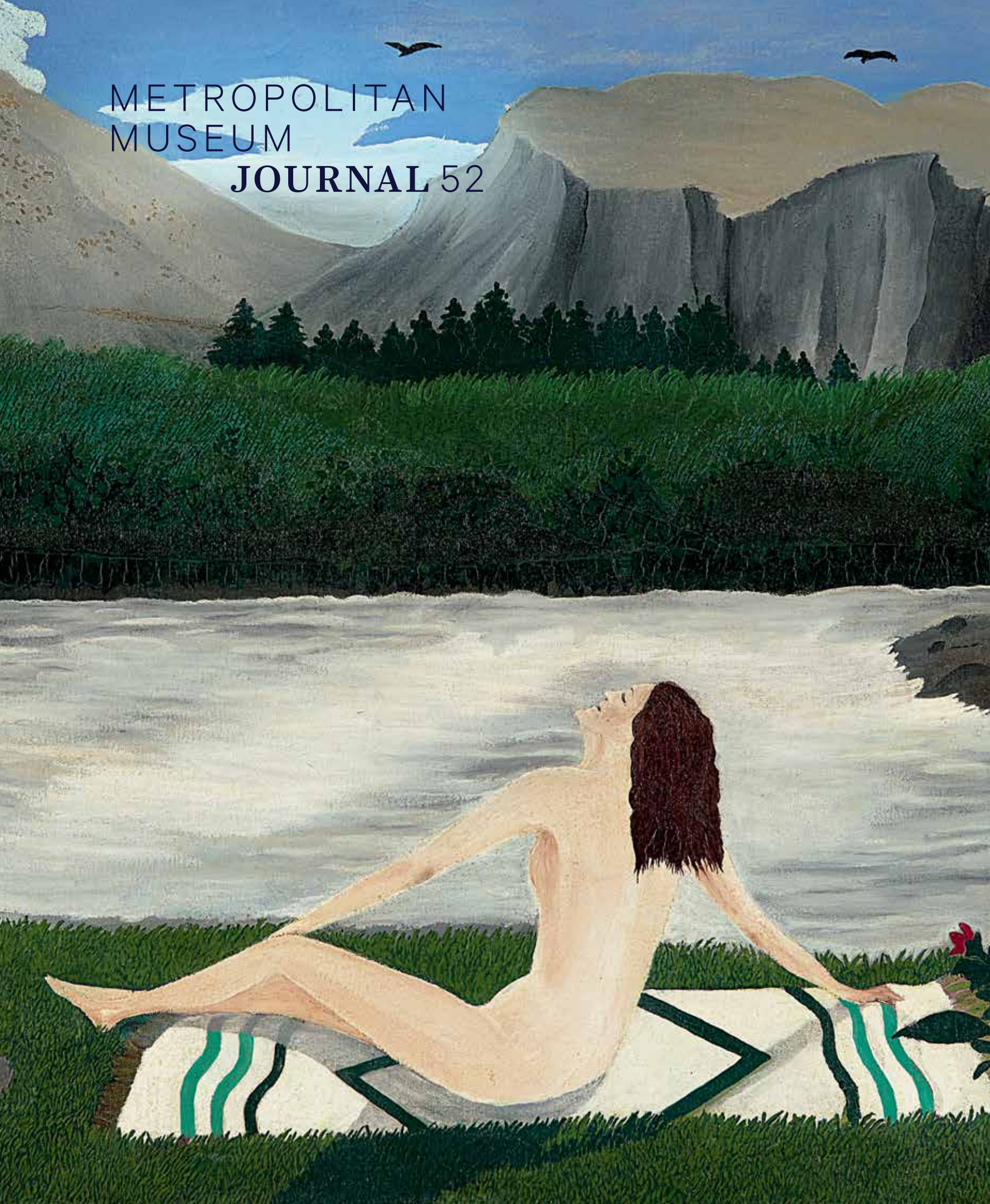

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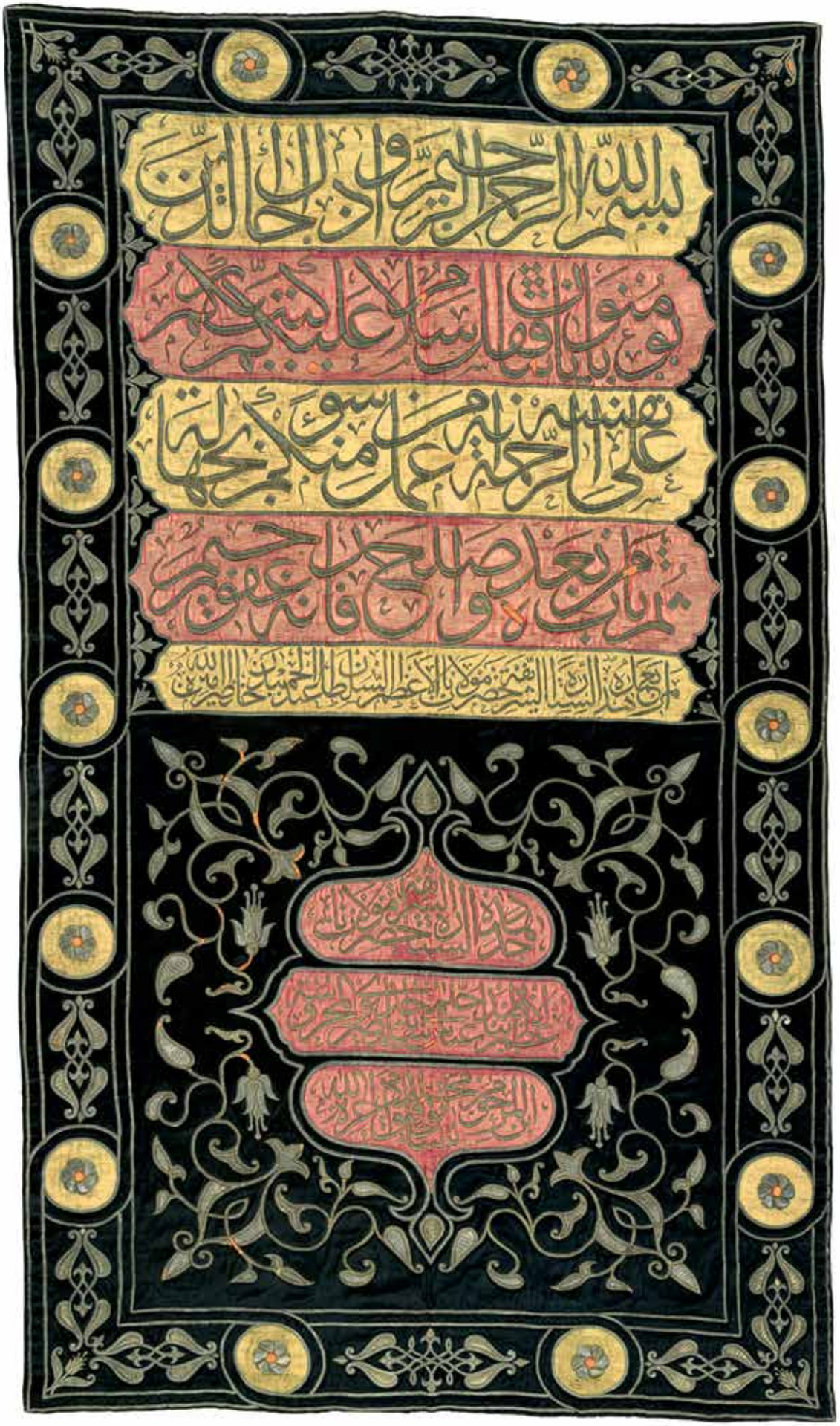

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The Sacred and the Modern: The History, Conservation, and Science of the Madina *Sitara*

This article examines the history and conservation and offers a scientific analysis of a *sitara* given to The Metropolitan Museum of Art in 2009. This *sitara*, one of only a small number known from published sources, is a late nineteenth-century Ottoman curtain that hung on the Bab al-Tawba (Door of Repentance) inside the Ka'ba in Mecca. Historical analysis situates this rare object within a centuries-old tradition of textile production for the most sacred sites in Islam. Examination of the yarns, dyes, weaving and embroidery techniques, metal wire thread, and other materials and processes that went into the production of this sacred and symbolic curtain presents it in the context of its manufacture in the globalized world of the late nineteenth century.

fig. 1 *Sitara*. Produced in the Warshat al-Khurunfish, Cairo, A.H. 1315/1897–98. Black silk, pink and green silk/cotton, white cotton lining; silver and silver-gilt metal wire thread, orange and white silk thread, orange and white linen thread; silver sequins; 110⅝ × 63 in. (281 × 160 cm). The Metropolitan Museum of Art, Gift of Professor Maan Z. Madina, in memory of his mother, Najiyya Khanum al-Kurdi, 2009 (2009.59.1)

HISTORY

Textiles produced for the Ka'ba in Mecca, Islam's holiest site, represent the most sacred and iconic objects in

Islamic art. In 2009, Maan Z. Madina, professor emeritus in the Department of Middle Eastern, South Asian, and African Studies at Columbia University, New York, gave the Metropolitan Museum one of these, an interior curtain (*sitara*) that hung on the Bab al-Tawba (fig. 1).[1]

While the textiles that draped the exterior of the Ka'ba are well represented in museums and private collections,[2] Bab al-Tawba *sitara*s have generally been less known to the larger community of art historians, having appeared in public or private art collections only recently. The production of sacred textiles for the Ka'ba has a long history that dates back to the earliest years of Islam, and the custom of draping the exterior walls and interior spaces with these textiles is well established in the historical record. Responsibility for commissioning the Ka'ba textiles and transporting them to Mecca generally fell to the ruler who held sovereignty over the holy cities. The Ottoman sultans were the longest serving of these rulers, having conquered Egypt, Mecca, and Medina in 1517. As rulers of Mecca and Medina, they thus acquired the title *Khadim al-Haramayn al-Sharifayn* (Custodian of the Two Noble Sanctuaries) and in this capacity held the privilege of ordering replacement of these textiles, an honor that continued until the end of the Ottoman dynasty in 1923. Throughout these centuries, the covering that draped the exterior walls of the Ka'ba (*kiswa*), the belt around the Ka'ba embroidered with Qur'anic inscriptions (*hizam*), and the curtain covering the door into the Ka'ba (*burqu'*) were seen by millions of pilgrims who performed the hajj.[3] Textiles hanging inside the Ka'ba, however, were seen only by the few dignitaries and special guests who were privileged to enter, or pilgrims who were present when the doors were opened for prayer. The Bab al-Tawba is the door to the stairway up to a mezzanine where the Prophet Muhammad is believed to have ordered the destruction of pagan idols as a ritual of repentance. This site later became a repository for

