serving stand A (2003-Tx-11). Were these "gold" textiles a source for the legend of King Midas's "golden touch"?

2003-Tx-2, front; 2003-Tx-3; and 2003-Tx-5: "mattress."

The issue of felt, matting, or "mattress" material remains perplexing. Whatever the fabric or fabrics once were, 2003-Tx-2, front; 2003-Tx-3; and 2003-Tx-5 have degraded into laminar, chunk-like entities that have only a tenuous connection to a felt or its lofted opposite, a bat-

ting. Bellinger and Ellis recognized the strong cultural and historic connection of felted materials, made of sheep's wool or of goat's wool (mohair), to the geographical area.<sup>53</sup> Yet in the extant fragments there appears to be no organic material remaining in a cohesive and identifiable condition. Optical microscopy cannot identify anything so completely degraded; FTIR is often ambiguous about proteins. Even amino acid analysis with High-Performance Liquid Chromatography (HPLC) cannot provide a definitive association with particular amino acids because of the absence of coherent organic residues.<sup>54</sup> The remnant strata suggest that, for the most part, the fibers were not mineralized, negatively or positively, since the space and volume the fibers originally occupied have shrunk to thin, flat layers.

These layers now appear to be composed of colorants, organic or inorganic. These compounds may be the actual residue original to the unknown textile-like materials as they lay in place in the tumulus. That is, these layers might indicate additional intentional colored coatings on fabrics. Throughout the tomb, other proteinaceous materials without a colored, mineral content have disappeared entirely: the flesh and hair of the king himself are gone, and only his

<sup>50</sup> Elements with quantities less than 1% by weight are not always listed. Consequently weight percentage may not total 100%.

<sup>51</sup> Gillard and Hardman, "Investigation of Fiber Mineralization Using Fourier Transform Infrared Microscopy," 180-181. See Blanchette and Simpson, "Soft Rot and Wood Pseudomorphs in an Ancient Coffin," for pseudomorphs of iron corrosion products that replicated wood cells from the Tumulus MM coffin.

<sup>52</sup> Kuhn, "Adsorption at the Liquid/Solid Interface: Metal Oxide Coated Textiles," 283.

<sup>53</sup> See also Gervers and Gervers, "Felt-making Crafts-

men of the Anatolian and Iranian Plateaux"; Steinkeller, "Mattresses and Felt in Early Mesopotamia." This reasoning is reinforced by economic pragmatism: the internal stuffing matter of cushioning tends to be low cost and ubiquitous—in western Europe and North America, horsehair was widely used as an upholstery stuffing.

<sup>54</sup> Personal communication, Dr. Amandine Péquignot, Musée National d'Histoire Naturelle, Paris. Dr. Péquignot prepared a sample of the red verso of 2003-Tx-2 and conducted amino acid analysis by High-Performance Liquid Chromatography (HPLC) at MCI. See Ballard, MCI Report #5277, Smithsonian Institution.



highly mineral (calcium) bones remained. Like the bones, the possibly inorganic colored compounds may be acting as circumstantial evidence that substantial protein fibers and fabrics once existed. The exact mechanisms of microbial decomposition lie outside the purview of the current discussion, but the extant material is consistent with microbial degradation.<sup>55</sup>

2003-Tx-3, 2003-Tx-4, and 2003-Tx-5: twined textiles.

Twined textiles were not previously recognized among the residues from Tumulus MM. Two twined textiles, from samples 2003-Tx-4 and 2003-Tx-5, are difficult to characterize by yarn and twist, due to the presence of debris, mineralization, or other degradation. Yet, in a fiber taken from 2003-Tx-5, traces of the birefringence typical of flax fiber were discovered. Within 2003-Tx-3, also associated with the coffin, a small area has the darker yarns and oblique angles observed with the other group of twined fabrics, found in the northeast corner of the tomb chamber (see below).

#### *Textiles from the Northeast Corner of the Tomb Chamber*

2003-Tx-6: "blanketing."

This sample ("blanketing") closely resembles 2003-Tx-2, front; 2003-Tx-3; and 2003-Tx-5 from the coffin, discussed above. It was described by the excavators as "blanketing" on "stool #2." About this sample, it is possible to gather some information, which can then be applied to the comparable material from the coffin. Distinct layers confer the possibility of successive homogeneous materials, multiple upholstery materials with different (mineral) compositions, as seen along the rims of textile fragment 2003-Tx-6. The aperture where no yarn now exists, seen in CD-Figure 28 (textile fragment 2003-Tx-6), and the large yarn seen in CD-Figure 12 (textile fragment 2003-Tx-3) share a common diameter and provide plausible evidence for the use of the heavy (400–700 gram) loom weights excavated at the city mound.<sup>56</sup> In order for non-woven felt to support the weight of a human body without sagging or splitting apart, it would be prudent

to strengthen it with a network of strong interlaced yarns—a coarse woven underlayer and perhaps successive interlayers. These might correlate to the spun fabric that Bellinger described; she also saw the multiple colors as an indication of multiple layers and intentional patterning of the "felt."<sup>57</sup>

Distinct from these woven and non-woven interlayers are the S-twisted cords that lay beneath the "felts" of 2003-Tx-6, visible now largely as impressions imbedded in the textile sample (seen in Plate 155B). The small fragment shows only vertical cords, but they would likely have been locked with perpendicular cording, perhaps to form some kind of knotted netting, in order to support weight and distribute it. And clearly the cording did hold its place unplayed, since the cords are still aligned. These cords were originally a material unrelated to the fiber of the "felts," for they have not undergone drastic flattening or dissolution. This cording is thought to have formed the seat of "stool #2" (see above, pp. 114, 211–213).