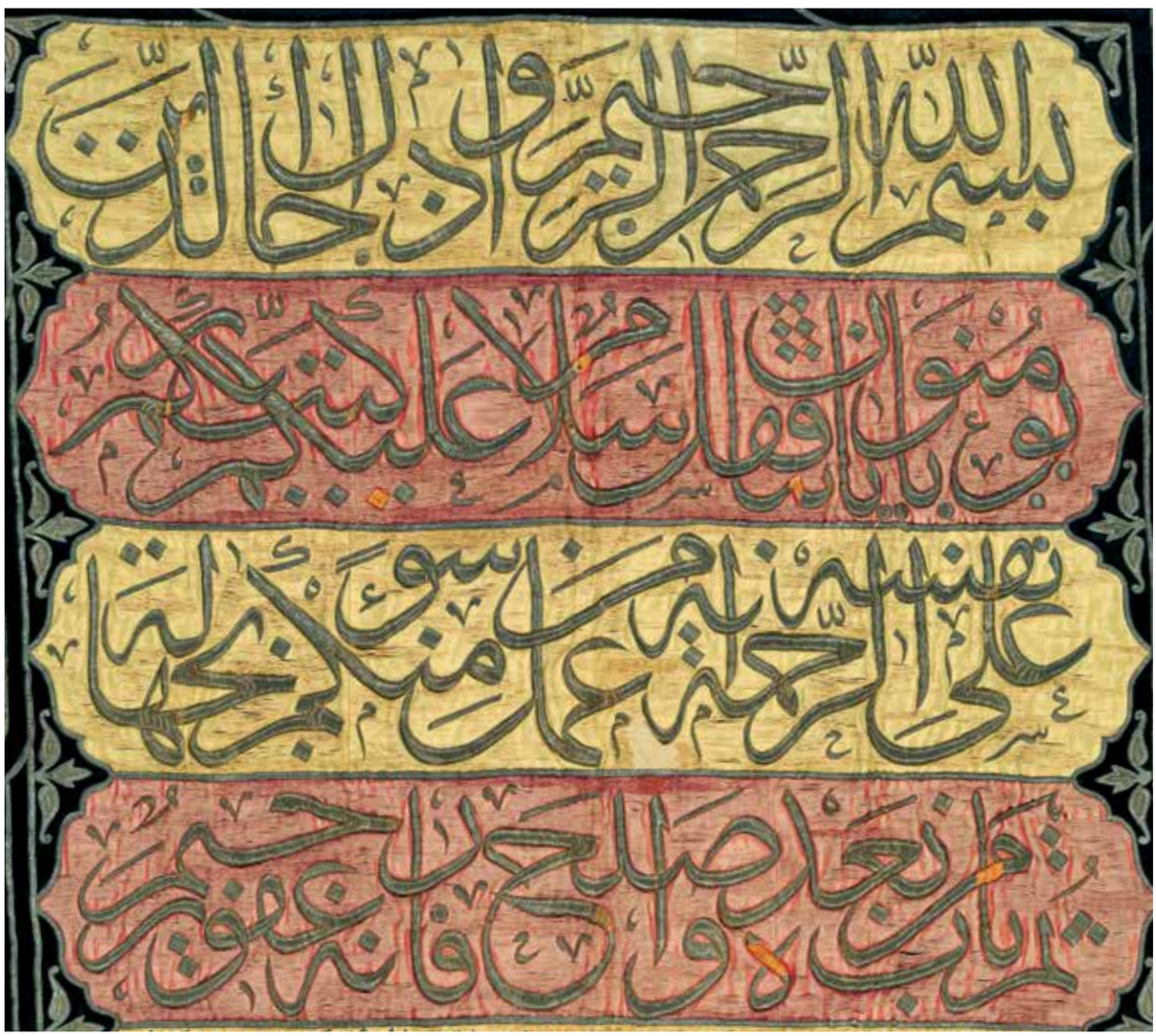


fig. 2 The four uppermost cartouches of the *sitara* in fig. 1 embroidered with the *basmala* and with Qur'anic *Ayat* 54 of *Sura* VI

fig. 3 The cartouche beneath the four cartouches in fig. 2, embroidered with the name of Sultan ʻAbd al-Hamid II, who had the imperial prerogative of ordering the replacement of textiles for the Kaʻba

precious gifts sent to the Kaʻba by Muslim rulers from around the world. The Bab al-Tawba *sitara*s are much less well known in the long historical record of coverings for the Kaʻba, and their production is perhaps of more recent origin. Although the British explorer Richard Burton, visiting the Kaʻba in 1853, chronicled in detail the exterior coverings, his account of the interior described the Bab al-Tawba without a curtain.[4] The earliest extant curtain known from published sources dates to 1893.[5] More examples are likely to appear in the future, but their rarity may be due to the fact that they were more private, the personal offerings of rulers who wished to receive the *baraka* (blessing) associated with this sacred space. They were also protected from the elements so they did not need to be replaced as frequently as the outer coverings, which were traditionally made anew yearly and transported to Mecca at the time of the hajj.

The Bab al-Tawba *sitara*s that are known from published sources (see note 5) and the Madina *sitara* are of the same basic design and have the same Qur'anic verse, *Ayat* 54 of *Sura* VI (*al-Anʻam*), embroidered on them. A variation occurs in only one of them, which is discussed below. In all of the examples, however, the fabric creates the structure that frames the textual message, making that message cohesive and coherent, one that calls to memory the underlying tenet of Islam. That tenet bids Muslims to remember the judgment day and reminds them of God's mercy for the repentant sinner, as well as proclaiming the authority and sovereignty of the rulers who commissioned and oversaw the production and transportation of the textiles. The primary decorative element is Arabic calligraphy in the *jali thuluth* script.[6] The top four cartouches of the Madina *sitara* (fig. 2) begin with an embroidered inscription of the *basmala* (In the name of God, the Most Gracious, the Most Merciful), an invocation focusing the believer on the glory and majesty of Allah. The inscription continues with the Qur'anic *Ayat* 54 of *Sura* VI (*al-Anʻam*):

بسم الله الرحمن الرحيم وَإِذَا جَاءَكَ الَّذِينَ
يُؤْمِنُونَ بِآيَاتِنَا فَقُلْ سَلَامٌ عَلَيْكُمْ كَتَبَ رَبُّكُمْ
عَلَىٰ نَفْسِهِ الرَّحْمَةَ أَنَّهُ مَنْ عَمِلَ مِنْكُمْ سُوءًا بِجَهَالَةٍ
ثُمَّ تَابَ مِنْ بَعْدِهِ وَأَصْلَحَ فَأَنَّهُ غَفُورٌ رَحِيمٌ

When those come to thee who believe in Our signs, Say: "Peace be on you: Your Lord hath inscribed for Himself (the rule of) Mercy: verily, if any of you did evil in ignorance, and thereafter repented, and amended (his conduct), lo! He is Oft-forgiving, Most Merciful."[7]

The connection between this verse and the Door of Repentance is clear: God will grant forgiveness and mercy to those believers who commit sins but repent with humility and without arrogance.

The fifth cartouche (fig. 3) contains an inscription naming Ottoman sultan ʻAbd al-Hamid II (r. 1876–1909) as the ruler who held imperial prerogative and sovereignty over the holy cities of Mecca and Medina and who thus had the honor of ordering the replacement of the *sitara*:

امر بعمل هذه السارة الشريفة حضرت مولانا الاعظم السلطان عبد الحميد خان نصره
الله امين

Our great Master, Sultan ʻAbd al-Hamid Khan, ordered the work of this noble curtain; God grant victory to him. Amen.

The inscription was a form of memorialization that symbolized the ruler's religious and political authority.[8]

The inscription in the lower three cartouches (fig. 4) designated ʻAbbas Hilmi Pasha, governor, or khedive, of Egypt from 1892 to 1914, with the honor of overseeing the production and transportation of the *sitara* and asked for God's victory or glory, a tradition thought to bring blessings and good omens.

جدد مذه الستارة الشريفة حضرت مولانا
الاعظم افندينا عباس حلمي باشا خديوي مصر المحروسة
ابن المرحوم محمد توفيق باشا ادام الله عزه

Our great Master, our Effendi, ʻAbbas Hilmi Pasha, Khedive of Egypt, the [divinely] protected, son of the late Muhammad Tawfiq Pasha, renewed this noble curtain; Lord make glory permanent with him.

The reign of this sultan and the rule of his governor overlapped, thereby narrowing the date of manufacture of the Madina *sitara* to the seventeen-year period

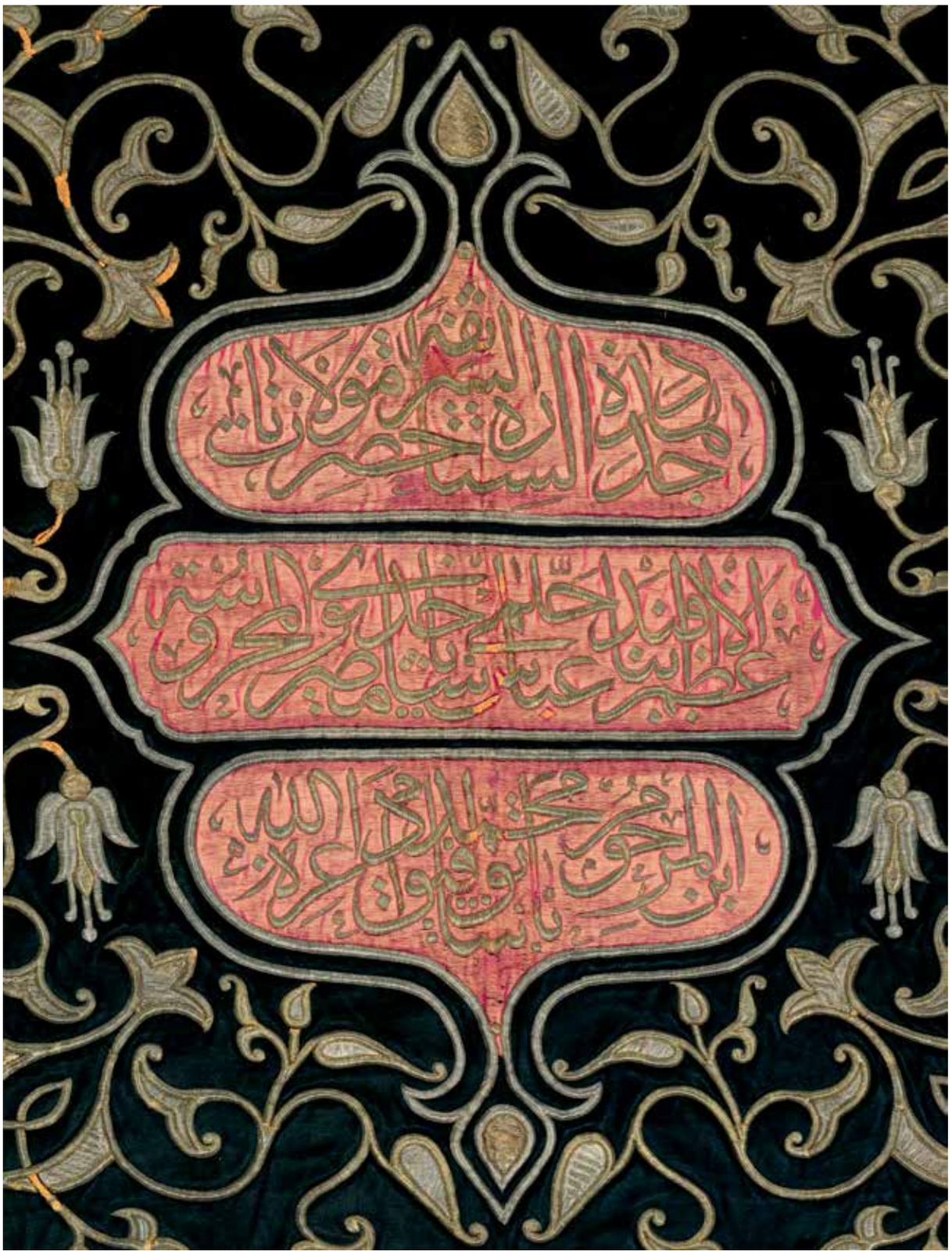


fig. 4 The three cartouches in the lower half of the *sitara* in fig. 1, embroidered with the name ʻAbbas Hilmi Pasha, the governor of Egypt who oversaw production of the textile at the Warshat al-Khurunfish in Cairo and its transportation during the hajj

a

b

fig. 5 Paper at the bottom edge of the *sitara* in fig. 1, inscribed in ink سنة ١٣١٥, identifying the date of production as the year A.H. 1315/1897–98. The paper is shown (a) in place between the black silk background fabric and the white cotton lining, and (b) in an X-radiograph showing the full size of the note, which is held in place with embroidery stitches.

between 1892, when ʻAbbas Hilmi came to power in Egypt, and 1909, the end of ʻAbd al-Hamid's rule as sultan. However, we can suggest a more precise date of production, for during conservation of the *sitara*, a piece of paper was discovered sewn among the layers of the curtain (fig. 5a). The paper is degraded and largely unreadable except for سنة ١٣١٥ (A.H. 1315/1897–98). The inscription on the sitara also honors the Khedive's father, "the late Muhammad Tawfiq Pasha" (d. 1892). ʻAbbas Hilmi Pasha was perhaps mourning his father's recent death and memorializing him in this inscription. But the same dedication appears on the *sitara* in the Topkapı Palace Museum, Istanbul, which is dated A.H. 1325/1907–8, thus late in ʻAbbas Hilmi Pasha's governorship.[9] It seems that his custom of inscribing his late father's name was a practice he followed throughout his time in office, one by which he sought to bring blessings associated with the sacred space to his father. The convention of naming deceased rulers was not ʻAbbas Hilmi Pasha's innovation, for the tradition of such dedications appears as early as the beginning of the eighteenth century on sacred textiles like the tomb covers for the Prophet Ibrahim and for the Prophet Muhammad in Medina. The tradition also appears on other Kaʻba textiles during the period of Sultan Abd al-Hamid II.[10]

Recent scholarship has suggested that the Bab al-Tawba's *sitara*s were replaced only upon the succession of a new sultan.[11] However, a comparative examination of some of the complete *sitara*s made anew during the reign of Sultan ʻAbd al- Hamid II and the governorship of ʻAbbas Hilmi Pasha shows that they were replaced more frequently. In addition to the Madina *sitara*, there is a *sitara* in the Nasser D. Khalili Collection of Islamic Art, dated A.H. 1311/1893–94, and one in the Topkapı Palace Museum, dated A.H. 1325/1907–8, as well as two other *sitara*s recently seen at auction, one that was manufactured between 1892 and 1909, and the other inscribed with the year of A.H. 1321/1903–4.[12] This frequency of renewal suggests that this interior textile was replaced every few years as needed.

The *sitara*s that are alike are composed of a central rectangle containing the cartouches, the lower ones surrounded by floral embroidery. The border around the rectangle contains rosettes interspersed with an arabesque design (see fig. 1). The stylistic and textual exception is the late-Ottoman *sitara* dated A.H. 1321/1903–4 that was auctioned at Sotheby's London in 2007 (fig. 6). It is inscribed with the underlying message of God's forgiveness and mercy in the upper rectangular cartouche embroidered with a portion of Qur'anic *Ayat* 25 of *Sura* XLII (*al-Shura*), "He is the One that accepts repentance from His Servants."[13] The main cartouche contains Qur'anic *Ayat* 255 (Verse of the Throne) of *Sura* II.[14] This verse is one of the Qur'an's most beloved

fig. 6 *Sitara*, dated A.H. [1]321/1903–4. Black and colored silk ground embroidered with silver and silver-gilt wire thread; 94½ × 70⅞ in. (240 × 180 cm). Sold, Sotheby's, London, 2007, lot 42

in its portrayal of God's incomparability and his all-powerfulness. But it does not have the same clear connection that Qur'anic 6:54 has to repentance and the Bab al-Tawba. The Verse of the Throne is, in fact, more often inscribed on the *burqu'* (the curtain for external door of the Ka'ba).[15] The roundels that flank the Verse of the Throne contain the names of the first four *Rashidun* (Rightly Guided) Caliphs, 'Abu Bakr, 'Umar, 'Uthman, and 'Ali, who ruled immediately after the death of Muhammad, as well as 'Ali's two sons and Muhammad's grandsons, Hasan and Husayn, who succeeded to rulership in the Shi'ite tradition. This convention is unique to this particular Bab al-Tawba *sitara*, for while the names of the Prophet Muhammad's grandsons do appear on his tomb covers in Medina, suggesting the close familial connection between Muhammad and his grandsons, their inscription on this *sitara* breaks from the tradition in the small number of known Bab al-Tawba *sitara*s that memorialize only sultans and khedives. In this case, the inclusion of the grandsons of the Prophet would remind the community (and particularly those dignitaries and believers who were privileged to enter the Ka'ba) of the sense of union in the pilgrimage and that in the most sacred sites of Islam unity of the community superseded sectarian Sunni-Shi'i divisions.

The Madina *sitara* and those discussed here were preserved intact, unlike the exterior *kiswa*s. The hangings on the exterior wall of the Ka'ba were commonly cut up and distributed when they were removed, a practice that was based on a hadith (tradition) from the Prophet Muhammad's wife 'A'isha', who said, "Sell those covers and spend the money you earn for the poor and the travelers who are on their way to Allah." Many of the textiles were returned to Istanbul to become holy relics in the imperial treasury, or they were repurposed as wall hangings or tomb covers for Ottoman royalty in their mausolea.[16] That the known Bab al-Tawba *sitara*s were left whole suggests that after their replacement their special baraka necessitated that they be given to dignitaries or followed the path of other textiles into the royal treasury or into use as tomb covers.[17]

The high quality of workmanship in the Madina *sitara* illustrated what was expected in such a sacred textile. In the 1860s, when seeing the Ka'ba textiles, the Ottoman historian Mustafa Naima was awestruck by the "majestic beauty" of the gold and silver embroidery.[18] Yet the Madina *sitara*, even though it hung in an interior space, was also sufficiently robustly made to have withstood long periods on view (see "Conservation, Materials, and Techniques" below). For most of the nineteenth century, textiles for the hajj were manufactured in Cairo at the Warshat al-Khurunfish (Khurunfish Workshop), established by the Ottoman governor Muhammad 'Ali in 1817.[19] This was, in fact, a complex of workshops that brought together European craftsmen and Egyptian trainees, and the machinery necessary for the production and embellishment of textiles. In addition to machinery, the men made tools for ironworking such as anvils and lathes, and added spinning wheels for producing silk thread and looms for weaving silk and cotton fabrics. There were facilities for dyeing, as well as studios for transfer-

fig. 7 Full-size design for a curtain for a door inside the Ka'ba, painted on paper. Nasser D. Khalili Collection of Islamic Art (MSS 1128.8). Areas to be embroidered in gold are colored yellow and those to be embroidered in silver are blue.

fig. 8 Photograph of Hajj Muhammad Hasan Amin Nada, veteran craftsman at the Warshat al-Khurunfish, Cairo, ca. 1900. In his right hand he holds a spool of metal-wire thread; with his left hand, under the panel he is embroidering, he brings the needle up through the fabric and then back down to couch the metal thread. Nasser D. Khalili Collection of Islamic Art

ring patterns to the fabric and for embroidery. In these studios, craftsmen cut, sewed, lined, and tightly stretched the background cloth on tension tables. They then transferred the designs to the cloth by pouncing and finally executed the labor-intensive and skillful embroidery (figs. 7, 8).[20]