2003-Tx-6, 2003-Tx-7, 2003-Tx-8, and 2003-Tx-9: twined textiles.

Most of the extant twined textiles (fragments 2003-Tx-6, 2003-Tx-7, 2003-Tx-8, and 2003-Tx-9) seem to share a similar fiber, yarn, coloration, and spacing. The fiber for both warp and weft seems to be dark, and the yarns have a low, almost imperceptible twist. Twist is necessary with short fibers ("staple") in order to connect them and to form a continuous yarn; more twists increase yarn cohesiveness and strength. Long continuous fibers, called "monofilaments," are actually weakened by twisting. Consequently, monofilaments like silk often have little twist, just enough to keep them bundled as yarn units. The yarns of the twined textiles from Tumulus MM appear to share this property. In addition to silk from the *Bombyx mori* moth, originally native to the Far East, true silk-like monofilaments are extruded by other moths and insects. Characteristics of silk are exhibited by other materials, from sinew to byssus.<sup>58</sup>

One alternative, "sea-silk" or byssus, is reported to have been favored as an Assyrian lux-

<sup>55</sup> For an interesting discussion of the complexity of microbial activity, see Filley, Blanchette, Simpson, and Fogel, "Nitrogen Cycling."

<sup>56</sup> Burke, "Textile Production at Gordion and the Phrygian Economy," 75–78. However, heavy loom weights can

also be used for fine yarns, according to Hoffman, *Warp-Weighted Loom*, 20–22.

<sup>57</sup> Bellinger, "Textiles from Gordion," 13.

<sup>58</sup> R. Forbes, *Studies in Ancient Technology* 4, 50–58.

ury good.<sup>59</sup> Byssus is the anchoring fiber produced by molluscs, notably the *Pinna nobilis* Linné and can be harvested.<sup>60</sup> Modern samples of byssus may reach 3 inches (8 cm) in length,<sup>61</sup> but this is not as long as flax fiber or many wools can be. All of these fibers require a substantial number of spinning twists for strength. Other alternatives are Coan silk from the *Pachypasa otus* Drury, a large moth native to the central and eastern Mediterranean,<sup>62</sup> or *Saturnia pyri*, the source of a strong and glossy dark brown silk.<sup>63</sup> One interesting aspect of *Bombyx mori* silk is its inherent resistance to microbial degradation;<sup>64</sup> perhaps these other more likely sources of the twined yarns share silk's measure of bacterial immunity.

All of the twined textiles appear to be very regular and fine. The yarns are thin, and the row spacings are narrow, as with a sheer, detailed netting. It should be noted that even monochromatic twined structures can be altered to produce designs and patterns. This kind of alteration may have been a feature of the Gordion textiles, and might account for the difficulty in deducing the weave structure and its technological origins. There are two contexts for these twined weavings. Fragments 2003-Tx-3, 2003-Tx-4, and 2003-Tx-5 are associated with the reddish-purplish material of the coffin. For the rest, textiles 2003-Tx-6, 2003-Tx-7, 2003-Tx-8, and 2003-Tx-9 were found in the northeast corner of the tomb and are most often layered with a white powder, not yet identified. For fragment 2003-Tx-3, there is, amidst the reddish-purplish fragments associated with the coffin, a small area in which the dark yarns are set vertically at oblique angles, with a white powder layer disposed in a laminar manner (see Table 4 above). The twined textiles appear to have a specific context, or designated use, that unites them, even in their pattern of degradation, and despite their different locations in the tomb. From our modern perspective, we might imagine twined textiles used for the decoration of pillows or for open-weave lined hangings; the

twined weavings might also have been used as storage containers for light-weight valuables, food or feathers, which now survive as the degraded white powder. The excavators' theory that there was a "bag" on "stool #2" in the northeast corner may point to these twined textiles.

*Plain Weaves from the Northeast Corner and Floor behind Serving Stand A*

2003-Tx-8, back; 2003-Tx-9, back; 2003-Tx-10; and 2003-Tx-11: balanced, faced, bicomponent, and union plain weaves.

The bicomponent tabby weave found behind serving stand A (2003-Tx-11, Fabric #2) shows an inventive method of incorporating indigo within a fabric. It may have been carried out using an active and passive yarn-plying technology, as suggested by another tan textile fragment (2003-Tx-8, back). Flax (or ramie) fiber from the bast fiber group was positively identified as the basis of the "pieces of fine material lifted from fibulae" on "stool #2" in the northeast corner (2003-Tx-10), but this fabric lacks congruency in yarn character and weave count with the other plain-weave fabrics. It may be that this fabric (2003-Tx-10) was imported or anomalous for some other reason. Coarser fabrics may have been considered more suitable for the application of a metallic coating—or for bedding.

As the study of the Gordion textiles is an ongoing project, the findings presented here may be augmented in the future. Some of the problems relating to the fiber and fabric construction have been resolved, yet others remain enigmatic, including the precise relationship of some of the fabrics to the wooden furniture. Separating the accidental synergy of various degradation processes from intentional workmanship remains a challenge. However, it is clear that the fabrics, like the furniture, show a high level of technological achievement, skill, inventiveness, and sophistication.

<sup>59</sup> Dalley, "Ancient Assyrian Textiles and the Origins of Carpet Design," 121-123.

<sup>60</sup> See Montegut, "Moth or Mollusc? A Technical Examination of Byssus Fibers."

<sup>61</sup> Author's measurement, National Museum of Natural

History, Smithsonian Institution.

<sup>62</sup> See Handschin, "Wild Silk Moths."

<sup>63</sup> See W. Forbes, "Silkworm of Aristotle."

<sup>64</sup> See Seves, et al., "Microbial Degradation of Silk."