Textile workshops throughout the Ottoman Empire, like the Warshat al-Khurunfish, were affected by the influx of European imports and the introduction of modern techniques and materials. The conventional view has long held that the decline of the Ottoman textile industry was a chronic condition that led to massive unemployment and impoverishment over the course of the nineteenth century. During the flood of European products from the 1820s through the 1850s, many Ottoman industries did indeed decline. Even workshops like the Warshat al-Khurunfish, with its highly specialized production of sacred textiles, retrenched during this period. About 1880, 'Ali Pasha Mubarak, an Ottoman-Egyptian reformer and modernizer, wrote that although the workshop was still functioning it had fallen into disrepair and was making only the *kiswa*.[21] The Warshat al-Khurunfish, however, withstood these challenges, was restructured, recovered, and, like other textile industries, managed to regain its position by the late nineteenth century. Success depended on a number of factors including the adaptation of textile workshops to new materials and technologies coming from Europe.[22] Not all materials were necessarily imported from Europe, however, for although artificial dyes were developed in England and Germany in the 1850s and 1860s, they did not displace the Ottoman dyestuff industry. That industry transformed from a labor-intensive operation, dependent on gathering and preparing vegetable dyes and subject to the vagaries of

nature, to a less expensive mechanized industry with dyes that were reliably produced and easier to apply. By the 1870s, the Ottomans were importing synthetic dyestuffs, but by the end of the nineteenth century they were also producing high-quality alizarin and cheaper but photosensitive aniline dyes, though they were not as fast as European dyes (see "Analysis of Metal Wires and Dyes" below).[23]

Although the history of producing silver and silver-gilt metal wire thread used for embroidering these sacred textiles is well documented from as early as 1540 in Bursa through the mid-eighteenth century in Istanbul, the status of the wire industry in the nineteenth century is not well known.[24] Archival documents from the Warshat al-Khurunfish, however, show that this facility had the capacity to draw and gild the silver wire they used in the embroidery process.[25] Other important industries throughout the nineteenth century included reeling silk and weaving cloth, with workshops employing more than 400,000 people throughout the Ottoman Empire. Silk products from Ottoman factories were particularly desirable after French and Italian cocoons were devastated by the silkworm disease epidemic in 1853. Bursa's silk industry, for example, remained competitive as a result of the establishment of steam-powered spinning mills in the 1840s and 1850s.[26] The disease eventually affected the Ottoman silk industry as well, and led European manufacturers to look for markets in East Asia after the opening of the Suez Canal in 1869, though the Ottoman silk industry recovered after the disease was brought under control. From 1880 onward the Ottomans more easily adapted to the demands of the world economy and the silk industry expanded with new mills opening in Bursa, Edirne, and Lebanon.

The Warshat al-Khurunfish was part of this late nineteenth-century expansion, with its capacity for spinning, dyeing, and weaving, including special looms for weaving silk cloth.[27] Over the course of the nineteenth century, this process of expansion was uneven, but ultimately workshops such as the Warshat al-Khurunfish were able to continue a long-standing tradition of sacred textile production within the late-Ottoman globalized world.

KMK

CONSERVATION, MATERIALS, AND TECHNIQUES

The Madina *sitara* is a black silk curtain appliquéd with pink and green silk/cotton cartouches that contain Arabic calligraphy (see figs. 1–4). It is further embellished throughout with arabesques and scrolling vines. Text, arabesques, and scrolling vines are embroidered in silver and silver-gilt metal wire thread (see fig. 9a). Sequins adorn the centers of the large rosettes around the border of the *sitara* (fig. 10). The metal-thread embroidery was executed skillfully and meticulously over padding to create a raised effect that was achieved by laying down layers of linen thread over which metal wire was applied by couching. Beneath the areas embroidered with silver-gilt wire thread, orange-colored linen padding thread was used; for the silver areas, white linen padding thread was used. Padding

a b

fig. 9 Photomicrography (10x) of a detail of the obverse and reverse of the *sitara* in fig. 1. The obverse (a) shows embroidery with silver-gilt wire thread couched with orange silk thread in the middle, and with silver wire thread couched with white silk thread above and below. The reverse (b) shows the double back stitch in orange silk threads supporting the silver-gilt wire embroidery and in white silk threads supporting the silver.

fig. 10 Sequins that border the centers of the rosettes in the border of the *sitara* in fig. 1

threads are clearly visible on the front of the *sitara* in areas where there is loss of metal thread. On the reverse of the embroidery, there is visual evidence that the bundles of padding threads were carried over from one motif to the next, a clear footprint of the original workmanship (see fig. 11). This also indicates that the padding threads penetrated the ground fabric from obverse to reverse and vice versa. In contrast, the metal wire was simply couched to the surface of the background fabric, not carried to the back where it would be unseen and thus wasted. Precious-metal wire was costly and by this method a significantly smaller amount of it was used. Metal embroidery was often raised this way because it better reflects light, adding a vibrant shimmer to the surface of the panel. This would have been even more dramatic and opulent when the *sitara* was first produced, at the end of the nineteenth century, before oxidation and corrosion marred the original sheen of the wire.

The metal thread was couched with silk thread, orange for the silver-gilt wire and white for the silver wire.[28] On the back, the couching appears in herringbone stitch, but on the front the metal thread is held in place at the edges of the motif with double back stitches (fig. 9a).[29] This stitch was used because of its strength and stability, as seen on the reverse where interlacing silk threads support the metal wires (fig. 9b).

The *sitara*, which weighs about 25 pounds, is composed of four layers of fabric (described here from the front toward the back), needed to support the heavy metal wire. The embroidery was executed through the black silk background fabric and a layer of white cotton muslin. The next layer is an additional lining of white cotton fabric coated with white pigment on the outer side, attached to the back with webbing around the edges. The final layer, the back of the *sitara*, is a green fabric, a color that was traditionally used to line *sitara*s. That this same fabric was also used for the green cartouches confirms that the green lining is original to the Madina *sitara*, not a later addition. The curtain was designed to be hung on the Bab al-Tawba inside the Kaʿba by five loops: three along the top and two at the bottom corners.

When acquired by the Metropolitan Museum in 2009, the *sitara* was in fragile condition, which has prevented its display. Though it was strong structurally because of its multilayered composition, its decoration, both the metal-thread embroidery and the appliquéd cartouches, was damaged and weakened, requiring considerable conservation. Textiles made of precious silk fabric with valuable metal-thread embroidery were usually made for religious purposes and for royalty and have therefore been better preserved. Nevertheless

fig. 11 Detail of the reverse of the *sitara* in fig. 1 illustrating the way the orange padding threads, in the middle of the photograph, are carried from one motif to another

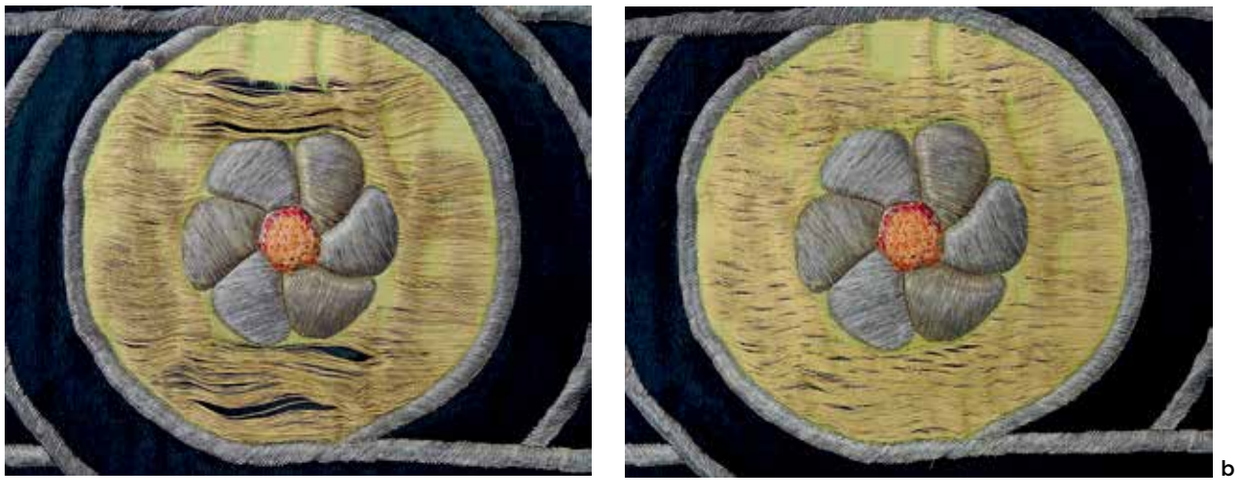


fig. 12 A rosette in the border of the *sitara* in fig. 1 before conservation (a) and after conservation (b)

such textiles often endured stresses related to their composition and use: metals corrode and can accelerate the aging process of textiles, and the sharp edges of metal wire can damage delicate silk fabric. As for the use of *sitara*s and the other hajj textiles, their considerable significance and status meant that they would have been preserved. However, little is known about the provenance of this *sitara* before it was acquired by Professor Maan Z. Madina in 1988 (see note 1) to explain the damage it incurred.

The most obvious deteriorated areas on the *sitara* are the pink and green fabrics of the appliquéd cartouches and rosettes. These fabrics are composed of thin silk warps and thicker cotton wefts, woven in a warp-faced satin weave.[30] Large areas display loss of warps, leaving behind long weft floats. These fabrics are also extremely faded, as demonstrated by areas uncovered during conservation that had not been exposed to light and thus retained some of their vibrant color.

fig. 13 Standish Mayflower Bleach stamp on the pigment-coated cotton lining of the *sitara* in fig. 1

Treating these fabrics, a priority, involved stabilizing the weft thread floats using conservation couching stitches (fig. 12a, b).[31] The types of dyes on the cartouche fabrics, discussed in "Analysis of Metal Wires and Dyes" below, will help interpret the origin of these fabrics and contribute to our understanding of their deteriorated condition.

The initial stage of the conservation treatment was to separate the layers of fabric making up the *sitara*. The white cotton lining covered in white pigment features a round blue trademark stamp reading "Standish Mayflower Bleach" (see fig. 13). Standish, a town in Lancashire, northwest England, was home to Standish Bleach Works, an industrial mill complex that operated from 1886 until 1998.[32] The presence of this stamp reinforces the date the *sitara* was produced, 1897–98, and the fact that the Cairo workshop imported this lining for the *sitara* from England, illustrating an example of trade relations between the Cairo workshop and England in the late nineteenth century.

During the close inspection and treatment of an object, exciting and unexpected discoveries are often made. Such was the case when a piece of paper annotated in ink, described in "History" above, was found attached to the bottom edge of the *sitara* between the black silk background fabric and its muslin lining (fig. 5a). One area of the note, on which is written سنة ١٣١٥ (A.H. 1315/1897–98), was exposed, analyzed, and conserved; the rest of the paper is inaccessible and may contain more writing. An X-radiograph of the area shows a shadow of the full note and its location (fig. 5b).[33] Unfortunately this technique did not show writing, probably because the ink used was carbon based rather than metal based, the latter more likely to be visible using X-ray.[34] Reflected infrared photography was experimented with in an attempt to read the concealed

inscription, but that, too, was unsuccessful.[35] Transmitted visible light infrared photography, which has shown some positive results, may prove successful.[36]

YR

ANALYSIS OF METAL WIRES AND DYES

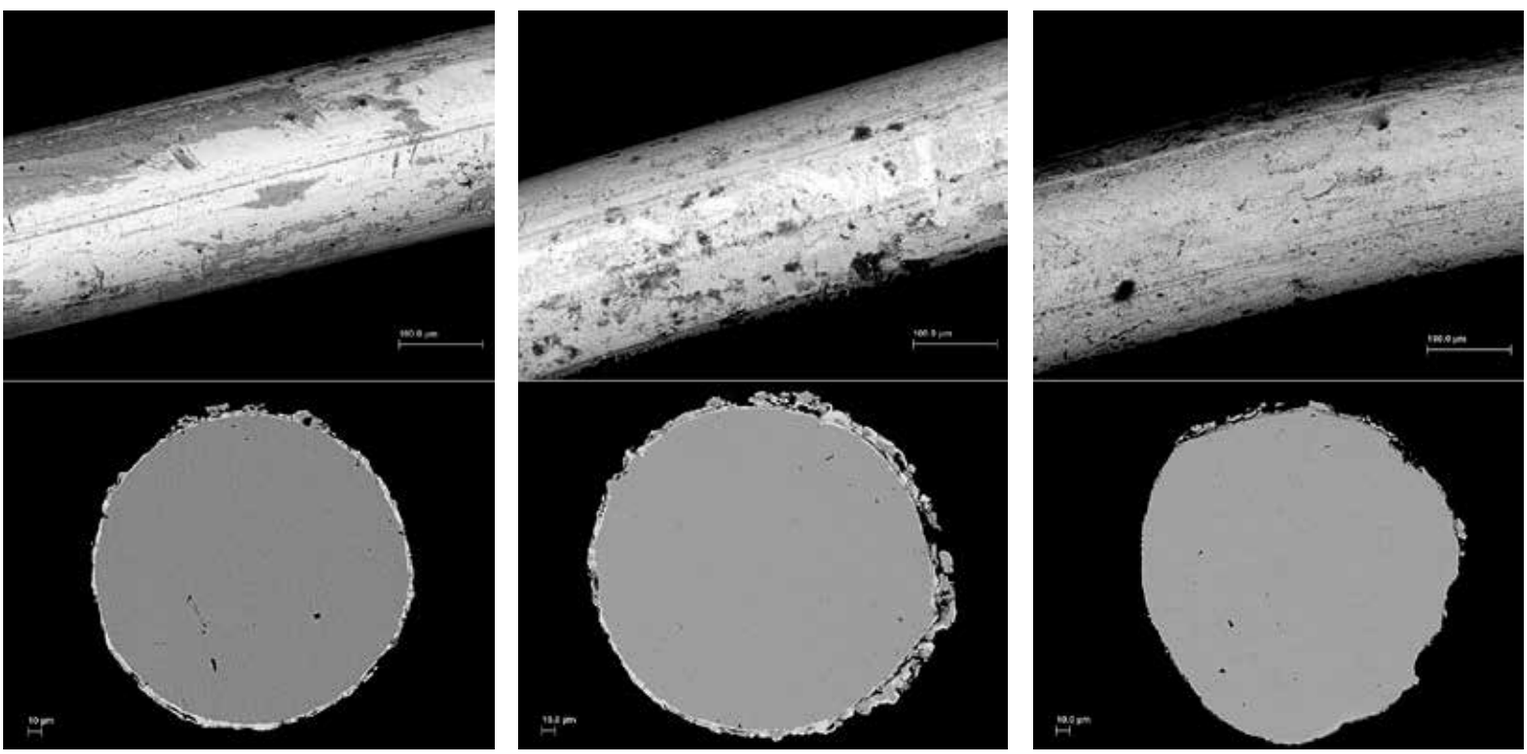
Insights into the production process of the Madina *sitara* can also be obtained from the scientific study of its constituent materials, such as the metal wires and the dyed threads, that were available to the Cairene workshop. While little is known about the techniques of manufacturing silver-gilt wire thread in the late Ottoman Empire, its production is documented at least until the mid-eighteenth century in Istanbul, and in Cairo in the nineteenth and twentieth centuries.[37] In Europe at the end of the nineteenth century, the manufacture of plain and worked drawn metal wires was fully industrialized, and metallic filaments of different composition were exported worldwide to serve a wide variety of applications. In *A Treatise upon Wire, Its Manufacture and Uses*, published in 1891, silver and silver-gilt wire are said to be "chiefly used for filigree, embroidery, and decorative work, as well as for some scientific instruments."[38] Belgium, Great Britain, France, and Germany are often cited as the leading producers of such wires.

Four wires from the *sitara*, one silver and three silver-gilt, were analyzed. One of the gilt-wire samples was taken from an area of embroidery hidden among the layers of padding threads. A single lacquered metal sequin was collected from the center of one of the large rosettes around the border. The wires and the sequin were first examined under a stereomicroscope, later mounted on carbon stubs and analyzed by scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS).[39] Fragments of the silver-gilt wires, the silver wire, and the sequin were also embedded in epoxy resin, cross sectioned, and investigated by SEM coupled with energy and dispersive X-ray spectroscopy (EDS-WDS) and electron backscattered diffraction analysis (EBSD).[40]

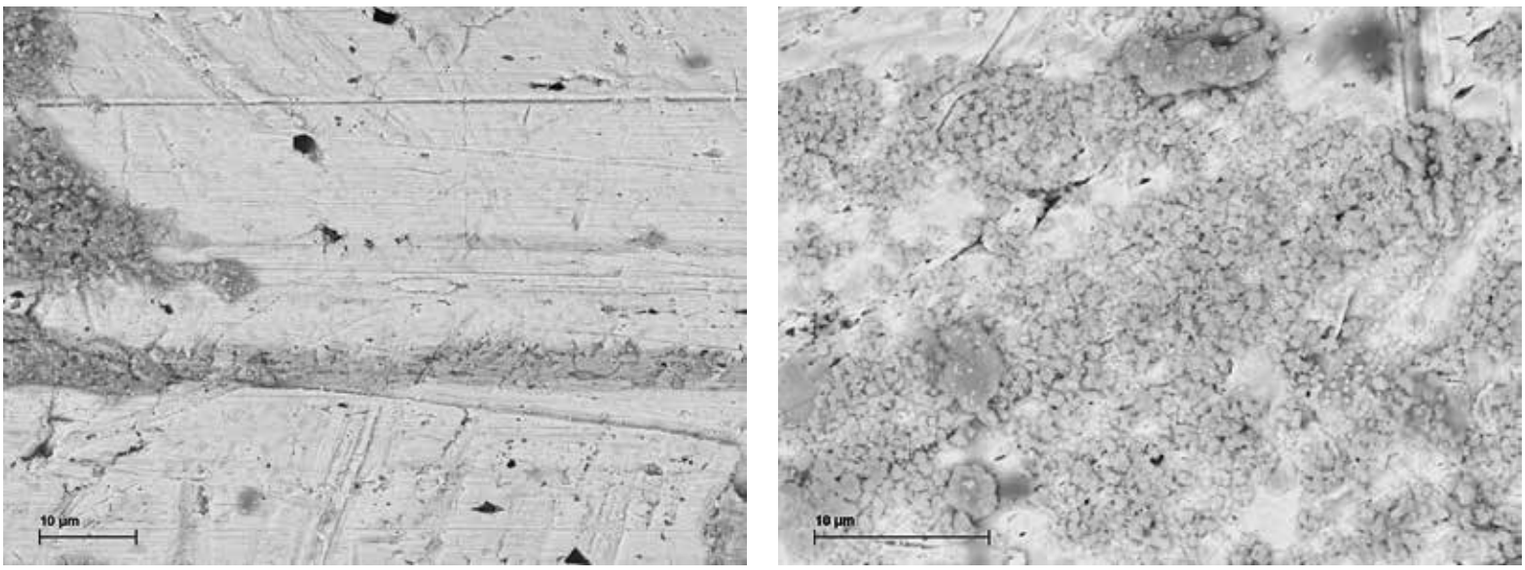
The wires all show clear signs of the drawing process used in their manufacture in the form of continuous parallel marks along the length of the wire (figs. 14, 15a). Die marks occasionally scratched the gilding of the silver-gilt wire and exposed the metal beneath (fig. 14a), which indicates that the wire was drawn after the gold was applied, most likely to a preliminary silver rod of a diameter larger than the final product.[41]

In cross section, the four wires that were tested appear very similar in diameter and shape (fig. 14). They all have an approximately circular section and a diameter of 230–240 micrometers. This size is very similar to British Standard Wire Gauge (SWG) number 34 of 0.0092 inch; the Standard Wire Gauge is a legal standard introduced in Great Britain in 1883.[42]

fig. 14 Backscattered electron (BSE) images of the surfaces and cross sections of the three typologies of wires tested: (a) silver-gilt wire with traces of copper; (b) silver-gilt wire with traces of lead and copper; and (c) the ungilded silver wire. The width of the top three images measures 600 µm; the width of the bottom three images measures about 350 µm.



a b c



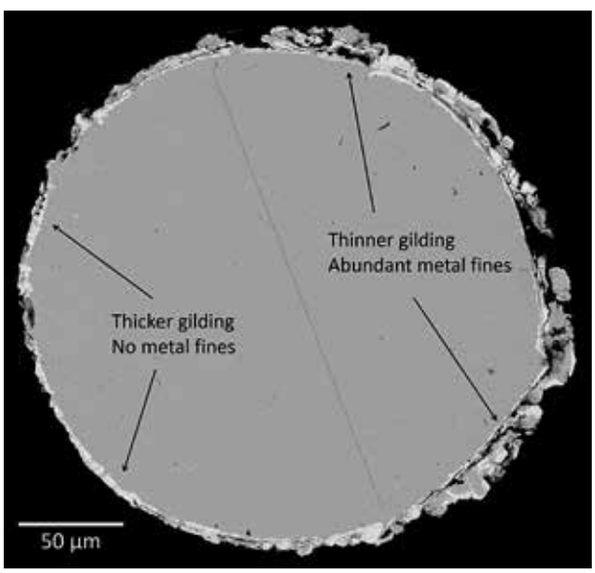
a b

fig. 15 Backscattered electron (BSE) images of the surfaces of wires, showing (a) die marks and corrosion products on the surface of the silver-gilt wire in fig. 14a; and (b) abundant silver chlorides on the surface of the silver-gilt wire, in fig. 14b that was concealed behind the embossed embroidery

fig. 16 Backscattered electron (BSE) image of the cross section of the silver-gilt wire with traces of lead and copper, showing uneven gold thickness and metal fines

Close observation of the wire surfaces in cross section reveals the presence of abundant metal fragments (fines) resulting from a combination of abrasive and adhesive wear,[43] which are limited to the sides of the wire with thinner gilding (fig. 16). These deformed metal flakes are both silver and silver-gilt, supporting the fact that the wires were drawn after gilding.

The wires and the sequin are all made of fine silver alloy,[44] containing trace amounts of copper and lead. Similar drawn silver-gilt wires with slightly higher copper content (up to 1% in weight) and variable sizes have been identified in five sixteenth- to nineteenth-century embroidered Ka'ba curtains in the Topkapı Palace Museum.[45] The slightly different composition and characteristic inclusions of the Madina *sitara*'s wires suggest that they were created from at least three different batches of silver of high purity.



The gilding thickness of each wire is extremely variable, from approximately 500 nanometers to 5.3 micrometers. There is no clear evidence of the gilding technique that was used, but the absence of elements other than gold and silver, the interdiffusion of gold and the underlying silver, and the considerable gilding thickness might indicate that a gold foil or leaf was attached to the silver rod, possibly by heating.[46]

An EBSD orientation map of a longitudinal cross section of the wire shows equi-axed grains and no preferred crystallographic orientation (fig. 17), a microstructure consistent with a final annealing treatment applied after the wire was drawn.[47] Annealing of silver wire was commonly done multiple times at intermediate stages of the manufacture,[48] and was necessary to restore the ductility of the metal to be drawn and to reduce the brittleness of the final product.

The sequin, measuring about 4.9 millimeters in diameter, was punched from a sheet of almost pure silver,[49] and the central hole, about 0.8 millimeter in diameter, was pierced at the same time. Before punching, the silver sheet was coated with an organic colored layer, as testified by the circular mark on the red layer of the pierced metal (fig. 18). Fourier transform infrared micro-spectroscopy (FTIR) of the sequin substrate identified proteinaceous matter consistent with the use of gelatin,[50] which was stained in red with eosin, as identified by EDS and HPLC (high performance liquid chromatography) analysis.[51] SEM investigation shows how corrosion products, consisting of silver chloride and sulfide crystals up to a few microns in size, are

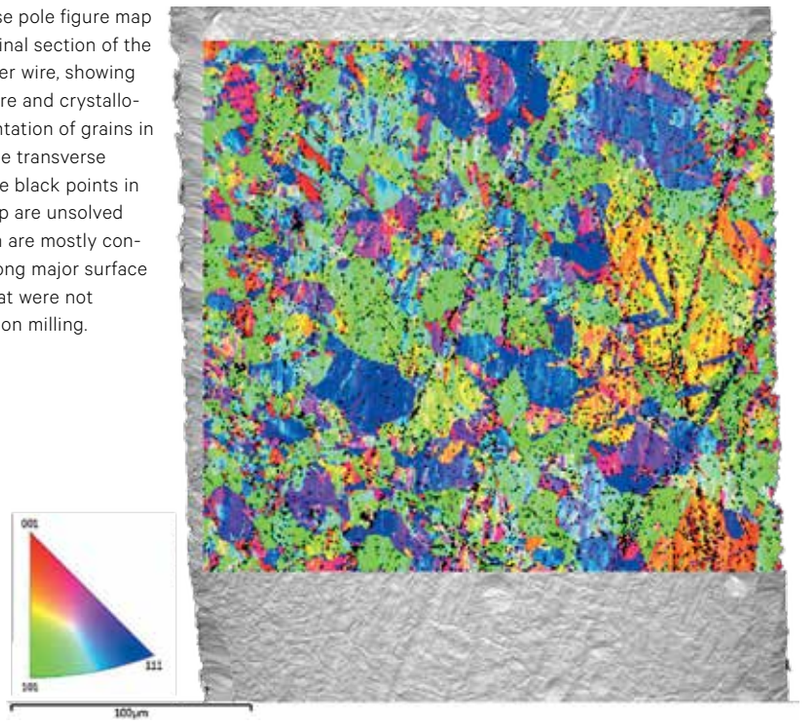


fig. 17 Inverse pole figure map of a longitudinal section of the ungilded silver wire, showing microstructure and crystallographic orientation of grains in respect to the transverse direction. The black points in the color map are unsolved points, which are mostly concentrated along major surface scratches that were not removed by ion milling.

limited in gilded wires to clusters of elongated islands parallel to the wire axis and tend to concentrate in the die marks (figs. 14, 15).

The characteristics of the *sitara*'s wires are consistent with late nineteenth- to early twentieth-century technical descriptions of wire making found in European and American treatises. The specific size of the wires suggests that they were drawn according to the British standard introduced at the end of the nineteenth century. The millesimal fineness of the *sitara*'s silver wires (close to 999) is particularly high when compared with other standard productions of the time and is consistent with the values documented in the archival record of the Warshat al-Khurunfish.[52] This last result suggests that the wires were produced in the Cairene workshop.

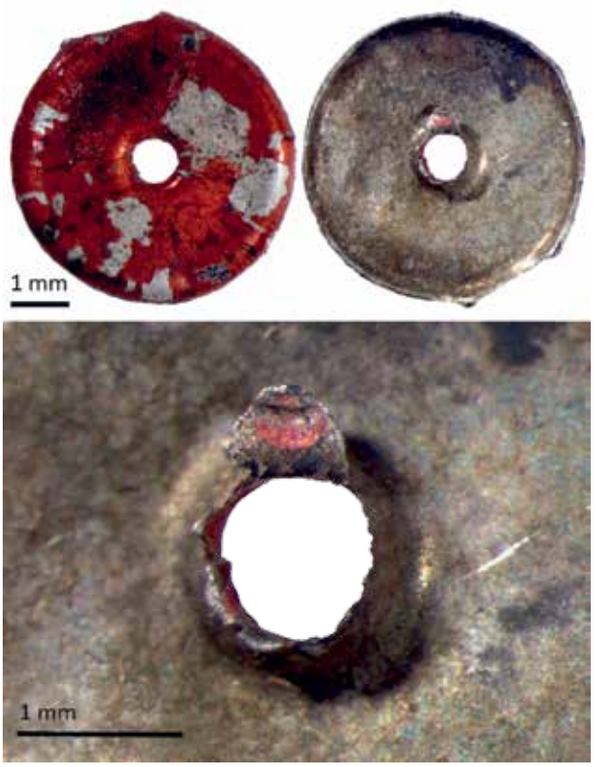


fig. 18 Front and back of the sampled sequin, with a detail of the pierced hole

Dyes used on the various yarns and the colorant used on the red sequins of the *sitara* were analyzed by high performance liquid chromatography–photodiode array detection (HPLC–PDA).[53] The summary of this analysis is found in the table in the Appendix.[54] Those dyes are primarily early synthetic organic dyes, developed in the second half of the nineteenth century. More than one type of dye was used on several of the yarns. Indigo, a main colorant of indigo dye, was detected on the black background fabric. Whether the indigo was from a plant source or was synthesized has not been determined. Synthetic indigo was available on a commercial scale from 1897 from a German chemical company, BASF.[55] Therefore, based on the date of the *sitara*, 1897–98, the indigo used on the background fabric could be either synthetic or natural indigo. The same types of dyes were used on both the warps and the wefts of each appliquéd cartouche, with an additional dye that was used only on the warps (see the table in the Appendix). The extra dye for the warps of the pink cartouche tested, eosin Y, and for the warps of the green cartouche tested, diamond green B, may have been added because of the weaving structure of the cartouches, in which the warps are more visible than the concealed wefts (see "Conservation, Materials, and Techniques" above). That the same types of dyes were found in the warps and wefts of each cartouche and that the extra dyes were added to the more visible warps may suggest that the choice of dyes was deliberate and was part of the dyeing process used on the *sitara*. This may indicate that dyeing of yarns for the *sitara* was planned as a part of the production process.

Ellagic acid was detected on both the silk warps and the cotton wefts of the cartouches, but not on the other yarns. Ellagic acid is derived from hydrolysable tannins found in various plants,[56] so plant extracts containing hydrolysable tannins were likely to have been used on the yarns along with the early synthetic dyes.

The tannins on the silk warps were probably used for weighting,[57] as well as to improve the strength and the drape of the silk.[58] Since the Middle Ages, perhaps even earlier, tannin has been considered an agent used

for weighting, and weighting with tannin alone is known not to damage silk.[59] Tannin-containing plants used for tanning fibers include gall nuts, sumac, and myrobalans.[60] Weighting using metal salts instead of tannins, in particular weighting with tin, began at the end of the nineteenth century, although it was soon found that tin-weighted silk would rapidly deteriorate.[61] Other mineral salts for weighting, such as lead acetate and zinc, were also used but to a lesser extent.[62] Elements of warps and wefts from the *sitara* were analyzed by SEM-EDS.[63] However, tin, the most used metal for weighting silk, was not detected on the silk warps. In addition, the use of other, lesser used metal elements known as weighting agents at that time appears to be unlikely, suggesting that the silk was probably weighted with tannins alone. In terms of tannins that were found on cotton wefts, they were probably used as mordant in order to fix dyes.[64] It is known that a tannin mordant was applied to cotton prior to its dyeing with basic dyes, the same ones that were used on the cotton wefts.[65]

Qualities of lightfastness and wash fastness of most early synthetic dyes are known to be poor, in particular those basic dyes that were used on the cartouches, although the fastness depends on the individual or class of dye, depth of shade, and substrates.[66] Indigo dye, used on the black background fabric, is known to be relatively fast to both light and washing.[67] The cartouches' current shades of pink, green, and yellow are most likely the colors that have faded to some extent.

Dyes used on the *sitara* appear to reflect the period when early synthetic organic dyes had become more popular than natural dyes because of their bright color, ease of application, and low cost.[68] Those early synthetic dyes were discovered in England and Germany in the mid-nineteenth century and then mass-produced and exported to the rest of the world,[69] indicating the influence of the globalized dye market on the *sitara*. However, the silks seem to have been weighted with tannins alone, a rather traditional technique, at a time when most European silks were weighted with tin salts.[70]

FC AND NS

CONCLUSION

This analysis of the Madina *sitara*, which once hung on the Bab al-Tawba (Door of Repentance) inside the Ka'ba in Mecca, examines it as an object of centuries-old religious symbolism and political memorialization as well as an object of material culture in the globalized world of the late nineteenth century. The information gathered during the *sitara*'s conservation and the scientific analysis of metals and dyes used in its production are consistent with scholarship on the late nineteenth-century economic history of the Ottoman Empire, where textile workshops were forced to reorganize after the onslaught of European imports, and to update their production methods with the latest materials and techniques. The artisans in the Warshat al-Khurunfish in Cairo, which specialized in producing textiles for the Ka'ba, utilized machinery and materials borrowed from or influenced by up-to-date manufacturing techniques. The choice of materials that went into the Madina *sitara* demonstrates the importance of the international market in the production of this sacred object: the precious-metal wires were drawn according to current technology, using high-purity silver alloy, while the yarns woven into fabrics were colored using the latest innovative synthetic organic dyes. Conservation was aided by the scientific analysis that revealed deterioration of the fabric elements and embroidery threads in relation to their proximity to the corroded silver wire. The colors of the pink and green cartouches had faded because of the inherently unstable nature of early synthetic organic dyes. The background fabric, dyed with the naturally more stable indigo, remained closer to its originally vibrant color.

The discovery during conservation of the dated note sewn among layers of the *sitara* was serendipitous, and more comprehensive analysis of the note is planned. Further, discovering the trademark stamp on one of the linings established a direct connection between the Cairo workshop and an industrial bleach mill in northwest England, a relationship based on the cotton trade between Egypt and England that has long been recognized in the historical record. The Metropolitan Museum's *sitara* is thus representative of late nineteenth-century global interactions involved in its production as well as an object that illustrates the extraordinary work of artisans carrying on a centuries-long tradition of embroidering inscriptions in precious-metal wire thread that convey the themes and messages most sacred to the religion of Islam.

ACKNOWLEDGMENTS

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APPENDIX

High-performance liquid chromatography–photodiode array detection (HPLC–PDA) analysis of dyes on some fabrics and threads used in making the Madina *sitara*

TESTED FABRICS AND THREADS IN THE *SITARA*		COLOR	MATERIAL	SUGGESTED MAJOR DYES AND AUXILIARY AGENTS	COLOUR INDEX (C.I.) GENERIC NAME OF THE DYE AND ITS YEAR OF DISCOVERY
Pink cartouche	Warp	Pink	Silk	Safranine T	C.I. Basic Red 2, 1859-
				Eosin Y	C.I. Acid Red 87, 1871-
				New Fuchsin	C.I. Basic Violet 2, 1889-
				Tannins	
	Weft	Pink	Cotton	Safranine T	C.I. Basic Red 2, 1859-
				New Fuchsin	C.I. Basic Violet 2, 1889-
				Tannins	
Green cartouche	Warp	Green	Silk	Diamond Green B	C.I. Basic Green 4, 1877-
				Thioflavin T	C.I. Basic Yellow 1, 1888-
				Quinoline yellow	C.I. Acid Yellow 3, 1882-
				Tannins	
				A small amount of natural yellow dye (flavonoid dye)	
	Weft	Yellow	Cotton	Thioflavin T	C.I. Basic Yellow 1, 1888-
				Quinoline yellow	C.I. Acid Yellow 3, 1882-
				Tannins	
Padding under the metal-thread embroidery		Orange	Bast fibers	Orange II	C.I. Acid Orange 7, 1876-
Sewing thread		Orange	Silk	Orange II	C.I. Acid Orange 7, 1876-
				Metanil yellow	C.I. Acid Yellow 36, 1879-
Background fabric		Black	Silk	Indigo	
Sequin		Red		Eosin Y	C.I. Acid Red 87, 1871-

NOTES

1 Professor Madina was a well-known collector and benefactor. At a Sotheby's auction in New York in 1988, he acquired a textile identified in the catalogue (lot 284) as a late eighteenth- to early nineteenth-century Mughal tomb covering. Knowing that it was misidentified, he assigned one of his graduate students, this author, to identify the textile, and she discovered that it was a *sitara* that had hung on the Bab al-Tawba. Professor Madina later donated the *sitara* to the Metropolitan Museum in memory of his mother, Najiyya Khanum al-Kurdi.

2 See, for example, İpek 2011.

3 The hajj is one of the Five Pillars of Islam. It is obligatory for all Muslims to make the pilgrimage to Mecca at least once in their lifetime, if they are able to physically and financially.

4 Burton (1893) 1964, vol. 2, pp. 207–16.

5 This earliest-known confirmed extant Bab al-Tawba *sitara* is in the Khalili Collection described below; see Porter 2012, p. 258, fig. 196. There is a *sitara* dated earlier, about 1880, that was auctioned in 2003 at Bonhams London (lot 105). This *sitara* was described as a Bab al-Tawba curtain similar to one auctioned at Christie's London in 1999 (lot 21), which was also labeled as having hung on the Bab al-Tawba. Both the Bonhams and Christie's catalogue descriptions cite a *sitara* in the collection of the Tareq Rajab Museum in Kuwait that is dated to the nineteenth century but not designated as a Bab al-Tawba curtain; see Safwat 1997, pp. 114–15. Although these three curtains and the Madina *sitara* are from the period of Sultan 'Abd al-Hamid II, the three differ from the Madina *sitara* iconographically and in choice of Qur'anic text. These three curtains are also significantly smaller in size than the Madina *sitara*, which indicates that further research needs to be conducted to confirm whether they were produced to drape the Bab al-Tawba or were intended to hang elsewhere.

6 *Jali thuluth* script originated with Ibn al-Bawwab (d. 1031), the celebrated medieval calligrapher from Baghdad; Khalili 2006, p. 43.

7 Qur'an 6:54, translation Ali (1934) 1946, vol. 1, pp. 302–3.

8 Stillman and Sanders 2000, p. 536.

9 For the *sitara* in the Topkapı Palace Museum, see Tezcan 1996, pp. 64–65. A dedication to Muhammad Tawfiq Pasha is also inscribed on the *sitara* auctioned at Christie's London 2005, lot 48, dating to 1892–1909.

10 See, for example, the covers for the Shrine of the Prophet Ibrahim (Christie's London 2005, lot 49, and Sotheby's London 2007, lot 41); and the curtain for the tomb of the Prophet Muhammad in Medina (Sotheby's London 2007, lot 40). For other Ka'ba textiles from the Hamidian period, see Bonhams London 2003, lot 105; Christie's London 1999, lot 21; and Safwat 1997, pp. 114–15.

11 Porter 2012, pp. 262–63.

12 For the *sitara* in the Khalili Collection, see ibid., p. 258; for the one in the Topkapı Palace Museum, see Tezcan 1996, pp. 64–65; for the curtain made between 1892 and 1909, see Christie's London 2005, lot 48; and for the one dated by Sotheby's as A.H. [1]321/1903–4, see Sotheby's London 2007, lot 42. Three other *sitara*s, the present locations of which are unknown, are recorded in publications; see Rif'at 1925, vol. 1, p. 264, ill.; Aḥmad 1937, p. 81, ill.; and Gouda 1989, p. 264, ill.

13 Qur'an 42:25, translation Ali (1934) 1946, vol. 2, p. 1313.

14 Qur'an 2:255, translation Ali (1934) 1946, vol. 1, pp. 102–3: "God! There is no god but He,—the Living, the Self-subsisting, Eternal. No slumber can seize Him nor sleep. His are all things in the heavens and on earth. Who is there [who] can intercede in His presence except as He permitteth? He knoweth what (appeareth to His creatures as) Before or After or Behind them. Nor shall they compass aught of His knowledge except as He willeth. His Throne doth extend over the heavens and the earth, and He feeleth no fatigue in guarding and preserving them. For He is the Most High, the Supreme (in glory)."

15 See, for example, the *burqu'* auctioned at Christie's London 2005, lot 46.

16 İpek 2011, pp. 59–60.

17 Porter 2012, p. 265; Tezcan 2007, pp. 229–30.

18 Cakir, Simsek, and Tezcan 2006, pp. 503, 510n3.

19 The Warshat al-Khurunfish is also known by the name Dar al-Kiswah al-Sharifa, which it received in 1953 and retained until its closing in 1962. In 2011 the Nasser D. Khalili Collection of Islamic Art acquired an important collection of hajj artifacts, including archival material from the Cairo workshop. This collection consists of many objects that shed light on the production process, including photographs of artisans at work, documents, embroidery templates, tools, and raw materials. Yael Rosenfield traveled to London to research *sitara*-related objects in the Khalili Collection and arranged for permission to publish their photographs, and this author would like to thank her for her contribution to this section.

20 Nassar 2013, pp. 175–83.

21 Ibid., p. 176.

22 Quataert 1994, p. 87.

23 Quataert 1993, pp. 30, 32; Quataert 1994, pp. 87–88, 100.

24 Cakir, Simsek, and Tezcan 2006, p. 504.

25 Nassar 2013, p. 176.

26 Quataert 1993, p. 29; Quataert 1994, pp. 87–88, 100.

27 Thompson 1999, pp. 30–34; Nassar 2013, p. 176.

28 The orange silk thread showed extensive signs of deterioration, causing the silver-gilt wire to come loose from the background.

29 The double back stitch, also known as the crossed back stitch, is used mainly for shadow-work embroidery; see Thomas 1989, p. 47. A similar technique can be found in Indian metal embroidery; see Morrell 1994, p. 104, fig. 92, sample i.

30 In this warp-faced satin weave, the cotton wefts are concealed by the silk warps; the fabric thus appears shiny and silk-like. According to Irene Emery (1966, p. 108), satin weave is one of the three basic weave structures (plain, twill, and satin). It is a simple float weave structure, with long floats in one set of elements, in this case the warps. In addition to this weave structure, satin also denotes a smooth lustrous fabric. The black silk ground fabric is also a satin weave.

31 For this couching, we used the thread Gutermann Skala 100% Polyester, 5000 m., which was strong and blended well with the ground fabric.

32 "Mayflower, Standish Conservation Area Appraisal, April 2010," www.wigan.gov.uk/Docs/PDF/Resident/Planning-and-Building-Control/Conservation-areas/April2010MayflowerCAA1199kb.pdf. According to section 3.1, "History: Modern Period," Standish Bleach Works "used the Mayflower ship as their trademark, an allusion to Captain Myles Standish."

33 Cristina Carr, conservator in the Department of Textile Conservation of the Metropolitan Museum, conducted the X-radiography.

34 O'Connor and Brooks 2007, p. 278.

35 Marina Ruiz Molina, associate conservator in the Department of Paper Conservation of the Metropolitan Museum, performed reflected infrared photography and shared her expertise with the process.

36 Thompson and Halliwell 2005.

37 Cakir, Simsek, and Tezcan 2006, p. 504; Nassar 2013, p. 180.
38 Smith 1891, p. 112.
39 Imaging and surface analysis of the wires and the sequin were realized in variable pressure mode at 20kV and 40 Pa, using a FE-SEM Zeiss Σigma HD, equipped with an Oxford Instrument X-MaxN 80 SDD detector.
40 Wires were sectioned both orthogonally and tangentially to the axis. After mechanical polishing with Micro-Mesh® and Buehler® MicroCloth down to¼ μm, samples were milled with a Hitachi IM400 argon gun, ion mill system, and coated with 12 nm carbon. SEM-EDS analysis was realized in high vacuum mode at 20kV, WDS with an Oxford Instrument Inca Wave spectrometer at 30kV, and EBSD with a Nordlys Nano detector at 20kV. EBSD data were processed with Oxford Instrument Aztec software.
41 Smith 1891, p. 25; Brenni 1930, pp. 14–17. These two texts, from the late nineteenth and the early twentieth century, report that the wire fabrication started with a silver rod of about 35–38 mm in diameter. This was heated before gold leaf was applied and then the two metals were drawn together.
42 Pöll 1999.
43 Abrasive wear and adhesive wear develop during drawing of wires through a die with asperities and from contact with other metal surfaces during the manufacturing process.
44 According to J. Bucknall Smith (1891, p. 11), the silver used for wire making was occasionally above standard purity, such as 992/1000 silver (i.e., 99.2% in weight). In the *sitara*, ungilt wire alloy is approximately 99.7% silver, 0.29% copper, with traces of lead, iron, and zinc about 0.01%, as determined by WDS. Iron and zinc are present in diffuse, discrete inclusions of oxides. The gilded wires were drawn from almost pure silver. One wire is 99.87% silver and 0.13% copper, while the other two, one of which is the hidden wire, are approximately 99.89% silver and 0.11% lead, with traces of copper below 0.02%. Discrete inclusions of lead with traces of gold and the mineral altaite, a lead telluride, were identified by EDS and EBSD in the latter two wires.
45 Cakir, Simsek, and Tezcan 2006.
46 Lechtman 1971.
47 Cho et al. 2006.
48 Smith 1891, p. 114.
49 The sequin is approximately 99.91% silver, with traces of copper about 0.09%, as determined by WDS.
50 FTIR was performed by Caterina Cappuccini and Adriana Rizzo, using a Hyperion 3000 Microscope interfaced to a Tensor 27 (Bruker Optics), equipped with a 15x FTIR objective and a MCT detector (mercury cadmium telluride), liquid nitrogen cooled. The FTIR spectra were acquired as 64 scans in the range of 4000 to 600 cm^{-1} and 4 cm^{-1} resolution.
51 EDS analysis identified the presence of bromine, while HPLC analysis identified eosin Y, an organic colorant having bromine in its structure.
52 Nassar 2013, p. 180.
53 Small yarn samples were taken from the textile, extracted with a mixture of 0.01 M aqueous oxalic acid, pyridine, and methanol (3/3/4, v/v/v) assisted with heat; the extract was dried in a vacuum desiccator. The residue was dissolved in a mixture of methanol and 1% aqueous formic acid (1/1, v/v). The solution was centrifuged; the supernatant was injected into the HPLC system. The analytical system used consisted of a 1525μ binary HPLC pump, 2996 PDA detector, 1500 series column heater, in-line degasser, and a Rheodyne 7725i manual injector with 20 μl loop (Waters Corporation, Milford, Mass.). An Xterra RP18 (3.5 μm-particle, 2.1 mm I.D. x 150.0 mm) reversed-phase column was used with a guard column (Xterra RP18 3.5 μm-particle, 2.0 mm I.D. x 10.0 mm) (Waters Corporation, Milford) with a flow rate of 0.2 ml/min. The column pre-filter (Upchurch Ultra-Low Volume Precolumn Filter with 0.5 μm stainless steel frit, Sigma-Aldrich, Saint Louis, Mo.) was attached in front of the guard column. Column temperature was 40° C. The mobile phase was eluted in a gradient mode of 1% formic acid in de-ionized water (v/v) (A) and methanol (B). The gradient system was 90% (A) for 3 min → to 60% (A) in 7 min. in a linear slope → to 0% (A) in 24 min. in a linear slope, and then back to 90% (A) in 1 min. and held at 90% (A) for 10 min. The operation and data processing software was Empower Pro (2002).
54 Although there were a few color components detected but not identified, they are also likely color components of early synthetic dyes because the UV-visible absorption spectra of the unknown color components were similar to those of the identified components of synthetic dyes. Also, those components do not match any known natural dyes. The Colour Index is a reference database of dyes and pigments, and it lists colorants using dual classification, Colour Index Generic Name and Colour Index Constitution Numbers. The *Colour Index* (1971, vol. 1, pp. 1001, 1607) states that basic dyes are dyes that in aqueous solution yield colored cations and that acid dyes are water-soluble anionic dyes that are applied to nitrogenous fibers such as wool, silk, nylon, and modified acrylic fibers from acid or neutral baths.
55 Balfour-Paul 1998, p. 82.
56 Haslam 1966, pp. 91–92.
57 Tannins are reported to have been used for weighting silk in order to compensate for a weight loss caused by the degumming process; this was for economic reasons because silk was expensive and was sold by weight; Hacke 2008, p. 3; Hofenk de Graaff 2004, p. 336; Matos 1915, p. 41; and Knecht, Rawson, and Loewenthal 1893, vol. 1, pp. 181–83. Raw-silk fibers are composed of two different types of proteinaceous materials: fibroin (the structural core) and sericin (the gum that coats fibroin). Sericin is removed by the degumming process in order to separate fibroin filaments and to make the silk more lustrous; Hacke 2008, p. 3.
58 Weighted silk is usually heavier with better draping quality; Hacke 2008, p. 3. Also, it is said that tanning strengthens the silk fibers; Bogle 1979, p. 4; Matos 1915, p. 41; Knecht, Rawson, and Loewenthal 1893, vol. 1, p. 181.
59 Hacke 2008, p. 4; Bogle 1979, p. 4.
60 Knecht, Rawson, and Loewenthal 1893, vol. 1, pp. 181–83, Matos 1915, p. 41.
61 Hacke 2008, p. 7; Bogle 1979, pp. 5–6.
62 Hacke 2008, p. 6.
63 The SEM-EDS analysis was performed using the same instrument and experimental conditions reported in note 39 above. EDS analysis of several selected yarns from the *sitara* identified various metal elements. Traces of Na, Mg, Al, Si, S, Cl, K, Ca, and Fe were detected in most of the samples. In some cases, specific elements were detected in discrete particles found at the surface of the threads, such as Cr in the pink warp, Pb in the yellow and pink wefts, as well as in the white weft lining. These findings are perplexing because dyeing manuals instructed that those basic and acid dyes were to be applied to silk directly without metal salts, and applied to cotton with either tannins or metal salts of aluminum or tin; *Colour Index* 1971, vol. 1, pp. 1001, 1607–9; Knecht, Rawson, and Loewenthal 1893, vol. 2, pp. 451–55, 456, 505–6, 509. Considering the complex history of the *sitara*, it is

challenging to interpret such findings and exclude unintentional contamination by the manufacturing process or airborne particulates or from manipulation of the textile before it entered the Museum's collection. In a few cases, material intentionally added to the surface of the threads was recognized, such as abundant barite (Ba, S) found in small, dispersed particles on the white weft lining and on the sewing thread; a kaolinitic clay (Al, Si) was found on the sewing thread, together with barite. Often, corrosion products of the metal wires have been found on both warp and weft threads, as well as on the sewing thread, in the form of silver chlorides and sulfides associated with traces of gold.

64 Knecht, Rawson, and Loewenthal 1893, vol. 1, p. 176. While cotton shows little power to retain dyes, cotton attracts tannins from aqueous solutions to form insoluble compounds with dyes.

65 Ibid., vol. 2, pp. 451–55; *Colour Index* 1971, vol. 1, pp. 1607–9.

66 *Colour Index* 1971, vol. 1, pp. 1004, 1017, 1075, 1153, 1607, 1611, 1633, 1649, 1680; Barnett 2007, p. 70. Some metal salts were also spoken of as having been used with tannins in order to improve wash fastness of early synthetic dyes, both on silk and cotton, from the end of the nineteenth century. Those metals were mainly antimony for light shades, and iron or tin for dark and dull shades; Scharff 1999, p. 657; Steelman 1922, p. 662; Matos 1915, p. 42; Knecht, Rawson, and Loewenthal 1893, vol. 2, p. 452. However, those metal elements typically used for light shades, the colors of the colored cartouches, were not detected by SEM-EDS analysis.

67 *Colour Index* 1971, vol. 3, p. 3775; Padfield and Landi 1966, pp. 183–89.

68 Barnett 2007, p. 74.

69 Ponting 1981, pp. 161–71.

70 Hacke 2008, p. 6.

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